DRAFT FOR REVIEW

VOLUME 2A

REMEDIAL INVESTIGATION / FEASIBILITY STUDY

FIELD SAMPLING PLAN

SITE-WIDE GROUNDWATER (OPERABLE UNIT 03)

WEST LAKE LANDFILL SITE

June 5, 2019

Project #: 63N-001-001

SUBMITTED BY: Trihydro Corporation

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ENGINEERING SOLUTIONS. ADVANCING BUSINESS.

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List of Acronyms

ALARA	as low as reasonably achievable
AOC	Administrative Order of Consent
ARAR	Applicable or Relevant and Appropriate Requirement
ASAOC	Administrative Settlement Agreement and Order on Consent
bgs	below ground surface
BL	Barometric Barologger
bmp	below measuring surface
CaCO3	Calcium Carbonate
C&D	Construction & Demolition
CEC	Cation Exchange Capacity
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Regulations
CH_4	methane
cm/sec	centimeters per second
cfs	cubic feet per second
CoC	chain of custody
COC	Constituents of Concern
cpm	counts per minute
CSR	Code of State Regulations
CWA	Clean Water Act
DA	Desktop Assessment
DL	Data Logger
DO	Dissolved Oxygen
DOE	United States Department of Energy

List of Acronyms (cont.)

DOT/IATA	Department of Transportation, International Air Transport Association
EDD	Electronic Data Deliverable
EM	electromagnetic
EMSI	Engineering Management Support, Inc
EPA	United States Environmental Protection Agency
ESRI	Environmental Systems Research Institute
eV	electronvolt
°F	degrees Fahrenheit
FS	Feasibility Study
FSP	Field Sampling Plan
ft	feet
FTL	Field Team Leader
ft/day	feet per day
ft^2/day	square feet per day
gpd	gallons per day
gpm	gallons per minute
GPS	Global Positioning System
H_2S	hydrogen sulfide
HASL	*EML Procedures Manual*, HASL-300, 28th Edition
HASP	Health and Safety Plan
ID	inner diameter
IDW	Investigation Derived Waste
LEL	lower explosive limit
µR/hr	microroentgens per hour

List of Acronyms (cont.)

MCLI	Materials & Chemistry Laboratory, Inc.
MDNR	Missouri Department of Natural Resources
mg/L	milligram per liter
mgd	million gallons per day
mm	millimeter
msl	mean sea level
mrem/hr	millirem per hour
mR/hr	milliroentgens per hour
mS/m	milliSiemens per meter
mV	millivolts
NAD83	North American Datum 1983
NAVD88	North American Vertical Datum 1988
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NPL	National Priorities List
N.S.L.	Bridgeton Landfill, LLC, Cotter Corporation
NTU	Nephelometric Turbidity Units
O_2	oxygen
OERR	Office of Emergency and Remedial Response
ohm-m	ohm-meters
ORP	oxygen reduction potential
OSWER	Office of Solid Waste and Emergency Response
OU	Operable Unit
%	percentage
PCB	Polychlorinated Biphenyl

List of Acronyms (cont.)

pCi/g	picocuries per gram
pCi/L	picocuries per liter
PDF	portable document format
P.E.	Professional Engineer
P.G.	Professional Geologist
PID	Photoionization detector
PPE	Personal Protective Equipment
PVC	Polyvinyl Chloride
QA	quality assurance
QAD	Quality Assurance Director
QAPP	Quality Assurance Project Plan
QC	Quality Control
R/hr	roentgens per hour
rem/hr	rem per hour
RCRA	Resource Conservation and Recovery Act
RCS	Radiation Control Supervisor
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
RIM	radiological impacted materials
ROW	Right of Way
RQD	Rock quality designation
RSO	Radiation Safety Officer
RSP	Radiation Safety Plan
SAP	Sampling and Analysis Plan

List of Acronyms (cont.)

SEM/EDS	Scanning Electron Microscope with Energy Dispersive x-ray Spectrometry
SHSO	Site Health and Safety Officer
SEM	Simultaneously Extracted Metals
SM	Standard Methods
SOP	Standard Operating Procedure
SOW	Statement of Work
SP	Spontaneous Potential
SQCO	Site Quality Control Officer
SU	Standard Units
SVOC	Semi-Volatile Organic Compound
TDS	Total Dissolved Solids
TOC	Total Organic Carbon
TPH	Total Petroleum Hydrocarbons
UAO	Unilateral Administrative Order
µg/L	microgram per liter
UPS	United Parcel Service
USCS	Unified Soil Classification System
USACOE	United States Army Corps of Engineers
VOC	Volatile Organic Compound
WP	Work Plan
XRD	x-ray Diffraction

1.0 INTRODUCTION

This Remedial Investigation/Feasibility Study (RI/FS) Field Sampling Plan (FSP) has been prepared by Trihydro Corporation (Trihydro) on behalf of Bridgeton Landfill, LLC, Cotter Corporation (N.S.L.), and the United States Department of Energy (DOE) (collectively Respondents), for site-wide groundwater (Operable Unit 3 or OU-3), at the West Lake Landfill Site (Site). The Site is located at 13570 St. Charles Rock Road, Bridgeton, Missouri (Figure 1-1). The FSP was prepared at the request of the United States Environmental Protection Agency (EPA) in accordance with requirements outlined in the Final RI/FS OU-3 Statement of Work (SOW) dated September 21, 2018, included as Appendix B in the Administrative Settlement Agreement and Order on Consent (ASAOC) dated February 6, 2019. This FSP and the Quality Assurance Project Plan (QAPP) are being submitted as the Sampling and Analysis Plan (SAP) as Volume 2 of the RI/FS Work Plan.

The Site was added to the Superfund National Priorities List (NPL) in 1990 and consists of three Operable Units (OUs) that include former industrial and municipal waste cells and groundwater. Operable Unit 1 (OU-1) includes former waste disposal areas Radiological Area 1 (Area 1) and Radiological Area 2 (Area 2) where radiological impacted materials (RIM) exist (EPA ID#MOD079900932). Operable Unit 2 (OU-2) has no areas impacted with RIM and includes the closed construction and demolition (C&D) cell, inactive sanitary landfill, and the North and South Quarry Portions of the Bridgeton Landfill. The Bridgeton Landfill and the C&D cell portions of OU-2 are managed by the Missouri Department of Natural Resources (MDNR) in contrast to the remedial actions for the Inactive Sanitary Landfill which are being addressed under EPA Superfund authority. OU-3 includes groundwater beneath the entire 212-acre Site.

1.1 SITE BACKGROUND AND SETTING

The Site is approximately 200-acres and is located on the east side of the Missouri River within the western portion of the St. Louis metropolitan area in northwestern St. Louis County. The Site address is 13570 St. Charles Rock Road approximately one mile north of the intersection of Interstate 70 and Interstate 270, within the City of Bridgeton, Missouri. It includes six historic waste disposal areas or units, including Area 1, Area 2, a closed C&D landfill, an inactive sanitary landfill, and the North Quarry and South Quarry portions of the permitted Bridgeton Landfill. A solid waste transfer station and an asphalt batch plant currently operate on the Site. A six-foot-high chain-link fence with a three-strand barbed wire canopy encloses the OU-1 and OU-2 areas of the property. The main access gate is located on the northeastern boundary and a secondary access gate is located on the southwestern boundary of the landfill property.

The landfill property is bordered by Crossroads Industrial Park to the northwest and St. Charles Rock Road (State Highway 180) to the north and east; Taussig Road, commercial facilities (including the Republic Services, Inc. hauling company facility), and agricultural land are located to the southeast; Old St. Charles Rock Road (now partially vacated) and the Earth City Industrial Park (Earth City) stormwater/ flood control pond to the south, west and north. The Earth City commercial/industrial complex continues to the west and north of the flood control pond and extends to the Missouri River. Earth City is separated from the river by an engineered levee system owned and maintained by the Earth City Flood Control District. Terrisan Reste mobile home park is the nearest residential area to the Site, which is located to the southeast of the Site, approximately 0.7 mile from Area 1 and 1.1 miles from Area 2. The Spanish Village residential subdivision is located to the south of the Site near the intersection of St. Charles Rock Road and I-270, approximately 1 mile from Area 1 and 1.25 miles from Area 2 (EMSI 2018).

The property on the west side of Area 2 was previously referred to as the Ford Property in the OU-1 RI (EMSI 2000) because it was previously owned by Ford Motor Credit, Inc (Ford). Most of the Ford Property was sold to Crossroad Properties, LLC in 1998 and has since been developed into the Crossroads Industrial Park. Ownership of this 1.78-acre parcel was subsequently transferred to Rock Road Industries, Inc., now Bridgeton Landfill, LLC, to provide a buffer between the landfill and adjacent property, and therefore this parcel has been identified as the "Buffer Zone." Crossroad Properties, LLC initially developed all the former Ford property except for Lot 2A2, a 3.58-acre parcel located immediately north of the Buffer Zone. Lot 2A2 was subsequently developed by AAA Trailer, the owner of much of the property immediately to the north of the Buffer Zone and Area 2, although Lot 2A2 is still owned by Crossroad Properties, LLC.

The West Lake Landfill Superfund NPL Site consists of the various parcels that comprise the landfill property (on-property) and adjacent properties (off-property) where radionuclides are identified in the soil. OU-1 includes on-property Areas 1 and 2, and the adjacent off-property Buffer Zone and Parcels B and C of Lot 2A2 of the Crossroads Industrial Park. These off-property areas were not used for waste disposal but are known to contain radionuclides in soil because of transport by surficial processes from OU-1. OU-2 consists of all other portions of the landfill property. A full discussion of the background and history of the Site is provided in the RI/FS Work Plan.

1.2 RI OBJECTIVES

The purpose of the Remedial Investigation (RI) is to generate data to further characterize the nature and extent of the contamination in OU-3 to support the development, and screening, and evaluation of alternatives in OU-3. The general objectives of the RI are:

- Identify and characterize sources of constituents of concern (COCs);

- Determine the nature and extent of impacts to groundwater and groundwater/surface water interactions;
- Develop a preliminary OU-3 boundary;
- Develop an appropriate groundwater model;
- Identify exposure pathways, evaluate current and future human health and ecological risks posed by the COCs present at the Site, and complete a risk assessment in accordance with EPA guidance;
- Determine the potential for vapor intrusion; and
- Develop and evaluate remedial alternatives for the Site.

1.3 RI FIELD WORK

The Respondents will perform the following field activities to help achieve these objectives. Each of these field activities, their description, and use is described in this FSP.

- Perform field screening;
- Perform site reconnaissance;
- Perform an ecological survey;
- Collect soil and bedrock samples;
- Collect groundwater samples;
- Install groundwater monitoring wells;
- Install and measure staff gauges;
- Survey wells, staff gauges and leachate riser elevations;
- Investigate vapor intrusion; and
- Perform decontamination procedures.

In addition, the following is described in this FSP:

- Preserving, packing, and shipping sample containers;
- Disposing of residual materials;
- Documenting of samples and their shipment; and
- Assuring quality control (QC).

1.4 PROJECT ORGANIZATION AND FIELD TEAM RESPONSIBILITIES

The OU-3 Respondents will direct this project. Trihydro and their subcontractors will perform the field investigation, prepare reports, and perform any subsequent studies. Gary Risse, P.E., will serve as the Project Director for Trihydro. Trihydro will provide project management, with the following personnel supporting the project at this time: Stephen Lombardo, P.G. (PM or Project Manager), Michael Sweetenham, P.G. (APM or Assistant Project Manager), Charles VanHeuvelen P.G. (FTL or Field Team Lead and Project Geologist), and Michael Phillips, Ph.D. (QAD or Quality Assurance Director). The expanded project Organization Chart with project personnel is included as Figure 1-2. The Organization Chart includes our proposed subcontractors: Feezor Engineering, Inc., Ameriphysics LLC, Pace Laboratories (Pace), and MCL Incorporated (MCLI). A qualified drilling contractor and geophysicist are To Be Determined (TBD).

1.4.1 FIELD TEAM LEADER

The Field Team Leader (FTL) will have overall responsibility for completion of all field activities according to the FSP. The FTL is the overall coordinator of activities at the Site and is the communication link between field team members, the Site Quality Control Officer (SQCO), and the Site Health and Safety Officer (SHSO). The FTL will assign specific field duties to team members in conjunction with the Project Manager and FTL or designee will be on-site during all field activities and oversee operations. The FTL will be responsible for mobilization and demobilization of the field team and subcontractors and will direct the activities of all subcontractors onsite. Any logistical problems hindering field activities, such as equipment malfunctions or availability, personnel conflicts, or weather dependent working conditions, will be relayed to, and resolved by the FTL.

Field team members will report directly to the FTL and provide daily verbal progress reports of field activities. The FTL or field team designee is responsible for completing the Site field logbook. The FTL is responsible for informing the PM of daily activities. The FTL is responsible for supplying field team members with appropriate field notebooks and field documentation forms.

1.4.2 FIELD TEAM MEMBERS

Field team members will: conduct Site reconnaissance; perform an ecological assessment; conduct a well inventory; oversee borehole advancement, borehole geophysical logging, packer testing, monitoring well installation, monitoring well development, surveying, and monitoring well abandonment; collect soil, aquifer matrix, and groundwater samples; conduct aquifer testing; and install and monitor staff gauges and pressure transducers. Decontamination of sampling equipment will be accomplished by the field team under the direction of the FTL. Field team members will complete, and file personal daily time logs and complete field documentation forms as indicated in the FSP. Field team members will submit field documentation forms to the SQCO and will relinquish custody of field samples to the contracted laboratory as outlined in the QAPP. Field team members will perform sample packaging and shipping. All field team members will comply with the provisions of the Site-Specific Health and Safety Plan (HASP) included as Volume 3 in the RI/FS Work Plan.

1.4.3 SITE QUALITY CONTROL OFFICER

The SQCO will check the completion of chain-of-custody forms, packaging and shipment of samples, and sample log book entries. The SQCO will check the daily time logs and field data forms for accuracy and compliance with the QAPP and FSP. The SQCO is responsible for maintaining field instrument calibration logs for field instruments. After review of documentation, the SQCO is responsible for storing and forwarding the documentation for filing in accordance with appropriate document control and security measures. The SQCO will be a member of the field team.

1.4.4 SITE HEALTH AND SAFETY OFFICER

The SHSO will be present on-site during Level A, B, or C field operations and will be responsible for health and safety activities and delegation of duties to the health and safety staff in the field. Because the West Lake Landfill Site is identified as low-hazard Level C or Level D, the SHSO may direct site health and safety efforts through the Radiation Safety Officer (RSO). The SHSO will be responsible for implementing the HASP. The SHSO has stop-work authority which can be executed upon his/her determination of an imminent safety hazard, emergency condition, or other potentially dangerous situations, such as detrimental weather conditions. Authorization to proceed with work will be issued by the SHSO in conjunction with the PM and RSO as needed after such action. The SHSO will initiate and execute contact with support facilities and personnel when this action is appropriate.

1.4.5 RADIATION SAFETY OFFICER

Ameriphysics' Radiation Safety Officer (RSO) is responsible for executive-level administration of the radiological control and safety program in accordance with prevailing procedures and industry practices. Specific responsibilities include the following:

- Establishing standards and guidelines for radiological operations;
- Scanning Site personnel entering/leaving OU-1 Exclusion Zone;
- Limiting occupational radiation exposures to levels that are as low as reasonably achievable (ALARA);

- Suspending any operation that presents a radiological or safety threat to employees, the environment, or the general public;
- Ensuring the quality of protective equipment for personnel and prescribing usage standards;
- Establishing procedures for radiological protection and monitoring; and
- Assuming overall responsibility for the radiation protection training program.

1.4.6 RADIOLOGICAL CONTROL SUPERVISOR

The RSO will assign a designated Radiation Control Supervisor (RCS) to the project. The RCS is responsible for field implementation of the radiological control and safety program at the project level. The RCS has the authority to and shall order any operations suspended when such operations present an imminent radiological or safety threat or hazard to employees, the environment, or the public. The RCS will be present onsite at any time work is conducted in Area 1 or Area 2. If the RCS must be away from the site, his or her responsibilities will be designated to an appropriately experienced Health-Physics Technician such that continuity of radiological supervision is maintained.

2.0 REQUEST FOR ANALYSES

Soil and groundwater samples will be collected for the analytes listed below and in greater detail in Table 2-1. A detailed discussion of the analyses narrative, the analytical test methods, and the detection limits are included in the QAPP.

Groundwater and soil samples may be analyzed for the following:

- Volatile Organic Compounds (VOCs) by Test Methods for Evaluating Solid Waste (SW-846) Method 8260B
- Semi-volatile organic compounds (SVOCs) by SW-846 Method 8270
- Total and dissolved metals by SW-846 Methods 6010 and 6020 and mercury by SW-846 Method 7470A
- Chloride, fluoride, and sulfate by SW-846 Method 9056
- Polychlorinated biphenyl (PCB)-1221 (Aroclor-1221) by SW-846 Method 8082
- Total Hardness by Standard Methods (SM) 2340B
- Total Dissolved Solids by SM 2540C
- Ferrous Iron by SM-3500-Fe-B
- Chemical Oxygen Demand by EPA Method 410.4
- Sulfide by SM 4500-S2-D
- Nitrogen, Nitrite plus Nitrate by EPA Method 353.2
- Nitrogen, Nitrite by EPA Method 353.2
- Nitrogen, Nitrate by EPA Method 353.2
- Phosphorus by EPA Method 365.1
- Nitrogen, Ammonia by SM 4500-NH3 G
- Total Organic Carbon by SM 5310C
- Radium-226 by EPA Method 903.1
- Radium-228 by EPA Method 904
- Isotopic Uranium (U-234, U-235, U-238) by *EML Procedures Manual*, HASL-300, 28th Edition (HASL) 300
- Isotopic Thorium (Th-228, Th-230, Th-232) by HASL 300
- Volatile Fatty Acids by Method AM23G

Soil samples will be analyzed for the following:

- Total Organic Carbon by Method Walkley-Black
- Radium-226 by EPA Method 903.1
- Radium-228 by EPA Method 904
- Isotopic Uranium (U-234, U-235, U-238) by EPA 6020
- Isotopic Thorium (Th-230, Th-232) by HASL 300
- Total metals (Barium, Calcium, Iron, Manganese, Magnesium, Potassium, and Sodium) by SW-846 Methods 6010
- Carbonate by SM 2320E
- Fluoride, Phosphate, and Sulfate by EPA Method 300.0
- Ferric Iron calculated between 6010 Iron and Ferrous Iron by SM 3500-Fe B
- Ferrous Iron by SM 3500-Fe B
- Sulfide by Method 6010/EPA-OW-OST 376.3
- U(VI) by SOP MCL-7737
- Cation Exchange Capacity (CEC) by EPA Method 9081
- pH by EPA Method 9045D
- X-Ray Diffraction by SOP MCL-7712
- Scanning Electron Microscope with Energy Dispersive x-ray Spectrometry (SEM/EDS)
- Percent Moisture by American Society of Testing and Materials (ASTM) D 2216-90
- Sequential extraction analysis

Solid extract samples will be analyzed for the following:

- Total Organic Carbon by SM 5310C
- Radium-226 by EPA Method 903.1
- Radium-228 by EPA Method 904 calculated following Sequential Extraction
- Total Radium calculated following Sequential Extraction
- Isotopic Thorium (Th-230, Th-232) by HASL 300

- Total Uranium calculated following Sequential Extraction
- Total metals (Barium calculated following Sequential Extraction Step 1, Calcium calculated following Sequential Extraction Step 1, Iron calculated following Sequential Extraction Step 1, Manganese calculated following Sequential Extraction Step 1, Magnesium, Potassium, and Sodium) by SW-846 Methods 6010
- Carbonate by SM 2320E
- Sulfate calculated based on Sequential Extraction Step 1
- pH by EPA Method 9045D

Outside of the analytical methods noted above, samples to be tested for fate and transport related parameters may be subject to the following procedures:

- X-Ray Diffraction (XRD)
- Further sequential extraction analysis
- SEM/EDS
- CEC

3.0 FIELD METHODS AND PROCEDURES

This section describes the procedures for sample collection, including sampling methods and equipment, sample preservation requirements, and field equipment decontamination procedures. Procedures for the collection of soil and water samples have been developed in accordance with industry standard practices and current relevant regulatory guidance. These procedures are intended to provide for the collection of consistent, comprehensive, and representative samples. The sample collection procedures described in this section will be used to ensure the quality of the data and support the investigation of COCs in groundwater, surface water, soils, and vapor. Due to the variety of different media anticipated to be sampled, the following sections detail the reasoning and procedures for collecting samples for OU-3.

3.1 FIELD EQUIPMENT

The FTL will be tasked with verifying that the equipment needed to complete the sampling activities outlined in this FSP will be inventoried, organized, and available at the Site prior to the arrival of the field team. The equipment lists for each field event will be compiled by the field task manager and reviewed during a pre-field readiness meeting. The field task manager will use the RI Work Plan, this FSP with the associated standard operating procedures (SOPs) and user manuals, the QAPP, and technical knowledge to assemble a list of sampling equipment and field analytical instruments. A list of equipment that is anticipated to be used on this project is shown for each task.

3.1.1 CALIBRATION OF FIELD EQUIPMENT

Prior to use, field instruments will be calibrated in accordance with the manufacturer's specifications and the attached Field Instrument Calibration SOP in Appendix A. Calibration will be repeated at prescribed intervals according to the manufacturer's requirements. The calibration frequency depends on the type and stability of equipment, the intended use of the equipment, and the recommendation of the manufacturer. Calibration information will be recorded in a field logbook or on field forms. An example of a field form is shown in Appendix B.

3.2 FIELD SCREENING

Field screening will be performed during investigation activities, which will include, but are not limited to drilling, fluid level gauging, well inspections, and groundwater monitoring. Various methods of field screening will be used and are discussed below.

3.2.1 PHOTOIONIZATION DETECTOR

As indicated in the following sections for collection of surface and subsurface soil samples, screening of the headspace of soil samples will be conducted with a photoionization detector (PID) equipped with 10.6 electronvolt (eV) lamp. The PID measures ionizable particles and is calibrated to an isobutylene standard to approximate petroleum hydrocarbons. The compounds measured with a 10.6eV lamp PID include aromatics, ketones and aldehydes, amines and amides, chlorinated hydrocarbons, sulfur compounds, unsaturated hydrocarbons, alcohols, and saturated hydrocarbons.

An aliquot of soil will be collected directly from the soil core and placed in a small ziploc-style bag. The bag will be filled half-full with soil and sealed. The soil particles will be manually broken within the bag and the bag will be allowed to equilibrate for several minutes out of direct sunlight in a 60-80 degrees Fahrenheit (°F) temperature environment (i.e. automobile or field office location). The PID will then be inserted into the bag without opening the bag significantly to collect vapor measurements. The PID results, in parts-per-million, will be recorded on field forms for each sample depth and location.

3.2.1.1 EQUIPMENT

PID equipment includes:

- MiniRae PID, or equivalent
- Regulator and calibration gas (isobutylene)
- Tubing and/or tedlar bag
- Field forms and logbook

3.2.1.2 DECONTAMINATION

The PID requires no decontamination in between sample points.

3.2.1.3 QUALITY CONTROL

Field documentation will be submitted to the FTL and reviewed by the SQCO. Original field forms will be stored in the project files.

3.2.1.4 DOCUMENTATION

Data collected will be recorded on the appropriate field forms and logbooks per the SOPs included in Appendix A and the field forms included in Appendix B.

3.2.2 MULTI-GAS METER

A portable multi-gas meter, such as a MultiRae, will be utilized at the Site for atmospheric monitoring. Portable air monitors are hand-held instruments that measure the concentration of combustible or toxic gases and vapors as well as oxygen concentrations. The instrument sounds an audible alarm when concentrations exceed preset limits. The meter will be configured to report hydrogen sulfide (H_2S), methane (CH_4) percentage (%), the lower explosive limit (LEL), and the percent oxygen (O_2 %). Readings will be collected while performing on-Site work every 2-hours, at a minimum, and recorded on the field form (Appendix B).

Routine periodic calibration along with bump tests will be conducted to verify that the monitoring equipment is operating within its acceptable calibration settings. The multi-gas meter will be inspected and calibrated according to the manufacture's recommendations. Calibration will be documented on field forms (Appendix B) and retained in the project file.

3.2.2.1 EQUIPMENT

Equipment used for atmospheric testing includes:

- MultiRae, or equivalent multi-gas meter
- Regulator and calibration gas (as per meter requirements)
- Tubing and/or tedlar bag
- Field forms and logbook

3.2.2.2 DECONTAMINATION

The multi-gas meter requires no decontamination in between sample points.

3.2.2.3 QUALITY CONTROL

Field documentation will be submitted to the field task leader and reviewed by the SQCO. Original field forms will be stored in the project files.

3.2.2.4 DOCUMENTATION

Data collected will be recorded on the appropriate field forms and logbooks per the SOPs included in Appendix A and the field forms included in Appendix B.

3.2.3 MICROR DETECTOR AND DUAL PHOSPHOR ALPHA BETA SCINTILLATOR

The recovered cores will be field screened using hand-held scintillators, as detailed in the Field Measurement of Residual Radiation SOP included in Appendix A and per the User Manuals included in Appendix C.

The MicroR instrument (e.g. Ludlum Model 19 Survey Meter) is a sodium iodide scintillation instrument that is used to measure low levels of gamma radiation that reports all gamma emissions. The detector has a speaker that provides an audible measure of the radiation emitted. The rate at which the clicks occur, allows real time monitoring of the strength of the radiation sources. Readout is generally in terms of microroentgens per hour (µR/hr).

A Dual Phosphor Alpha/Beta Scintillation detector (e.g. Ludlum Model 43-93 detector w/ Ludlum Model 2360 (or Equivalent)) will be primarily used to detect alpha/beta emissions. The instrument has a speaker, the pulses also give an audible click. The readout is displayed are counts per minute (cpm). These Alpha/beta detectors are commonly used with a variety of different hand-held scalers/rate meters for contamination measurements.

3.2.3.1 EQUIPMENT

Equipment used to measure radiation includes:

- MicroR and Dual Phosphor Alpha/Beta Scintillation detectors
- Field forms and logbook

3.2.3.2 DECONTAMINATION

The detector and scintillator do not require decontamination in between sample points.

3.2.3.3 QUALITY CONTROL

Field documentation will be submitted to the field task leader and reviewed by the SQCO. Original field forms will be stored in the project files.

3.2.3.4 DOCUMENTATION

Data collected will be recorded on the appropriate field forms and logbooks per the SOP included in Appendix A and the field forms included in Appendix B.

3.3 SITE RECONNAISSANCE

Site reconnaissance will be conducted to document the current conditions of the Site and proposed drilling locations. Respondents will request access agreements with AAA Trailers, Earth City, the City of Bridgeton, and Earth City Levee District for off-Site monitoring well locations. Field personnel and subcontractors will inspect and photo-document the Site and proposed monitoring well locations to identify any potential issues with access or utilities. A handheld global positioning system (GPS) will be used to survey proposed locations.

3.3.1 EQUIPMENT

Equipment used for site reconnaissance includes:

- Field forms and logbook
- Camera
- GPS

3.3.2 DECONTAMINATION

None required.

3.3.3 QUALITY CONTROL

Field documentation will be submitted to the field task leader and reviewed by the SQCO. Original field forms will be stored in the project files.

3.3.4 DOCUMENTATION

Data collected will be recorded on the appropriate field forms and logbooks per the SOPs included in Appendix A and the field forms included in Appendix B.

3.4 ECOLOGICAL SURVEY

Ecological risk assessment (ERA) consists of three phases, including: (1) problem formulation, (2) analysis, and (3) risk characterization. This FSP describes the steps that will be taken to perform Phase 1. Data collected during Phase 1 will assist with the design and implementation of Phase 2 and 3 if necessary. Phase 1 will include a desktop assessment (DA) to characterize current habitat types, overall quality, and regional/landscape position by evaluating the best publicly available information at the regional, local, and Site-specific scale. The DA will identify the anticipated ecological communities and habitat types, and biota likely to occur within those habitats. In accordance with the RI Objectives, potential exposure of ecological receptors to groundwater that is connected to surface water bodies within and/or adjacent to the Site will be the primary emphasis of Phase 1 of the ERA. As such, areas demonstrating potential connectivity to groundwater, including surface water bodies (i.e. streams, rivers, and ponds) and wetlands, will be the primary focus during Phase 1. Biota identified in these areas who may come in contact with surface expressed groundwater (i.e. potentially complete exposure pathway) will be considered potential ecological receptors that may be considered during subsequent ERA Phases, as necessary.

Following the desktop assessment (DA), an ecological survey of the flora and fauna on-Site and near-Site will be conducted by a biologist. The survey will evaluate the findings of the DA, by reviewing the existing vegetation communities, the nature, location, and extent of aquatic resources described above, and the identification of potential ecological receptors relative to potential exposure to groundwater and/or groundwater/surface water interface. Data collection will include photographs, field notes, and GPS coordinates delineating notable points or boundaries. If subsequent ERA Phases are necessary, and data gaps resulting from Phase 1 prevent adequate analysis and risk characterization, additional Site-specific information may be obtained through the design and implementation of potential targeted sampling events. (e.g. vegetation surveys, wildlife inventories, characterization of benthic macroinvertebrate assemblages, plant or animal tissue sampling, etc.).

3.4.1 EQUIPMENT

Equipment used during the ecological survey includes:

- Field forms and logbook
- Camera
- GPS

3.4.2 DECONTAMINATION

None required.

3.4.3 QUALITY CONTROL

Field documentation will be submitted to the field task leader and reviewed by the SQCO. Original field forms will be stored in the project files.

3.4.4 DOCUMENTATION

Data collected will be recorded within the field logbooks.

3.5 WELL INVENTORY AND WELL REPAIR

A full monitoring well inventory will be conducted during Phase I Site Characterization to review the existing monitoring well network and, as needed, re-survey existing well locations, as shown on Figure 3-1. The inventory will document each well's current condition and will include surveying and recording construction details on the existing and new wells. This will be compared to the existing well construction summary table (Table 3-1) to evaluate monitoring well integrity. Nearby residential wells, industrial wells, municipal wells, and water intake structures will also be located during the well inventory to identify any potential receptors. Locations will be surveyed using a handheld GPS, recorded on field forms, and photo-documented.

3.5.1 EQUIPMENT

Equipment utilized during well inventory and repair includes:

- Field forms and logbook
- Camera
- GPS
- Well keys
- Water level indicator

3.5.2 DECONTAMINATION

Water level sounding equipment will be decontaminated before and after use in each well as follows:

1. Wash with detergent and water solution
2. Rinse with distilled water

3.5.3 QUALITY CONTROL

Field documentation will be submitted to the field task leader and reviewed by the SQCO. Original field forms will be stored in the project files.

3.5.4 DOCUMENTATION

Data collected will be recorded on the appropriate field forms and logbooks included in Appendix B.

3.6 DRILLING, SOIL/BEDROCK SAMPLING, AND AQUIFER TESTING

The following section describes the methods and procedures for drilling, sampling and geologic logging of the alluvium and bedrock at new monitoring well locations, and aquifer testing. Samples will be collected from eleven (11) borings advanced adjacent to or for installation of new monitoring wells. The borings will be advanced to further define the stratigraphy of the site and identify transmissive units in alluvium and bedrock for monitoring well completion. Approximate locations are shown on Figures 3-2, 3-3, and 3-4. The proposed monitoring well network and boring numbers with proposed sampling depths are presented in Table 3-2 and Table 3-3, respectively.

3.6.1 DRILLING AND SAMPLING PROCEDURES

Borings will be advanced using sonic drilling techniques, as per the selected drillers' standard operating procedures. The deepest borehole for each proposed well cluster will be advanced to total depth first at each location. Boreholes will be continuous cored, logged by a field geologist, field screened, sampled, and logged using geophysical techniques. Borehole advancement will be performed by a MDNR certified well installation contractor and drilling company, with the appropriate OSHA required asbestos training, as required for on-site well boring advancement. The sonic method is a type of rotary vibratory drilling that includes rotary motion and oscillation, which causes a high frequency force to be superimposed on the drill string. The sonic technique involves advancing a 6-inch (in) core barrel and an 8-inch override casing to prevent the borehole from collapse when the core is retrieved. The core barrel is advanced at 10-foot intervals telescoping from below the override casing. The technique utilizes the rotating and vibrating core barrel and override casing simultaneously to drill a clean borehole minimizing the amount of drill cuttings. The diameter of the borehole and override casing will be a minimum of 4 inches greater than the diameter of the installed well casing and screen, thus a minimum of 6-inch core barrel and 8-inch override casing size will be used. The addition of potable water during sonic drilling will be kept to a minimum during the drilling. A petroleum hydrocarbon-free and VOC-free thread lubricant may be used on the core and casing joints.

Bedrock coring will be conducted after alluvium has been drilled through to rock by first drilling and setting 6-inch, Schedule 80 conductor casing at the bedrock contact. The bedrock coring will be performed using a wireline coring system with a diamond impregnated coring bit. The core barrel assembly consists of core barrel assembly and an overshot component. The core barrel assembly will be a split barrel, 5- to 10- feet in length, 94-mm ID, advanced in 5- to 10-foot intervals with rotation from the drill head and the borehole cleared using an air compressor. Upon completion of the 5- to 10-foot interval the wireline attached to the overshot assembly will be used to retrieve the core barrel assembly. This process will continue until between approximately 100 to 200 feet of core is retrieved. Table 3-3 details the total depth and rock coring length.

Recovered cores will be inspected by a field geologist. Alluvial descriptions will include the Unified Soil Classification System (USCS), color, grain size, stiffness or density, moisture content, sorting, angularity, mineralogy, and plasticity as applicable. Bedrock descriptions will include weathering, bedding, color, grain/crystal size, strength, lithologic description, geologic formation, and geologic formation. Bedrock borehole logs will also include core recovery, RQD, fractures per foot, weathering index, strength index, and discontinuity data. Bedrock cores will be placed in core boxes, labeled, and stored; either on-site within Conex trailers for radiologically impacted soils, or at a designated off-site location for those soils that are not impacted, for future reference as needed. Soils will also be field screened with a PID for VOCs and for radioactivity with a MicroR Detector and Dual Phosphor Alpha Beta Scintillator as discussed in Section 3.2.

A minimum of four (4) soil samples from the alluvial deposits at each boring location will be sent to the laboratory for geotechnical testing. Samples may be tested for grain size distribution by sieve and hydrometer methods, and also tested for Atterberg Limits (if applicable).

3.6.1.1 EQUIPMENT

Equipment and materials used during soil boring and geotechnical sampling activities will include:

1. Fully-equipped drill rigs capable of:
    a. Advancing soil borings via rotosonic methods, using a Prosonic, PS 600T drill rig, or equivalent to an approximate 175-foot depth typically; up to a maximum depth of 300 feet bgs, as determined by the FTL, dependent upon the geologic strata encountered.
    b. Performing continuous sampling, ability to Shelby tubes for undisturbed samples.
    c. Rock coring to depths of up to 200 feet bgs, NQ™ or HQ™ core barrel size.
    d. Completing monitoring well installation.
2. Fiberglass tape of adequate length to measure depth of boring.

3. Electric water level indicator of adequate length (300 feet).
4. Generator, steam cleaner, and related equipment.
5. Munsell Soil Color Chart.
6. Field logs and data forms.
7. Field notebook.
8. Indelible marking pen and black ink pen.
9. Sample jars (as listed in Table 2-1), labels, tags, and forms.
10. Personal PPE

3.6.1.2 DECONTAMINATION

The sampling apparatus will be decontaminated using detergent and steam between samples to prevent cross-contamination.

3.6.1.3 QUALITY CONTROL

Field documentation will be submitted to the field task leader and reviewed by the SQCO. Original field forms will be stored in the project files.

3.6.1.4 DOCUMENTATION

Data collected will be recorded on the appropriate field forms and logbooks per the SOPs included in Appendix A and the field forms included in Appendix B.

3.6.2 ALLUVIUM AND BEDROCK AQUIFER MATRIX SAMPLING

Alluvium (unconsolidated) and bedrock samples will be collected from the water-bearing zones in the pilot boreholes only. The sample intervals will be selected by the field geologist based upon the relative depths shown in Table 3-3, significant changes in stratigraphy, or other significant field observations. Samples will be selected from those zones proposed for monitoring screened intervals and will include alluvial materials and limestone bedrock. A total of up to four (4) samples from each pilot borehole will be selected for analysis; three (3) from alluvium and one (1) bedrock sample. Note that the alluvium samples will be collected from the water table depth, medial depth, and in the basal unit above the top of bedrock. Samples will be logged for geologic description and photographed. Soils from the intervals selected by the field geologist will be placed in either a 1-gallon heat seal bag that is vacuumed sealed, and the laboratory provided sample jar, and properly labeled. Sample nomenclature will consist of the borehole identification and the depth at which the sample was collected (i.e. PZ103SS (0-5')). Once the soils are bagged, they will be placed within an opaque cooler with dry ice to flash freeze, per MCLI's SOP, or within an opaque cooler with ice to cool, per Pace's SOP.

The soil samples will be analyzed for total metals, radionuclides, mineralogy, cation exchange capacity, total organic carbon content, acid volatile sulfides (AVS)/simultaneously extracted metals (SEM), and sequential extraction. The samples will be sent to MCLI except for TOC samples (from the same intervals) which will be sent to Pace. Samples that require dry ice (solid samples of soil/bedrock for analyses conducted by MCLI) will be shipped per the Packaging and Shipping of DOT/IATA Hazardous Substances SOP. A HAZMAT Employee will be utilized as the authorized shipper.

3.6.2.1 EQUIPMENT

Equipment used for drilling sample collection includes:

- Field forms and logbook
- Well keys
- Trash bags (i.e. lawn and leaf or contractor bags)
- 1-gallon heat seal bags (used for vacuum sealing soil) and labels
- Vacuum sealer
- Coolers and dry ice to freeze samples
- Coolers and bagged ice to cool samples
- CoC and custody seals
- Personal PPE

3.6.2.2 DECONTAMINATION

The sampling apparatus will be decontaminated using detergent and steam between samples to prevent cross-contamination.

3.6.2.3 QUALITY CONTROL

Field documentation will be submitted to the FTL and reviewed by the SQCO. Original field forms will be stored in the project files.

3.6.2.4 DOCUMENTATION

Data collected will be recorded on the appropriate field forms and logbooks per the SOPs included in Appendix A and the field forms included in Appendix B.

3.6.3 BOREHOLE GEOPHYSICAL LOGGING

Downhole geophysical logging will be conducted after the borehole is advanced to total depth in the cased portion of the alluvium and the open borehole in bedrock to evaluate well placement and hydrogeologic properties. The downhole geophysical work will be subcontracted to a qualified firm. Geophysical tools may include, but are not limited to, an acoustic televiewer, spontaneous potential (SP)/resistivity, induction/conductivity, heat pulse flow meter, fluid temperature and resistivity, gamma-gamma-density, natural gamma, and caliper as applicable for open and cased holes.

3.6.3.1 EQUIPMENT

Acoustic Televiewer. The acoustic televiewer is used to collect a continuous image of the borehole wall. The image can be analyzed to determine lithology, characterize voids (or core loss zones), and calculate strike and dip of planar features that intersect the boring such as bedding planes, fractures, joints, and foliation. The images are constructed by recording the arrival times and amplitudes of ultrasonic pulses generated from a source located in the borehole. The source is oriented towards the borehole wall and spinning 360 degrees. The borehole must be filled with water or drilling fluid and the hole should be uncased. However, some material behind casing may be imaged by analyzing secondary arrivals (echo from the casing).

Spontaneous Potential (SP)/Resistivity. The SP/resistivity probe contains electrodes at various separations, each producing a different lateral distance for penetration of the electric field into the formation. In general, the borehole resistivity probes respond to the conductivity/resistivity variations within geologic materials that are often related to mineralogy, water content, and porosity and are used to resolve conductive materials such as clay and shale within resistive units such as dense limestone or dry, non-cohesive soils. SP is reported in units of milliVolts (mV) and resistivity is reported in units of ohm-meters (ohm-m). The cased borehole in alluvium or open borehole in rock must be filled with water or drilling fluid.

Induction/Conductivity. Electromagnetic (EM) induction logs include induction resistivity and formation conductivity, both of which are based on porosity, hydraulic conductivity, water content, total dissolved solids within the interstitial water, and clay content. Data are collected by generating a primary field within the measurement volume. The primary field induces a secondary magnetic field. The strength of the secondary field is related to the formation conductivity. The formation conductivity is reported in units of milliSiemens per meter (mS/m) and is used to resolve details within conductive materials such as clay and shale. The induction resistivity is reported in units of ohm-meters (ohm-m) and is used to resolve details within resistive units such as dense limestone or dry, non-cohesive soils. Therefore, the formation conductivity is good for detecting clay-rich zones within epikarst and the induction resistivity is useful for detecting top of competent bedrock.

Heat Pulse Flow Meter. The heat pulse flow meter utilizes a pulse of heat to measure the time required for water at a specific location in the water column, to flow through a known area. The test can be conducted under both static and pumping conditions.

Fluid Temperature and Resistivity. Fluid temperature logs and resistivity logs provide variations in temperature and electrical resistivity of the borehole fluid with depth, respectively. Fluid resistivity changes reflect changes in the dissolved-solids concentration of the water. The temperature and resistivity variations assist in determining water-producing and water-receiving zones in addition to zones of vertical borehole flow. Vertical borehole flow is characterized by zones for which the borehole fluid temperature and resistivity have little or no vertical variation.

Gamma-Gamma Density. Gamma-gamma density logging involves measuring the intensity of radiation from a down hole source after the radiation has attenuated due to back-scattering off materials in and around the bore hole. The attenuation of the back-scattered radiation is attributed to the bulk density of the surrounding geologic materials. Therefore, the gamma-gamma log can assist in assigning lithologic variations with depth.

Natural Gamma. Natural gamma logging involves measuring the natural gamma radiation emitted by material surrounding the borehole. The primary radioactive elements within geologic materials are Potassium-40, Thorium-232, Uranium-238, and the daughter products in their decay series. These elements typically reside in clays and shales and are not prevalent in clean sands and limestone. Therefore, natural gamma data is useful for identifying clay-rich zones or shale partings within limestone. Natural gamma data represent total gamma ray emissions in units of counts per second (cps).

Caliper. The borehole diameter is logged using a 3-arm caliper probe. These data also provide generalized information regarding hole condition such as the presence of voids, vugs, or solution-widened joints or bedding planes.

3.6.3.2 DECONTAMINATION

The downhole instruments will be decontaminated using detergent and steam between borehole locations to prevent cross-contamination.

3.6.3.3 QUALITY CONTROL

Field documentation will be submitted to the FTL and reviewed by the SQCO. Original field forms will be stored in the project files.

3.6.3.4 DOCUMENTATION

Data collected will be recorded on the appropriate field forms and logbooks. The geophysics vendor will provide the output from the various downhole equipment in real time and as part of a report generated documenting the results of the geophysical investigation.

3.6.4 PACKER TESTING

Packer testing will be conducted to evaluate aquifer properties of the bedrock and identify higher transmissivity zones for screen placement. Constant head injection packer tests will be conducted in all open bedrock holes on select intervals identified during continuous coring based on based on fracture frequency and porosity, and intervals identified during borehole geophysical logging. Double (straddle) and single downhole packer assemblies will be lowered to the desired depth using the sonic drilling rig based on the presence or absence of fractures and the porosity. Straddle packer tests will generally isolate 5 to 10 feet of borehole length using pneumatic straddle packers.

3.6.4.1 EQUIPMENT

Downhole packer testing equipment will be supplied by the selected drilling contractor and connected via the drilling rods to a surface assembly consisting of a variable rate water pump, a flow meter manifold, a pressure gauge, valving, and hoses. This is the typical set-up for packer testing in open boreholes in rock. Step tests will be conducted where possible.

The specific packer testing equipment will be provided by the selected drilling contractor. The drilling contractor will provide SOPs after the contract is awarded.

3.6.4.2 DECONTAMINATION

The downhole instruments will be decontaminated using detergent and steam between samples to prevent cross-contamination.

3.6.4.3 QUALITY CONTROL

Field documentation will be submitted to the FTL and reviewed by the SQCO. Original field forms will be stored in the project files.

3.6.4.4 DOCUMENTATION

Data collected will be recorded on the appropriate field forms and logbooks.

3.6.5 MONITORING WELL INSTALLATION

Results of continuous coring, geophysical testing, and packer testing (conducted in bedrock borings per Section 3.6.4) will be used to select screened intervals of the 11 new monitoring well clusters (up to 44 new wells total), which will generally target more transmissive zones. At a minimum each nest will include a shallow alluvial well, an intermediate alluvial well, and deep alluvial well if encountered; and one or two bedrock wells depending upon the formation present at that location. The first deep borehole installed at each location will be completed as a bedrock monitoring well in the most transmissive zone identified during packer testing, and will be installed following the SOP included in Appendix A. Example monitoring well construction is shown on Figure 3-5.

Bedrock monitoring well installation will follow MDNR procedures with additional precautions taken to prevent vertical migration of groundwater from the alluvial deposits above. Wells advanced beyond the bedrock/alluvium interface will be double-cased to minimize the chance of downward migration of potentially impacted groundwater of the boreholes advanced into bedrock. The boring will be over-drilled through the alluvium, into competent bedrock. An outer casing will then be installed and seated approximately 1-2 feet below fractures into the bedrock. The grout seal will be delivered via tremie from approximately 1-2 feet below fractures in the bedrock surface to 2 feet above the top of bedrock inside the outer casing, and to the surface outside the outer casing, to minimize the chance of alluvial formation groundwater transport pathways. An inner boring will then be advanced through the outer casing to construct the bedrock well.

As detailed in the MDNR Water Well Construction Code, monitoring wells will generally be constructed of 2-inch inner diameter (ID), Schedule 80 flush threaded polyvinyl chloride (PVC) pipe with 0.005-inch factory slotted Schedule 80 PVC screen. The screen lengths for each well will be a minimum of 10 feet to intersect the water bearing zone, as determined in the field. A flush threaded, Schedule 80 PVC end cap will be placed on the bottom of the monitoring well screen. A Schedule 80, flush threaded, PVC riser will be placed above the screen to a height of approximately 3 feet above grade. The riser will be cut down during installation of the flush-mount well box, if necessary. Until the pump is installed, a locking waterproof cap (J-plug) will seal each monitoring well.

Filter pack material surrounding the screen will generally consist of 40-60 or equivalent mesh silica sand, depending upon market availability. The top of the filter pack will extend at least 2 feet above the top of the well screen. The filter pack will be capped with approximately 2 feet of bentonite (chips for a dry hole or coated pellets if constructed in water) used to form a hydraulic seal. Bentonite chips, if used, will be hydrated with potable water and allowed to rest a minimum of 1 hour before applying grout to the annular space. The surface of the bentonite seal will be measured with a clean measuring tape to document the thickness of the seal. The remaining annulus above the seal will be filled with cement-bentonite grout; a slurry of cement, bentonite, and potable water. The amount of bentonite added will not exceed 8% bentonite per dry weight of cement. The volume of additional water used in preparing these slurries will be limited to three quarters of a gallon per 94-pound sack of cement for each 1% of bentonite added. The cement bentonite grout will be placed in lifts to the surface. The grout will be tremie-piped into the annular space to within approximately 2 to 5 feet of ground surface. After the grout has been allowed to settle, additional grout will be placed to the surface. The remaining annular space will be sealed with concrete during surface completion, as described below.

It is anticipated that many of the monitoring wells clusters will be installed within public right-of-way. Well clusters may be completed as nested wells based on spatial limitations. Shallow, intermediate, and deep alluvial/bedrock wells will be either be nested within a 12-inch borehole or installed as individual discreet wells within a cluster.

Most off-site wells will be completed with a flush-mounted, watertight well box with a cover set in a concrete apron. A bolted, flush-mount cover will be installed to minimize the potential for entry of fluids from the ground surface. The well box will be placed above the existing ground surface with the concrete apron sloping from the well box for efficient drainage. The well box for monitoring wells that may be installed in sidewalks, street or drive/parking areas subject to snow removal shall be flush with or slightly below (up to ½ inch) the ground surface, depending on City of Bridgeton or Earth City requirements. Monitoring wells will be identified with the well number marked on the well cover, when possible, and metal labels of the well ID will also be included in the vault. In areas not subject to vehicle or pedestrian traffic, above-ground well protectors may be used.

The well completions on-Site will be constructed with a target riser height of 3 feet. After well construction is complete, a protective outer casing will be added. Protective outer metal casings will include a 6-inch diameter, or 6-inch square well protective casing buried at least approximately 18 inches into the ground with the top of the protective casing located approximately 36 inches above the top of the cement pad. Accurate placement of the protective casing is critical to ensure ease of access and compatibility with sampling equipment. The steel casings will be equipped with a locking cap and rust resistant locks. All well locks will be keyed alike. Surface well pads will be constructed of concrete, 4 inches thick (approximately 2 inches below ground surface and 2 inches above ground surface), with a surface dimension of 3 by 3 feet. The concrete pads will be sloped slightly away from the protective outer metal casings to the edge of the pad to drain precipitation. Well pads will be oriented with one edge parallel with surrounding roads or fences, or with one edge of the pad trending north. If vehicle traffic may be nearby, bollards will be used to protect above-ground well casings.

Once wells are completed, and after slug tests have been conducted, a dedicated bladder pump will be installed in each of the new wells. Each pump will be specifically configured for each well, based on the total depth and the depth to static groundwater. The bladder pumps will be purchased from the same manufacturer (similar model) as those used in the Bridgeton Landfill monitoring well network.

3.6.5.1 EQUIPMENT

Equipment to be used during monitoring well installation activities will include, but are not limited to:

1. A fully equipped drill rig (s) with the capability of:
   - Advancing soil borings via rotosonic methods, using a Prosonic, PS 600T drill rig, or equivalent to an approximate 300-foot depth. The rig should be capable of driving 12-inch steel casing to an approximate 150-foot depth.
   - Completing monitoring well installation.
   - Facilitating geophysical logging.
2. Fiberglass tape of adequate length to measure the bottom of the well.
3. Electric water level indicator of adequate length (300 feet).
4. Field notebook and field documentation forms.
5. Tap water.
6. Liquinox/Alconox detergent, distilled water, and 5-gallon buckets.
7. Generator, steam cleaner, and related equipment.
8. Camera.

9. Well construction materials to be supplied by drilling subcontractor include:

- 2-inch (I.D.), flush-threaded 0.005-inch slot Schedule 80 PVC screen.
- 2-inch (I.D.), flush-threaded Schedule 80 PVC riser pipe.
- 2-inch (I.D.), flush-threaded PVC cap and bottom plug.
- 8-inch (I.D.) metal casing, 50 ft lengths.
- Rubber 0-rings or Teflon-thread wrap tape.
- Neat cement, cement-bentonite, or Volclay grout.
- Bentonite pellets.
- Washed, well-sorted 40-60 silica sand.
- 6-inch nominal diameter steel protective casing with locking cover.
- Keyed-alike locks.

3.6.5.2 DECONTAMINATION

Drilling and monitoring well installation equipment will be decontaminated upon arrival onsite and between well locations. Decontamination of the rig, vehicles, and other equipment will be accomplished with a high-pressure steam cleaning unit within a designated area onsite. Decontamination of handheld well installation equipment will consist of a soap and water wash and a distilled water rinse. Decontamination water generated during well installation will be collected and either stored on-site within a temporary tank pending analytical data or transferred to the on-site leachate water treatment system.

PVC risers, well screens and end caps will be contained within the manufacturers' packaging until use. Workers shall wear clean gloves when handling the riser and well screen.

3.6.5.3 QUALITY CONTROL

Field documentation will be submitted to the FTL and reviewed by the SQCO. Original field forms will be stored in the project files.

3.6.5.4 DOCUMENTATION

Data collected will be recorded on the appropriate field forms and logbooks per the SOPs included in Appendix A and the field forms included in Appendix B.

3.6.6 MONITORING WELL DEVELOPMENT

The objectives of the well development are to:

- Ensure that groundwater enters the well screen freely, thus yielding a representative groundwater sample and water level measurements.
- Remove water that may have been introduced during drilling and well installation.
- Remove very fine-grained sediment in the filter pack to minimize groundwater sample turbidity and silting of the well.
- Maximize the efficiency of the filter pack.

The new monitoring wells will be developed, no sooner than 48 hours after grouting is completed, by mechanically surging the well, followed by pumping, as detailed in the EPA SOP included in Appendix A. At least 10 well casing volumes will be removed from the new wells during development.

Casing volumes will be calculated based on total well depth, standing water level, and casing diameter. One casing volume will be calculated as:

$$\mathbf{V = \pi d^2\ h / 77.01}$$

where: **V** is the volume of one well casing of water ($1ft^3 = 7.48$ gallons);
d is the inner diameter of the well casing (in inches);
h is the total depth of water in the well (in feet).

Surging will consist of forcing water into and out of the formation using a surge block. The surging action will be relatively gentle to avoid slumping formation material into the screen. Surging will be concentrated over 5-foot intervals, starting at the top of the screen, to avoid sand locking the surge block.

Immediately following surging activities, groundwater and any sediment in the bottom of the well will be evacuated using a bailer or pump. The volume evacuated from each well, and physical characteristics of the purge water (color, relative turbidity, sediments, etc.) will be recorded during regular intervals during development activities. If natural recharge rates are adequate, development activities will continue until the extracted water is visibly free of sediment, or until parameters (pH, temperature, and turbidity) are stable. If natural recharge rates are insufficient to attain the well development objectives, the rational for discontinuing well development activities will be documented. The addition of water to aid in well development is not anticipated but may be necessary if water is limited. If water should need to be added, potable water will be used. Water levels and total depths will be measured before and after well development and documented on the monitoring well development form.

During the well inventory, should existing wells that will be included in the proposed monitoring well network be found to require re-development due to sediment collection in the bottom of the well, these wells will be re-developed following the same procedures as discussed above. Dedicated pumps will be removed and stored within clean plastic sheeting to inhibit contamination. Once the well has been re-developed, the dedicated pump will be placed back in the well.

3.6.6.1 EQUIPMENT

Equipment used during monitoring well development includes:

- Electric water level indicator of adequate length (300 feet)
- Submersible pump, tubing, controller, and generator
- Surge block and wireline
- Downrigger
- Water quality meter
- Field notebook and field documentation forms.
- Distilled water
- Alconox/Liquinox detergent, 5-gallon buckets
- Generator, steam cleaner, and related equipment.
- Personal PPE

3.6.6.2 DECONTAMINATION

Decontamination of well development equipment will consist of: soap and water wash, then a rinse with distilled water. Water removed from the wells during development, will be system. collected and either stored on-site within a temporary tank pending analytical data or transferred to the on-site leachate water treatment system.

3.6.6.3 QUALITY CONTROL

Field documentation will be submitted to the field task leader and reviewed by the SQCO. Original field forms will be stored in the project files.

3.6.6.4 DOCUMENTATION

Data collected will be recorded on the appropriate field forms and logbooks per the SOPs included in Appendix A and the field forms included in Appendix B.

3.6.7 AQUIFER TESTING

Aquifer testing will be conducted on new and existing inactive monitoring wells not previously tested after monitoring wells are developed to determine the hydraulic conductivity of the formation materials near each well. Aquifer testing will be conducted using pneumatic slug testing where possible and traditional slug testing if the screened interval intersects the water table, per the SOPs included in Appendix A and the user manuals included in Appendix C. Rising head tests will be performed on all monitoring wells. The procedure for conducting pneumatic slug tests includes: 1) deploy water level transducer in the well and fix an air tight cap with a pressure relief valve to the top of the well; 2) use an air pump to increase pressure inside the well casing causing the water level to decrease; and 3) then open the valve allowing the water level to rise. Two rising head tests will be conducted for each well. Aquifer tests will be evaluated in AQTESOLV software; the Bouwer-Rice method will be used to calculate hydraulic conductivity for each well.

3.6.7.1 EQUIPMENT

Equipment used for aquifer testing includes:

- Tape measure (subdivided into tenths of feet)
- Water-pressure transducer, Solnist Levelogger 3001 or equivalent
- Electric water-level indicator
- Weighted tapes

- Steel tape (subdivided into tenths of feet)
- Electronic data-logger (if the transducer method is used)
- Stainless steel or PVC slug of a known volume, for traditional slug testing
- Pneumatic slug assembly, valve assembly with a gauge, compression coupling assembly, pipe clamps, hand pump, screwdriver, and Teflon tape
- Watch or stopwatch with second hand
- Semi-log graph paper (if required)
- Waterproof ink pen and logbook
- Thermometer
- Appropriate references and calculator
- Electrical duct tape
- Compact portable computer or equivalent with applicable software (transducer-specific or Excel) installed on the hard disk
- Field notebook and field documentation forms.
- Distilled water
- Alconox/Liquinox detergent and 5-gallon buckets
- Personal PPE

3.6.7.2 DECONTAMINATION

Decontamination of slug testing equipment will consist of: soap and water wash, and a rinse with distilled water. Pressure transducers will be decontaminated using a distilled water rise only. Wastewater fluids generated decontamination efforts will be collected and either stored on-site within a temporary tank pending analytical data or transferred to the on-site leachate water treatment system.

3.6.7.3 QUALITY CONTROL

Field documentation will be submitted to the field task leader and reviewed by the SQCO. Original field forms will be stored in the project files.

3.6.7.4 DOCUMENTATION

Data collected will be recorded on the appropriate field forms and logbooks per the SOPs included in Appendix A, the user manuals included in Appendix C, and the field forms included in Appendix B.

3.7 GROUNDWATER SAMPLING

This section presents the groundwater sample collection, handling, and reporting procedures when conducting groundwater sampling monitoring events. Quarterly groundwater monitoring is proposed for eight (8) consecutive quarters until the investigation is complete and, as warranted, until a remedial action is selected and implemented at the Site. A total of 132 wells will be sampled for 8 quarters during the Phase I Characterization. The wells are listed on Table 3-1 and shown on Figure 3-6.

The groundwater monitoring program will measure for radiological and non-radiological contaminants that have historically been detected at the Site (e.g., dissolved radium and total radium, benzene, chlorobenzene, dissolved lead, total lead, dissolved arsenic, and total arsenic), geochemical indicators (e.g., redox couples – Fe, Mn, N, S species, dissolved oxygen and ORP), major ion suite, landfill leachate indicators (e.g., bromide, iodide, tritium, and select human-waste indicators), and stable isotopes (e.g., oxygen, hydrogen, carbon, sulfur, strontium, and lead). Additionally, other broader indicators are needed to assess the site-specific natural attenuation processes (e.g., biodegradation, dispersion, dilution, sorption, transformation, radioactive decay, volatilization, etc.).

3.7.1 WATER LEVEL MEASUREMENTS

Depth to static groundwater will be measured monthly, within a 48-hour timeframe, at each groundwater monitoring well in the network for a period of 24 consecutive months, as well as prior to purging for groundwater sampling events, as per the fluid level measurement SOPs included in Appendix A. An electronic sounder, accurate to the nearest +/- 0.01 feet, will be used to measure depth to water in each well. When using an electronic sounder, the probe is lowered down the casing to the top of the water column. The graduated markings on the probe wire or tape are used to measure the depth to water from the surveyed point on the rim of the well casing. Typically, the measuring device emits a constant tone when the probe is submerged in standing water and most electronic water level sounders have a visual indicator consisting of a small light bulb or diode that turns on when the probe encounters water. Total well depth will be sounded from the surveyed top of casing by lowering the weighted probe to the bottom of the well. Total well depths will be measured by lowering the weighted probe to the bottom of the well and recording the depth to the nearest 0.1 feet. For wells with dedicated pumps installed, a depth to top of pump measurement may be performed in lieu of a total well depth measurement.

Water levels will be measured in wells which have the least amount of known contamination first. Wells with known or suspected contamination will be measured last.

The Site's groundwater monitoring wells and piezometers will be routinely evaluated for indications that sediment is accumulating inside the well. If it is determined that substantial sediment has accumulated in a well, the well will be redeveloped. The specific methods used to redevelop a well will be determined on a case by case basis, based in part on well design, sediment character and quantity, aquifer properties, and other factors.

3.7.1.1 EQUIPMENT

Equipment used during groundwater sampling includes:

- Water Level Indicator and/or Interface Probe
- Keys for well locks
- Decontamination kit with 5-gallon buckets
- Paper towels
- Personal PPE

3.7.1.2 DECONTAMINATION

Water level sounding equipment will be decontaminated before and after use in each well as follows:

1. Wash with detergent and water solution
2. Rinse with distilled water

3.7.1.3 QUALITY CONTROL

Field documentation will be submitted to the field task leader and reviewed by the SQCO. Original field forms will be stored in the project files.

3.7.1.4 DOCUMENTATION

Data collected will be recorded on the appropriate field forms and logbooks per the SOPs included in Appendix A and the field forms included in Appendix B.

3.7.2 PURGING

Purging of monitoring wells prior to sampling is necessary to remove stagnant or thermally stratified groundwater from the well casing and sand pack that may not be representative of groundwater within the aquifer. If possible, purging will be performed at a rate at or below the well's recovery rate to minimize the migration of groundwater above the well screen. Purged water will be containerized and either stored on-site within a temporary tank pending analytical data or transferred to the on-site leachate water treatment system. of in the facilities leachate treatment system.

All wells will be purged prior to sampling utilizing a dedicated bladder pump and as detailed in the Well Purging and Sampling SOP and the EPA Low Flow Sampling SOP included in Appendix A. Pumps will be placed 2 to 3 feet from the bottom of the well to permit reasonable draw down while preventing cascading conditions. For most of the monitored groundwater zones, the pump will be set within the well's screened interval. The exception is within wells with exceptionally deep screened intervals (i.e. the Keokuk Zone wells). The pump installation at such wells incorporates an intake drop tube that extends to the screened interval, while the pump itself is set at a higher elevation. Pumping rates will be regulated or controlled to minimize turbulent flow, prevent damage to the monitoring well components, and minimize the introduction of sediment into the well.

Throughout the purging process, groundwater will be monitored for the following field parameters: pH, specific conductance, temperature, turbidity, dissolved oxygen (DO) and oxidation-reduction potential (ORP). Field parameter values will be monitored and recorded at regular intervals, with a minimum interval of three (3) to five (5) minutes. A flow through cell will be used for all field parameter measurements to ensure that the water quality meter's sensors are in contact with flowing water. Purging will continue until field parameter equilibrium is achieved. Equilibrium is achieved when parameters exhibit variation equal to or less than the EPA prescribed tolerances for low flow sampling, which is included in Appendix A, for a minimum of three consecutive field parameter readings. Approximate pumping rates and the approximate volume of groundwater removed from the well will be recorded on the field form and/or field logbook. Allowances may be made regarding the definition of equilibrium based on the aquifer's characteristics at individual wells and will be documented on the field forms and/or field logbooks. If a well purges dry prior to the achievement of field parameter equilibrium, the well will be purged to the lowest reasonable groundwater elevation, permitted to recover, and then sampled within 24-hours of completion of purging.

3.7.2.1 EQUIPMENT

Equipment used during groundwater purging includes:

- Dedicated bladder pump
- Water Level Indicator and/or Interface Probe

- MP-10H controller and/or air compressor or nitrogen gas cylinder and regulator
- Water Quality Meter with Flow Through Cell and calibration solution (Horiba U-52 or equivalent)
- Tubing
- 5-gallon buckets
- Measuring cup
- Stopwatch
- Decontamination kit, including distilled water and Alconox/Liquinox detergent
- Personal PPE

3.7.2.2 DECONTAMINATION

Each well will be equipped with a dedicated pump. Water level sounding equipment will be decontaminated before and after use in each well as follows:

1. Wash with detergent and water solution
2. Rinse with distilled water

3.7.2.3 QUALITY CONTROL

Field documentation will be submitted to the field task leader and reviewed by the SQCO. Original field forms will be stored in the project files.

3.7.2.4 DOCUMENTATION

Data collected will be recorded on the appropriate field forms and logbooks per the SOPs included in Appendix A, the user manuals included in Appendix C, and the field forms included in Appendix B.

3.7.3 WELL SAMPLING

A total of 132 wells will be sampled for 8 quarters during the Phase I Site characterization. The wells are listed on Table 3-1 and shown on Figure 3-6. A groundwater monitoring well may be sampled as soon as the field parameters have stabilized, or if purged to dry, as soon as it has recovered sufficiently, but typically no more than 24-hours after purging. The same methods used for well purging will be utilized for sample collection, as per the EPA Low Flow Sampling SOP included in Appendix A. Once the tubing is disconnected from the flow through cell, sample bottles will be filled directly from the pump's discharge tube to minimize agitation and aeration. The final set of parameter values will be used for the sampling. If the well is sampled later, a new set of parameter values will be measured and recorded concurrently with sampling.

Individual sample containers will be filled in order of decreasing sensitivity to potential volatilization of the analytical constituents. Sample containers for volatile organic compounds (VOCs) will be filled in such a manner to eliminate head space within the container. At each sampling location, all bottles designated for a particular analysis (e.g., VOCs) will be filled sequentially before bottles designated for the next analysis are filled (e.g., semi-volatile organic compounds). If a duplicate sample is to be collected at this location, all bottles designated for a particular analysis for both sample designations will be filled sequentially before bottles for another analysis are filled. In the filling sequence for duplicate samples, bottles with the two different sample designations will alternate (e.g., volatile organic compounds designation GW-2, volatile organic compounds designation DUP (duplicate of GW-2), metals designation GW-2, and metals designation DUP (duplicate of GW-2), etc.). Groundwater samples will be transferred directly into the appropriate sample containers with preservative, if required, chilled if appropriate, and processed for shipment to the laboratory. See Section 5.4 for preservation and shipping procedures.

If the turbidity of the groundwater from a well is above 5 Nephelometric Turbidity Units (NTUs), both a filtered and unfiltered sample will be collected for metals and radium, thorium and uranium analyses. An in-line filter will be used to remove particles that have been entrained in the water sample. The size of the in-line water filter will be determined based on groundwater conditions and which filter will provide the most optimal results. A clean, unused filter will be used for each filtered sample collected. Groundwater samples will be transferred from the filter directly into the appropriate sample containers with a preservative and processed for shipment to the laboratory. Depending on the viability of the proposed filtration process, this methodology may be altered as necessary in the field. Proposed alterations will be discussed with project stakeholders prior to implementation. When transferring samples, care will be taken not to touch the filter to the sample container. See Section 5.4 for preservation and shipping procedures.

3.7.3.1 EQUIPMENT

Equipment used during groundwater sample collection includes:

- Water Level Indicator and/or Interface Probe
- MP-10H controller and/or air compressor or nitrogen gas cylinder and regulator
- Tubing
- In-line filters (size to be determined in the field but may be 0.1 micron, 0.2 micron or 0.45 micron)

- Decontamination kit including phosphate free detergent (Alconox or Liquinox), 5-gallon buckets, spray bottles, distilled water, paper towels
- Sample containers and labels
- Field forms and field logbook
- Coolers with ice
- Packaging tape
- CoC forms, custody seals
- Trash bags
- Personal PPE

3.7.3.2 DECONTAMINATION

Each well will be equipped with a dedicated pump. Water level sounding equipment will be decontaminated before and after use in each well as follows:

- Wash with detergent and water solution
- Rinse with distilled water

3.7.3.3 QUALITY CONTROL

Field documentation will be submitted to the field task leader and reviewed by the SQCO. Original field forms will be stored in the project files.

3.7.3.4 DOCUMENTATION

Data collected will be recorded on the appropriate field forms and logbooks per the SOPs included in Appendix A, the user manuals included in Appendix C, and the field forms included in Appendix B.

3.8 STAFF GAUGES

Staff gauges will be installed at 4 locations, as per the United States Army Corps of Engineers (USACOE) instructions included in Appendix C. Staff gauges will be installed in the locations shown on Figure 3-6. The newly installed gauges will be measured monthly, concurrently with the monthly fluid level measurement events so that interconnection of the surface water and groundwater can be evaluated. Rain events will be noted in the logbook. The staff gauges will consist of 2-inch diameter, coupled, galvanized pipe. The staff gauges will be securely driven into the base so that water levels can be read easily. The gauges will be clearly labeled in 0.01-foot increments. Final installed locations and top of pipe elevations will be surveyed. Surface water elevations will be recorded on field forms and/or logbooks to the nearest 0.01-foot.

3.8.1 EQUIPMENT

Equipment used when installing and reading staff gauges includes:

- Four coupled galvanized -steel staff gauges labeled in 0.01-foot increments
- Sledge hammer and/or post driver
- Four metal fence posts
- Bracket fasteners and wire
- Field logbook and forms
- Waders/life preservers
- Personal PPE

3.8.2 DECONTAMINATION

No decontamination is necessary.

3.8.3 QUALITY CONTROL

Field documentation will be submitted to the field task leader and reviewed by the SQCO. Original field forms will be stored in the project files.

3.8.4 DOCUMENTATION

Data collected will be recorded on the appropriate field forms and logbooks per the instruction manual included in Appendix C and the field forms included in Appendix B.

3.9 PRESSURE TRANSDUCERS

After completing the initial round of water level measurements, absolute pressure transducers/data loggers (DLs) and one barometric barologger (BL) will be placed in 32 wells. Table 3-4 identifies the proposed wells that DLs will be placed in. The Solinst Model 3001 Leveloggers and Barologger will be used at the Site. The DLs measure groundwater levels and temperature. Water levels are displayed as temperature compensated pressure readings and are barometrically compensated with the aid of the BL. The BL uses algorithms based on the air pressure. It measures and logs changes in the atmospheric pressure, which are then used to compensate water levels recorded by the DL.

The DLs and BL will be placed with direct read cables and will be hung from specialized well caps. The DLs will be placed approximately 10 feet below the static water level in each well. The BL will be placed in an adjacent well, approximately 2 feet below the well cap and above the static water level. These DLs and BL will remain within the wells for approximately 2 years, while the quarterly groundwater monitoring occurs. The DLs will be programmed to collect readings every hour. During each quarterly groundwater monitoring event, the data will be downloaded from the transducers and saved within the project files. A copy of the DL deployment form is included in Appendix B and the manufacturers guides are included in Appendix C.

3.9.1 EQUIPMENT

The equipment used for installing and reading pressure transducers includes:

- 32 Solinst Leveloggers
- 1 Solinst Barologger
- Braided monofilament line, minimum test weight of 25 pounds
- Twine
- Water Level Indicator and/or Interface Probe
- Decontamination kit including detergent (Alconox or Liquinox), 5-gallon buckets, spray bottles, distilled water, paper towels
- Field forms and field logbook
- Laptop computer with Solinst software installed
- Specialized well caps (33 total)
- Well locks and keys

3.9.2 DECONTAMINATION

Water level sounding equipment will be decontaminated before and after use in each well as follows:

- Wash with detergent and water solution
- Rinse with distilled water

The DLs will be dedicated and should not require decontamination prior to being placed. However, should decontamination be required, only distilled water will be used so the probe is not damaged.

3.9.3 QUALITY CONTROL

Field documentation will be submitted to the field task leader and reviewed by the SQCO. Original field forms will be stored in the project files.

3.9.4 DOCUMENTATION

Data collected will be recorded on the appropriate field forms and logbooks per the SOPs included in Appendix A, the field forms included in Appendix B, and the user manuals in Appendix C.

3.10 SURVEYING

A State of Missouri registered surveyor will complete a well, staff gage, and leachate riser survey at West Lake Landfill, as per the SOP included in Appendix A. Surveyed well data will include: Northing, Easting, top of casing (riser pipe) elevation, and ground surface elevation. Collected well survey data will be input into the database. Spatial information requirements for each surveyed location are:

- Northing and Easting, reported to 0.5-ft, US Survey Feet
- Latitude and longitude reported to 0.01-ft North American Datum of 1983 (NAD 83)
- Top of well casing, reported to 0.01-ft, North American Vertical Datum of 1988 (NAVD 88) Datum
- Ground surface elevation, reported to 0.01-ft, NAVD 88 Datum
- All coordinates reported in NAD 83, Missouri East State Plane Zone.

Collected survey data will be submitted in Environmental Systems Research Institute (ESRI)-compatible format as either a shapefile or geodatabase. The survey will include installation of two permanent on-site control points, development of a topographic map of the Site, and horizontal and vertical control of the locations. The survey will be based on National Geodetic Survey monuments located near the Site.

3.10.1 EQUIPMENT

Survey equipment includes:

- Field forms and field logbook
- Well locks and keys
- Survey equipment

3.10.2 DECONTAMINATION

No decontamination is required.

3.10.3 QUALITY CONTROL

Field documentation will be submitted to the field task leader and reviewed by the SQCO. Original field forms will be stored in the project files.

3.10.4 DOCUMENTATION

Data collected will be recorded on the appropriate field forms and logbooks per the SOPs included in Appendix A.

3.11 VAPOR INTRUSION INVESTIGATION

As part of the RI investigation, an investigation will be performed to determine the potential for contaminant vapors to emanate from impacted vadose zone material and/or the partitioning of COCs in groundwater located beneath the Site and adjacent study area. An assessment will be performed to determine the potential for completion of vapor intrusion pathways in on-site or off-site occupied structures.

Once review of historical vapor intrusion activities has been performed, Trihydro will determine the path forward for future activities that may include, but are not limited to, passive soil gas vapor sampling, installation of soil gas vapor wells, soil gas vapor sampling, sub-slab vapor sampling, indoor air quality, and installation of mitigation systems. During future characterization activities, a separate Work Plan/FSP will be submitted for the vapor intrusion investigation.

3.12 DECONTAMINATION PROCEDURES

The decontamination procedures that will be followed are in general accordance with the Equipment Decontamination SOP included in Appendix A, and as detailed within each specific task. Decontamination will occur prior to and after each use of a piece of equipment. Decontamination of sampling equipment must be conducted consistently as to assure the quality of samples collected. All equipment that comes into contact with potentially contaminated soil or water will be decontaminated using a non-phosphate detergent solution, followed by a rinse with distilled water. Disposable equipment intended for one-time use will not be decontaminated but will be packaged for appropriate disposal.

Equipment will be decontaminated in a predesignated area on pallets or plastic sheeting, and clean bulky equipment will be stored on plastic sheeting in uncontaminated areas. Cleaned small equipment will be stored in plastic bags. Materials to be stored more than a few hours will also be covered.

4.0 DISPOSAL OF RESIDUAL MATERIALS

In the process of collecting environmental samples, the sampling team will generate different types of potentially contaminated Investigation Derived Waste (IDW) that include the following:

- Used personal protective equipment (PPE)
- Disposable sampling equipment
- Decontamination fluids
- Soil cuttings from soil
- Purged groundwater and excess groundwater collected for sample container filling

The EPA's National Contingency Plan (NCP) requires that management of IDW generated during sampling comply with all applicable or relevant and appropriate requirements (ARARs) to the extent practicable. The sampling plan will follow the *Office of Emergency and Remedial Response (OERR) Directive 9345.3-02* (May 1991), which provides the guidance for the management of IDW. In addition, other legal and practical considerations that may affect the handling of IDW will be considered.

- Used PPE and disposable equipment will be double bagged and placed in a municipal refuse dumpster. These wastes are not considered hazardous and can be sent to a municipal landfill. Any PPE and disposable equipment that is to be disposed of which can still be reused will be rendered inoperable before disposal in the refuse dumpster. Any PPE generated within OU-1 Areas 1 and 2 will be managed per site protocols.
- Decontamination fluids that will be generated in the sampling event will consist of distilled water, residual contaminants, and water with non-phosphate detergent. The volume and concentration of the decontamination fluid will be containerized and either stored on-site within a temporary tank pending analytical data, or transferred to the on-site leachate water treatment system.
- Soil cuttings generated during the subsurface sampling will be characterized and disposed of in an appropriate manner.
- Purged groundwater will be containerized and either stored on-site within a temporary tank pending analytical data or transferred to the on-site leachate water treatment system.

5.0 SAMPLE DOCUMENTATION AND SHIPMENT

5.1 FIELD NOTES

Field logbooks and field forms will provide the means of recording the data collection activities. All field logbooks and field forms will be scanned to create portable document format (PDF) files for electronic archiving with the central project file. Field data recorded on field forms will not be duplicated in the field logbook, and vice versa. A SOP for field recordkeeping is included in Appendix A and example field forms are included in Appendix B.

5.1.1 FIELD LOGBOOKS

Field logbooks will be used to document field observations and activities. The field notes will be clear, with sufficient detail so that events can be reconstructed later if necessary. Field logbooks will document any deviations from the RI/FS WP and/or FSP, as well as the reason for the changes. Requirements for logbook entries will include the following:

- Separate field activity logbooks will be kept for each task.
- Logbooks will be bound, with consecutively numbered pages.
- Entries will be made legibly with dark, indelible ink.
- Unbiased, accurate language will be used.
- Entries will be made while activities are in progress or as soon afterward as possible with the date and time that the notation is made. The weather and any precipitation events will be noted at the beginning of each day.
- Each consecutive day's first entry will begin on a new, blank page.
- The date and time, based on military time, will be recorded on each page.
- When a field activity is complete, the logbook will be entered into the permanent project file.
- The person recording the information will print and sign each page of the logbook. If more than one individual makes entries on the same page, each recorder will print and sign the entry.
- Logbook corrections will be made by drawing a single line through the original entry, initialed, and dated.

5.1.2 FIELD DATASHEETS/FORMS

Field datasheets/forms will be utilized when appropriate to achieve efficient and standardized recording of field measurements and observations. The type of field data sheet and the information recorded it on it may vary by activity.

At a minimum, field datasheets will be completed for each sample to document the unique sample identifier assigned, provide information on whether the sample is representative of a primary sample or a quality control sample (i.e. field blank, field duplicate, etc.), provide information regarding the sample media, sample date, sample location, and sampling team members. Information from the field datasheets will be entered into the database as needed. Datasheets may also be used to document information such as habitat descriptions, water level gauging data, surface water and groundwater sample field observations and measurements, soil sample characteristics, well construction details, etc. A reference date and activity will be entered in the field logbook to refer to the field datasheets being generated. The field datasheets will be scanned into a PDF and become a permanent record within the project file. Examples of field datasheets/forms are included in Appendix B.

5.1.3 PHOTOGRAPHS

Photographs will be taken at the sampling locations and at other areas of interest on the site or sampling area. They will serve to verify information entered in the field logbook. For each photograph taken, the following information will be written in the logbook or recorded in a separate field photography log:

- Time, date, location, and weather conditions
- Description of the subject photographed
- Name of person taking the photograph

5.2 LABELING

All field measurement locations, sampling locations, and samples, including those collected for QA/QC purposes, will be assigned a unique identification (ID) number. The ID number will be used to track field-screening data and laboratory analytical results in the project database, as well as presentation of the data in reports. During the field work, the sample ID numbers will be recorded in the field logbook, on field datasheets, on the sample jars, and on the Chain of Custody (CoC) paperwork.

For sample collection, each sample container is identified with a label. The information, which appears on the sample container label includes:

- Sample identification number (for groundwater samples use the well name and/or the QAQC type (i.e. MW-304-SS, TB1-20190514, BD1-20190514), for soil samples use the well name and depth at which the soil was collected (i.e. MW-304-SS (0-5'))
- Place of collection (or project number)

- Date and time of collection
- Personnel collecting the sample
- Preservative
- Analyses requested

5.3 SAMPLE CHAIN-OF-CUSTODY FORMS AND CUSTODY SEALS

Samples will be delivered or shipped to the analytical laboratory under CoC protocol (Appendix A) and sent with the samples for each laboratory and each shipment. If multiple coolers are sent to a single laboratory during a single day, CoCs will be completed and sent with the samples for each cooler. A copy of the CoC is kept in the project files. The CoC part of the form provides documentation necessary to trace sample possession continuously from the time of collection until the time of receipt in the laboratory, and the condition of the samples and sample container upon receipt. Sample collection details will be documented on a sample collection form or an associated field form. When the samples leave custody of the sampling team, the shipping container is sealed with a custody seal to ensure that the samples have not been disturbed during transportation to the laboratory. The laboratory personnel receiving the coolers note the condition of the seal and the sample containers within the cooler on the CoC and notifies the Trihydro Quality Assurance Director (QAD) of any deficiencies. If samples are transferred directly from sampling personnel to laboratory personnel custody seals are not required, but CoCs must be completed to document the transfer.

5.4 SAMPLE CONTAINERS, PRESERVATION, PACKAGING, AND SHIPPING

The type of sample containers, volumes, and preservatives are listed in Table 2-1 and included in the QAPP. The containers are pre-cleaned and will not be rinsed prior to sample collection. Sample containers requiring preservatives will be provided by the contract laboratories, Pace Laboratories (Pace), and Materials and Chemistry Laboratory, Inc. (MCLI). All sample containers will be placed in opaque coolers and shipped per the details outlined in the Packaging and Shipping SOPs included in Appendix A. Samples will be shipped via FedEx and/or UPS overnight to the laboratories.

6.0 QUALITY CONTROL

The quality assurance objectives provide quantitative and qualitative measures of the ability to produce high quality results through a properly designed sampling and analysis program. The objectives of the overall QA/QC program are to:

- Document procedures, including changes from the Work Plan protocol
- Conduct sampling and analytical procedures according to sound scientific principles
- Monitor the performance of the field sampling team and laboratory with a systematic audit program and provide for corrective action necessary to assure quality
- Evaluate the quality of the analytical data through a system of quantitative and qualitative criteria
- Properly record and archive data and observations

6.1 FIELD QUALITY CONTROL SAMPLES

6.1.1 FIELD QUALITY CONTROL CHECKS

The level of quality control effort will be consistent with that required under SW-846. The number/frequency for each quality assurance sample type is summarized below:

- Blind Duplicate Samples: 1 blind duplicate per 10 groundwater and soil samples will be collected for every analysis collected.
- Equipment Blanks: 1 equipment blank per 10 groundwater and soil samples will be collected for every analysis collected using non-disposable equipment.
- Field Blanks: 1 field blank per 10 groundwater and soil samples will be collected for every analysis collected.
- Trip Blanks: 1 within the shipping container containing samples for VOCs in groundwater samples.
- Matrix Spike: 1 for every twenty samples for soil and groundwater samples.
- Matrix Spike Duplicate: 1 for every twenty samples for soil and groundwater samples.

6.2 LABORATORY QUALITY CONTROL SAMPLES

Laboratory QA/QC samples are detailed in the QAPP.

7.0 REFERENCES

EMSI. 2018. Remedial Investigation Addendum, West Lake Landfill, Operable Unit 1. January 25, 2018.

TABLES

TABLE 2-1. ANALYTES, HOLDING TIME AND PRESERVATION REQUIREMENTS
WEST LAKE LANDFILL OU-3
REMEDIAL INVESTIGATION / FEASIBILITY STUDY FIELD SAMPLING PLAN

Matrix	Analytical Group	Containers (number, size, and type)	Preservation Requirements (chemical, temperature, light protected)	Maximum Holding Time (preparation / analysis)
Water	Polychlorinated Biphenyls-1221 (EPA 8082)	One 100mL widemouth amber glass bottle	Cool to ≤6°C	Extract within 6 months of collection and analyze within 40 days of extraction
Water	Chloride Fluoride Sulfate (EPA 9056)	One 125mL plastic or glass bottle	Cool to ≤6°C	Nitrate or Nitrite: Analysis must be completed within 48 hours of collection date/time. Other Anions: Analysis must be completed within 28 days of collection date.
Water	Ferrous Iron (HACH Method 8146)	One 250mL amber glass bottle	Cool to ≤6°C 2 mL of Hydrochloric Acid per 100 mL of sample	Ferrous Iron must be completed within 24 hours of collection date/time. No headspace should be present in the sample bottle.
Water	Barium, Boron, Calcium, Cobalt, Iron, Magnesium, Manganese, Nickel, Sodium, Zinc (EPA 6010)	250mL in plastic container	Nitric Acid to pH <2* Ambient or Cool to ≤6°C	Must be analyzed within 6 months of the collection date.
Water	Antimony, Arsenic, Beryllium, Cadmium, Chromium, Copper, Lead, Selenium, Silver, Thallium, Vanadium (EPA 6020)	250mL in plastic container	Nitric Acid to pH <2* Ambient or Cool to ≤6°C	Must be analyzed within 6 months of the collection date.
Water	Mercury (EPA 7470)	500mL in plastic container	Nitric Acid to pH <2* Ambient	Analysis must be completed within 28 days of collection date.
Water	Total Hardness (EPA 2340B)	250mL in plastic container	Nitric Acid to pH <2* Ambient or Cool to ≤6°C	Must be analyzed within 6 months of the collection date.
Water	Semivolatile Organic Compounds (EPA 8270)	1 x1L or 100mL amber glass container with Teflon-lined lid, preferably widemouth	Cool to ≤6°C	Sample must be extracted within 7 days of collection date and extract must be analyzed within 40 days of extraction date.
Water	Volatile Organic Compounds (EPA 8260)	Minimum 3 VOA vials. Additional sample is required if MS/MSD is required.	Acidified w/ 1:1 Hydrochloric Acid to pH<2, no headspace Cool to ≤6°C	pH>2: Analysis must be completed within 7 days of collection date. pH <2: Analysis must be completed within 14 days of collection date. (pH determined post analysis)
Water	Total Dissolved Solids (SM 2540C)	250mL minimum in plastic container	Cool to ≤6°C	Sample must be analyzed within 7 days of collection date.
Water	Chemical Oxygen Demand (EPA 410.4)	One 250mL plastic or glass container	Sulfuric Acid to pH <2 Cool to ≤6°C	Sample must be analyzed within 28 days of collection date.

TABLE 2-1. ANALYTES, HOLDING TIME AND PRESERVATION REQUIREMENTS
WEST LAKE LANDFILL OU-3
REMEDIAL INVESTIGATION / FEASIBILITY STUDY FIELD SAMPLING PLAN

Matrix	Analytical Group	Containers (number, size, and type)	Preservation Requirements (chemical, temperature, light protected)	Maximum Holding Time (preparation / analysis)
Water	Sulfide (SM 4500-S2-D)	250mL in plastic container. Fill container completely without overflowing.	pH>9 with 1mL of 1:1 Sodium Hydroxide plus 0.5mL of 1N Zinc Acetate per 250mL sample. Cool to ≤6°C	Preserved: Analysis must be completed within 7 days of collection. Unpreserved: Analysis must be completed within 24 hours of collection.
Water	Nitrogen, Nitrate + Nitrite (EPA 353.2) Nitrogen, Nitrite (EPA 353.2) Nitrogen, Nitrate (EPA 353.2)	250mL in plastic container.	For combined nitrate/nitrite analysis Sulfuric Acid to pH <2 For nitrate or nitrite individually, unpreserved. Cool to ≤6°C	For preserved samples, analysis must be completed within 28 days of collection date. For unpreserved samples, analysis must be completed within 48 hours of collection.
Water	Phosphorus (EPA 365.1)	125mL in plastic or glass container.	Sulfuric Acid to pH <2 Cool to ≤6°C	Sample must be analyzed within 28 days of collection date.
Water	Ammonia as Nitrogen (SM 4500-NH3 G)	250mL in plastic or glass container.	Sulfuric Acid to pH <2 Cool to ≤6°C	Sample must be analyzed within 28 days of collection date.
Water	Total Organic Carbon (SM 5310C)	250mL amber glass bottle	Sulfuric Acid or Phosphoric Acid to pH <2 Cool to ≤6°C	Sample must be analyzed within 28 days of collection date.
Water	Radium-226 (EPA Methods 903.1) Radium-228 (EPA Methods 904.0) Isotopic Uranium (U-234, U-235, U-238) and Isotopic Thorium (Th-228, Th-230, Th-232) (HASL 300)	1L plastic or glass container	Nitric acid pH<2	Sample must be analyzed within 180 days
Water	Volatile Fatty Acids	2-40mL amber glass VOA vials	benzalkonium chloride (BAK) per sample	Store just above freezing but below 6 degrees C. 14 day hold time
Soil	Total Organic Carbon (Walkley Black)	4 oz glass container	Thermal to ≤6°C-Preservation On ice ≤6° Celsius-Shipment	Sample must be analyzed within 28 days of collection date.
Soil	Radium-226 (EPA Methods 903.1) Radium-228 (EPA Methods 904.0) Isotopic Uranium (U-234, U-235, U-238) and Isotopic Thorium (Th-230, Th-232) (HASL 300)	1L plastic or glass container	Nitric acid pH<2	Sample must be analyzed within 180 days

TABLE 2-1. ANALYTES, HOLDING TIME AND PRESERVATION REQUIREMENTS
WEST LAKE LANDFILL OU-3
REMEDIAL INVESTIGATION / FEASIBILITY STUDY FIELD SAMPLING PLAN

Matrix	Analytical Group	Containers (number, size, and type)	Preservation Requirements (chemical, temperature, light protected)	Maximum Holding Time (preparation / analysis)
Soil	Barium, Calcium, Iron, Magnesium, Manganese, Potassium, Sodium(EPA 6010)	1L vacuum-sealed bag (only 1L of sample needed for all soil analysis)	Frozen on dry ice	Analyze with 6 months
Soil	Carbonate (SM 2320E)			Analyzed within 24 hours after extraction
Soil	Fluoride, Phosphate, and Sulfate by EPA Method 300.0			Analyze within 28 days
Soil	Ferrous Iron and Ferric Iron by SM 3500-Fe B			Analyze immediately after extraction
Soil	Sulfide by Method EPA-OW-OST 376.3			Analyze within 180 days
Soil	U(VI) by SOP MCL-7737			Analyze within 7 days after extraction
Soil	Cation Exchange Capacity by EPA Method 9081			Analyze within 6 months
Soil	pH by EPA Method 9045D			Analyze within 28 days after extraction
Soil	X-Ray Diffraction by SOP MCL-7708			Analyzed within 24 hours after extraction
Soil	Percent Moisture by American Society of Testing and Materials (ASTM) D 2974-87			Analyze within 6 months
Solid Sample	Radium-226 (EPA Methods 903.1) Total Radium Total Thorium Total Uranium	1L plastic or glass container	Nitric acid pH<2	Analyze within 28 days

TABLE 2-1. ANALYTES, HOLDING TIME AND PRESERVATION REQUIREMENTS
WEST LAKE LANDFILL OU-3
REMEDIAL INVESTIGATION / FEASIBILITY STUDY FIELD SAMPLING PLAN

Matrix	Analytical Group	Containers (number, size, and type)	Preservation Requirements (chemical, temperature, light protected)	Maximum Holding Time (preparation / analysis)
Aqueous Extracts	Total metals (Barium calculated based on Sequential Extraction Step 1, Calcium calculated based on Sequential Extraction Step 1, Iron calculated based on Sequential Extraction Step 1, Manganese calculated based on Sequential Extraction Step 1, Magnesium, Potassium, and Sodium) by SW-846 Methods 6010	Lab container	Cool to ≤6°C	Analyze within 6 months
Aqueous Extracts	Carbonate by SM 2320E	Lab container	Cool to ≤6°C	Analyze within 24 hours after extraction
Aqueous Extracts	Sulfate calculated based on Sequential Extraction Step 1	Lab container	Cool to ≤6°C	Analyze within 28 days
Aqueous Extracts	pH by EPA Method 9045D	Lab container	Cool to ≤6°C	Analyze within 24 hours after extraction

Notes:
L: Liter
mL: milliliter
oz: Ounce
SM: Standard Methods for the Examination of Water and Wastewater
SOP: Standard Operating Procedure
EPA: United States Environmental Protection Agency
VOA: Volatile Organic Analysis

* Samples received at pH >2 must be preserved to pH <2 with HNO_3 and be allowed to equilibrate for 24 hours before being prepared for analysis. Acidification date and time are recorded in the Sample Preservation Logbook.

TABLE 3-1. MONITORING WELL SURVEY AND CONSTRUCTION DATA
WEST LAKE LANDFILL OU-3
REMEDIAL INVESTIGATION / FEASIBILITY STUDY FIELD SAMPLING PLAN

Borehole ID	Env. Control Prefix	Env. Control Point Number	Hydro Zone	Monitoring Status	Alias	Install Date	Northing (ft)	Easting (ft)	MPE (ft msl)	GSE (ft msl)	Survey Source	2012 Cap Ht. Above Grade	Borehole diameter (in)
D-3	D	3	AD	I	WL-105A	34912	1069177.97	836047	468.338	465.118	EMSI 2012 Survey	3.22	8.25
D-6	D	6	AD	I	WL-206	34912	1070235.1	834723.492	447.623	444.332	EMSI 2012 Survey	3.291	8.25
D-12	D	12	AD	I	WL-216A	34973	1069877.227	835110.755	479.736	477.157	EMSI 2012 Survey	2.579	8.25
D-13	D	13	AD	I	WL-224	34973	1070527.015	835776.5617	470.2467	467.7344	EMSI 2012 Survey	2.5123	8.25
D-14	D	14	LR	X	WL-109B	34973	1068988.873	836700.023	482.9692	480.7088	EMSI 2012 Survey	2.2604	8.25
D-81	D	81	AD	I		30907	1067378.728	834638.553	450.654	448.074	EMSI 2012 Survey	2.58	5" (0 - 15 ft), 4 1/2" (15 - 61.5 ft)
D-83	D	83	AD	I		30910	1070970.858	834807.7922	448.2116	444.8426	EMSI 2012 Survey	3.369	5" (0-15 ft) 4 1/2" (15-115.3 ft)
D-85	D	85	AD	A		30895	1069667.265	836605.173	457.264	454.257	EMSI 2012 Survey	3.007	5" (0-10 ft) 4 1/2" (10-84.1 ft)
D-87	D	87	AD	I		30895	1069252.38	835579.372	464.472	461.221	EMSI 2012 Survey	3.251	5" (0 - 30 ft) 4 1/2" (30-111.7 ft)
D-89	D	89	AI	I		30921	1067010.97	835274.7	456.698	453.698	EMSI 2018 - Calculated	n/a	5" (0-25 ft) 4 1/2" (25-49 ft)
D-90	D	90	AI	X		31266	1066200.97	834474.7	450.198	445.598	EMSI 2018 - Calculated	n/a	4", 3 7/8"
D-91	D	91	AI	X		31260	1065260.97	833944.7	452.968	447.598	EMSI 2018 - Calculated	n/a	4", 3 7/8"
D-92	D	92	AD	X		31146	1069800.97	835264.7	474.968	475.098	EMSI 2018 - Calculated	n/a	4" (0 - 40 ft), 3 7/8" (40 -143.6 ft)
D-93	D	93	AD	I		31155	1069369.757	834443.556	450.839	448.283	EMSI 2012 Survey	2.556	6" (0-8 ft) 4 7/8" (8-119.2ft)
D-94	D	94	AD	X		31138	1070685.97	835994.7	442.278	438.098	EMSI 2018 - Calculated	n/a	3 7/8"
D-95	D	95	AD	X		31138	1070861.545	836524.5192	452.688	449.598	Georeferenced/Calculated	n/a	3 7/8"
F-1-D	F	1	AD	X		33086	1068649.65	836034.74	461.228	458.378	McLaren Hart 1996	n/a	8"
F-1-S	F	1	AS	X		33086	1068643.97	836040.05	460.948	458.698	McLaren Hart 1996	n/a	8"
F-2	F	2	AS	X		33095	1067725.97	834591.7	449.698	447.498	EMSI 2018	n/a	8"
F-3	F	3	AS	X		33086	1070530.77	835994.53	468.828	466.528	McLaren Hart 1996	n/a	8"
I-2	I	2	AI	X		Unknown	1069739.23	834386.88	446.008	442.798	McLaren Hart 1996	n/a	8.25
I-4	I	4	AI	I	WL-105B	34912	1069189.97	836064.6	465.74	462.951	EMSI 2012 Survey	2.789	8.25
I-7	I	7	AI	U	WL-207	Unknown	1070784.02	834474.57	446.568	444.098	McLaren Hart 1996	n/a	8.25
I-9	I	9	AI	I	WL-229	34943	1069358.403	834444.232	449.879	447.915	EMSI 2012 Survey	1.964	8.25
I-11	I	11	AI	I	WL-216C	34912	1069860.187	835099.736	480.108	477.582	EMSI 2012 Survey	2.526	8.25
I-50	I	50	AI	X	N-1	30590	1065231.29	834006.66	453.258	448.598	McLaren Hart 1996	n/a	n/a
I-55	I	55	AI	X	35	28667	1067827.97	834649.7	n/a	471.498	EMSI 2018	n/a	6"
I-56	I	56	AI	X	34	28668	1068097.97	834661.7	n/a	474.698	EMSI 2018	n/a	6"
I-58	I	58	AI	X	40	28669	1068914.97	834632.7	n/a	477.098	EMSI 2018	n/a	6"
I-59	I	59	AI	X	N-2	30590	1069372.97	834463.7	n/a	444.498	EMSI 2018	n/a	n/a
I-62	I	62	AI	I	N-3	30590	1070979.147	834821.3336	446.1413	444.3429	EMSI 2012 Survey	1.7984	n/a
I-65	I	65	AI	I	N-4	30590	1070994.104	835507.9937	441.257	438.9301	EMSI 2012 Survey	2.3269	n/a
I-66	I	66	AI	I	N-5	30590	1070645.385	836025.9553	441.696	438.9587	EMSI 2012 Survey	2.7373	n/a
I-67	I	67	AI	I	N-6	30590	1070142.391	836418.549	441.683	439.341	EMSI 2012 Survey	2.342	n/a
I-68	I	68	AI	A	N-7	30590	1069612.97	836861.2	450.199	447.405	EMSI 2012 Survey	2.794	n/a
I-72	I	72	AI	X	39	28642	1067930.97	835519.7	464.998	462.298	EMSI 2018 - Calculated	n/a	n/a
I-73	I	73	AI	A	38	28642	1067735.843	835745.2921	461.0784	457.9765	EMSI 2012 Survey	3.1019	n/a
LR-100	LR	100	LR	I		34976	1067334.448	835068.653	468.113	465.343	EMSI 2012 Survey	2.77	8 1/4"
LR-101	LR	101	LR	X		34982	1068443.22	834893.11	NA	NA	Golder 1996	n/a	n/a
LR-102	LR	102	LR	X		34980	1068978.18	834962.83	513.118	511.598	Golder 1996	n/a	8 1/4"
LR-103	LR	103	LR	I		34992	1068567.541	835392.1821	470.2369	466.8659	EMSI 2012 Survey	3.371	8 1/4"
LR-104	LR	104	LR	I		34990	1068105.763	835808.4902	459.6505	457.7914	EMSI 2012 Survey	1.8591	8 1/4"
LR-105	LR	105	LR	I		34975	1067750.35	834699.951	485.205	482.362	EMSI 2012 Survey	2.843	8 1/4"
MW-41	MW	41		X		28642	1069327.97	834551.7	n/a	n/a	EMSI 2018	n/a	n/a
MW-101	MW	101	AS	X		32964	1070871.45	834598.7	446.428	444.958	McLaren Hart 1996	n/a	8
MW-102	MW	102	AS	X		32964	1070135.676	834707.412	447.833	445.66	EMSI 2012 Survey	2.173	8
MW-103	MW	103	AS	I		32964	1068668.893	834508.8	438.915	437.065	EMSI 2012 Survey	1.85	8
MW-104	MW	104	AS	I		32964	1067565.651	834513.706	440.812	437.809	EMSI 2012 Survey	3.003	8
MW-105	MW	105	AS	X		4/12/1990	1067565.651	833405.95	439.768	442.068	McLaren Hart 1996*	n/a	8

TABLE 3-1. MONITORING WELL SURVEY AND CONSTRUCTION DATA
WEST LAKE LANDFILL OU-3
REMEDIAL INVESTIGATION / FEASIBILITY STUDY FIELD SAMPLING PLAN

Pipe Size (in)	Pipe Type	Perforation detail	Surface Casing	Total Pipe Length (ft)	Boring Depth (ft)	Bottom Elev (ft MSL)	Cap Ht. Above Grade (ft)	Solid Length[1] (ft)	Screen Length (ft)	Screen From	Screen To	Top Screen Elevation (msl)	Bottom Screen Elevation (msl)	Total Pipe Length (ft)	Construction Source
2	Sch. 80 PVC	0.010 slotted	Locking steel protective cover	109.62	106.5	357.798	3.12	96.5	10	96.5	106.5	370.298	360.298	109.62	As-built
2	Sch. 40 PVC	0.010 slotted	Locking steel protective cover	109.7	106.5	334.998	3.2	96.5	10	96.5	106.5	347.498	337.498	109.7	As-built
2	Sch. 80 PVC	0.010 slotted	Locking steel protective cover	146.21	143.7	330.798	2.51	133.7	10	133.7	143.7	343.298	333.298	146.21	As-built
2	Sch. 80 PVC	0.010 slotted	Locking steel protective cover	135.7	133	334.998	2.7	123	10	123	133	344.998	334.998	135.7	As-built
2	Sch. 40 PVC	0.010 slotted	Locking steel protective cover	61.77	58.5	425.098	3.27	53.5	5	53.5	58.5	430.598	425.598	61.77	As-built
2	PVC	0.01 inch machine slot	n/a		61.5	385.898	3	48	15	45	60	402.398	387.398	60	RIA
2	PVC	0.01 inch machine slot	n/a		115.3	328.698	3.2	80.2	20	77	97	366.998	346.998	97	RIA
2	PVC	0.01 inch machine slot	n/a		84.1	372.648	3	65	20	62	82	390.698	370.698	82	RIA
2	PVC	0.01 inch machine slot	n/a		111.7	347.898	3	94	20	91	111	368.598	348.598	111	RIA
2	PVC	0.01 inch machine slot	n/a		49	404.698	3	36	15	33	48	420.698	405.698	48	RIA
2	PVC	0.01 inch machine slot	n/a		47	398.598	n/a	n/a	n/a	37	47	408.598	398.598	47	RIA
2	Sch 50 PVC Riser, Sch 20 PVC Screen	200 slots	n/a		45	402.598	5	40	10	35	45	412.598	402.598	45	RIA
2	PVC	0.01 inch machine slot	n/a		143.6	331.498	-0.2	122.8	20	123	143	352.098	332.098	143	RIA
2	PVC	0.01 inch machine slot	n/a		119.2	337.798	3.3	95.3	20	92	112	358.298	338.298	112	RIA
2	PVC	0.01 inch machine slot	n/a		109	329.098	2.6	91.6	20	86	106	352.098	332.098	106	RIA
2	PVC	0.01 inch machine slot	n/a		101	348.598	3.3	84.3	20	81	101	368.598	348.598	101	RIA
2	Sch 40 PVC	10 slot	Locking steel protective cover		79.5	n/a	2.85	76.95	5	n/a	n/a	n/a	n/a	79.1	RIA
2	Sch 40 PVC	10 slot	Locking steel protective cover	34.9	32.9	n/a	2.4	22.5	10	22.5	32.5	436.198	426.198	34.9	As-built
2	Sch 40 PVC	10 slot	Locking steel protective cover	27.55	25.7	n/a	2.25	10.3	15	10.3	25.3	437.198	422.198	27.55	As-built
2	Sch 40 PVC	10 slot	Locking steel protective cover	45.1	46	n/a	2.3	32.8	10	32.8	42.8	433.728	423.728	45.1	As-built
2	Sch. 40 PVC	0.010 slotted	Locking steel protective cover	52.71	52	393.298	3.21	39.5	10	39.5	49.5	403.298	393.298	52.71	As-built
2	Sch. 40 PVC	0.010 slotted	Locking steel protective cover	79.07	79	389.098	2.57	66.5	10	66.5	76.5	399.098	389.098	79.07	As-built
2	Sch. 40 PVC	0.010 slotted	Locking steel protective cover	49.97	50	396.598	2.47	37.5	10	37.5	47.5	406.598	396.598	49.97	As-built
2	Sch. 40 PVC	0.010 slotted	Locking steel protective cover	55.59	55.6	394.998	2.49	43.1	10	43.1	53.1	404.998	394.998	55.59	As-built
2	Sch. 80 PVC	0.010 slotted	Locking steel protective cover	93.17	93	386.698	2.67	80.5	10	80.5	90.5	396.698	386.698	93.17	As-built
0	0	0	n/a		40.6	407.998	4.48	35.08	10	30.6	40.6	417.998	407.998	40.6	RIA
2	PVC	n/a	n/a		60	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	60	RIA
2	PVC	n/a	n/a		60	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	60 (61.1 well schedule)	RIA
2	PVC	n/a	n/a		60	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	60	RIA
n/a	n/a	n/a	n/a		43.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	43.5	RIA
n/a	n/a	n/a	n/a		44	399.698	1.98	35.98	10	34	44	409.698	399.698	44	RIA
n/a	n/a	n/a	n/a		36	402.098	3.3	29.3	10	26	36	412.098	402.098	36	RIA
n/a	n/a	n/a	n/a		36.9	400.398	4.1	31	10	26.9	36.9	410.398	400.398	36.9	RIA
n/a	n/a	n/a	n/a		35.4	400.698	2.58	27.98	10	25.4	35.4	410.698	400.698	35.4	RIA
n/a	n/a	n/a	n/a		31.2	409.298	7.42	28.62	10	21.2	31.2	419.298	409.298	31.2	RIA
n/a	n/a	n/a	n/a		50	412.298	2.7	49.7	3	47	50	415.298	412.298	50	RIA
n/a	n/a	n/a	n/a		50	412.298	3.7	50.7	3	43.2	46.2	415.298	412.298	50	RIA
2	Sch 80 PVC	0.01 inch machine slot	Locking steel protective cover	26.72	26	442.298	1.92	19.7	4.8	19.7	24.5	447.098	442.298	26.72	As-built
n/a	n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	RIA
2	Sch 80 PVC	0.01 inch machine slot	Locking steel protective cover	61.52	76	451.898	1.52	54.9	4.8	54.9	59.7	456.698	451.898	61.52	As-built
2	Sch 80 PVC	0.01 inch machine slot	Locking steel protective cover	39.8	40	420.998	1.1	28.6	9.8	28.6	38.4	431.098	421.298	39.8	As-built
2	Sch 80 PVC	0.01 inch machine slot	Locking steel protective cover	40.23	40	419.098	1.73	28.4	9.8	28.4	38.2	429.198	419.398	40.23	As-built
2	Sch 80 PVC	0.01 inch machine slot	Locking steel protective cover	38.89	38	447.498	2.59	26.2	9.8	26.2	36	457.598	447.798	38.89	As-built
n/a	n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	RIA
2	PVC	0.010 slotted	Locking steel protective cover	29.6	25	n/a	2.3	17.3	10	17.3	27.3	427.658	417.658	29.6	As-built
2	PVC	0.010 slotted	Locking steel protective cover	29.1	25	n/a	2.3	16.8	10	16.8	26.8	428.86	418.86	29.1	As-built
2	PVC	0.010 slotted	Locking steel protective cover	21.1	18	n/a	2.7	8.4	10	8.4	18.4	428.665	418.665	21.1	As-built
2	PVC	0.010 slotted	Locking steel protective cover	22.8	17	n/a	2.9	9.9	10	9.9	19.9	427.909	417.909	22.8	As-built
2	PVC	0.010 slotted	Locking steel protective cover	17.3	15	15	2.3	7.3	10	5	15	437.068	427.068	n/a	As-built

TABLE 3-1. MONITORING WELL SURVEY AND CONSTRUCTION DATA
WEST LAKE LANDFILL OU-3
REMEDIAL INVESTIGATION / FEASIBILITY STUDY FIELD SAMPLING PLAN

Borehole ID	Env. Control Prefix	Env. Control Point Number	Hydro Zone	Monitoring Status	Alias	Install Date	Northing (ft)	Easting (ft)	MPE (ft msl)	GSE (ft msl)	Survey Source	2012 Cap Ht. Above Grade	Borehole diameter (in)
MW-106	MW	106	AS	X		4/12/1990	1065996.72	833791.62	443.378	439.768	McLaren Hart 1996	n/a	8
MW-107	MW	107	AS	X		32964	1064711.71	833775.82	447.738	n/a	McLaren Hart 1996	n/a	8
MW-1201	MW	1201	AS	I	PZ-1201-SS & 1201	31107	1067343.97	837077.7	482.438	480.198	EMSI 2018	n/a	n/a
MW-1202	MW	1202	AS	X		31107	1067383.97	837049.7	482.178	480.098	EMSI 2018	n/a	n/a
MW-1203	MW	1203	AS	X		31229	1067229.97	837129.7	483.608	480.698	EMSI 2018	n/a	n/a
MW-1204	MW	1204	SD	A		33329	1066461.146	835998.972	485.358	483.091	EMSI 2012 Survey	2.267	8
MW-1205	MW	1205	AS	X		33329	1067428.36	835795.45	386.368	384.098	Foth & Van Dyke 1991	n/a	11 and 6
MW-1206	MW	1206	AS	X		33298	1067437.24	835799.07	388.078	385.798	Foth & Van Dyke 1991	n/a	8
PZ-100-KS	PZ	100	KS	A	1209	34747	1068883.062	837386.265	485.954	484.82	EMSI 2012 Survey	1.134	10 1/4" (0-34 ft) 5 7/8" (34-391 ft)
PZ-100-SD	PZ	100	SD	A	1208	34753	1068892.808	837369.99	486.084	484.492	EMSI 2012 Survey	1.592	10 1/4 "(0-51 ft) 5 7/8" (51-246 ft)
PZ-100-SS	PZ	100	SS	A	1207	34755	1068908.761	837349.65	486.147	484.835	EMSI 2012 Survey	1.312	10 1/4 "(0-51 ft) 5 7/8" (51-94.5 ft)
PZ-101-SS	PZ	101	SS	A	1210	34764	1068513.92	836797.322	491.161	488.947	EMSI 2012 Survey	2.214	10 1/4 "(0-14 ft) 5 7/8" (14-140 ft)
PZ-102R-SS	PZ	102	SS	A	1211	34868	1068172.734	837033.545	486.05	484.176	EMSI 2012 Survey	1.874	10 1/4 "(0-35 ft) 5 7/8" (35-90.3 ft)
PZ-102-SS	PZ	102	SS	A		34770	1068128.683	837062.591	484.245	482.06	EMSI 2012 Survey	2.185	10 1/4 "(0-37 ft) 5 7/8" (37-90.4 ft)
PZ-103-SS	PZ	103	SS	A	1212	34756	1067701.303	836897.822	483.803	479.904	EMSI 2012 Survey	3.899	10 1/4 "(0-51 ft) 5 7/8" (51-145.5 ft)
PZ-104-KS	PZ	104	KS	A	1215	34869	1067034.018	836995.216	484.197	481.838	EMSI 2012 Survey	2.359	10 1/4 "(0-249 ft) 5 7/8" (249-408 ft)
PZ-104-SD	PZ	104	SD	A	1214	34867	1067054.135	837009.268	483.751	481.474	EMSI 2012 Survey	2.277	10 1/4 "(0-38 ft) 5 7/8" (38-252.5 ft)
PZ-104-SS	PZ	104	SS	A	1213	34854	1067068.815	837021.987	483.596	481.648	EMSI 2012 Survey	1.948	10 1/4 "(0-37 ft) 5 7/8" (37-145 ft)
PZ-105-SS	PZ	105	SS	A	1216	34843	1066462.138	836405.054	483.635	480.805	EMSI 2012 Survey	2.83	10 1/4 "(0-45 ft) 5 7/8" (45-149 ft)
PZ-106-KS	PZ	106	KS	A	1219	34781	1066744.652	835606.899	464.324	462.143	EMSI 2012 Survey	2.181	10 1/4 "(0-204 ft) 5 7/8" (204-375 ft)
PZ-106-SD	PZ	106	SD	A	1218	34782	1066755.685	835590.703	463.435	461.418	EMSI 2012 Survey	2.017	10 1/4 "(0-26 ft) 5 7/8" (26-201.1 ft)
PZ-106-SS	PZ	106	SS	A	1217	34794	1066767.07	835574.642	462.704	460.952	EMSI 2012 Survey	1.752	10 1/4 "(0-23 ft) 5 7/8" (23-165.4 ft)
PZ-107-SS	PZ	107	SS	A	1220	34841	1067204.044	835429.345	465.003	462.852	EMSI 2012 Survey	2.151	10 1/4 "(0-32ft) 5 7/8" (32-103 ft)
PZ-108-SS	PZ	108	SS	X	1221	34787	1067719.34	836147.31	455.798	453.698	Golder 1996	n/a	10 1/4 "(0-20ft) 5 7/8" (20-143.9 ft)
PZ-109-SS	PZ	109	SS	A	1222	34814	1068052.306	836318.4981	458.8977	456.8957	EMSI 2012 Survey	2.002	10 1/4 "(0-15ft) 5 7/8" (15-135.7 ft)
PZ-110-SS	PZ	110	SS	I	1223	34839	1068376.97	836094.3	461.0591	458.0299	EMSI 2012 Survey	3.0292	10 1/4 "(0-61ft) 5 7/8" (61-111.5 ft)
PZ-111-KS	PZ	111	KS	A	1225	34825	1068661.958	836025.2057	465.3987	461.3366	EMSI 2012 Survey	4.0621	14 3/4 "(0-84ft) 10" (84.0-215.5) 5 7/8" (215.5-368.8 ft)
PZ-111-SD	PZ	111	SD	A	1224	34810	1068678.166	836009.0044	466.1727	461.9501	EMSI 2012 Survey	4.2226	10" (0-98 ft) 5 7/8" (98-210 ft)
PZ-111-SS	PZ	111	SS	A		42976	1068631.93	835989.4	464.228	461.708	Feezor 2017	n/a	8"
PZ-112-AS	PZ	112	AS	A	1226	34799	1069042.848	835849.449	462.132	458.41	EMSI 2012 Survey	3.722	8 1/4"
PZ-113-AD	PZ	113	AD	A	1228	34822	1069273.97	835934.5	461.835	459.467	EMSI 2012 Survey	2.368	10 1/4"
PZ-113-AS	PZ	113	AS	A	1227	34800	1069264.97	835922.4	461.783	459.58	EMSI 2012 Survey	2.203	8 1/4"
PZ-113-SS	PZ	113	SS	A	1229	34839	1069282.97	835951.3	462.255	459.654	EMSI 2012 Survey	2.601	9 3/4" (0-115 ft) 5 7/8" (115-159 ft)
PZ-114-AS	PZ	114	AS	A	1230	34809	1069459.999	836942.992	451.739	449.564	EMSI 2012 Survey	2.175	10 1/4"
PZ-115-SS	PZ	115	SS	A	1231	34840	1069449.628	836929.871	452.497	450.213	EMSI 2012 Survey	2.284	9 7/8" (0-39ft) 5 7/8" (39-85ft)
PZ-116-SS	PZ	116	SS	A	1232	34870	1066451.146	836018.584	486.038	483.548	EMSI 2012 Survey	2.49	10 1/4 "(0-33ft) 5 7/8" (33-162 ft)
PZ-200-SS	PZ	200	SS	A		34758	1068537.089	837146.557	485.828	483.548	EMSI 2012 Survey	2.28	10 1/4 "(0-27.5ft) 5 7/8" (27.5-98.3 ft)
PZ-201A-SS	PZ	201	SS	A	1223	34812	1067872.76	837021.163	481.928	479.87	EMSI 2012 Survey	2.058	10 1/4 "(0-33ft) 5 7/8" (33-90 ft)
PZ-201-SS	PZ	201	SS	X		34764	1067860.52	837036.76	479.928	477.598	Golder 1996	n/a	10 1/4 "(0-33ft) 5 7/8" (33-39 ft)
PZ-202-SS	PZ	202	SS	A	1234	34770	1067361.152	837276.124	481.416	479.474	EMSI 2012 Survey	1.942	10 1/4" (0-33.5 ft) 5 7/8" (33.5-90 ft)
PZ-203-SS	PZ	203	SS	A	1235	34853	1066702.372	836782.546	486.783	484.123	EMSI 2012 Survey	2.66	10 1/4" (0-56 ft) 5 7/8" (56-110 ft)
PZ-204A-SS	PZ	204A	SS	A	1236	34932	1066470.424	835731.2717	464.8759	464.8759	EMSI 2012 Survey	0	10 1/4" (0.0-14 ft) 5 7/8" (14-90 ft)
PZ-204-SS	PZ	204	SS	A		34768	1066470.424	835731.2717	464.8759	464.8759	EMSI 2012 Survey	0	10 1/4" (0-14 ft) 5 7/8" (14-90.3 ft)
PZ-205-AS	PZ	205	AS	A	1237	34824	1067504.507	835637.878	460.482	458.538	EMSI 2012 Survey	1.944	14 3/4 "(0-29ft) 8 1/4" (29-49ft)
PZ-205-SS	PZ	205	SS	A	1238	34840	1067524.521	835652.192	461.872	459.616	EMSI 2012 Survey	2.256	9 3/4" (0-54 ft) 5 7/8" (54-90 ft)
PZ-206-SS	PZ	206	SS	A	1239	34813	1068071.821	835984.0148	460.3876	458.1918	EMSI 2012 Survey	2.1958	10" (0-52 ft) 5 7/8" (52-125.5 ft)
PZ-207-AS	PZ	207	AS	A	1240	34799	1069685.45	836212.47	462.244	460.156	EMSI 2012 Survey	2.088	8 1/4"
PZ-208-SS	PZ	208	SS	A	1241	34868	1069260.125	837344.084	474.791	472.48	EMSI 2012 Survey	2.311	10 1/4" (0-17 ft) 5 7/8" (17-99.2 ft)
PZ-209-SS	PZ	209	SS	A		41562	1067112.511	837283.267	489.278	486.988	H&A As-Built		9" for soil, 6" for rock
PZ-209-SD	PZ	209	SD	A		41551	1067116.709	837279.115	489.178	486.838	H&A As-Built		9" for soil, 6" for rock
PZ-210-SS	PZ	210	SS	A		41563	1066869.351	836952.107	486.498	484.128	H&A As-Built		9" for soil, 6" for rock
PZ-210-SD	PZ	210	SD	A		41563	1066865.005	836947.817	486.598	484.078	H&A As-Built		9" for soil, 6" for rock
PZ-211-SS	PZ	211	SS	A		41555	1067101.755	837195.851	487.008	484.658	H&A As-Built		9" for soil, 6" for rock

TABLE 3-1. MONITORING WELL SURVEY AND CONSTRUCTION DATA
WEST LAKE LANDFILL OU-3
REMEDIAL INVESTIGATION / FEASIBILITY STUDY FIELD SAMPLING PLAN

Pipe Size (in)	Pipe Type	Perforation detail	Surface Casing	Total Pipe Length (ft)	Boring Depth (ft)	Bottom Elev (ft MSL)	Cap Ht. Above Grade (ft)	Solid Length[1] (ft)	Screen Length (ft)	Screen From	Screen To	Top Screen Elevation (msl)	Bottom Screen Elevation (msl)	Total Pipe Length (ft)	Construction Source
2	PVC	0.010 slotted	Locking steel protective cover	n/a	15		n/a	n/a	10	5	15	434.768	424.768	n/a	As-built
2	PVC	0.010 slotted	Locking steel protective cover	na	15	n/a	n/a	5	10	5	10	n/a	n/a	na	As-built
n/a	n/a	n/a	n/a		250	230.198	2.24	53	197	53	250	427.198	230.198	250	RIA
n/a	n/a	n/a	n/a		250	230.098	2.08	n/a	n/a	n/a	n/a	n/a	n/a	250	RIA
n/a	n/a	n/a	n/a		250	230.698	2.91	n/a	n/a	n/a	n/a	n/a	n/a	250	RIA
2	Sch. 80 PVC	0.010 slotted	Locking steel protective cover	225.8	227	n/a	2.3	213.5	10	213.5	223.5	269.591	259.591	225.8	As-built
2	Sch. 80 PVC	0.010 slotted	Locking steel protective cover	125.3	132	n/a	2.3	113	10	113	123	271.098	261.098	125.3	As-built
2	Sch. 80 PVC	0.010 slotted	Locking steel protective cover	75.3	73	n/a	2.3	63	10	63	73	322.798	312.798	75.3	As-built
2	Sch 80 PVC	0.01 inch machine slot	Locking steel protective cover	386.01	391.2	99.228	1.88	374	9.8	374	383.8	109.358	99.558	386.01	As-built
2	Sch 80 PVC	0.01 inch machine slot	Locking steel protective cover	246.4	246	239.018	1.47	234.8	9.8	234.8	244.6	249.148	239.348	246.4	As-built
2	Sch 80 PVC	0.01 inch machine slot	Locking steel protective cover	95.42	94.5	390.018	1.49	73.96	19.64	73.96	93.6	409.988	390.348	95.42	As-built
2	Sch 80 PVC	0.01 inch machine slot	Locking steel protective cover	141.4	140	334.878	1.79	129.48	9.8	129.48	139.28	345.008	335.208	141.4	As-built
2	Sch 80 PVC	0.01 inch machine slot	Locking steel protective cover	91.08	90.3	394.138	1.12	79.83	9.8	79.83	89.63	404.268	394.468	91.08	As-built
2	Sch 80 PVC	0.01 inch machine slot	Locking steel protective cover	92.63	90.4	390.818	1.8	79.7	9.8	79.7	89.5	401.948	392.148	92.63	As-built
2	Sch 80 PVC	0.01 inch machine slot	Locking steel protective cover	147.22	145.5	332.548	2.39	134.7	9.8	134.7	144.5	342.678	332.878	147.22	As-built
2	Sch 80 PVC	0.01 inch machine slot	6 5/8" Steel Casing elev 483.3 - 233.32	409.22	408	74.418	1.72	397.37	9.8	397.37	407.17	84.548	74.748	409.22	As-built
2	Sch 80 PVC	0.01 inch machine slot	Locking steel protective cover	246.92	252.5	236.368	1.59	235.2	9.8	235.2	245	246.498	236.698	246.92	As-built
2	Sch 80 PVC	0.01 inch machine slot	Locking steel protective cover	146.7	145	336.528	2.07	134.5	9.8	134.5	144.3	346.658	336.858	146.7	As-built
2	Sch 80 PVC	0.01 inch machine slot	6 5/8" Steel Casing elev 482.7 - 436.22	151.02	149	332.188	2.39	138.5	9.8	138.5	148.3	342.318	332.518	151.02	As-built
2	Sch 80 PVC	0.01 inch machine slot	6 5/8" Steel Casing elev 463.3 - 257.77	376.39	375	87.468	2.49	363.75	9.8	363.75	373.57	97.618	87.798	376.39	As-built
2	Sch 80 PVC	0.01 inch machine slot	Locking steel protective cover	202.9	201.1	260.118	1.97	190.79	9.8	190.79	200.59	270.258	260.458	202.9	As-built
2	Sch 80 PVC	0.01 inch machine slot	Locking steel protective cover	297.2	165.4	295.118	1.75	155.3	9.8	155.3	165.1	305.248	295.448	297.2	As-built
2	Sch 80 PVC	0.01 inch machine slot	6 5/8" Steel Casing elev 463.6 - 407.63	104.76	103	359.498	2.03	92.6	9.8	92.6	102.4	369.628	359.828	104.76	As-built
2	Sch 80 PVC	0.01 inch machine slot	Locking steel protective cover	145.76	143.9	310.038	2.08	133.54	9.8	133.54	143.35	320.178	310.368	145.76	As-built
2	Sch 80 PVC	0.01 inch machine slot	Locking steel protective cover	137.56	135.7	320.538	1.73	125.7	9.8	125.7	135.5	330.668	320.868	137.56	As-built
2	Sch 80 PVC	0.01 inch machine slot	6 5/8" Steel Casing elev 457.3 - 395.84	113.37	111.5	345.138	2.07	100.9	9.8	100.9	110.7	355.538	345.738	113.37	As-built
2	Sch 80 PVC	0.01 inch machine slot	10 7/8" Steel Casing elev 459.9 - 375.38; 6 5/8" Steel Casing elev 460.2 - 243.88	368.99	368.8	91.478	1.69	357.15	9.8	357.15	366.96	101.628	91.818	368.99	As-built
2	Sch 80 PVC	0.01 inch machine slot	6 5/8" Steel Casing elev 459.7 - 361.22	211.83	210	249.318	2.33	199.4	9.8	199.4	209.2	259.418	249.618	211.83	As-built
2	Sch 80 PVC	0.01 inch machine slot	6" Steel Casing 0 - 93 ft bgs		0	0	0	0	0	462.11	462.11	0	0	0	RIA
2	Sch 80 PVC	0.01 inch machine slot	Locking steel protective cover	36.63	36	422.798	1.9	29.6	4.8	29.6	34.4	427.928	423.128	36.63	As-built
2	Sch 80 PVC	0.01 inch machine slot	Locking steel protective cover	110.33	108.7	350.728	1.6	98.6	9.8	98.6	108.4	360.858	351.058	110.33	As-built
2	Sch 80 PVC	0.01 inch machine slot	Locking steel protective cover	40.53	40	420.488	1.5	28.9	9.8	28.9	38.7	430.618	420.818	40.53	As-built
2	Sch 80 PVC	0.01 inch machine slot	6 5/8" Steel Casing elev 460.4 - 344.96	160.51	159	300.858	1.81	148.57	9.8	148.57	158.37	310.988	301.188	160.51	As-built
2	Sch 80 PVC	0.01 inch machine slot	Locking steel protective cover	31.56	30.5	419.348	1.53	19.9	9.8	19.9	29.7	429.478	419.678	31.56	As-built
2	Sch 80 PVC	0.01 inch machine slot	Locking steel protective cover	86.5	85	365.398	1.69	74.68	9.8	74.68	84.48	375.528	365.728	86.5	As-built
2	Sch 80 PVC	0.01 inch machine slot	6 5/8" Steel Casing elev 451.6 - 411.61	163.13	162	321.338	1.8	151.4	9.8	151.4	161	331.268	331.668	163.13	As-built
2	Sch 80 PVC	0.01 inch machine slot	Locking steel protective cover	99.99	98.7	385.238	2.02	9.62	88.02	9.62	97.64	473.588	385.568	99.99	As-built
2	Sch 80 PVC	0.01 inch machine slot	Locking steel protective cover	91.94	90	387.818	1.81	80	9.8	80	89.8	397.948	388.148	91.94	As-built
2	Sch 80 PVC	0.01 inch machine slot	Locking steel protective cover	90.96	89	388.968	2.32	9.75	78.56	9.75	88.31	467.858	389.298	90.96	As-built
2	Sch 80 PVC	0.01 inch machine slot	6 5/8" Steel Casing elev 480 - 445.01	91.59	90	389.178	2.16	40.2	48.9	40.2	89.1	438.408	389.508	91.59	As-built
2	Sch 80 PVC	0.01 inch machine slot	6 5/8" Steel Casing elev 484.7 - 428.08	112.11	110	374.078	2.41	99.6	9.8	99.6	109.4	384.178	374.378	112.11	As-built
2	Sch. 80 PVC	0.010 slotted	Locking steel protective cover	90.93	90	376.828	1.5	79.5	9.6	79.5	89.1	386.758	377.158	90.93	As-built
2	Sch 80 PVC	0.01 inch machine slot	Locking steel protective cover	92.28	90.3	376.948	2.6	10.95	78.4	10.95	89.35	455.678	377.278	92.28	As-built
2	Sch 80 PVC	0.01 inch machine slot	6 5/8" Steel Casing elev 460 - 430.33	50.34	49	410.248	1.66	38.55	9.8	38.55	48.35	420.378	410.578	50.34	As-built
2	Sch 80 PVC	0.01 inch machine slot	6 5/8" Steel Casing elev 460.5 - 405.53	100.36	99	360.428	1.66	88.57	9.8	88.57	98.37	370.558	360.758	100.36	As-built
2	Sch 80 PVC	0.01 inch machine slot	6 5/8" Steel Casing elev 459.1 - 406.38	126.82	125.5	332.978	1.82	115	9.8	115	124.8	342.978	333.178	126.82	As-built
2	Sch 80 PVC	0.01 inch machine slot	Locking steel protective cover	41.72	40	421.448	1.69	34.9	4.8	34.9	39.7	426.578	421.778	41.72	As-built
2	Sch 80 PVC	0.01 inch machine slot	Locking steel protective cover	100.55	99.2	373.298	1.72	88.7	9.8	88.7	98.5	383.428	373.628	100.55	As-built
2	Sch. 80 PVC	0.010 slotted	Locking steel protective cover	152.29	150	336.988	2.29	140	10	140	150	346.988	336.988	152.29	As-built
2	Sch. 80 PVC	0.010 slotted	Locking steel protective cover	252.34	250	236.838	2.34	240	10	240	250	246.838	236.838	252.34	As-built
2	Sch. 80 PVC	0.010 slotted	Locking steel protective cover	150.37	148	336.128	2.37	138	10	138	148	346.128	336.128	150.37	As-built
2	Sch. 80 PVC	0.010 slotted	Locking steel protective cover	250.52	248	236.078	2.52	238	10	238	248	246.078	236.078	250.52	As-built
2	Sch. 80 PVC	0.010 slotted	Locking steel protective cover	149.35	147	337.658	2.35	137	10	137	147	347.658	337.658	149.35	As-built

TABLE 3-1. MONITORING WELL SURVEY AND CONSTRUCTION DATA
WEST LAKE LANDFILL OU-3
REMEDIAL INVESTIGATION / FEASIBILITY STUDY FIELD SAMPLING PLAN

Borehole ID	Env. Control Prefix	Env. Control Point Number	Hydro Zone	Monitoring Status	Alias	Install Date	Northing (ft)	Easting (ft)	MPE (ft msl)	GSE (ft msl)	Survey Source	2012 Cap Ht. Above Grade	Borehole diameter (in)
PZ-211-SD	PZ	211	SD	A		41554	1067097.668	837191.308	487.058	484.428	H&A As-Built		9" for soil, 6" for rock
PZ-212-SS	PZ	212	SS	A		41565	1067531.957	838151.155	482.388	479.758	H&A As-Built		9" for soil, 6" for rock
PZ-212-SD	PZ	212	SD	A		41568	1067536.663	838155.084	482.318	480.078	H&A As-Built		7.25
PZ-300-AD	PZ	300	AI	X		34966	1065254.81	834002.76	449.218	447.698	Golder 1996	n/a	8 1/4"
PZ-300-AS	PZ	300	AS	X		34968	1065539.41	834042.53	450.258	448.098	Golder 1996	n/a	8 1/4"
PZ-300-SS	PZ	300	SS	X		34968	1065245.72	834024.51	449.198	447.998	Golder 1996	n/a	9 7/8" (0-46ft) 5 7/8" (46-93ft)
PZ-301-SS	PZ	301	SS	X		34965	1064842.65	835691.69	514.308	512.698	Golder 1996	n/a	8 1/4" (0-19 ft) 5 7/8" (19-161.5 ft)
PZ-302-AI	PZ	302	AI	I		34968	1067250.868	834895.669	451.194	449.771	EMSI 2012 Survey	1.423	8 1/4"
PZ-302-AS	PZ	302	AS	I		34967	1067238.22	834912.693	451.572	449.355	EMSI 2012 Survey	2.217	8 1/4"
PZ-303-AS	PZ	303	AS	I		34977	1067703.94	834600.481	453.277	451.04	EMSI 2012 Survey	2.237	8 1/4"
PZ-304-AI	PZ	304	AI	I		34974	1068166.325	834609.398	454.151	451.756	EMSI 2012 Survey	2.395	8 1/4"
PZ-304-AS	PZ	304	AS	I		34969	1068187.019	834609.304	453.89	451.731	EMSI 2012 Survey	2.159	8 1/4"
PZ-305-AI	PZ	305	AI	I		34991	1068119.659	835797.8921	459.9808	458.0891	EMSI 2012 Survey	1.8917	8 1/4"
PZ-1201-SS	PZ	1201	SS	X		34887	1067343.39	837078.26	482.018	479.998	Golder 1996	n/a	Unknown (0-53 ft) 5 7/8" (53-250)
S-1	S	1	AS	X		1981	1069726.8	834379.71	446.108	442.898	McLaren Hart 1996	n/a	8.25
S-5	S	5	AS	I	WL-105C	34912	1069196.97	836075.6	466.225	463.022	EMSI 2012 Survey	3.203	8.25
S-8	S	8	AS	I	WI-228	34943	1071085.014	834898.6739	443.9346	441.5499	EMSI 2012 Survey	2.3847	8.25
S-10	S	10	AS	I	WL-216C; WL-232	34943	1069868.787	835106.242	480.1	477.603	EMSI 2012 Survey	2.497	8.25
S-51	S	51	AS	X	HL-3	1981	1066202.28	834495.42	449.168	445.898	McLaren Hart 1996	n/a	n/a
S-52	S	52	AS	X	HL-2	1981	1066510.97	834374.7	446.678	444.298	EMSI 2018 - Calculated	n/a	n/a
S-53	S	53	AS	I	HL-1	1981	1066911.169	834671.966	444.099	441.041	EMSI 2012 Survey	3.058	n/a
S-54	S	54	AS	X	36	Unknown	1067646.97	834642.7	n/a	469.598	EMSI 2018	n/a	n/a
S-60	S	60	AS	X	S-2	29768	1069790.97	834484.7	446.528	442.698	EMSI 2018 - Calculated	n/a	n/a
S-61	S	61	AS	X	S-1	29768	1070200.944	834754.559	449.202	445.496	EMSI 2012 Survey	3.706	n/a
S-75	S	75	AS	X	37	Unknown	1067291.38	834893.45	461.678	458.398	McLaren Hart 1996	n/a	n/a
S-76	S	76	AS	X	37A	28642	1067446.97	834743.7	n/a	473.998	EMSI 2018	n/a	n/a
S-80	S	80	AS	X		30922	1065232.74	834033.05	452.708	447.998	McLaren Hart 1996	n/a	5"
S-82	S	82	AS	I		30921	1069352.643	834447.496	450.113	448.172	EMSI 2012 Survey	1.941	5"
S-84	S	84	AS	A		30895	1069674.22	836614.269	457.044	454.24	EMSI 2012 Survey	2.804	5"
S-88	S	88	AS	X		30895	1068439.36	835408.73	462.358	459.598	McLaren Hart 1996	n/a	5" (0-30 ft), 4 1/2" (30-41.5)

TABLE 3-1. MONITORING WELL SURVEY AND CONSTRUCTION DATA
WEST LAKE LANDFILL OU-3
REMEDIAL INVESTIGATION / FEASIBILITY STUDY FIELD SAMPLING PLAN

Pipe Size (in)	Pipe Type	Perforation detail	Surface Casing	Total Pipe Length (ft)	Boring Depth (ft)	Bottom Elev (ft MSL)	Cap Ht. Above Grade (ft)	Solid Length[1] (ft)	Screen Length (ft)	Screen From	Screen To	Top Screen Elevation (msl)	Bottom Screen Elevation (msl)	Total Pipe Length (ft)	Construction Source
2	Sch. 80 PVC	0.010 slotted	Locking steel protective cover	240.46	247	237.428	2.63	237	10	237	247	347.428	237.428	240.46	As-built
2	Sch. 80 PVC	0.010 slotted	Locking steel protective cover	146.63	150	329.758	2.63	134	10	134	144	345.758	335.758	146.63	As-built
2	Sch. 80 PVC	0.010 slotted	Locking steel protective cover	246.24	245	235.078	2.24	234	10	234	244	246.078	236.078	246.24	As-built
2	Sch 80 PVC	0.01 inch machine slot	Locking steel protective cover	43.72	42.2	405.498	1.52	37.1	4.8	37.1	41.9	410.598	405.798	43.72	As-built
2	Sch 80 PVC	0.01 inch machine slot	Locking steel protective cover	22.16	20	428.098	2.16	9.9	9.8	9.9	19.7	438.198	428.398	22.16	As-built
2	Sch 80 PVC	0.01 inch machine slot	6 5/8" Steel Casing elev 447.6 - 402.4	95.2	94.5	353.998	1.2	83.88	9.8	83.88	93.7	364.118	354.298	95.2	As-built
2	Sch 80 PVC	0.01 inch machine slot	Locking steel protective cover	162.61	161.5	351.698	1.61	150.9	9.8	150.9	160.7	361.798	351.998	162.61	As-built
2	Sch 80 PVC	0.01 inch machine slot	Locking steel protective cover	43.85	43	406.898	1.15	32.6	9.8	32.6	42.4	416.998	407.198	43.85	As-built
2	Sch 80 PVC	0.01 inch machine slot	Locking steel protective cover	24.22	22.3	426.798	1.92	12.2	9.8	12.2	22	436.898	427.098	24.22	As-built
2	Sch 80 PVC	0.01 inch machine slot	Locking steel protective cover	28.48	26.5	424.298	2.38	16	9.8	16	25.8	434.398	424.598	28.48	As-built
2	Sch 80 PVC	0.01 inch machine slot	Locking steel protective cover	51.52	50	402.098	2.42	39	9.8	39	48.8	412.198	402.398	51.52	As-built
2	Sch 80 PVC	0.01 inch machine slot	Locking steel protective cover	29.51	28	423.798	2.31	17.1	9.8	17.1	26.9	433.898	424.098	29.51	As-built
2	Sch 80 PVC	0.01 inch machine slot	Locking steel protective cover	64.98	64	393.898	1.68	53.2	9.8	53.2	63	403.998	394.198	64.98	As-built
2	Sch 80 PVC	0.01 inch machine slot	6 5/8" Steel Casing elev 483-427.41		250	229.998	2.01	139.71, 0.33	9.6	137.69	147.29	342.308	332.708	147.63	RIA
2	Sch. 40 PVC	0.010 slotted	Locking steel protective cover	25.71	25	417.898	3.21	2.5	20	2.5	22.5	440.398	420.398	25.71	As-built
2	Sch. 40 PVC	0.010 slotted	Locking steel protective cover	42.95	49.3	415.998	2.95	30	10	30	40	435.298	425.298	42.95	As-built
2	Sch. 40 PVC	0.010 slotted	Locking steel protective cover	29.23	29.3	411.898	2.43	6.8	20	6.8	26.8	434.398	414.398	29.23	As-built
2	Sch. 40 PVC	0.010 slotted	Locking steel protective cover	49.22	54.5	422.598	2.78	32	20	32	52	445.098	425.098	49.22	As-built
n/a	n/a	n/a	n/a		25.8	420.098	1.42	24.22	3	22.8	25.8	423.098	420.098	25.8	RIA
n/a	n/a	n/a	n/a		25.2	419.098	2.38	24.58	3	22.2	25.2	422.098	419.098	25.2	RIA
n/a	n/a	n/a	n/a		23.7	420.698	4.2	24.9	3	20.7	23.7	423.698	420.698	23.7	RIA
n/a	n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	40.4	RIA
n/a	n/a	n/a	n/a		21	421.698	3.83	n/a	n/a	n/a	21	n/a	421.698	21	RIA
n/a	n/a	n/a	n/a		21.5	423.698	4.57	n/a	n/a	n/a	21.5	n/a	423.698	21.5	RIA
n/a	n/a	n/a	n/a		26	432.398	1.1	24.1	3	23	26	435.398	432.398	26	RIA
n/a	n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	50	RIA
2	PVC	0.01 inch machine slot	n/a		22	425.998	5	15	10	10	20	437.998	427.998	20	RIA
2	PVC	0.01 inch machine slot	n/a		26.5	420.798	3	18.5	10	15.5	25.5	431.798	421.798	25.5	RIA
2	PVC	0.01 inch machine slot	n/a		31.5	420.998	4	24.9	10	20.9	30.9	431.598	421.598	30.9	RIA
2	PVC	0.01 inch machine slot	n/a		41.5	418.098	2.7	33	10	30	40	429.598	419.598	40	RIA

Notes:
ft - feet
in - inches
msl - mean sea level
n/a - not applicable

EMSI - Environmental Management Support, Inc
RIA - Remedial Investigation Addendum
MPE - Measuring Point Elevation
GSE - Ground Surface Elevation
PVC - Polyvinyl Chloride
Sch - Schedule

Monitoring Status
A - Active
I - Inactive
U - Unknown
X - Abandoned

Environmental Control Prefix
D - Deep
F - Foth
I - Intermediate
LR - Leachate Riser
MW - Monitoring Well
PZ - Piezometer
S - Shallow

Hydrological Zone
AD - Deep Alluvial
AS - Shallow Alluvial
AI - Intermediate Alluvial
LR - Leachate Riser
KS - Keokuk Formation
SD - Salem Formation
SS - Upper Salem/St. Louis Formation

TABLE 3-2. PROPOSED MONITORING WELL NETWORK
WEST LAKE LANDFILL OU-3
REMEDIAL INVESTIGATION / FEASIBILITY STUDY FIELD SAMPLING PLAN

Prefix	Series	Zone	Well ID	Current Monitoring Status
PZ	112	AS	PZ-112-AS	A
PZ	113	AS	PZ-113-AS	A
PZ	114	AS	PZ-114-AS	A
PZ	205	AS	PZ-205-AS	A
PZ	207	AS	PZ-207-AS	A
S	84	AS	S-84	A
MW	103	AS	MW-103	I
MW	104	AS	MW-104	I
MW	1201	AS	MW-1201	I
PZ	302	AS	PZ-302-AS	I
PZ	303	AS	PZ-303-AS	I
PZ	304	AS	PZ-304-AS	I
S	5	AS	S-5	I
S	8	AS	S-8	I
S	10	AS	S-10	I
S	53	AS	S-53	I
S	82	AS	S-82	I
MW	400	AS	MW-400-AS	P
MW	401	AS	MW-401-AS	P
MW	402	AS	MW-402-AS	P
MW	500	AS	MW-500-AS	P
MW	501	AS	MW-501-AS	P
MW	502	AS	MW-502-AS	P
MW	600	AS	MW-600-AS	P
MW	603	AS	MW-603-AS	P
I	68	AI	I-68	A
I	73	AI	I-73	A
D	89	AI	D-89	I
I	4	AI	I-4	I
I	9	AI	I-9	I
I	11	AI	I-11	I
I	62	AI	I-62	I
I	65	AI	I-65	I
I	66	AI	I-66	I
I	67	AI	I-67	I
PZ	302	AI	PZ-302-AI	I
PZ	304	AI	PZ-304-AI	I
PZ	305	AI	PZ-305-AI	I
MW	400	AI	MW-400-AI	P
MW	401	AI	MW-401-AI	P
MW	402	AI	MW-402-AI	P
MW	500	AI	MW-500-AI	P
MW	501	AI	MW-501-AI	P
MW	502	AI	MW-502-AI	P
MW	600	AI	MW-600-AI	P
MW	603	AI	MW-603-AI	P
I	7	AI	I-7	U

TABLE 3-2. PROPOSED MONITORING WELL NETWORK
WEST LAKE LANDFILL OU-3
REMEDIAL INVESTIGATION / FEASIBILITY STUDY FIELD SAMPLING PLAN

Prefix	Series	Zone	Well ID	Current Monitoring Status
D	85	AD	D-85	A
PZ	113	AD	PZ-113-AD	A
D	3	AD	D-3	I
D	6	AD	D-6	I
D	12	AD	D-12	I
D	13	AD	D-13	I
D	81	AD	D-81	I
D	83	AD	D-83	I
D	87	AD	D-87	I
D	93	AD	D-93	I
MW	304	AD	MW-304-AD	P
MW	400	AD	MW-400-AD	P
MW	401	AD	MW-401-AD	P
MW	402	AD	MW-402-AD	P
MW	500	AD	MW-500-AD	P
MW	501	AD	MW-501-AD	P
MW	502	AD	MW-502-AD	P
MW	600	AD*	MW-600-AD*	P
MW	603	AD*	MW-603-AD*	P
LR	100	LR	LR-100	I
LR	103	LR	LR-103	I
LR	104	LR	LR-104	I
LR	105	LR	LR-105	I
PZ	100	SS	PZ-100-SS	A
PZ	101	SS	PZ-101-SS	A
PZ	102	SS	PZ-102R-SS	A
PZ	102	SS	PZ-102-SS	A
PZ	103	SS	PZ-103-SS	A
PZ	104	SS	PZ-104-SS	A
PZ	105	SS	PZ-105-SS	A
PZ	106	SS	PZ-106-SS	A
PZ	107	SS	PZ-107-SS	A
PZ	109	SS	PZ-109-SS	A
PZ	111	SS	PZ-111-SS	A
PZ	113	SS	PZ-113-SS	A
PZ	115	SS	PZ-115-SS	A
PZ	116	SS	PZ-116-SS	A
PZ	200	SS	PZ-200-SS	A
PZ	201	SS	PZ-201A-SS	A
PZ	202	SS	PZ-202-SS	A
PZ	203	SS	PZ-203-SS	A
PZ	204A	SS	PZ-204A-SS	A
PZ	204	SS	PZ-204-SS	A
PZ	205	SS	PZ-205-SS	A
PZ	206	SS	PZ-206-SS	A
PZ	208	SS	PZ-208-SS	A
PZ	209	SS	PZ-209-SS	A
PZ	210	SS	PZ-210-SS	A
PZ	211	SS	PZ-211-SS	A
PZ	212	SS	PZ-212-SS	A
PZ	110	SS	PZ-110-SS	I

TABLE 3-2. PROPOSED MONITORING WELL NETWORK
WEST LAKE LANDFILL OU-3
REMEDIAL INVESTIGATION / FEASIBILITY STUDY FIELD SAMPLING PLAN

Prefix	Series	Zone	Well ID	Current Monitoring Status
MW	304	SS	MW-304-SS	P
MW	601	SS	MW-601-SS	P
MW	602	SS	MW-602-SS	P
MW	400	SS*	MW-400-SS*	P
MW	401	SS*	MW-401-SS*	P
MW	402	SS*	MW-402-SS*	P
MW	500	SS*	MW-500-SS*	P
MW	500	SS*	MW-500-SS*	P
MW	500	SS*	MW-500-SS*	P
MW	600	SS*	MW-600-SS*	P
MW	603	SS*	MW-603-SS*	P
MW	1204	SD	MW-1204	A
PZ	100	SD	PZ-100-SD	A
PZ	104	SD	PZ-104-SD	A
PZ	106	SD	PZ-106-SD	A
PZ	111	SD	PZ-111-SD	A
PZ	209	SD	PZ-209-SD	A
PZ	210	SD	PZ-210-SD	A
PZ	211	SD	PZ-211-SD	A
PZ	212	SD	PZ-212-SD	A
MW	304	SD	MW-304-SD	P
MW	400	SD	MW-400-SD	P
MW	401	SD	MW-401-SD	P
MW	402	SD	MW-402-SD	P
MW	500	SD	MW-500-SD	P
MW	501	SD	MW-501-SD	P
MW	502	SD	MW-502-SD	P
MW	600	SD	MW-600-SD	P
MW	601	SD	MW-601-SD	P
MW	602	SD	MW-602-SD	P
MW	603	SD	MW-603-SD	P
PZ	100	KS	PZ-100-KS	A
PZ	104	KS	PZ-104-KS	A
PZ	106	KS	PZ-106-KS	A
PZ	111	KS	PZ-111-KS	A

Notes:

Environmental Control Prefix
S - Shallow
I - Intermediate
D - Deep
LR - Leachate Riser
MW - Monitoring Well
PZ - Piezometer

Monitoring Status
A - Active
I - Inactive
U - Unknown
P - Proposed

Hydrological Zone
AS - Shallow Alluvial
AI - Intermediate Alluvial
AD - Deep Alluvial
LR - Leachate Riser
SS - Upper Salem/St. Louis Formation
SD - Salem Formation
KS - Keokuk Formation

Samples will not be collected from well I-4 due to compromised casing

TABLE 3-3. PROPOSED MONITORING WELL RATIONALE
WEST LAKE LANDFILL OU-3
REMEDIAL INVESTIGATION / FEASIBILITY STUDY FIELD SAMPLING PLAN

Prefix	Series	Zone	Borehole ID	Total Depth (ft bgs)	Ground Surface Elevation (ft msl)	Bottom Screen Elevation (ft msl)	Borehole Diameter (inches)	Well Construction	Nearby Wells/Piezometers/Staff Gauges	Data Gaps Addressed	Additional Rationale	Drilling Method	Property Owner	Acoustic Televiewer	Multi-elect. Resistivity	Induction/ Conductivity	Flow Meter	Fluid Resistivity	Fluid Temp.	Gamma-Gamma-Density	Natural Gamma	Spectral Gamma	Caliper	Hydraulic Conductivity Test
MW	304	AD	MW-304-AD	111	451	340	9	2-inch Sch. 80 PVC	PZ-304 Cluster	2, 3, 5, 6, 7, 9	No deep or bedrock wells exist at PZ-304 cluster	Air/Sonic/Continuous Core	Bridgeton Landfill, LLC			X	X	X	X					Pneumatic Slug
MW	304	SS	MW-304-SS	151	451	300	9/6	2-inch Sch. 80 PVC	PZ-304 Cluster	2, 3, 5, 6, 7, 9	No deep or bedrock wells exist at PZ-304 cluster	Air/Sonic/Continuous Core	Bridgeton Landfill, LLC				X	X	X					Pneumatic Slug
MW	304	SD	MW-304-SD	211	451	240	9/6	2-inch Sch. 80 PVC	PZ-304 Cluster	2, 3, 5, 6, 7, 9	No deep or bedrock wells exist at PZ-304 cluster	Air/Sonic/Continuous Core	Bridgeton Landfill, LLC	X	X	X	X	X	X	X	X	X	X	Packer and Pneumatic Slug
MW	400	AS	MW-400-AS	26	446	420	12	2-inch triple nested Sch. 80 PVC	S-61, MW-102, D-6	2, 3, 5, 6, 7, 9	S-61 and MW-102 abandoned, D-6 slated for abandonment	Air/Sonic/Continuous Core	AAA Trailers				X	X	X					Traditional/Pneumatic Slug
MW	400	AI	MW-400-AI	51	446	395	12	2-inch triple nested Sch. 80 PVC	S-61, MW-102, D-6	2, 3, 5, 6, 7, 9	S-61 and MW-102 abandoned, D-6 slated for abandonment	Air/Sonic/Continuous Core	AAA Trailers				X	X	X					Pneumatic Slug
MW	400	AD	MW-400-AD	106	446	340	12	2-inch triple nested Sch. 80 PVC	S-61, MW-102, D-6	2, 3, 5, 6, 7, 9	S-61 and MW-102 abandoned, D-6 slated for abandonment	Air/Sonic/Continuous Core	AAA Trailers				X	X	X					Pneumatic Slug
MW	400	SS*	MW-400-SS*	146	446	300	9/6	2-inch Sch. 80 PVC	S-61, MW-102, D-6	2, 3, 5, 6, 7, 9	S-61 and MW-102 abandoned, D-6 slated for abandonment	Air/Sonic/Continuous Core	AAA Trailers				X	X	X					Pneumatic Slug
MW	400	SD	MW-400-SD	206	446	240	9/6	2-inch Sch. 80 PVC	S-61, MW-102, D-6	2, 3, 5, 6, 7, 9	S-61 and MW-102 abandoned, D-6 slated for abandonment	Air/Sonic/Continuous Core	AAA Trailers	X	X	X	X	X	X	X	X	X	X	Packer and Pneumatic Slug
MW	401	AS	MW-401-AS	25	445	420	12	2-inch triple nested Sch. 80 PVC	S-6, I-62, D-83	2, 3, 5, 6, 7, 9	S-8, I-62, and D-83 slated for abandonment	Air/Sonic/Continuous Core	AAA Trailers				X	X	X					Traditional/Pneumatic Slug
MW	401	AI	MW-401-AI	50	445	395	12	2-inch triple nested Sch. 80 PVC	S-6, I-62, D-83	2, 3, 5, 6, 7, 9	S-8, I-62, and D-83 slated for abandonment	Air/Sonic/Continuous Core	AAA Trailers				X	X	X					Pneumatic Slug
MW	401	AD	MW-401-AD	105	445	340	12	2-inch triple nested Sch. 80 PVC	S-6, I-62, D-83	2, 3, 5, 6, 7, 9	S-8, I-62, and D-83 slated for abandonment	Air/Sonic/Continuous Core	AAA Trailers				X	X	X					Pneumatic Slug
MW	401	SS*	MW-401-SS*	145	445	300	9/6	2-inch Sch. 80 PVC	S-6, I-62, D-83	2, 3, 5, 6, 7, 9	No bedrock wells exist at this location	Air/Sonic/Continuous Core	AAA Trailers				X	X	X					Pneumatic Slug
MW	401	SD	MW-401-SD	205	445	240	9/6	2-inch Sch. 80 PVC	S-6, I-62, D-83	2, 3, 5, 6, 7, 9	No bedrock wells exist at this location	Air/Sonic/Continuous Core	AAA Trailers	X	X	X	X	X	X	X	X	X	X	Packer and Pneumatic Slug
MW	402	AS	MW-402-AS	34	454	420	12	2-inch triple nested Sch. 80 PVC	I-66, D-13	2, 3, 5, 6, 7, 9, 10	No shallow alluvial well exists at this location	Air/Sonic/Continuous Core	Bridgeton Landfill, LLC				X	X	X					Traditional/Pneumatic Slug
MW	402	AI	MW-402-AI	59	454	395	12	2-inch triple nested Sch. 80 PVC	I-66, D-13	2, 3, 5, 6, 7, 9	No intermediate alluvial well exists at this location	Air/Sonic/Continuous Core	Bridgeton Landfill, LLC											Pneumatic Slug
MW	402	AD	MW-402-AD	114	454	340	12	2-inch triple nested Sch. 80 PVC	I-66, D-13	2, 3, 5, 6, 7, 9	Replace well D-6	Air/Sonic/Continuous Core	Bridgeton Landfill, LLC											Pneumatic Slug
MW	402	SS*	MW-402-SS*	154	454	300	9/6	2-inch Sch. 80 PVC	I-66, D-13	2, 3, 5, 6, 7, 9	No bedrock wells exist at this on-site location	Air/Sonic/Continuous Core	Bridgeton Landfill, LLC				X	X	X					Pneumatic Slug
MW	402	SD	MW-402-SD	214	454	240	9/6	2-inch Sch. 80 PVC	I-66, D-13	2, 3, 5, 6, 7, 9	No bedrock wells exist at this on-site location	Air/Sonic/Continuous Core	Bridgeton Landfill, LLC	X	X	X	X	X	X	X	X	X	X	Packer and Pneumatic Slug
MW	500	AS	MW-500-AS	19	439	420	12	2-inch triple nested Sch. 80 PVC	SG-500*	2, 3, 5, 6, 8, 9,10	Downgradient of Inactive Sanitary Landfill	Air/Sonic/Continuous Core	Earth City Right-of-Way				X	X	X					Traditional/Pneumatic Slug
MW	500	AI	MW-500-AI	44	439	395	12	2-inch triple nested Sch. 80 PVC	SG-500*	2, 3, 5, 6, 9,10	Downgradient of Inactive Sanitary Landfill	Air/Sonic/Continuous Core	Earth City Right-of-Way				X	X	X					Pneumatic Slug
MW	500	AD	MW-500-AD	99	439	340	12	2-inch triple nested Sch. 80 PVC	SG-500*	2, 3, 5, 6, 9,10	Downgradient of Inactive Sanitary Landfill	Air/Sonic/Continuous Core	Earth City Right-of-Way			X	X	X	X					Pneumatic Slug
MW	500	SS*	MW-500-SS*	139	439	300	9/6	2-inch Sch. 80 PVC	SG-500*	2, 3, 5, 6, 9,10	Downgradient of Inactive Sanitary Landfill	Air/Sonic/Continuous Core	Earth City Right-of-Way											Pneumatic Slug
MW	500	SD	MW-500-SD	199	439	240	9/6	2-inch Sch. 80 PVC	SG-500*	2, 3, 5, 6, 9,10	Downgradient of Inactive Sanitary Landfill	Air/Sonic/Continuous Core	Earth City Right-of-Way	X	X	X	X	X	X	X	X	X	X	Packer and Pneumatic Slug
MW	501	AS	MW-501-AS	18	438	420	12	2-inch triple nested Sch. 80 PVC	SG-400*	2, 3, 5, 6, 8, 9,10	Downgradient of wells D-83 and D-6	Air/Sonic/Continuous Core	Earth City Right-of-Way				X	X	X					Traditional/Pneumatic Slug
MW	501	AI	MW-501-AI	43	438	395	12	2-inch triple nested Sch. 80 PVC	SG-400*	2, 3, 5, 6, 9,10	Downgradient of wells D-83 and D-6	Air/Sonic/Continuous Core	Earth City Right-of-Way				X	X	X					Pneumatic Slug
MW	501	AD	MW-501-AD	98	438	340	12	2-inch triple nested Sch. 80 PVC	SG-400*	2, 3, 5, 6, 9,10	Downgradient of wells D-83 and D-6	Air/Sonic/Continuous Core	Earth City Right-of-Way			X	X	X	X					Pneumatic Slug
MW	501	SS*	MW-501-SS*	138	438	300	9/6	2-inch Sch. 80 PVC	SG-400*	2, 3, 5, 6, 9,10	Downgradient of wells D-83 and D-6	Air/Sonic/Continuous Core	Earth City Right-of-Way											Pneumatic Slug
MW	501	SD	MW-501-SD	198	438	240	9/6	2-inch Sch. 80 PVC	SG-400*	2, 3, 5, 6, 9,10	Downgradient of wells D-83 and D-6	Air/Sonic/Continuous Core	Earth City Right-of-Way	X	X	X	X	X	X	X	X	X	X	Packer and Pneumatic Slug
MW	502	AS	MW-502-AS	25	445	420	12	2-inch triple nested Sch. 80 PVC	USGS St. Charles Missouri River Gauge	2, 3, 5, 6, 8, 9,10	Downgradient of wells D-83 and D-6	Air/Sonic/Continuous Core	Earth City Levee District				X	X	X					Traditional/Pneumatic Slug
MW	502	AI	MW-502-AI	50	445	395	12	2-inch triple nested Sch. 80 PVC	USGS St. Charles Missouri River Gauge	2, 3, 5, 6, 9,10	Downgradient of wells D-83 and D-6	Air/Sonic/Continuous Core	Earth City Levee District				X	X	X					Pneumatic Slug
MW	502	AD	MW-502-AD	105	445	340	12	2-inch triple nested Sch. 80 PVC	USGS St. Charles Missouri River Gauge	2, 3, 5, 6, 9,10	Downgradient of wells D-83 and D-6	Air/Sonic/Continuous Core	Earth City Levee District			X	X	X	X					Pneumatic Slug
MW	500	SS*	MW-500-SS*	145	445	300	9/6	2-inch Sch. 80 PVC	USGS St. Charles Missouri River Gauge	2, 3, 5, 6, 9,10	Downgradient of wells D-83 and D-6	Air/Sonic/Continuous Core	Earth City Levee District											Pneumatic Slug
MW	502	SD	MW-502-SD	205	445	240	9/6	2-inch Sch. 80 PVC	USGS St. Charles Missouri River Gauge	2, 3, 5, 6, 9,10	Downgradient of wells D-83 and D-6	Air/Sonic/Continuous Core	Earth City Levee District	X	X	X	X	X	X	X	X	X	X	Packer and Pneumatic Slug
MW	600	AS	MW-600-AS	25	445	420	12	2-inch double/triple nested Sch. 80 PVC	SG-600*	2, 3, 4, 5, 6, 9	Sidegradient background alluvial well	Air/Sonic/Continuous Core	City of Bridgeton				X	X	X					Traditional/Pneumatic Slug
MW	600	AI	MW-600-AI	50	445	395	12	2-inch double/triple nested Sch. 80 PVC	SG-600*	2, 3, 4, 5, 6, 9	Sidegradient background alluvial well	Air/Sonic/Continuous Core	City of Bridgeton				X	X	X					Pneumatic Slug
MW	600	AD*	MW-600-AD*	105	445	340	12	2-inch triple nested Sch. 80 PVC	SG-600*	2, 3, 4, 5, 6, 9	Sidegradient background alluvial well	Air/Sonic/Continuous Core	City of Bridgeton				X	X	X					Pneumatic Slug
MW	600	SS*	MW-600-SS*	145	445	300	9/6	2-inch Sch. 80 PVC	SG-600*	2, 3, 4, 5, 6, 9	Sidegradient background bedrock well	Air/Sonic/Continuous Core	City of Bridgeton			X	X	X	X					Pneumatic Slug
MW	600	SD	MW-600-SD	205	445	240	9/6	2-inch Sch. 80 PVC	SG-600*	2, 3, 4, 5, 6, 9	Sidegradient background bedrock well	Air/Sonic/Continuous Core	City of Bridgeton	X	X	X	X	X	X	X	X	X	X	Packer and Pneumatic Slug
MW	601	SS	MW-601-SS	232	532	300	9/6	2-inch Sch. 80 PVC	N/A	2, 3, 4, 5, 6, 9	Background bedrock wells	Air/Sonic/Continuous Core	City of Bridgeton				X	X	X					Pneumatic Slug
MW	601	SD	MW-601-SD	292	532	240	9/6	2-inch Sch. 80 PVC	N/A	2, 3, 4, 5, 6, 9	Background bedrock wells	Air/Sonic/Continuous Core	City of Bridgeton	X	X	X	X	X	X	X	X	X	X	Packer and Pneumatic Slug
MW	602	SS	MW-602-SS	214	514	300	9/6	2-inch Sch. 80 PVC	N/A	2, 3, 4, 5, 6, 9	Background bedrock wells	Air/Sonic/Continuous Core	City of Bridgeton				X	X	X					Pneumatic Slug
MW	602	SD	MW-602-SD	274	514	240	9/6	2-inch Sch. 80 PVC	N/A	2, 3, 4, 5, 6, 9	Background bedrock wells	Air/Sonic/Continuous Core	City of Bridgeton	X	X	X	X	X	X	X	X	X	X	Packer and Pneumatic Slug
MW	603	AS	MW-603-AS	14	434	420	12	2-inch double/triple nested Sch. 80 PVC	SG-600*	2, 3, 5, 6, 8, 9,10	Sidegradient background alluvial well	Air/Sonic/Continuous Core	EarthCity Right-of-Way				X	X	X					Traditional/Pneumatic Slug
MW	603	AI	MW-603-AI	39	434	395	12	2-inch double/triple nested Sch. 80 PVC	SG-600*	2, 3, 5, 6, 9,10	Sidegradient background alluvial well	Air/Sonic/Continuous Core	EarthCity Right-of-Way				X	X	X					Pneumatic Slug
MW	603	AD*	MW-603-AD*	94	434	340	12	2-inch triple nested Sch. 80 PVC	SG-600*	2, 3, 5, 6, 9,10	Sidegradient background alluvial well	Air/Sonic/Continuous Core	EarthCity Right-of-Way			X	X	X	X					Pneumatic Slug
MW	603	SS*	MW-603-SS*	134	434	300	9/6	2-inch Sch. 80 PVC	SG-600*	2, 3, 5, 6, 9,10	Sidegradient background bedrock well	Air/Sonic/Continuous Core	EarthCity Right-of-Way											Pneumatic Slug
MW	603	SD	MW-603-SD	194	434	240	9/6	2-inch Sch. 80 PVC	SG-600*	2, 3, 5, 6, 9,10	Sidegradient background bedrock well	Air/Sonic/Continuous Core	EarthCity Right-of-Way	X	X	X	X	X	X	X	X	X	X	Packer and Pneumatic Slug

Notes:

Data Gaps

1 Adequacy, usability, and status of existing and abandoned on-site and perimeter monitoring wells and associated data;
2 Aquifer properties, including recharge/discharge rates and hydraulic conductivities;
3 Regional and localized hydraulic gradients and flow directions within and between the alluvial aquifer and shallow and deep units (upper and lower intervals) of the bedrock aquifer system (Mississippian age);
4 Background groundwater quality of aquifers located at and near the Site;
5 Occurrence and extent of groundwater contamination;
6 Groundwater geochemistry parameters, redox couples, and organic content;
7 Effects of the Bridgeton Landfill related infrastructure (leachate extraction system, EVOH cover, etc.) and hydraulic characteristics of landfill material on the groundwater system, and leachate chemistry/occurrence;
8 Vapor intrusion;
9 Temporal variability in groundwater levels and flow direction;
10 Temporal and spatial water elevation effects from nearby surface water features (Missouri River) and storm events.

Series Explanation

100 Immediately adjacent to the perimeter of the active sanitary landfill
200 Within 500 feet of the active sanitary landfill
300 Adjacent to inactive landfill areas in western portion of site and upgradient of site
400 Within 500 feet of Area 2
500 Downgradient
600 Background

Zone Explanation

AS Shallow Alluvial
AI Intermediate Alluvial
AD Deep Alluvial
SS Deep St. Louis/Shallow Salem Formation
SD Salem Formation
KS Keokuk Formation

* - Proposed in RI/FS WP
All boreholes drilled using air/sonic drilling techniques and piezometers constructed using 0.005-inch factory slotted PVC screen
PVC - polyvinyl chloride
Sch. - Schedule
N/A - not applicable
TBD - to be determined if deep alluvium present at this location
Alluvial samples will be collected from deepest hole at each location and submitted for laboratory analysis
Borehole geophysical tools dependent on subcontractor availability and equipment

TABLE 3-4. WELL NEST LOCATIONS TO CONSIDER FOR DATALOGGER PLACEMENT
WEST LAKE LANDFILL OU-3
REMEDIAL INVESTIGATION / FEASIBILITY STUDY FIELD SAMPLING PLAN

NEW OFFSITE WELL LOCATIONS

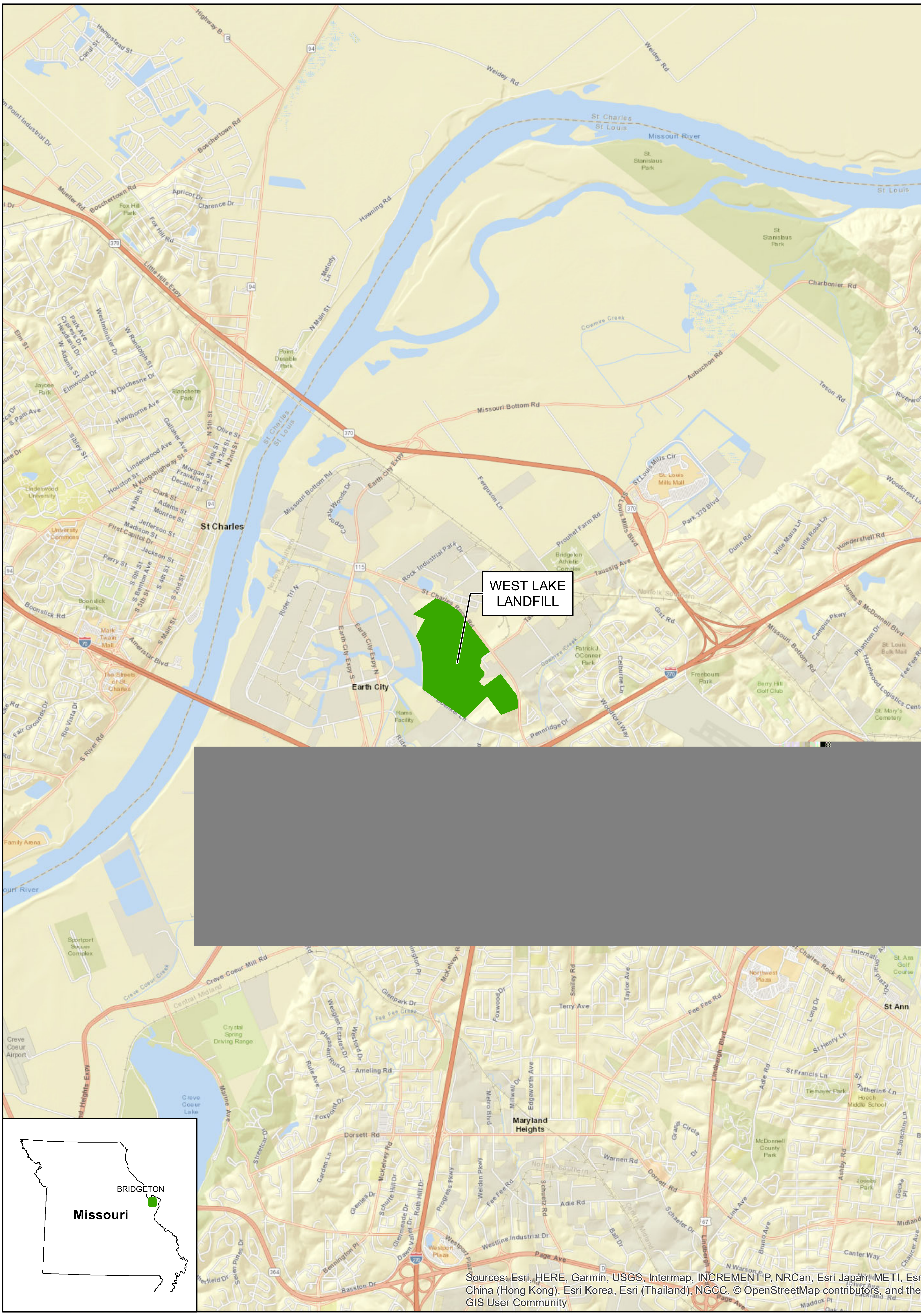
	Aquifer Monitoring Intervals					
Well ID	**AS**	**AI**	**AD**	**SS**	**SD**	**KS**
MW-500	X	X	X	X		
MW-502	X	X	X	X		
MW-600	X	X	X	X	X	
MW-600				X	X	

EXISTING ONSITE WELL LOCATIONS

	Aquifer Monitoring Intervals					
Well ID	**AS**	**AI**	**AD**	**SS**	**SD**	**KS**
S-8	X					
I-62		X				
D-83			X			
S-82	X					
I-9		X				
D-93			X			
PZ-202				X		
PZ-209				X	X	
PZ-211				X	X	
PZ-113	X		X	X		
PZ-100				X	X	X

Notes:
AS = Shallow Alluvium
AI = Intermediate Alluvium
AD = Deep Alluvium
SS = St. Louis and Upper Salem Formations
SD = The base of the Salem Formation
KS = Keokuk Formation

FIGURES



EXPLANATION

LANDFILL BOUNDARY

LATITUDE: 38.768106
LONGITUDE: -90.444574
LATITUDE AND LONGITUDE ARE IN NAD83

N

0 4,000 '

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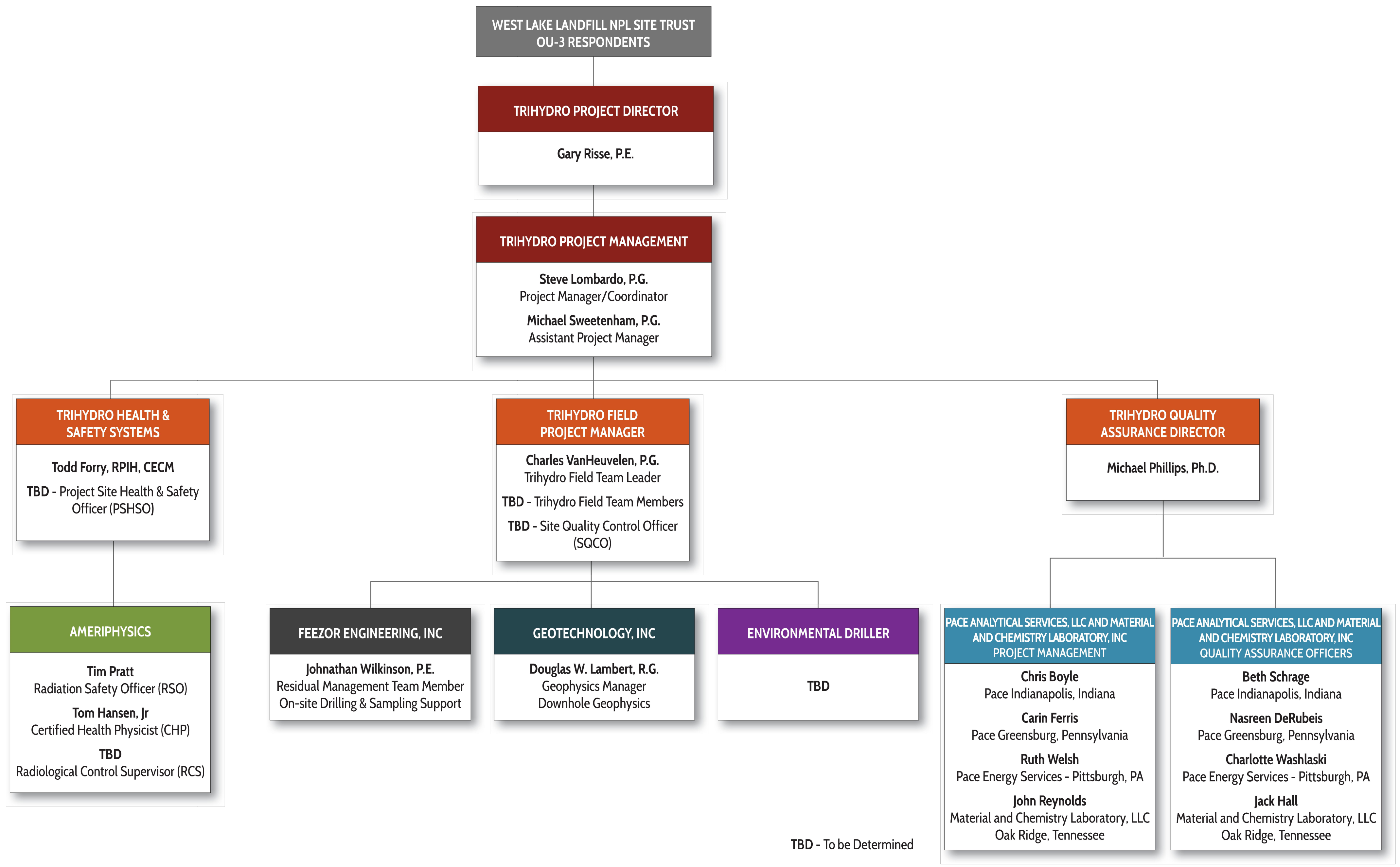
FIGURE 1-1

SITE LOCATION MAP

WEST LAKE LANDFILL OU-3
REMEDIAL INVESTIGATION / FEASIBILITY STUDY
FIELD SAMPLING PLAN

Drawn By: KEJ	Checked By: MS	Scale: 1 " = 4,000 '	Date: 5/9/19	File: 1-1_SiteLocation_Fig1-1.mxd



TBD - To be Determined

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FIGURE 1-2

PROJECT ORGANIZATIONAL CHART

WEST LAKE LANDFILL OU-3
REMEDIAL INVESTIGATION / FEASIBILITY STUDY
FIELD SAMPLING PLAN

Drawn By: REP	Checked By: MH	Scale: NONE	Date: 5/16/19	File: 63N-FSP_ORGCHART_20190509

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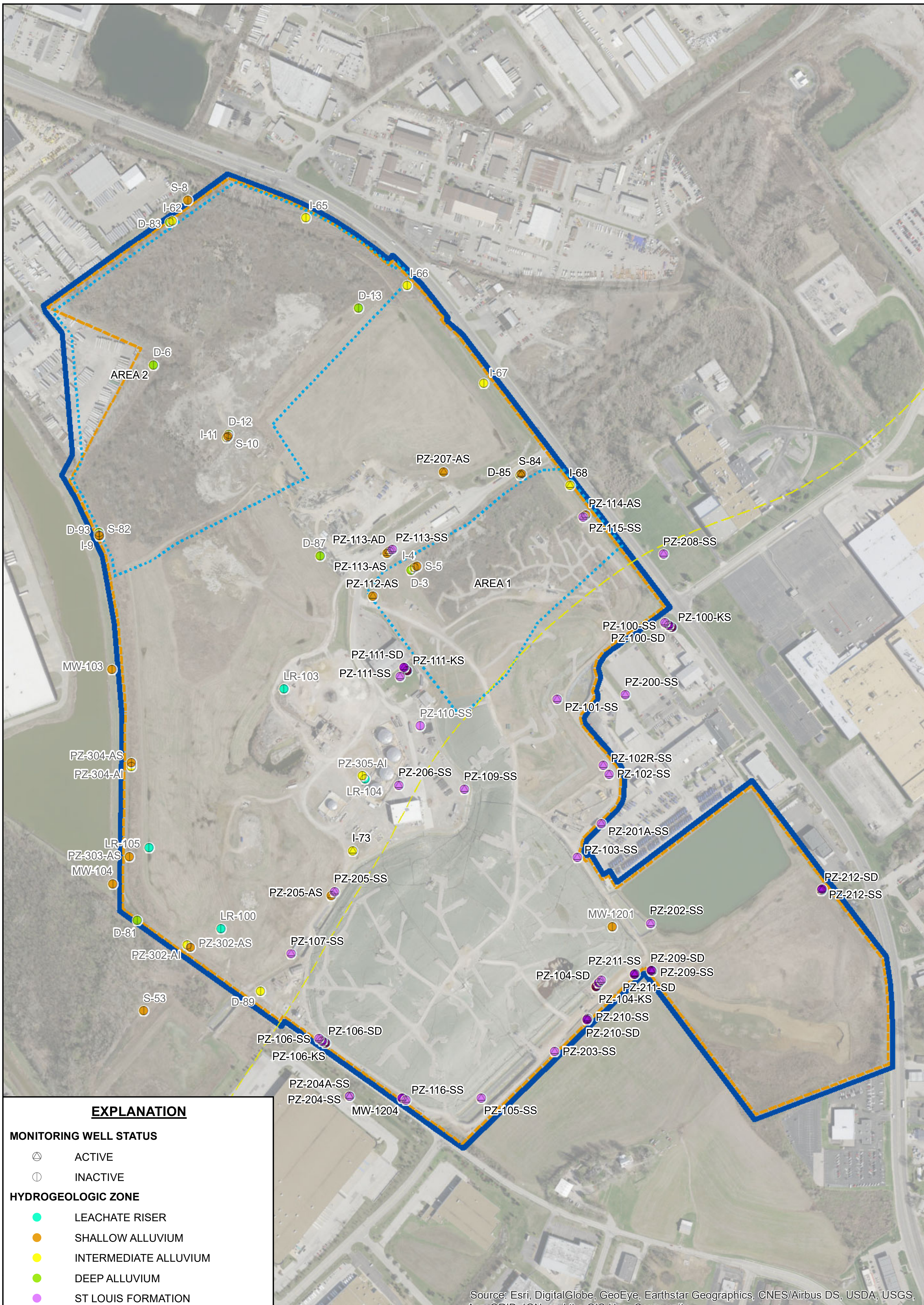

EXPLANATION

MONITORING WELL STATUS

- ACTIVE
- INACTIVE

HYDROGEOLOGIC ZONE

- LEACHATE RISER
- SHALLOW ALLUVIUM
- INTERMEDIATE ALLUVIUM
- DEEP ALLUVIUM
- ST LOUIS FORMATION
- SALEM FORMATION
- KEOKUK FORMATION
- EDGE OF ALLUVIUM (APPROXIMATE)

SITE FEATURES

- OU-1
- LANDFILL BOUNDARY
- SUPERFUND SITE BOUNDARY

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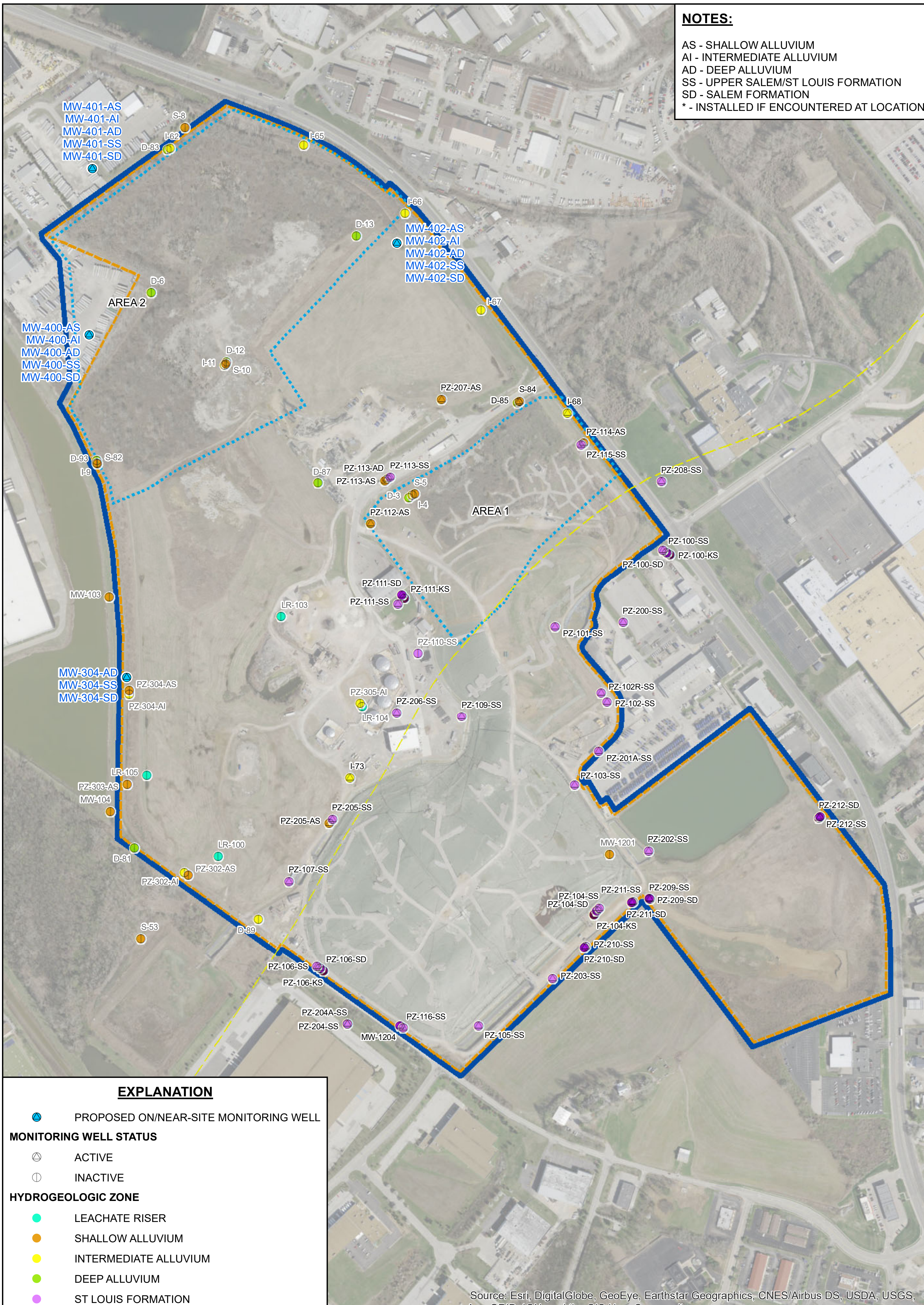
FIGURE 3-1

CURRENT MONITORING WELL NETWORK

WEST LAKE LANDFILL OU-3
REMEDIAL INVESTIGATION / FEASIBILITY STUDY
FIELD SAMPLING PLAN

Drawn By: MGS	Checked By: SLL	Scale: 1 " = 500 '	Date: 5/9/19	File: 3-1_MWNetwork_Fig3-1.mxd



EXPLANATION

PROPOSED ON/NEAR-SITE MONITORING WELL

MONITORING WELL STATUS

ACTIVE

INACTIVE

HYDROGEOLOGIC ZONE

LEACHATE RISER

SHALLOW ALLUVIUM

INTERMEDIATE ALLUVIUM

DEEP ALLUVIUM

ST LOUIS FORMATION

SALEM FORMATION

KEOKUK FORMATION

EDGE OF ALLUVIUM (APPROXIMATE)

SITE FEATURES

OU-1

LANDFILL BOUNDARY

SUPERFUND SITE BOUNDARY

N

0 500 '

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FIGURE 3-2

PROPOSED ON-SITE AND NEAR-SITE MONITORING WELLS

WEST LAKE LANDFILL OU-3
REMEDIAL INVESTIGATION / FEASIBILITY STUDY
FIELD SAMPLING PLAN

Drawn By: MGS	Checked By: SLL	Scale: 1 " = 500 '	Date: 5/9/19	File: 3-2_On-SiteMW_Fig3-2.mxd

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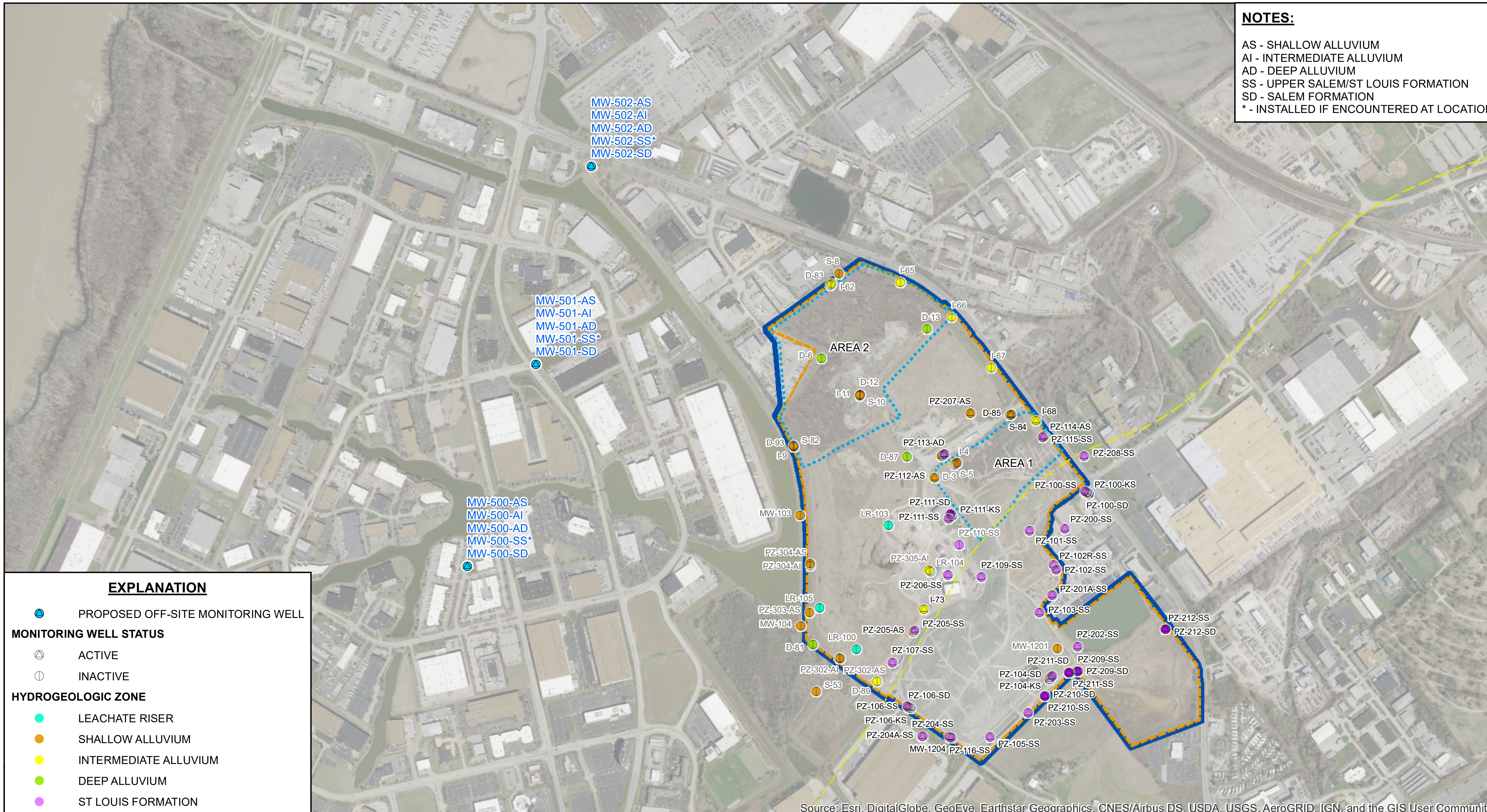

NOTES:

AS - SHALLOW ALLUVIUM
AI - INTERMEDIATE ALLUVIUM
AD - DEEP ALLUVIUM
SS - UPPER SALEM/ST LOUIS FORMATION
SD - SALEM FORMATION
* - INSTALLED IF ENCOUNTERED AT LOCATION

EXPLANATION

PROPOSED OFF-SITE MONITORING WELL

MONITORING WELL STATUS

ACTIVE
INACTIVE

HYDROGEOLOGIC ZONE

LEACHATE RISER
SHALLOW ALLUVIUM
INTERMEDIATE ALLUVIUM
DEEP ALLUVIUM
ST LOUIS FORMATION
SALEM FORMATION
KEOKUK FORMATION
EDGE OF ALLUVIUM (APPROXIMATE)

SITE FEATURES

OU-1
LANDFILL BOUNDARY
SUPERFUND SITE BOUNDARY

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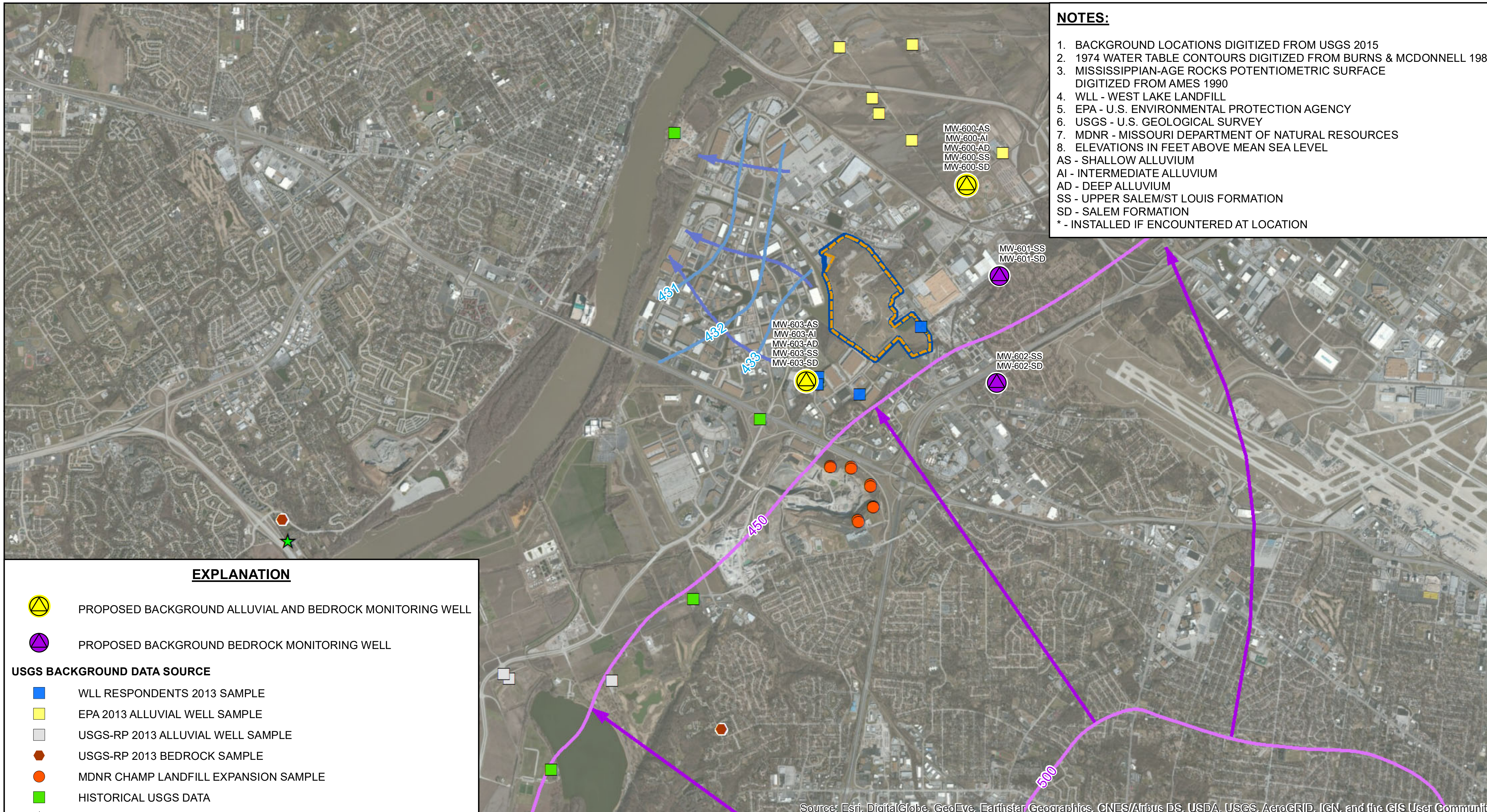
FIGURE 3-3

PROPOSED OFF-SITE MONITORING WELLS

WEST LAKE LANDFILL OU-3
REMEDIAL INVESTIGATION / FEASIBILITY STUDY
FIELD SAMPLING PLAN

Drawn By: MGS	Checked By: SLL	Scale: 1 " = 1,000 '	Date: 5/9/19	File: 3-3_Off-SiteMW_Fig3-3.mxd

\\TRIHYDRO.COM\CLIENTS\WTOZ\WESTLAKELANDFILL\GIS\MAPPING\201905_FSP_DRAFT\3-3_OFF-SITEMW_FIG3-3.MXD



NOTES:

1. BACKGROUND LOCATIONS DIGITIZED FROM USGS 2015
2. 1974 WATER TABLE CONTOURS DIGITIZED FROM BURNS & MCDONNELL 1986
3. MISSISSIPPIAN-AGE ROCKS POTENTIOMETRIC SURFACE DIGITIZED FROM AMES 1990
4. WLL - WEST LAKE LANDFILL
5. EPA - U.S. ENVIRONMENTAL PROTECTION AGENCY
6. USGS - U.S. GEOLOGICAL SURVEY
7. MDNR - MISSOURI DEPARTMENT OF NATURAL RESOURCES
8. ELEVATIONS IN FEET ABOVE MEAN SEA LEVEL

AS - SHALLOW ALLUVIUM
AI - INTERMEDIATE ALLUVIUM
AD - DEEP ALLUVIUM
SS - UPPER SALEM/ST LOUIS FORMATION
SD - SALEM FORMATION
* - INSTALLED IF ENCOUNTERED AT LOCATION

EXPLANATION

PROPOSED BACKGROUND ALLUVIAL AND BEDROCK MONITORING WELL
PROPOSED BACKGROUND BEDROCK MONITORING WELL

USGS BACKGROUND DATA SOURCE

WLL RESPONDENTS 2013 SAMPLE
EPA 2013 ALLUVIAL WELL SAMPLE
USGS-RP 2013 ALLUVIAL WELL SAMPLE
USGS-RP 2013 BEDROCK SAMPLE
MDNR CHAMP LANDFILL EXPANSION SAMPLE
HISTORICAL USGS DATA
MDNR PUBLIC-DRINKING WATER BRANCH
1974 ALLUVIAL WATER TABLE
1974 ALLUVIAL FLOW DIRECTION
MISSISSIPPIAN-AGE ROCKS POTENTIOMETRIC SURFACE CONTOUR
MISSISSIPPIAN-AGE ROCKS FLOW DIRECTION
LANDFILL BOUNDARY
SUPERFUND SITE BOUNDARY

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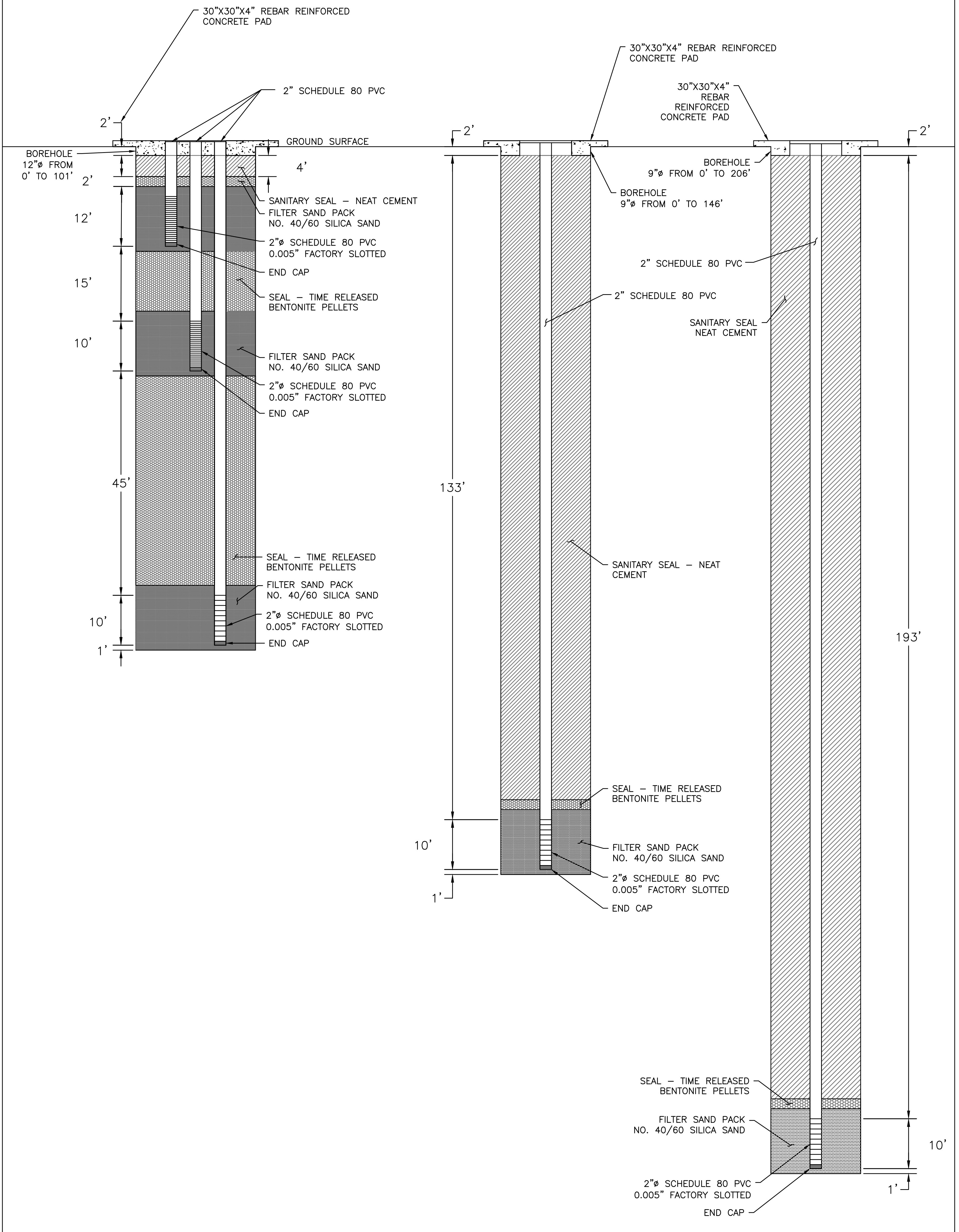
FIGURE 3-4

PROPOSED BACKGROUND MONITORING WELLS

WEST LAKE LANDFILL OU-3
REMEDIAL INVESTIGATION / FEASIBILITY STUDY
FIELD SAMPLING PLAN

Drawn By: MGS	Checked By: SLL	Scale: 1 " = 4,000 '	Date: 5/9/19	File: 3-4_BGMW_Fig3-4.mxd



NOTES:

1. DRAWING IS SCALED VERTICALLY TO SHOW DEPTH. HORIZONTAL SCALE IS ADJUSTED TO SHOW FEATURES AND IS INDEPENDENT OF VERTICAL SCALE.
2. BGS = BELOW GROUND SURFACE
3. ACTUAL INTERVALS MAY VARY BASED ON FIELD CONDITIONS.
4. WELL CLUSTERS MAY BE COMPLETED AS NESTED WELLS BASED ON SPATIAL LIMITATIONS.

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FIGURE 3-5

EXAMPLE MONITORING WELL CONSTRUCTION DETAILS

WEST LAKE LANDFILL OU-3
REMEDIAL INVESTIGATION / FEASIBILITY STUDY
FIELD SAMPLING PLAN

Drawn By: DMB	Checked By: MGS	Scale: NONE	Date: 5/9/2019	File: 63N-FSP_MONWELLDETAIL201903

M:\WTOZ\WESTLAKELANDFILL\PROJECTDOCS\WESTLAKELANDFILLOU3\CADD\FIELDSAMPLINGPLAN_201906\63N-FSP_MONWELLDETAIL201903

NOTES:

AS - SHALLOW ALLUVIUM
AI - INTERMEDIATE ALLUVIUM
AD - DEEP ALLUVIUM
SS - UPPER SALEM/ST LOUIS FORMATION
SD - SALEM FORMATION
* - INSTALLED IF ENCOUNTERED AT LOCATION

EXPLANATION

PROPOSED MONITORING WELL
PROPOSED STAFF GAUGE

MONITORING WELL STATUS

PHASE I ACTIVE

HYDROGEOLOGIC ZONE

LEACHATE RISER
SHALLOW ALLUVIUM
INTERMEDIATE ALLUVIUM
DEEP ALLUVIUM
ST LOUIS FORMATION
SALEM FORMATION
KEOKUK FORMATION
EDGE OF ALLUVIUM (APPROXIMATE)

SITE FEATURES

OU-1
LANDFILL BOUNDARY
SUPERFUND SITE BOUNDARY

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FIGURE 3-6

PROPOSED MONITORING WELL NETWORK

WEST LAKE LANDFILL OU-3
REMEDIAL INVESTIGATION / FEASIBILITY STUDY
FIELD SAMPLING PLAN

Drawn By: MGS	Checked By: SLL	Scale: 1 " = 1,200 '	Date: 5/9/19	File: 3-6_MWNetwork_Fig3-6.mxd

APPENDIX A

STANDARD OPERATING PROCEDURES

United States Environmental Protection Agency
Office of Research and Development
Office of Solid Waste and Emergency Response
EPA/540/S-93/503
February 1993

EPA Ground Water Issue

Suggested Operating Procedures for Aquifer Pumping Tests

Paul S. Osborne*

The Regional Superfund Ground Water Forum is a group of ground-water scientists, representing EPA's Regional Superfund Offices, organized to exchange up-to-date information related to ground water remediation at Superfund sites.

A very important aspect of ground water remediation is the capability to determine accurate estimates of aquifer hydraulic characteristics. This document was developed to provide an overview of all the elements of an aquifer test to assist RPMs and OSCs in the initial design of such tests or in the review of tests performed by other groups.

For further information, contact Jerry Thornhill, RSKERL-Ada, 405/436-8604 or Paul Osborne, EPA Region VIII, 303/293-1418.

INTRODUCTION

In recent years, there has been an increased interest in ground water resources throughout the United States. This interest has resulted from a combination of an increase in ground water development for public and domestic use; an increase in mining, agricultural, and industrial activities which might impact ground water quality; and an increase in studies of already contaminated aquifers. Decision-making agencies involved in these ground water activities require studies of the aquifers to develop reliable information on the hydrologic properties and behavior of aquifers and aquitards.

The most reliable type of aquifer test usually conducted is a pumping test. In addition, some site studies involve the use of short term slug tests to obtain estimates of hydraulic conductivity, usually for a specific zone or very limited portion of the aquifer. It should be emphasized that slug tests provide very limited information on the hydraulic properties of the aquifer and often produce estimates which are only accurate within an order of magnitude. Many experts believe that slug tests are much too heavily relied upon in site characterization and contamination studies. This group of professionals recommends use of slug testing during the initial site studies to assist in developing a site conceptual model and in pumping test design.

This document is intended as a primer, describing the process for the design and performance of an “aquifer test” (how to obtain reliable data from a pumping test) to obtain accurate estimates of aquifer parameters. It is intended for use by those professionals involved in characterizing sites which require corrective action as well as those which are proposed for ground water development, agricultural development, industrial development, or disposal activities. The goal of the document is to provide the reader with a complete picture of all of the elements of aquifer (pumping) test design and performance and an understanding of how those elements can affect the quality of the final data.

The determination of accurate estimates of aquifer hydraulic characteristics is dependent on the availability of reliable data from an aquifer test. This document outlines the planning, equipment, and test procedures for designing and conducting an accurate aquifer test. The design and operation of a slug test is not included in this document, although slug tests are often run prior to the design and implementation of an aquifer test. The slug test information can be very useful in developing the aquifer test design (see ASTM D-18

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Technology Innovation Office
Office of Solid Waste and Emergency Response, US EPA, Washington, DC

Walter W. Kovalick, Jr., Ph.D.
Director

Committee, D4050 and D4104). If an accurate conceptual model of the site is developed and the proper equipment, wells, and procedures are selected during the design phase, the resulting data should be reliable. The aquifer estimates obtained from analyzing the data will, of course, depend on the method of analysis.

This document is not intended to be an overview of aquifer test analysis. The analysis and evaluation of pumping test data is adequately covered by numerous texts on the subject (Dawson and Istok, 1991; Kruseman and de Ridder, 1991; Walton, 1962; and Ferris, Knowles, Brown, and Stallman, 1962). It should be emphasized, however, that information on the methods for analyzing test data should be reviewed in detail during the planning phase. This is especially important for determining the number, location, and construction details for all wells involved in the test.

A simple "pump" (specific capacity) test involves the pumping of a single well with no associated observation wells. The purpose of a pump test is to obtain information on well yield, observed drawdown, pump efficiency, and calculated specific capacity. The information is used mainly for developing the final design of the pump facility and water delivery system. The pump test usually has a duration of 2 to 12 hours with periodic water level and discharge measurements. The pump is generally allowed to run at maximum capacity with little or no attempt to maintain constant discharge. Discharge variations are often as high as 50 percent. Short-term pump tests with poor control of discharge are not suitable for estimating parameters needed for adequate aquifer characterization. If the pump test is, however, run in such a way that the discharge rate varies less than 5 percent and water levels are measured frequently, the test data can also be used to obtain some reliable estimates of aquifer performance. It should be emphasized that an estimate of aquifer transmissivity obtained in this manner will not be as accurate as that obtained using an aquifer test including observation wells.

By controlling the discharge variation and pumping for a sufficient duration, it is possible to obtain reliable estimates of transmissivity using water level data obtained during the pump test. However, this method does not provide information on boundaries, storativity, leaky aquifers, and other information needed to adequately characterize the hydrology of an aquifer. For the purpose of this document, an aquifer test is defined as a controlled field experiment using a discharging (control) well and at least one observation well.

The aquifer test is accomplished by applying a known stress to an aquifer of known or assumed dimensions and observing the water level response over time. Hydraulic characteristics which can be estimated, if the test is designed and implemented properly, include the coefficient of storage, specific yield, transmissivity, vertical and horizontal permeability, and confining layer leakage. Depending on the location of observation wells, it may be possible to determine the location of aquifer boundaries. If measurements are made on nearby springs, it may also be possible to determine the impact of pumping on surface-water features.

TEST DESIGN

Adequate attention to the planning and design phase of the aquifer pumping test will assure that the effort and expense of conducting a test will produce useful results. Individuals involved in designing an aquifer test should review the relevant ASTM Standards relating to: 1) appropriate field procedures for determining aquifer hydraulic properties (D4050 and D4106); 2) selection of aquifer test method (D4043); and 3) design and installation of ground water monitoring wells (D5092). The relevant portions of these standards should be incorporated into the design.

All available information regarding the aquifer and the site should be collected and reviewed at the commencement of the test design phase. This information will provide the basis for development of a conceptual model of the site and for selecting the final design. It is important that the geometry of the site, location and depth of observation wells and piezometers, and the pumping period agree with the mathematical model to be used in the analysis of the data. A test should be designed for the most important parameters to be determined, and other parameters may have to be de-emphasized.

Aquifer Data Needs

The initial element of the test design, formulating a conceptual model of the site, involves the collection and analysis of existing data regarding the aquifer and related geologic and hydrologic units. All available information on the aquifer itself, such as saturated thickness, locations of aquifer boundaries, locations of springs, information on all on-site and all nearby wells (construction, well logs, pumping schedules, etc.), estimates of regional transmissivities, and other pertinent data, should be collected. Detailed information relating to the geology and hydrology is needed to formulate the conceptual model and to determine which mathematical model should be utilized to estimate the most important parameters. It is also important to review various methods for the analyses and evaluation of pumping test data (Ferris, Knowles, Brown, and Stallman, 1962; Kruseman and De Ridder, 1991; and Walton, 1962 and 1970). Information relating to the various analytical methods and associated data needs will assist the hydrologist in reviewing the existing data, identifying gaps in information, and formulating a program for filling any gaps that exist.

The conceptual model of the site should be prepared after carrying out a detailed site visit and an evaluation of the assembled information. The review of available records should include files available from the U. S. Geological Survey, appropriate state agencies, and information from local drillers with experience in the area. Formulation of a conceptual model should include a brief analysis of how the local hydrology/geology fits into the regional hydrogeologic setting.

Aquifer Location

The depth to, thickness of, areal extent of, and lithology of the aquifer to be tested should be delineated, if possible.

Aquifer Boundaries

Nearby aquifer discontinuities caused by changes in lithology or by incised streams and lakes should be mapped. All known and suspected boundaries should be mapped such that observation wells can be placed (chosen) where they will provide the best opportunity to measure the aquifer's response to the pumping and the boundary effects during the pumping test.

Hydraulic Properties

Estimates of all pertinent hydraulic properties of the aquifers and pertinent geologic units must be made by any means feasible. Estimates of transmissivity and the storage coefficient should be made, and if leaky confining beds are detected, leakage coefficients should be estimated. The estimation of transmissivity and the storage coefficient should be carried out by making a close examination of existing well logs and core data in the area or by gathering information from nearby aquifer tests, slug tests, or drill stem tests conducted on the aquifer(s) in question. It may also be feasible to run a slug test on the wells near the site to get preliminary values. (See ASTM Committee D-18 Standards D4044 and D4104). It should be noted that some investigators have found that slug tests often produce results which are as much as an order of magnitude low. Although some investigators have reported results which are two orders of magnitude high because the sand pack dominated the test. Such tests will, however, provide a starting point for the design. If no core analyses are available, the well log review should form a basis for utilizing an available table which correlates the type of aquifer material with the hydraulic conductivity. If detailed sample results from drill holes are available and they have grain size analyses, there are empirical formulas for estimation of transmissivity. Estimation of storage coefficient is more difficult, but can be based on the expected porosity of the material or the expected confinement of the aquifer. It is recommended that a range of values be chosen to provide a worst case and best case scenario (Freeze and Cherry, 1979). Trial calculations of well drawdown using these estimated values should be made to finalize the design, location, and operation of test and observation wells (Ferris and others, 1962; Campbell and Lehr, 1972; and Stallman, 1971).

If local perched aquifers are of a significant size and location to impact the pump test, this impact should be estimated if possible. The final test design should include adequate monitoring of any perched aquifers and leaky confining beds. This might involve the placing of piezometers into and/or above the leaky confining zone or into the perched aquifer.

Evaluation of Existing Well Information

Because the drilling of new production wells and observation wells expressly for an aquifer test can be expensive, it is advisable to use existing wells for conducting an aquifer test when possible. However, many existing wells are not suitable for aquifer testing. They may be unsuitably constructed (such as a well which is not completed in the same aquifer zone as the pumping well) or may be inappropriately located. It is also important to note that well logs and well completion data for existing facilities are not always reliable. Existing data should be verified whenever possible. The design of each well, whether existing or to be drilled, must be carefully considered to determine if it will meet the needs of the proposed test plan and analytical methods. Special attention must be paid to well location, the depth and interval of the well screen or perforation, and the present condition of existing perforations.

After the process of developing the site model and determining which analytical methods should be used, it is possible to move to the final design stage. The final stage of the design involves development of the key elements of the aquifer test: 1) number and location of observation wells; 2) design of observation wells; 3) approximate duration of the test; and 4) discharge rate.

Design of Pumping Facility

There are seven principal elements to be considered during the pumping facility design phase: 1) well construction; 2) the well development procedure; 3) well access for water level measurements; 4) a reliable power source; 5) the type of pump; 6) the discharge-control and measurement equipment; and 7) the method of water disposal. These elements are discussed in the following sections.

Well Construction

The diameter, depth and position of all intervals open to the aquifer in the pumping well should be known, as should total depth. The diameter must be large enough to accommodate a test pump and allow for water level measurements. All openings to the aquifer(s) must be known and only those openings located in the aquifer to be tested should be open to the well during the testing. If the pumping well has to be drilled, the type, size, and number of perforations should be established using data from existing well logs and from the information obtained during the drilling of the new well itself. The screen or perforated interval should be designed to have sufficient open area to minimize well losses caused by fluid entry into the well (Campbell and Lehr, 1972; and Driscoll, 1986).

A well into an unconsolidated aquifer should be completed with a filter pack in the annular space between the well screen and the aquifer material. To design an adequate filter pack, it is essential that the grain size makeup of the aquifer be defined. This is generally done by running a sieve analysis of the major lithologic units making up the aquifer. The sizing of the filter pack will depend on the grain size distribution of the aquifer material. The well screen size would be established by the sizing of the chosen filter pack (Driscoll,1986). The filter pack should extend at least one (1) foot above the top of the well screen. A seal of bentonite pellets should be placed on top of the filter pack. A minimum of three (3) feet of pellets should be used. An annulus seal of cement and/or bentonite grout should be placed on top of the bentonite pellets. The well casing should be protected at the surface with a concrete pad around the well to isolate the wellbore from surface runoff (ASTM Committee D-18, D5092; and Barcelona, Gibb, and Miller, 1983).

Well Development

Information on how the pumping well was constructed and developed should be collected during the review of existing site information. It may be necessary to interview the driller. If the well has not been adequately developed, the data collected from the well may not be representative of the aquifer. For instance, the efficiency of the well may be reduced, thereby causing increased drawdown in the pumping well. When a well is pumped, there are two components of drawdown: 1) the head losses in the aquifer; and 2) the head losses associated with entry into the well. A well which is poorly constructed or has a plugged well screen will have a high head loss associated with entry into the well. These losses will affect the accuracy of the estimates of aquifer hydraulic parameters made using data from that well. If the well is suspected to have been poorly developed, or nothing is known, it is advisable to run a step drawdown test on the well to determine the extent of the problem. The step drawdown test entails conducting three or more steps of increasing discharge, producing drawdown curves such as shown in Figure 1. The data provided by the step drawdown test (multiple discharge test) can be analyzed using various techniques (Rorabough, 1953; and Driscoll, 1986) to obtain an estimate of well entry losses. If a determination is made that plugging results in significant losses, the well should be redeveloped prior to the pumping test using a surge block and/or a pump until the well discharge is clear: i. e. the development results in the well achieving acceptable turbidity unit limits (Driscoll, 1986). In many cases, running a step drawdown test to determine well efficiency after the well has been surged is needed to assess the results of the development process. The results of the post development test should be compared with the step-drawdown test run prior to development. This analysis will provide a means of verifying the success of the well development.

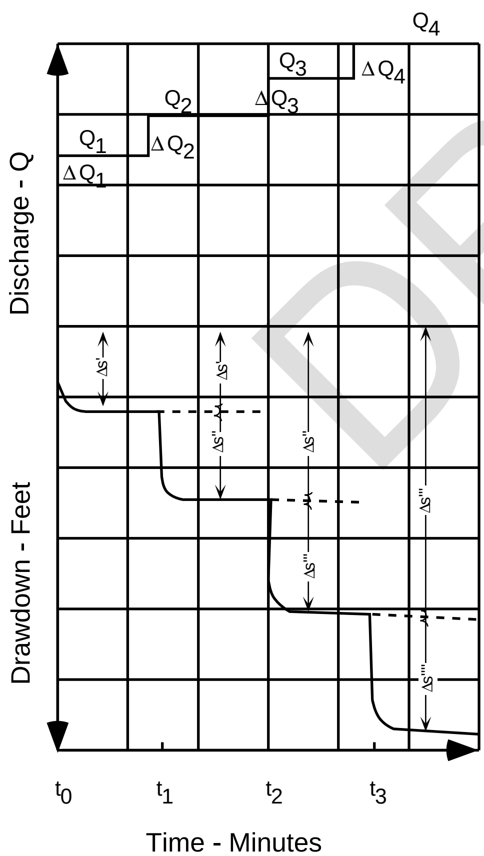

Figure 1. Variation of discharge and drawdown in multiple discharge tests (step drawdown tests).

Water Level Measurement Access

It must be possible to measure depth to the water level in the pumping well before, during, and after pumping. The quickest and generally the most accurate means of measuring the water levels in the pumped well during an aquifer test is to use an electric sounder or pressure transducer system. The transducer system may be expensive and may be difficult to install in an existing well. It may be possible to run a 1/4 inch copper line into the well as an air line. If the control well is newly constructed, the continuous copper line should be strapped to the pump column as it is being installed. If it is correctly installed, an air line can be used with somewhat less accuracy than an electric sounder or steel tape. An air line with a bubbler and either a transducer or precision pressure gage should be adequate for running an aquifer test.

With adequate temperature compensation, a surface mounted pressure transducer is as precise as one that is submerged. Steel tapes cannot always be used quickly enough in a pumping well, except in wells with a small depth to water (less than 100 feet) where the pump test crew has a fair amount of experience and the well is modified for access of the steel tape. Such modification often involves hanging a 3/4 inch pipe in the well as access for the steel tape. The pipe should be capped at the bottom with numerous 1/16 to 1/8 inch holes drilled in the pipe and cap (especially needed for wells subject to cascading water or surging). This will dampen water-level surging caused by the pump and will eliminate the problems caused by cascading water. In general, the use of a steel tape is usually confined to the later stages of the pump test where rapid changes in water levels are not occurring.

In cases where the pump is isolated by a packer to allow production from a particular zone, a transducer system should be used to monitor pumping hydraulic heads. It is important, however, to calibrate the transducers before and after the test. In addition, reference checks with an electric sounder or steel tape should be made before, during, and after the test. The ASTM Standard Test Method for determining subsurface liquid levels in a borehole or monitoring well (D4750) should be reviewed as part of the design process.

Reliable Power Source

Having power continuously available to the pump, for the duration of the test, is crucial to the success of the test. If power is interrupted during the test, it may be necessary to terminate the test and allow for sufficient recovery so that pre-pumping water-level trends can be extrapolated. At that point, a new test would be run. If, however, brief interruptions in power occur late in the test, the affect of the interruption can be eliminated by pumping at a calculated higher rate for some period so that the average rate remains unchanged. The increased rate must be calculated such that the final portion of the test compensates for the pumpage that would have occurred during the interruption of pumping.

Pump Selection

A reliable pump is a necessity during an aquifer test. The pump should be operated continuously during the test. Should a pump fail during the pumping period of the test, the time, effort, and expense of conducting the test could be wasted. Electrically powered pumps produce the most constant discharge and are often recommended for use during an aquifer test. However, in irrigation areas, line loads can fluctuate greatly, causing variations in the pumping rate of electric motors. Furthermore, electric motors are nearly constant-load devices, so that as the lift increases (water level declines), the pumping rate decreases. This is a particular problem for inefficient wells or low transmissivity aquifers.

The discharge of engine-powered (usually gasoline or diesel) pumps may vary greatly over a 24 hour period, requiring more frequent monitoring of the discharge rate during the test. For example, under extreme conditions a diesel-powered turbine pump may have more than a 10 percent change in discharge as a result of the daily variation in temperature. The change in air temperature affects the combustion ratio of the engine resulting in a variation in engine revolutions per minute (rpm). The greater the daily temperature range,the greater the range in engine rpm. Variations in barometric pressure may also affect the engine operation and resulting rpm. Running the engine at full throttle will reduce operational flexibility for adjusting engine rpm and the resulting discharge. In areas where outside temperatures are extreme, such as the desert or a very cold region, it may be advisable to undertake measures to prevent the engine from overheating or freezing.

In order to obtain good data during the period of recovery at the end of pumping, it is necessary to have a check valve installed at the base of the pump column pipe in the discharging well. This will prevent the back flow of water from the column pipe into the well when the pumping portion of the test is terminated and the recovery begins. Any back flow into the well will interfere with or totally mask the water level recovery of the aquifer and this would make any aquifer analysis based on recovery data useless or, at best, questionable (Schafer, 1978).

Discharge-Control and Measurement Equipment

The well bore and discharge lines should be accessible for installing discharge control and monitoring equipment. When considering an existing well for the test well to be pumped (control well), the well must either already be equipped with discharge measuring and regulating equipment, or the well must have been constructed such that the necessary equipment can be added.

Control of the pumping rate during the test requires an accurate means for measuring the discharge of the pump and a convenient means of adjusting the rate to keep it as nearly constant as possible. Common methods of measuring well discharge include the use of an orifice plate and manometer, an inline flow meter, an inline calibrated pitot tube, a calibrated weir or flume, or, for low discharge rates, observing the length of time taken for the discharging water to fill a container of known volume (e.g. 5 gallon bucket; 55 gallon drum).

In addition to the potentially large variation in discharge associated with the pump motor or engine, the discharge rate is also related to the drop in water level near the pumping well during the aquifer test. As the pumping lift increases, the rate of discharge at a given level of power (such as engine rpm) will decrease. The pump should not be operated at its maximum rate. As a general rule, the pumping unit, including the engine, should be designed so that the maximum pumping rate is at least 20 percent more than the estimated long term sustainable yield of the aquifer. The long term yield of the aquifer should be determined by collecting data on pumping rates in nearby wells. If possible, a short term test of one to two hours should be run when the pump is installed. This test data should be compared to the historic data as part of the estimation process.

The pumping rate can be controlled by placing valves on the discharge line and/or by placing controls on the pump power source. A valve installed in the discharge line to create back pressure provides effective control of the discharge rate while conducting an aquifer test, especially when using an electric-powered pump. A rheostatic control on the electric pump will also allow accurate control of the discharge rate. When an engine-powered pump is being utilized, installation of a micrometer throttle adjustment device to accurately control engine rpm is recommended in addition to a valve in the line.

Water Disposal

Discharging water immediately adjacent to the pumping well can cause problems with the aquifer test, especially in tests of permeable unconfined alluvial aquifers. The water becomes a source of recharge which will affect the results of the test. It is essential that the volumes of produced water, the storage needs, the disposal alternatives, and the treatment needs be assessed early in the planning process. The produced water from the test well must be transported away from the control well and observation wells so it cannot return to the aquifer during the test. This may necessitate the laying of a temporary pipeline (sprinkler irrigation line is often used) to convey the discharge water a sufficient distance from the test site. In some cases, it may be necessary to have on-site storage, such as steel storage tanks or lined ponds. This is especially critical when testing contaminated zones where water treatment capacity is not available. The test designer should carefully review applicable requirements of the RCRA hazardous waste program, the underground injection control program, and the surface water discharge program prior to making decisions about this phase of the design. It may be necessary to obtain permits for on-site storage and final disposal of the contaminated fluids. Final disposal could involve treatment and reinjection into the source aquifer or appropriate treatment and discharge.

Design of Observation Well(s)

Verification of well response

As part of the process of selecting the location of the observation wells needed for the chosen aquifer test design, existing wells should be tested for their suitability as observation wells. The existing information regarding well construction should be reviewed as a screening mechanism for identifying suitable candidates. The wells that are identified as potential observation wells should be field tested to verify that they are suitable for monitoring aquifer response. The perforations or well screens of abandoned wells tend to become restricted by the buildup of iron compounds, carbonate compounds, sulfate compounds or bacterial growth as a result of not pumping the well. Consequently, the response test is one of the most important pre-pumping examinations to be made if such wells are to be used for observation (Stallman, 1971; and Black and Kip, 1977). The reaction of all wells to changing water levels should be tested by injecting or removing a known volume of water into each well and measuring the subsequent change of water level. Any wells which appear to have poor response should be either redeveloped, replaced, or dropped from consideration in favor of another available well selected.

Total Depth

In general, observation wells should penetrate the tested aquifer to the same stratigraphic horizon as the well screen or perforated interval of the pumping well. This will require close evaluation of logs to adjust for dipping formations. This assumes the observation well is to be used for monitoring response in the same aquifer from which the discharging well is pumping. Actual screen design will depend on aquifer geometry and site specific lithology. If the aquifer test is designed to detect hydraulic connection between aquifers, one observation well should be screened in the strata for which hydraulic inter-connection is suspected. Depending on how much information is needed, additional wells screened in other strata may be needed (Bredehoeft and others, 1983; Walton, 1970; Dawson and Istok, 1991; and Hamlin, 1983).

Well Diameter

In general, observation well casing should have a diameter just large enough to allow for accurate, rapid water level measurements. A two-inch well casing is usually adequate for use as an observation well in shallow aquifers which are less than 100 feet in depth. They are, however, often difficult to develop. A four- to six-inch diameter well will withstand a more vigorous development process, and should have better aquifer response when properly developed. Additionally, a four or six inch diameter well may be required if a water-depth recorder is planned, depending on the type of recording equipment to be used. The difficulties in drilling a straight hole usually dictate that a well over 200 feet deep be at least four inches in diameter.

Well Construction

Ideally, the observation well(s) should have five to twenty feet of perforated casing or well screen near the bottom of the well. The final well screened interval(s) will depend on the nature of geologic conditions at the site and the types of parameters to be estimated. Any openings which allow water to enter the well from aquifers which are not to be tested should be sealed or closed off for the duration of the test. Ideally, the annular space between the casing and the hole wall should be gravel packed adjacent to the perforated interval to be tested. The use of a filter pack in wells with more than one screened interval will, however, create a problem. There is no reliable method for sealing the annular space of any unwanted filter packed interval even though the screen can be isolated. The size of the filter material should be based on the grain size distribution of the zone to be screened (preferably based on a sieve analysis of the material). The screen size should be determined based on the filter pack design (Driscoll, 1986). The space above the gravel should be sealed with a sufficient amount of bentonite or other grout to isolate the gravel pack from vertical flow from above. If the bentonite does not extend to the surface, it will be necessary to put a cement seal on top of the bentonite prior to back filling the remaining annular space. A concrete pad should be placed around the well to prevent surface fluids from entering the annular material. After installation is finished, the observation well should be developed by surging with a block, and/or submersible pump (Campbell and Lehr, 1972; and Driscoll, 1986) for a sufficient period (usually several hours) to meet a pre-determined level of turbidity.

Radial Distance and Location Relative to the Pumped Well

If only one observation well is to be used, it is usually located 50 to 300 feet from the pumped well. However, each test situation should be evaluated individually, because certain hydraulic conditions may exist which warrant the use of a closer or more distant observation well. If the test design requires multiple observation wells, the wells are often placed in a straight line or along rays that are perpendicular from the pumping well. In the case of multiple boundaries or leaky aquifers, the observation wells need to be located in a manner which will identify the location and effect of the boundaries. If the location of the boundary is suspected before the test, it is desirable to locate most of the wells along a line parallel to the boundary and running through the pumping well, as shown in Figure 2. If aquifer anisotropy is expected, the observation wells should be located in a pattern based on the suspected or known anisotropic conditions at the site (Bentall and others, 1963; Ferris and others, 1962; Walton, 1962 and 1970; and Dawson and Istok, 1991). If the principal directions of anisotropy are known, drawdown data from two wells located on different rays from the pumping well will be sufficient. If the principal directions of anisotropy are not known, at least three wells on different rays are needed.

FIELD PROCEDURES

Well thought out field procedures and accurate monitoring equipment are the key to a successful aquifer test. The following three sections provide an overview of the methods and equipment for establishing a pre-test baseline condition and running the test itself.

Necessary Equipment for Data Collection

During an aquifer test, equipment is needed to measure/ record water levels, well discharges, and the time since the beginning of the test, and to record accumulated data. Appendix One contains a detailed description of the types of equipment commonly used during an aquifer test. Appendix Two is an example form for recording test data.

Establish Baseline Trend

Collecting data on pre-test water levels is essential if the analysis of the test data is to be completely successful. The baseline data provides a basis for correcting the test data to account for on-going regional water level changes. Although the wells on-site are the main target for baseline measurements, it is important to measure key wells adjacent to the site and to account for off-site pumping which may affect the test results.

Baseline water levels

Prior to beginning the test, it will be necessary to establish a

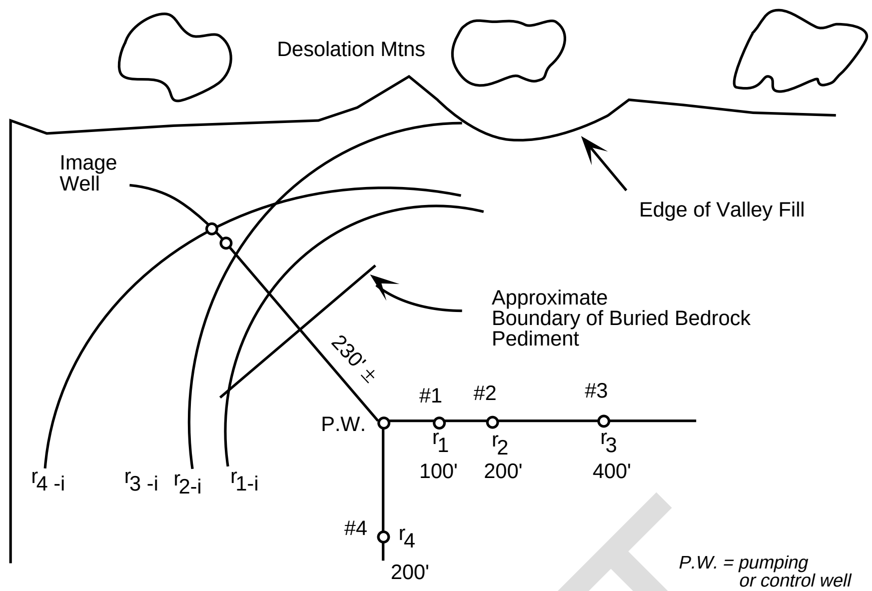

Figure 2. Observation well/pumping well location to determine buried impermeable boundary.

baseline trend in the water levels in the pumping and all observation wells. As a general rule, the period of observation before the start of the test (t_0), should be at least one week. Baseline measurements must be made for a period which is sufficient to establish the pre-pumping water level trends on site (see Figure 3). The baseline data must be sufficient to explain any differences between individual observation wells. As shown in Figure 3, the water levels in on-site wells were declining prior to the test. The drawdown during the test must be corrected to account for the pre-pumping trend.

Nearby pumping activities

During the baseline measurements, the on-off times should be recorded for any nearby wells in use. The well discharge rates should be noted as should any observed changes in the proposed on-site control well and observation wells. Baseline water level measurements should be made in all off-site wells within the anticipated area of influence. As shown in Figure 3, the baseline period should be sufficient to establish the pretest pumping trends and to explain any differences in trends between individual off-site wells.

Significant effects due to nearby pumping wells can often be removed from the test data if the on-off times of the wells are monitored before and during the test. Interference effects may not, however, always be observable. In any case, changes associated with nearby pumping wells will make analysis more difficult. If possible, the cooperation of nearby well owners should be obtained to either cease pumping prior to and during the test period or to control the discharge of these wells during the baseline and test period. The underlying principle is to minimize changes in regional effects during the baseline, test and recovery periods.

Barometric pressure changes

During the baseline trend observation period, it is desirable to monitor and record the barometric pressure to a sensitivity of plus or minus 0.01 inches of mercury. The monitoring should continue throughout the test and for at least one day to a week after the completion of the recovery measurement period. This data, when combined with the water level trends measured during the baseline period, can be used to correct for the effects of barometric changes that may occur during the test (Clark, 1967).

Local activities which may affect test

Changes in depth to water level, observed during the test, may be due to several variables such as recharge, barometric response, or “noise” resulting from operation of nearby wells, or loading of the aquifer by trains or other surface disturbances (King, 1982). It is important to identify all major activities (especially cyclic activities) which may impact the test data. Enough measurements have to be made to fully characterize the pre-pumping trends of these activities. This may necessitate the installation of recording equipment. A summary of this information should be noted in the comments section of the pumping test data forms.

Test Procedures

Initial water level measurements

Immediately before pumping is to begin, static water levels in all test wells should be recorded. Measurements of drawdown in the pumping well can be simplified by taping a calibrated steel tape to the electric sounder wire. The zero point of the tape may be taped at the point representing static water level. This will enable the drawdown to be measured directly rather than by depth to water.

Measuring water levels during test

If drawdown is expected in the observation well(s) soon after

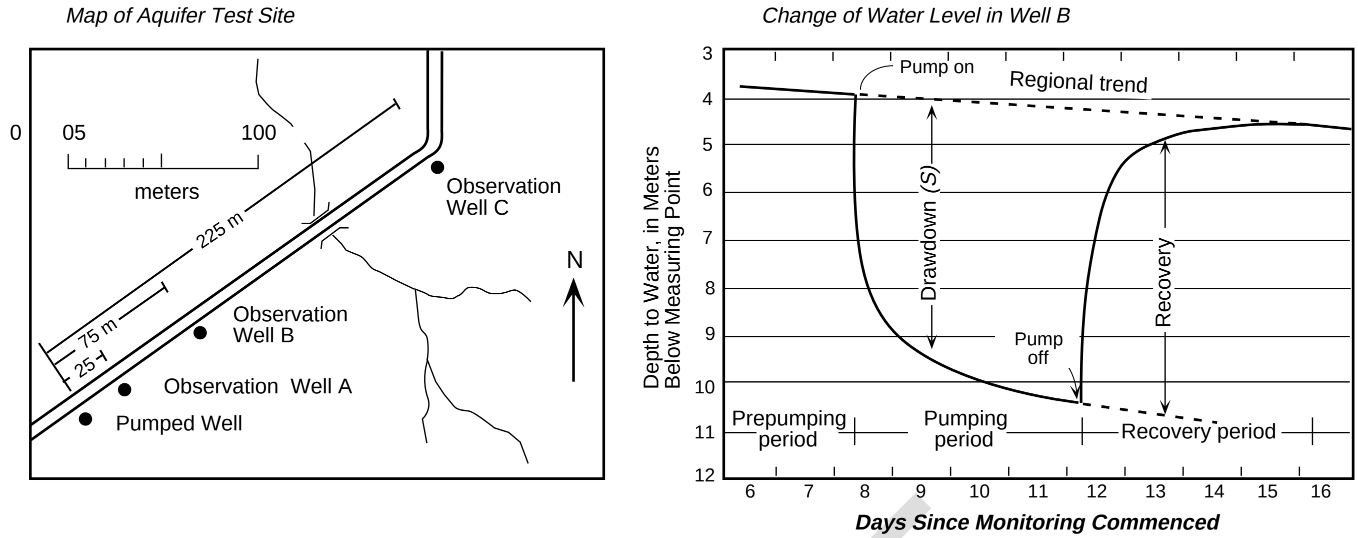

Figure 3. Example test site showing baseline, pumping test, and recovery water level measurements in one of the wells.

testing begins and continuous water level recorders are not installed, an observer should be stationed at each observation well to record water levels during the first two to three hours of testing. Subsequently, a single observer is usually able to record water levels in all wells because simultaneous measurements are unnecessary. If there are numerous observation wells, a pressure transducer/data-logging system should be considered to reduce manpower needs.

Time frame for measuring water levels

Table 1 shows the recommended maximum time intervals for recording water levels in the pumped well. NOTE: the times provided in Table 1 are only the maximum recommended time intervals--more frequent measurements may be taken if test conditions warrant. For instance, it is recommended that water level measurements be taken at least every 30 seconds for the first several minutes of the test (see ASTM Committee D-18, D 4050). Figure 4 is a hypothetical logarithmic plot of drawdown versus time for an observation well. This plot illustrates the need for the frequency of measurements given in Table 1. As shown on the plot, frequent measurements during early times are needed to define the drawdown curve. The data used in Figure 4 was collected with a downhole pressure transducer and electronic data recording equipment. Thus, water levels could be collected about every 6 seconds initially and less frequently as the test progresses. As time since pumping started increases, the logarithmic scale dictates that less frequent measurements are needed to adequately define the curve.

Measurements in the observation well(s) should occur often enough and soon enough after testing begins to avoid missing the initial drawdown values. Actual timing will depend on the aquifer and well conditions which vary from test area to test area. Estimates for timing should be made during the planning stages of aquifer testing using estimated aquifer parameters based on the conceptual model of the site.

Table 1. Maximum Recommended Time Intervals for Aquifer Test Water Level Measurements*

0 to 3 minutes	every 30 seconds
3 to 15 minutes	every minute
15 to 60 minutes	every 5 minutes
60 to 120 minutes	every 10 minutes
120 min. to 10 hours	every 30 minutes
10 hours to 48 hours	every 4 hours
48 hours to shut down	every 24 hours

** Dr. John Harshbarger, personal communication, 1968.*

Monitoring discharge rate

During the initial hour of the aquifer test, well discharge in the pumping well should be monitored and recorded as frequently as practical. Ideally, the pretest discharge will equal zero. If it does not, the discharge should be measured for the first time within a minute or two after the pump is started.

It is important when starting a test to bring the discharge up to the chosen rate as quickly as possible. How frequently the discharge needs to be measured and adjusted for a test depends on the pump, well, aquifer, and power characteristics. Output from electrically driven equipment requires less frequent adjustments than from all other pumping equipment. Engine-driven pumps generally require adjustments several times a day because of variation that occurs in the motor performance due to a number of factors, including air temperature effects. At a minimum, the discharge should be checked four times per day: 1) early

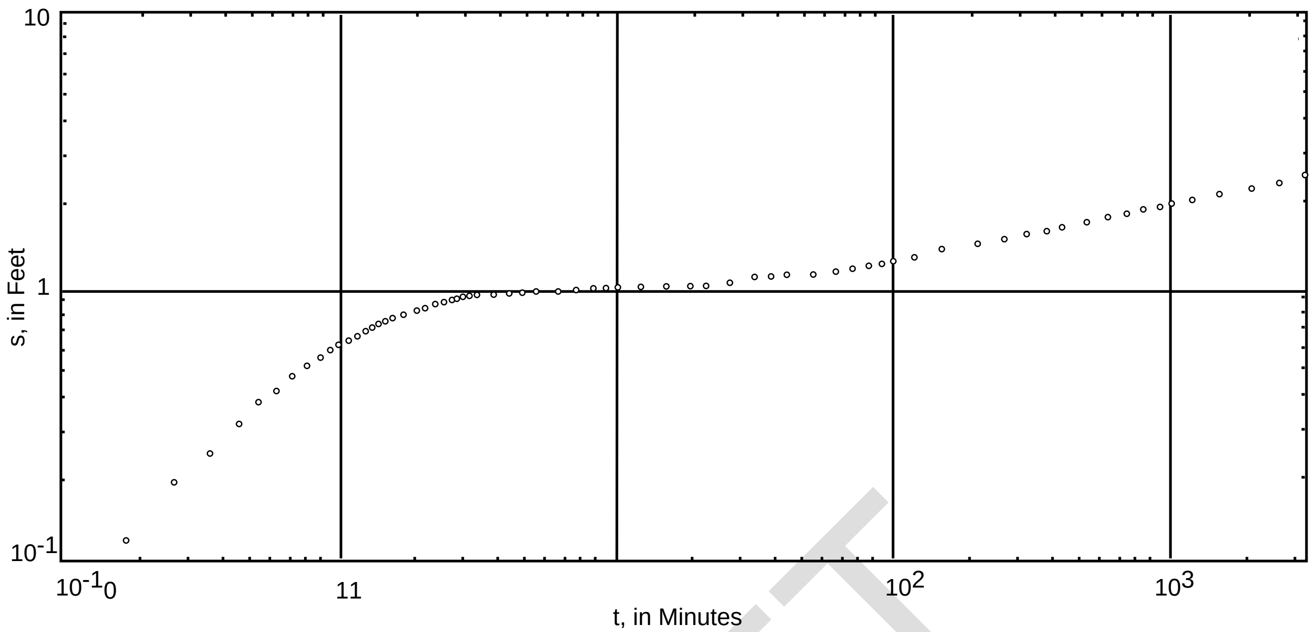

Figure 4. Logarithmic plot of s vs t for observation well.

morning (2 AM); 2) mid-morning (10 AM); 3) mid-afternoon (3 PM); and 4) early evening (8 PM). The discharge should never be allowed to vary more than plus or minus 5 percent (Ferris, J. G., personal communication, 1/19/68). The lower the discharge rate, the more important it is to hold the variation to less than 5 percent. The variation of discharge rate has a large effect on permeability estimates calculated using data collected during a test. The importance of controlling the discharge rate can be demonstrated using a sensitivity analysis of pumping test data. An analysis of this type indicates that a 10 percent variation in discharge can result in a 100 percent variation in the estimate of aquifer transmissivity. Thus, short-term pumping tests with poor control of discharge are not suitable for estimating parameters needed for adequate site characterization. If, however, the pumping test is run in such a way that the discharge rate varies less than 5 percent and water levels are measured frequently, the short-term pumping test data can be used to obtain some reliable estimates of aquifer performance.

It should be emphasized, however, that some random, short-term variations in discharge may be acceptable, if the average discharge does not vary by more than plus or minus 5 percent. A systematic or monotonic change in discharge (usually, a decrease in discharge with increasing time) is, however, unacceptable.

Water level recovery

Recovery measurements should be made in the same manner as the drawdown measurements. After pumping is terminated, recovery measurements should be taken at the same frequency as the drawdown measurements listed above in Table 1.

Length of test

The amount of time the aquifer should be pumped depends on the objectives of the test, the type of aquifer, location of suspected boundaries, the degree of accuracy needed to establish the storage coefficient and transmissivity, and the rate of pumping. The test should continue until the data are adequate to define the shape of the type curve sufficiently so that the parameters required are defined. This may require pumping for a significant period after the rate of water level change becomes small (so called water level “stabilization”). This is especially the case when the locations of boundaries or the effects of delayed drainage are of interest. Their influence may occur a few hours after pumping starts (see Figure 3), or it may be days or weeks. Some aquifer tests may never achieve equilibrium, or exhibit boundary effects.

Although it is not necessary for the pumping to continue until equilibrium is approached, it is recommended that pumping be continued for as long as possible and at least for 24 hours. Recovery measurements should be made for a similar period or until the projected pre-pumping water level trend has been attained. The costs of running the pump a few extra hours are low compared with the total costs of the test, and the improvement in additional information gained could be the difference between a conclusive and an inconclusive aquifer test.

Water disposal

As discussed previously, the water being pumped must be disposed of legally within applicable local, State, and Federal rules and regulations. This is especially true if the ground water is contaminated or is of poor quality compared to that at the point of disposal. During the pumping test, the individuals carrying out the test should carry out water quality monitoring as required by the test plan and any necessary disposal permits. This monitoring should include periodic checks to assure that the water disposal procedures are following the test design and are not recharging the aquifer in a manner that would adversely affect the test results. The field notes for the test should document when and how monitoring was performed.

Recordkeeping

All data should be recorded on the forms prepared prior to testing (See Appendix 2). An accurate recording of the time, water level, and discharge measurements and comments during the test will prove valuable and necessary during the data analyses stage following the test.

Plotting data

During the test, a plot of drawdown versus time on semi-log paper should always be prepared and updated as new data is collected for each observation well. A plot of the data prepared during the actual test is essential for monitoring the status and effectiveness of the test. The plot of drawdown versus time will reveal the effects of boundaries or other hydraulic features if they are encountered during the test, and will indicate when enough data for a solution have been recorded. A semi-log or log-log mass plot of water level data from all observation wells should be prepared as time allows. Such a plot can be used to show when aquifer conditions are beginning to affect individual wells. More importantly, it enables the observer to identify erroneous data. This is especially important if transducers are being used for data collection. The utilization of a portable PC with a graphics package is an option for use in carrying out additional field manipulation of the data. It should not, however, be a substitute for a manual plot of the data.

Precautions

(a) Care should be taken for all observers to use the same measuring point on the top of the well casing for each well. If it is necessary to change the measuring point during the test, the time at which the point was changed should be noted and the new measuring point described in detail including the elevation of the new point.

(b) Regardless of the prescribed time interval, the actual time of measurement should be recorded for all measurements. It is recognized that the measurements will not be taken at the exact time intervals suggested.

(c) If measurements in observation well(s) are taken by several individuals during the early stages of testing, care should be taken to synchronize stop watches to assure that the time since pumping started is standardized.

(d) It is important to remember to start all stop watches at the time pumping is started (or stopped if performing a recovery test).

(e) Comments can be valuable in analyzing the data. It is important to note any problems, or situations which may alter the test data or the accuracy with which the observer is working.

(f) If several sounders are to be used, they should be compared before the start of the test to assure that constant readings can be made. If the sounder in use is changed, the change should be noted and the new sounder identified in the notes.

PUMPING TEST DATA REDUCTION AND PRESENTATION

All forms required for recording the test data should be prepared prior to the start of the test and should be attached to a clip board for ease of use in the field. It is an option to have a portable PC located on-site with appropriate spreadsheets and graphics package to allow for easier manipulation of the data during the test. The hard copy of the forms should be maintained for the files.

Tabular Data

All raw data in tabular form should be submitted along with the analysis and computations. The data should clearly indicate the well location(s), and date of test and type of test. All data corrections, for pre-pumping trends, barometric pressure fluctuations and other corrections should be given individually and clearly labeled. All graphs used for corrections should be referenced on the specific table. These graphs should be attached to the data package.

Graphs

All graphs or plots should be drafted carefully so that the individual points which reflect the measured data can be retrieved. Semi-logarithmic and logarithmic data plots (see Figures 5 and 6) should be on paper scaled appropriately for the anticipated length of the test and the anticipated drawdown. All X-Y coordinates shall be carefully labeled on each plot. All plots must include the well location, date of test, and an explanation of any points plotted or symbols used.

ANALYSIS OF TEST RESULTS

Data analysis involves using the raw field data to calculate estimated values of hydraulic properties. If the design and field-observation phases of the aquifer test are conducted successfully, data analyses should be routine and successful. The method(s) of analysis utilized will depend, of course, on particular aquifer conditions in the area (known or assumed) and the parameters to be estimated.

Calculations

All calculations and data analyses must accompany the final report. All calculations should clearly show the data used for input, the equations used and the results achieved. Any assumptions made as part of the analysis should be noted in the calculation section. This is especially important if the data were corrected to account for barometric pressure changes, off-site pumping changes, or other activities which have affected the test. The calculations should reference the appropriate tables and graphs used for a particular calculation.

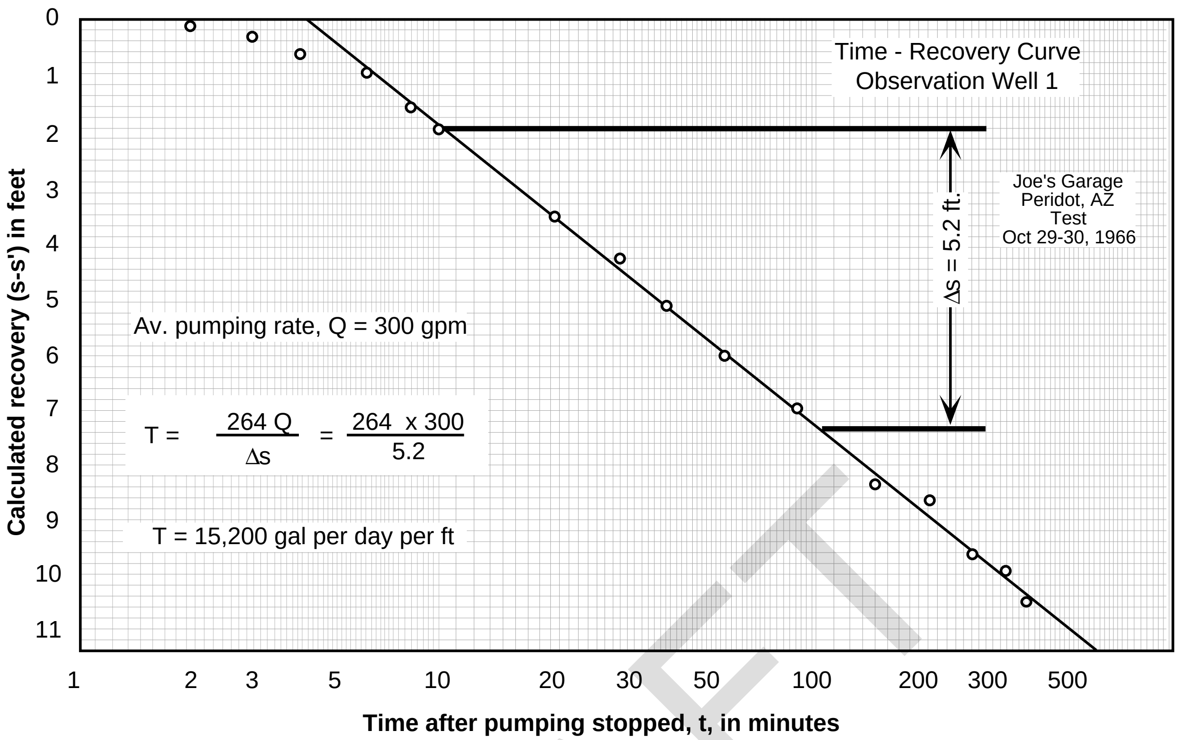

Figure 5. Time recovery curve for observation well - October 30, 1966.

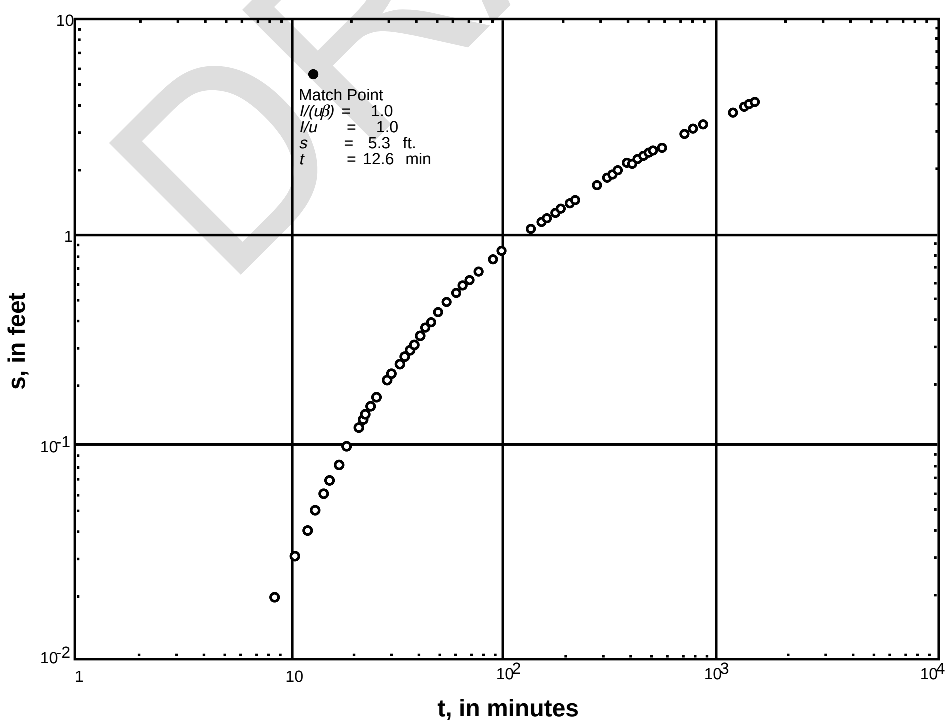

Figure 6. Logarithmic plot of s vs t for Observation Well 23S/25E-17Q$_2$ at Pixley, CA.

Aquifer Test Results

The results of an aquifer pumping and recovery test should be submitted in narrative format. The narrative report should include the raw data in tabular form, the plots of the data, the complete calculations and a summary of the results of the test. The assumptions made in utilizing a particular method of analysis should also be included.

SUMMARY-EXAMPLE FACILITY DESIGN

As a means of focusing the discussions presented in the preceding sections, the following example of an aquifer pumping test is described. The facility layout is shown in Figure 7. The site is located near a normally dry river channel which is subject to flood flows. The site was constructed for the purpose of carrying out experiments relating to artificial recharge of a shallow alluvial aquifer. The proposed methods of recharge involved use of a pit and a well.

The aquifer at the site is comprised of unconsolidated basin fill material, mainly silty sand and gravel with some clay lenses. The depth to water is generally greater than 50 feet and the river is a source of recharge when it flows. There are extensive gravel lenses above the water table which outcrop at the base of the river channel. These lenses occur beneath the site.

Figure 7 shows the locations of the various monitoring wells relative to the recharge facilities and the river. The well locations were selected to facilitate both characterization of the site and subsequent evaluation of the various recharge tests. The recharge well (used as the pumping well during the site aquifer tests) and the eight inch observation wells were completed to a depth of 150 feet in the upper water bearing unit of a basin fill aquifer. The depth to water in the area was about 75 feet. The recharge and observation wells were screened from about 80 feet to 140 feet. The 1-3/4 inch access tubes were 80-100 feet deep with a five-foot well screen on the bottom of each tube.

The eight-inch observation wells were placed in a line parallel to the river to assess both the effect of flood flows on the aquifer and the hydraulic characteristics of the recharge site itself. The 1-3/4 inch access tubes were positioned for monitoring ground-water movement near the top of the water table in response to aquifer recharge and discharge (pumping) tests. The two inch piezometers at varying depths were constructed to evaluate shallow ground-water movement in response to recharge.

Figure 8 is a plan view of the recharge facility showing the pumping/recharge well and the water distribution system. The pumping well was equipped with a downhole turbine pump powered by a methane driven, 6-cylinder engine. As indicated

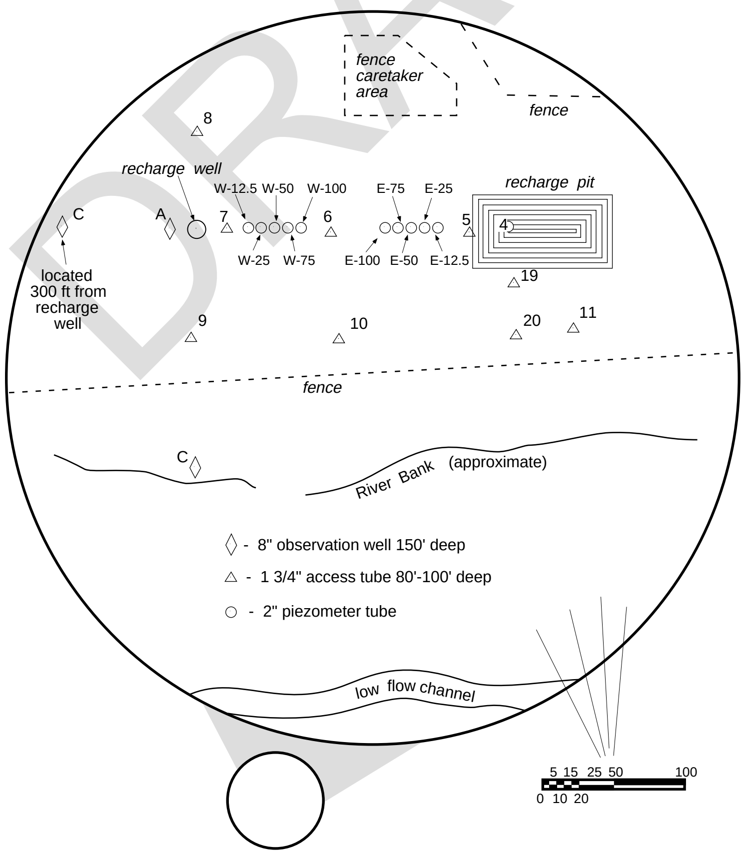

Figure 7. Recharge facility well layout.

on Figure 8, the pump discharge was measured using a Parshall flume (see Figure 9). The water from pumping tests was discharged off-site via the concrete box and distribution line. To prevent interference with test results from nearby recharge of the pumping test water, a temporary pipeline was constructed from irrigation pipe. This temporary line ran from the end of the river drain line to a point 1200 feet down stream out of the estimated area of influence. The ground water was not contaminated. Thus, special water quality monitoring was not required.

The pumping tests for site characterization involved the following monitoring procedure:

1. The eight-inch observation well closest to the recharge well (Well A) was equipped with a Stevens water stage recorder with an electric clock geared for a 4-hour chart cycle;

2. The other two eight-inch observation wells (Wells B and C) were equipped with Stevens water stage recorders with an electric clock geared for a 12-hour chart cycle;

3. The pumping well was equipped with a stilling well composed of a 3/4-inch pipe strapped to the pump column. The stilling well was drilled with 1/4-inch holes through the length. The stilling well was used for assessing the well for water level measurements with a 150-foot steel tape. The steel tape was marked in 0.01 ft. increments for the first 100 feet and in 0.1 ft. increments for the remaining 50 feet;

4. The 1-3/4 inch access wells were monitored at least once a day with a neutron moisture logger to assess changes in saturation as the water level declined in response to the test. This information was used to verify the water level declines in the regular monitoring wells and to aid in assessing the delayed drainage effects which were to be estimated using the water level response data from the eight-inch observation wells;

5. A continuous recording barograph was located in a standard construction, USDA weather station shed located between access Wells 9 and 10; and

6. The pump engine was equipped with an rpm gage to monitor pump performance and a micrometer adjustment on the throttle.

A step drawdown test and several short-term pumping tests were run at the site prior to running the principal aquifer characterization test. The step drawdown test was used as a means of selecting the final pumping test design. The short term tests were used to obtain an initial picture of aquifer response.

The results of the step drawdown test run on the recharge well after development indicated that the well was suitable for use as a test well. The results of the step test were also used to estimate well efficiency at different rates. Table 2 gives the efficiencies for three (3) discharge rates. As indicated, the well efficiency was greater than 90% for a rate of about 200

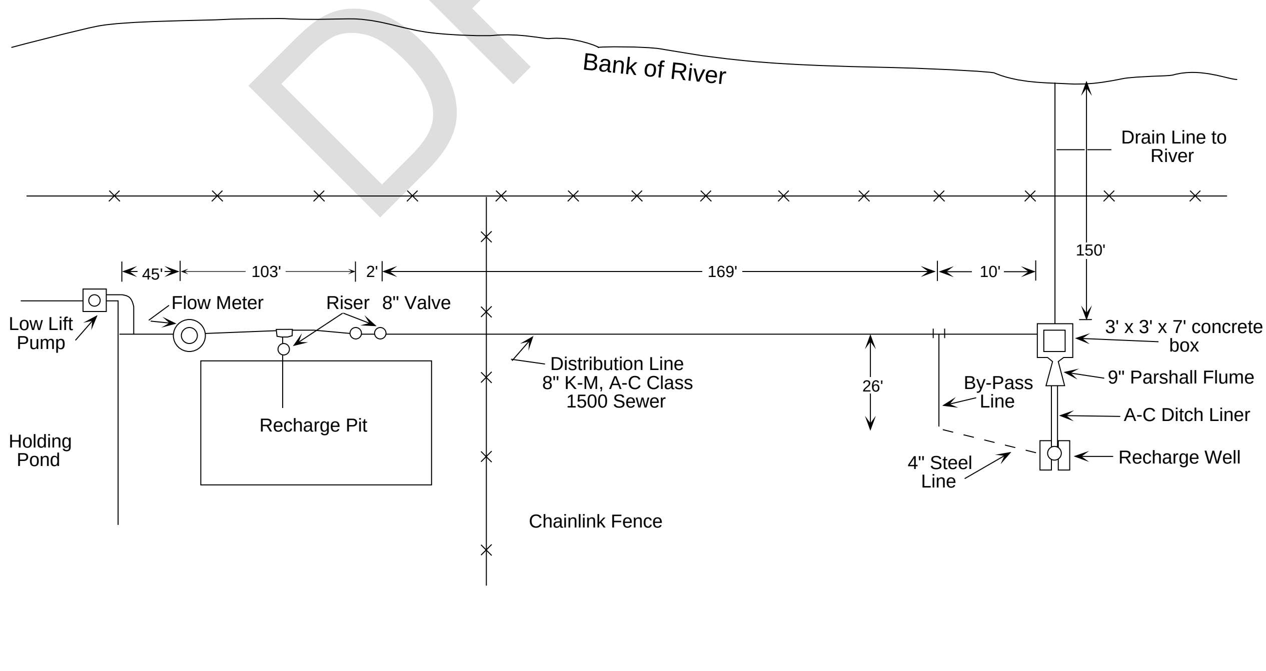

Figure 8. Water distribution and drainage facilities at the artificial recharge site.

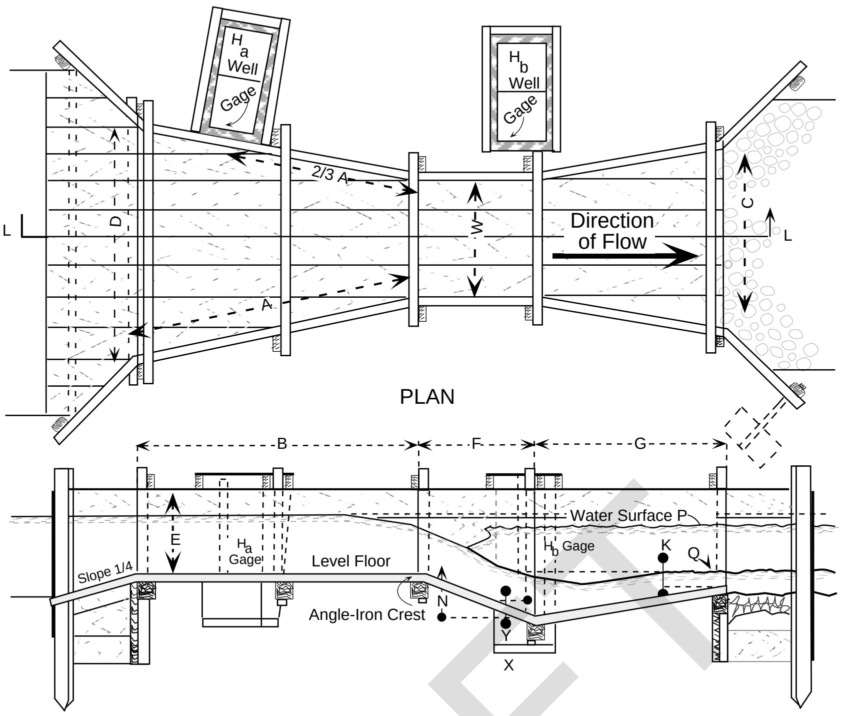

Figure 9. Parshall flume dimensions.

gpm. Based on this data, the design rate for the long-term test was set at about 200 gpm (actual average was 204 gpm).

Table 2. Well Efficiency of R#1 after 200 Minutes of Pumping

Discharge	Theoretical Drawdown	Actual Drawdown	Well Efficiency
gpm	*ft*	*ft*	*percent*
189	7.00	7.51	92
326	11.88	14.71	81
474	17.27	25.41	68

Because the initial short-term tests indicated that delayed drainage was an issue at the site, the main test was designed to run for a continuous period of at least 20 days. The actual scheduling of the test was established to try to avoid flow in the river as a result of a major precipitation event during the background, pumping, and recovery periods. The chosen test period was in the fall after the end of the irrigation season, which also minimized off-site pumping that might affect the results. It should be noted that two short-term tests were planned to follow the main pumping test during the winter rainy season when flow in the river was possible. This was done to allow the impacts of an uncontrolled recharge event on the system to be assessed. The main pumping test would provide a basis for comparison.

The discharging well was measured on a time schedule per the criteria in Table 1, except that measurements for the initial 10 minute period were taken every 30 seconds. The observation wells were observed manually on the same schedule for the initial 30 minute period and then the recorders were utilized. Discharge measurements were monitored at least every 5 minutes for the first 30 minutes and then were monitored with water levels for the first 12 hours. Discharge measurements were monitored at least four times daily until the end of the test. The access tubes were monitored twice daily to assess changes in saturation near the water table.

The results from the long term pumping test are shown on Figure 10 as a semi-log data mass plot (drawdown versus log time) of the data for the three (3) observation wells. The large initial water level decline for Observation Well A is due to its close proximity to the pumping well (15 feet). The rise in water level at the end of the test was caused by a slight decrease in discharge rate.

Values of T and S were obtained by the non-equilibrium method. The plots of drawdown as a function of log time did not give a good overlay on the non-equilibrium type curve for early times. For later times, it was possible to obtain a good match. The match points obtained for the three observation wells are listed in Table 3. The values of T and S are also shown in Table 3. As indicated, the estimates of T and S were in close agreement.

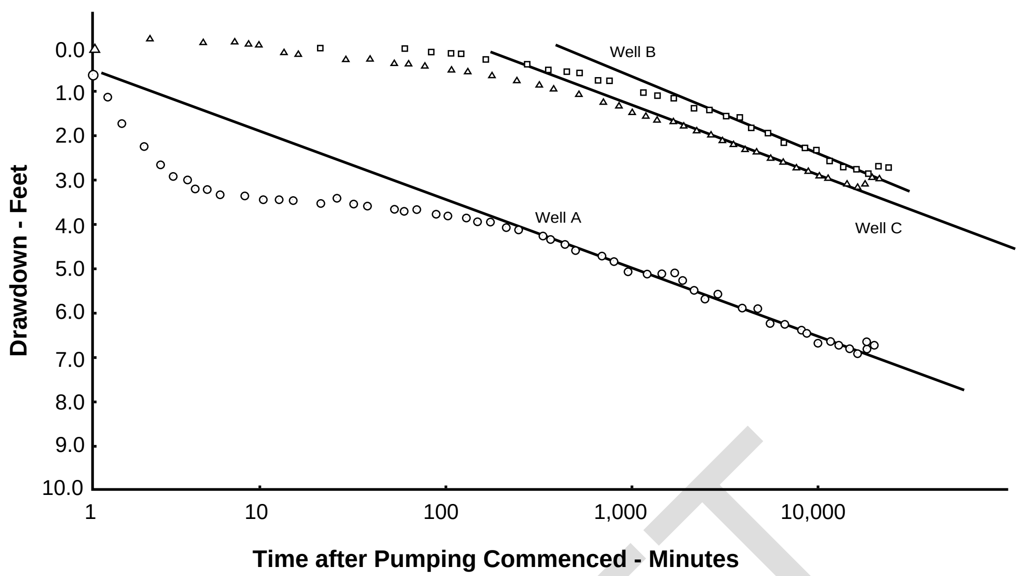

Figure 10. Drawdown versus log of time in observation wells A, B, and C during pumping of R#1.

Table 3. Values of T and S Obtained by Non-Equilibrium Equation for Discharge Conditions.

Location	w(u)	l/u	s	t	r	T	S
			ft	*min*	*ft*	*gpd/ft*	
Well A	110	10^5	0.62	14900	14.7	37,600	0.01
Well B	1	10	0.62	1780	280.0	37,600	0.03
Well C	1	10	0.58	530	175.4	40,200	0.03

The estimates for storativity were also in reasonable agreement. It is important to note that the test results showed delayed drainage to be a significant factor at this site. The initial estimates of storativity using data from the early part of the test were about 1 x 10^{-5} rather than 3 x 10^{-2} estimated after 20 days of pumping. This effect was expected because of the heterogeneous nature of the basin fill. As a means of comparison, water balance studies on a large well field located 15 miles away (completed in the same material) were reviewed. These studies provided an estimate of storage coefficient (based on 10 years of pumpage) of about 0.15. Thus, it was concluded that the aquifer at the site was under water table conditions, but significant delayed drainage effects were present.

The results of the pumping tests at the site were used to characterize the site and design several long-term recharge experiments. This included monitoring design for evaluation of the effect of river flows on the regional aquifer.

Appendix One

Equipment for Data Collection

a. Water Levels

Water level measurements can be made with electric sounders, air line and pressure gages, calibrated steel tapes, or pressure transducers (Garber and Koopman, 1968; and Bentall and others, 1963).

(1) Electric Sounders

(a) An electric sounder is recommended for measuring water levels in the pumping well because it will allow for rapid, multiple water level readings, especially important during the early stages of aquifer pumping and recovery tests.

(b) A dedicated sounder should be assigned to each observation well throughout the duration of the test. This is particularly important in ground-water quality studies to prevent cross contamination.

(c) Each sounder should be calibrated prior to the commencement of testing to assure accurate readings during the test.

(2) Air Lines and Pressure Gages

(a) Air lines are only recommended when electric sounders or steel tapes cannot be used to obtain water level measurements. Their usefulness is limited by the accuracy of the gage used and by difficulties in eliminating leakage from the air line. A gage capable of being read to 0.01 psi will be needed to obtain the necessary level of accuracy for determining water level change. A continuous copper or plastic line of known length should be strapped to the column pipe when the pump is installed. This will minimize the potential for leaks.

(b) When air lines are used, the same precision pressure gage should be used on all wells.

(c) Each pressure gage should be calibrated immediately prior to and after the test to assure accurate readings.

(d) The air line and pressure gage assembly should also be calibrated prior to the test by obtaining static water level by another method, if possible.

(3) Calibrated Steel Tapes

(a) Steel tapes marked to .01 ft. are preferred unless rapid water level drawdown or buildup is anticipated. If rapid drawdown, cascading water, or high frequency oscillation are anticipated, electric sounders, float actuated recorders or pressure transducers are preferred.

(b) Steel tapes are not recommended for use in the pumping well because of fluctuating water levels caused by the pump action, possible cascading water and the necessity for obtaining rapid water level measurements during the early portions of the aquifer pumping and recovery tests. If tapes are used, and the water level fluctuates, the well must be equipped with a means of dampening fluctuating water levels. Additional manpower will be needed during the initial stages of the test.

(4) Pressure Transducers

Pressure transducers are often used in situations where access to the well is restricted, such as a well where packers are being used to isolate a certain zone. They may also be applicable in large-scale tests using a computerized data collection system. Such a system will significantly reduce the manpower needed during the initial stages of a multiple well test. The most common installation uses down hole transducers with recording of the results taking place on the surface.

(a) Transducers should be calibrated prior to installation, and should be capable of accurately detecting changes of less than .005 psi. Transducer systems which will accurately record water level changes of .001 feet are available. The resolution of transducers, however, depends on the full scale range. Where large drawdowns are expected, such resolution is not possible.

(b) After installation, the transducers and recording equipment should be calibrated by comparing pressure readings to actual water level measurements taken with a steel tape. Periodic measurements of the water level should be made during the test to verify that the transducers are functioning properly.

(c) The effect of barometric changes on the transducers should be determined prior to and during the test. This will require continuous monitoring of the barometric pressure at the site as well as periodic comparisons of water level and transducer readings (Clark, 1967).

b. Discharge Measurement

The equipment commonly used for measuring discharge in the pumping well includes orifice plates, in-line water meters, Parshall flumes and recorders, V-notch weirs, or, for low discharge rates, a container of known volume, and a stop watch (Driscoll, 1986). The choice of method will depend upon a combination of factors, including i) accuracy needed, ii) planned discharge rate, iii) facility layout, and iv) point of discharge. If, for instance, it is necessary to discharge the water a half mile from the pump, a flume or weir will probably not be used, because the distance between the point of discharge control and the point of discharge would make logistics too difficult. An in-line flow meter or a pitot tube would be the most likely calibrated devices (U.S. Bureau of Reclamation, 1981; King, 1982; U.S. EPA, 1982; and Leopold and Stevens, 1987).

(1) Orifice Plate

(a) Orifice plates with manometers (see Figure 11) are an inexpensive and accurate means of obtaining discharge measurements during testing. The thin plate orifice is the best choice for the typical pump test. An orifice plate has an opening smaller than that of the discharge pipe. A manometer is installed into and onto the end of the discharge pipe. The diameter of the plate opening must be small enough to ensure that the discharge pipe behind the plate is full at the chosen rate of discharge. The reading shown on the manometer represents the difference between the upstream and downstream heads.

(b) Assuming the devices are manufactured accurately and are installed correctly, an orifice plate will provide an accuracy of between two and five percent. The orifice tube must be horizontal and full at all times to achieve the design accuracy.

(c) The accuracy should be established prior to testing by pumping into a container of known volume over a given time. This should be repeated for several rates.

(2) In-line Flow Meter

(a) In-line flow meters can give accurate readings of the flow if they are installed and calibrated properly. The meter must be located sufficiently far from valves, bends in the pipe, couplings, etc., to minimize turbulence which will affect the accuracy of the meter. **The meter must be installed so that it is completely submerged during operation.**

(b) Use of a meter is an easy way to monitor the discharge rate by recording the volume of flow through the meter using a totalizer or other means at one minute intervals and subtracting the two readings. Some meters register instantaneous rate of flow and total flow volume.

(c) The meter should be calibrated after installation (prior to the test) to insure its accuracy.

(3) Flumes and Weirs

(a) There are numerous accurate flumes and weirs on the market. The choice depends mainly on the approximate discharge anticipated, the location of the discharge point and the nature of the facility. The cost of installation will preclude use at many non-permanent facilities.

(b) The weir (see Figure 12) or flume should be located close to the pump. There should be a permanent recorder on the device as well as means of making manual measurements (e.g., staff gage).

(c) The discharge canal should have a sufficient length of unobstructed upstream channel so as not to affect the accuracy of the chosen weir or flume.

(4) Pitot Tube

(a) The pitot tube is a velocity meter which is installed in the discharge pipe to establish the velocity profile in the pipe. Commercially available devices consist of a combined piezometer and a total head meter.

(b) The tube must be installed at a point such that the upstream section is free of valves, tees,

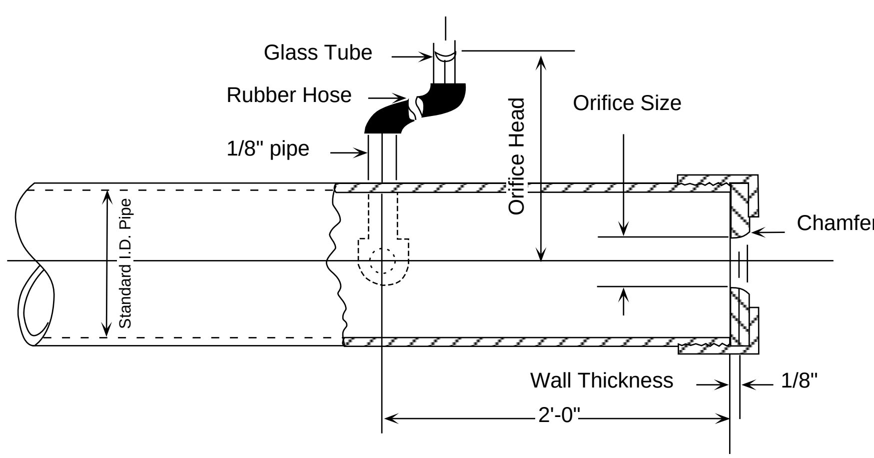

Figure 11. Diagram of orifice meter.

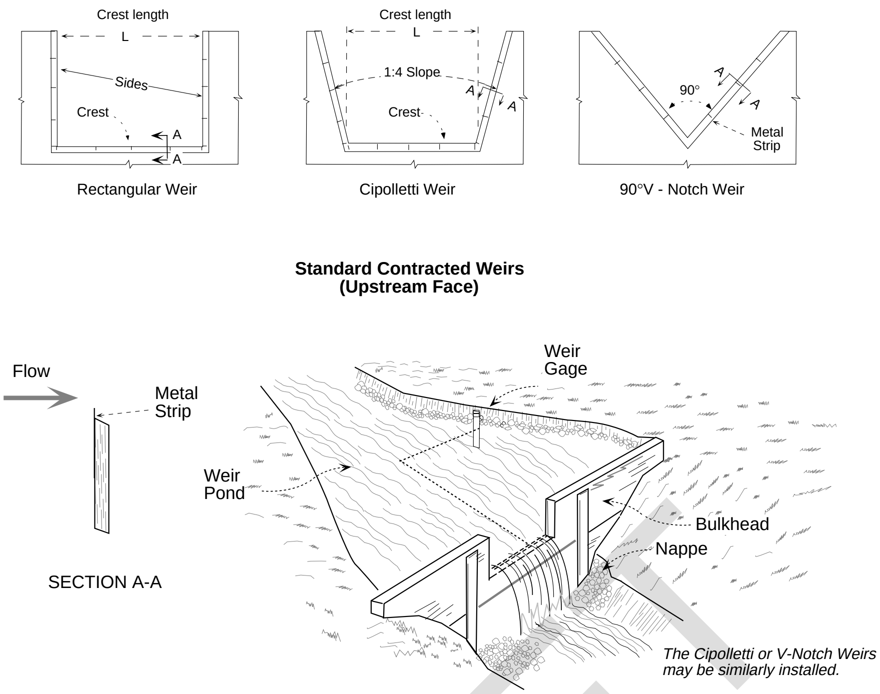

Figure 12. Standard contracted weirs, and temporary discharging at free flow.

elbows, etc., for a minimum distance equal to 15 to 20 times the pipe diameter to minimize turbulence at the location of the tube.

(c) Since the pitot tube becomes inaccurate at low velocities, the diameter of the pipe should be small enough to maintain reasonably high velocities.

(5) Container of Known Volume and Stop Watch

(a) The use of a container of known volume and a stop watch is a simple way to measure the discharge rate of a low volume discharging well.

(b) By recording the length of time taken for the discharging water to fill a container of known volume, the discharge rate can be calculated.

(c) This method can be used only where it is possible to precisely measure the time interval required for a known volume to be collected. If rates are sufficiently high so that water “sloshes” in the container, or they prohibit development of a relatively smooth surface on the water in the container, this method is likely to be inaccurate. Restricting use of this method to flows of less than 10 gpm is probably a conservative rule of thumb.

c. Discharge Regulation

(1) The size of the discharge line and the gate valve should be such that the valve will be from one-half to three-fourths open when pumping at the desired rate (during the initial phase of the test) with a full pipe.

(2) The valve should be placed a minimum of five (5) pipe diameters down-stream from an in-line flow meter, to ensure that the pipe is full and flow is not disturbed by excessive turbulence. In the case of some meters, such as a pitot tube, an in-line manometer, or an orifice plate, the valve would need to be upstream. (In this case the pipe downstream of the valve must be sized to be full at all times.)

d. Time

(1) A stop watch is recommended for use during an aquifer pumping and recovery test. Time should be recorded to the nearest second while drawdown is rapid, and to the nearest minute as the time period between measurements is increased beyond 15 minutes.

(2) If more than one stop watch is to be used during the testing, then all watches should be synchronized to assure that there is no error caused by the imprecise measurements of elapsed time.

(3) Accuracy of time is critical during the early stage of a pump or aquifer test and it is crucial to have all stop watches reflect the exact time. Later in the test the time recorded to the nearest minute becomes less critical.

(4) A master clock should be kept on site for tests longer than one day. This will provide a backup in case of

stop watch problems.

Appendix Two

Recording Forms

It is very important that each well data form stand alone. The data forms must contain all information which may have a bearing on the analysis of the data. See the suggested format for pumping test data recording sheets located at the end of this appendix. The form should allow for the following data to be recorded on the data sheet for each well:

(a) date
(b) temperature
(c) discharge rate
(d) weather
(e) well location
(f) well number
(g) owner of the well
(h) type of test (drawdown or recovery)
(i) description of measuring point
(j) elevation of measuring point
(k) type of measuring equipment
(l) radial distance from center of pumped well to the center of the observation well
(m) static depth to water
(n) person recording the data
(o) page number of total pages

In addition to the above information to be recorded on each page, the forms should have columns for recording of the following data:

(a) the elapsed time since pumping started, shown as the value (t)
(b) the elapsed time since pumping stopped, shown as (t')
(c) the depth in feet to the water level
(d) drawdown or recovery of the water level in feet
(e) the time since pumping started divided by the time since pumping stopped, shown as (t/t')
(f) the discharge rate in gallons per minute
(g) a column for comments to note any problems encountered, weather changes (i.e. barometric changes, precipitation), natural disasters, or other pertinent data.

AQUIFER TEST FIELD DATA SHEET

Page___ of____

________ Pumped Well No.__________________ Date ____
________ Observation Well No._______________ Weather ____
Owner ________________________________ Location ____
Observers: ____

Measuring Point is ________________ which is __________________ feet above/below surface.
Static Water Level _________________________ feet below land surface.
Distance to pumped well _____________________ feet. Type of Test ______________________________
Discharge rate of pumped well ______________ gpm (gallons per minute).
Total number of observation wells _____________________________ .
Water Measurement Technique ________________________________ .
Recorded by ___________________________ . Temperature during test ______________________________ .

Clock Time	Elapsed Time Since Pump Started or Stopped (min)	Depth to Water Below Land (feet)	Drawdown or Recovery (feet)	Discharge or Recharge (GPM)	t/t'	Comments

AQUIFER TEST FIELD DATA SHEET

Continuation Sheet

Distance to pumped well __________________ Bearing __________________ Page _____ of _______

________ Pumped Well No.________________ Date ____

________ Observation Well No.______________ Recorded by ____

Clock Time	Elapsed Time Since Pump Started or Stopped (min)	Depth to Water Below Land (feet)	Drawdown or Recovery (feet)	Discharge or Recharge (GPM)	t/t'	Comments

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Glossary

Aquifer: A unit of geologic material that contains sufficient saturated permeable material to conduct ground water and to yield economically significant quantities of ground water to wells and springs. The term was originally defined by Meinzer (1923, p. 30) as any water-bearing formation. Syn: water horizon; ground-water reservoir; nappe; aquafer.

Aquifer Test: A test involving the withdrawal of measured quantities of water from, or addition of water to, a well and the measurement of resulting changes in head in the aquifer both during and after the period of discharge or addition.

Aquitard: A confining bed that retards but does not prevent the flow of water to or from an adjacent aquifer; a leaky confining bed. It does not readily yield water to wells or springs, but may serve as a confining bed storage unit for ground water. Cf: aquifuge; aquiclude.

Capillary Fringe: The lower subdivision of the zone of aeration, immediately above the water table in which the interstices contain water under pressure less than that of the atmosphere, being continuous with the water below the water table but held above it by surface tension. Its upper boundary with the intermediate belt is indistinct, but is sometimes defined arbitrarily as the level at which 50 percent of the interstices are filled with water. Syn: zone of capillarity; capillary-moisture zone.

Confined Aquifer: An aquifer bounded above and below by impermeable beds or beds of distinctly lower permeability than that of the aquifer itself; an aquifer containing confined ground water. Syn: artesian aquifer.

Confining Bed: A confining bed is a unit of distinctly less permeable geologic material stratigraphically adjacent to an aquifer. "Aquitard" is a commonly used synonym. Confining beds can have a wide range of hydraulic conductivities and a confining bed of one area may have a hydraulic conductivity greater than an aquifer of another area.

Drawdown: The vertical distance between the static water level and the surface of the cone of depression at a given location and point of time.

Effective Porosity: Effective porosity refers to the amount of interconnected pore space and fracture openings available for the transmission of fluids, expressed as the volume of interconnected pores and openings to the volume of rock.

Ground Water: Subsurface water that occurs beneath the water table in soils and geologic formations that are fully saturated.

Hydraulic Conductivity: Hydraulic conductivity, K, replaces the term "coefficient of permeability" and is a volume of water that will move in unit time under a unit hydraulic gradient through a unit area measured at right angles to the direction of flow. Hydraulic conductivity is a function of the properties of the medium and the fluid viscosity and specific gravity; intrinsic permeability times specific gravity divided by viscosity. Dimensions are L/T with common units being centimeters per second or feet/day.

Hydraulic Gradient: Hydraulic gradient is the change in head per unit of distance in the direction of maximum rate of decrease in head.

Hydraulic Head: Hydraulic head is the sum of two components: the elevation of the point of measurement and the pressure head.

Intrinsic Permeability: Intrinsic permeability, k, is a property of the porous medium and has dimensions of L^2. It is a measure of the resistance to fluid flow through a given porous medium. It is, however, often used incorrectly to mean the same thing as hydraulic conductivity.

Porosity: Porosity of a rock or soil expresses its property of containing interstices or voids and is the ratio of the volume of interstices to the total volume, expressed as a decimal or percentage. Total porosity is comprised of primary and secondary openings. Primary porosity is controlled by shape, sorting and packing arrangements of grains and is independent of grain size. Secondary porosity is that void space created sometime after the initial formation of the porous medium due to secondary solution phenomena and fracture formation.

Potentiometric Surface: Potentiometric surface is an imaginary surface representing the static head of ground water and defined by the level to which water will rise in a well under static conditions. The water table is a particular potentiometric surface for an unconfined aquifer representing zero atmospheric gage pressure.

Recharge Zone: A recharge zone is the area in which water is absorbed and added to the saturated soil or geologic formation, either directly into a formation, or indirectly by way of another formation.

Residual Drawdown: The difference between the original static water level and the depth to water at a given instant during the recovery period.

Saturated Zone: The saturated zone is that part of the water-bearing material in which all voids are filled with water. Fluid pressure is always greater than or equal to atmospheric, and the hydraulic conductivity does not vary with pressure head.

Specific Capacity: The rate of discharge of a water well per unit of drawdown, commonly expressed in gpm/ft. It varies with duration of discharge.

Specific Storage: Specific storage, S, is defined as the volume of water that a unit volume of aquifer releases from storage because of expansion of the water and compression of the matrix or medium under a unit decline in average hydraulic head within the unit volume. For an unconfined aquifer, for all practical purposes, it has the same value as specific yield. The dimensions are L^1. It is a property of both the medium and the fluid.

Specific Yield: Specific yield is the fraction of drainable water yielded by gravity drainage when the water table declines. It is the ratio of the volume of water yielded by gravity to the volume of rock. Specific yield is equal to total porosity minus specific retention. Dimensionless.

Storage Coefficient: The storage coefficient, S, or storativity, is defined as the volume of water an aquifer releases from or takes into storage per unit surface area of aquifer per unit change in hydraulic head. It is dimensionless.

Transmissivity: Transmissivity, T, is defined as the rate of flow of water through a vertical strip of aquifer one unit wide extending the full saturated thickness of the aquifer under a unit hydraulic gradient. It is equal to hydraulic conductivity times aquifer saturated thickness. Dimensions are L^2/t.

Unconfined Ground Water: Unconfined ground water is water in an aquifer that has a water table. Also, it is aquifer water found at or near atmospheric pressure.

Unsaturated Zone: The unsaturated zone (also referred to as the vadose zone) is the soil or rock material between the land surface and water table. It includes the capillary fringe. Characteristically this zone contains liquid water under less than atmospheric pressure, with water vapor and other gases generally at atmospheric pressure.

Water Table: The water table is an imaginary surface in an unconfined water body at which the water pressure is atmospheric. It is essentially the top of the saturated zone.

Well Efficiency: The well efficiency is the theoretical drawdown divided by the measured drawdown. The theoretical drawdown is estimated by using pumping test data from several observation wells to construct a distance drawdown graph to estimate drawdown in the pumping well if there were no losses.

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memorandum

To: Trihydro Employees
From: OSE
Date: May 30, 2017
Re: Standard Operating Procedure – Aquifer Testing
(Authors: Ryan Athey and Tim Moloney)

1.0 PURPOSE

The purpose of this standard operating procedure (SOP) is to provide general instructions for aquifer testing. The procedure includes the minimum required steps and quality checks that employees and subcontractors should follow when performing the task.

2.0 SCOPE

This SOP describes standards for designing, implementing, and analyzing aquifer tests conducted for Trihydro projects. For the purposes of this SOP, aquifer tests include slug, specific capacity, step drawdown, and single and multiple well constant-rate pumping tests. The SOP addresses technical requirements and required documentation. Responsibilities of individuals performing the work are also detailed. Additional project-specific requirements for aquifer testing may be developed, as necessary, to supplement this procedure and to address project-specific conditions and objectives.

3.0 DEFINITIONS

Aquifer Testing - Refers to physical testing methods used to determine the hydraulic properties of aquifers or water-bearing formations. Slug, specific capacity, step-drawdown, and constant-rate pumping tests are commonly used testing methods and are collectively covered under the term "aquifer testing" in this SOP.

Slug Tests - Short-term, small-scale tests to determine hydraulic conductivity. Conducted by instantaneously (or nearly instantaneously) changing the water level in a well by adding, removing, or displacing a known volume of water and then monitoring the water-level recovery in the well. Slug tests are performed with either falling or rising head within a monitoring well.

Specific Capacity Tests - Short-term single-well pumping tests used to determine well efficiency and to approximate well-production rate. The method consists of measuring the stabilized drawdown in the well while pumping at a constant discharge (or as a step-drawdown test). Specific capacity tests can be conducted immediately after well development using the development pump. The tests provide fast and easy-to-interpret data for estimating well efficiency and well-production rate.

Step-Drawdown Tests - Conducted by pumping the well at several successively higher rates and measuring the corresponding water-level drawdown. These tests are used to estimate well performance, determine a sustainable optimum pumping rate for the well, and estimate aquifer properties. Specific capacity can be determined for each pumping step to determine the most-efficient extraction rate. The purpose of a step-drawdown test is similar to a specific capacity test, but step-drawdown tests typically give a better estimate of well performance due to the range of flow rates evaluated.

Constant-Rate Pumping Tests - A long-term test conducted to estimate aquifer transmissivity or aquifer properties over a wide area. The method generally involves extracting water at a constant rate from a well by pumping, and monitoring (measuring) the corresponding water-level drawdown in nearby observation wells. The recovery of water levels in the observation wells may also be monitored after pumping is terminated (recovery test). Water-level monitoring during a pumping and recovery test commonly includes the pumping well and one or more nearby observation wells. In certain instances, observation wells are not available and water-level monitoring is limited to the pumping well.

Cone of Depression - A depression in the groundwater table or potentiometric surface that has the shape of an inverted cone around a well from which water is being withdrawn.

Confined Aquifer - An aquifer that is overlain by a confining layer(s) of lower hydraulic conductivity.

Drawdown (s) - The difference between the height of the static water level and that of the water level in a well during pumping or water withdrawal. Or, in a confined aquifer, the reduction of the pressure head as a result of the water withdrawal.

Discharge (Q) - Volume of water removed per unit of time from a well.

Electric Well Tape or Electric Sounder - A water-level measuring device that uses a light, or sounds a buzzer, to show that the end of the tape has entered the water. The water in the well completes an electric circuit that turns on the light or sounds the buzzer. The tape is graduated to show the depth to water in the well. Also referred to as water-level meter. Some models differentiate between polar and non-polar fluids by measuring differences in electrical conductivity. These may be referred to as an oil/water-interface probe.

Flow Regulator - Flow regulators (flow controllers) are used to control the discharge rate (in volume/time) of water from the well while pumping. The discharge from the mechanical pump is normally set at a constant rate.

Hydraulic Conductivity (K) - A quantitative measure of the ability of a porous material to transmit water. Also defined as the volume of water that will flow through a unit cross-sectional area of porous material per unit time under a unit hydraulic gradient. Hydraulic conductivity depends on material and fluid properties.

Hydraulic Head (total) - The sum of the elevation head, the pressure head, and the velocity head at a given point in an aquifer.

Measuring Point - A fixed and clearly identified reference point from which water levels in a monitoring or extraction well may be measured. It is generally established on the upper rim of the outer protective well casing and has a surveyed location and elevation.

Mechanical Pump - A powered water pump (generally electric) used to withdraw water from the well during a pumping test.

Observation or Monitoring Well - A non-pumping well used to monitor the groundwater levels during a pumping test. Generally located within a few hundred feet of the pumping well. The most-useful observation wells are often located within 50 feet of the pumping well.

Potentiometric Surface - A surface that represents the level to which water will rise in a tightly cased well. If head varies significantly with depth in an aquifer, there may be more than one potentiometric surface. The water table is the uppermost potentiometric surface of an unconfined aquifer.

Pressure Transducer and Data Logger - An electronic sensor and storage device that can accurately measure hydrostatic pressure and store the data for future use. By relating hydrostatic pressure to depth below the water surface, the water level in the well can be electronically measured by the pressure transducer. Periodic water-level measurements can be taken and stored automatically by the data logger, without operator assistance, for later recall and data evaluation.

Recovery - The time rate of return to the static water level during an aquifer test. This is related to the aquifer's response to the change in water level during the test. After the water level has been raised or lowered, the water will return to static conditions (static water level). The water level is usually allowed to recover to 80 to 90 percent of the initial condition, but in some cases recovery can be as high as 95 percent before ending or repeating the test. The degree of required recovery depends on the formation storage coefficient.

Saturated Thickness (b) - For unconfined aquifers, the interval between the water table and base of the unconfined water-bearing unit. For confined aquifers, the interval between the base of the upper confining unit and the top of the lower confining unit.

Slug - A solid metallic or PVC rod (or weighted cylinder) of known volume that is lowered into and removed from a well to displace the water during a slug test.

Specific Capacity (Q/s) - A measure of the efficiency of a pumping well recorded as discharge per unit of drawdown in a pumping well.

Specific Yield (Sy) - The volume of water that saturated soil or rock will yield, under the influence of gravity, per unit volume of the saturated soil or rock. Specific yield is dimensionless.

Storage Coefficient or Storativity (S) - The volume of water that an aquifer releases from or takes into storage per unit area of aquifer, per unit change in head. Storage coefficient is dimensionless.

Transmissivity (T) - A quantitative measure of the ability of an aquifer to transmit water. It is the product of the hydraulic conductivity (K) and saturated thickness (b). Also defined as the volume of water that will flow through a unit thickness of an aquifer per unit time under a unit hydraulic gradient.

Unconfined Aquife - An aquifer in which the water table forms the upper boundary.

Water Level - The position of the air-water interface in a well. The water level is usually measured as the depth to the water from a measuring point (such as the top of the outer protective well casing) by the use of a weighted measuring tape or electric sounder. Changes in the water level over time may also be monitored by a pressure transducer installed at a known depth within the water column inside the well. The water level is called the static water level when it is not influenced by well-drilling activities, aquifer testing, well development, or groundwater sampling.

Water Table - The saturated zone surface at which the pore-water pressure is equal to atmospheric pressure. The water table is the uppermost potentiometric surface for an unconfined aquifer.

4.0 RESPONSIBILITIES

Trihydro employees performing this task, or any portion thereof, are responsible for meeting the requirements of this SOP. Trihydro employees conducting technical review of task performance are also responsible for following appropriate portions of this SOP. For those projects where the activities of this SOP are conducted, the Project Manager, or designee, is responsible for ensuring that those activities are conducted per this and other appropriate procedures. Project participants are responsible for documenting information in sufficient detail to provide objective documentation (i.e., check prints, calculations, reports, etc.) that the requirements of this SOP have been met. Such documentation should be retained as project records.

5.0 PROCEDURE

This section presents planning, basic methodology, documentation, and review requirements for aquifer testing. Basic procedures for conducting aquifer tests are provided as Attachments 1 through 4. Attachment 5 provides some special considerations for setting up and performing slug and pumping tests.

5.1 Planning

Aquifer testing is a controlled field experiment conducted to determine the approximate hydraulic properties (e.g., transmissivity, hydraulic conductivity, and storage coefficient) of water-bearing materials. Aquifer testing should incorporate and be tailored to the following:

- Known or assumed site-specific hydrogeologic conditions (e.g., confined, unconfined, leaky aquifer, fractured or low-yield formations, etc.).
- Targeted parameters to be evaluated.
- Analytical methodologies, assumptions, and limitations.

These factors should be considered and the aquifer tests designed before field implementation. Aquifer testing information and specifications to be considered include:

- Aquifer-test objectives
- Aquifer parameters to be evaluated
- Known or assumed hydrogeologic conditions
- Types of aquifer tests to be conducted
- Aquifer-test method limitations
- Test duration
- Procedures for tests to be conducted
- Site access and restrictions on equipment layout
- Exact wells to be used for testing
- Construction and condition of the wells to be used
- Distance wells are spaced apart and distance and direction from pumping well
- Equipment to be used (simple or complex)
- Type, duration, and frequency of measurements to be made
- Water handling and disposal
- Data-analysis techniques to be used (including analytical software)
- Additional procedures or requirements beyond those covered in this SOP (e.g., permitting)

The above information and specifications should be compiled during the planning and design phases of the testing and should be included in project-specific work plans. The assumptions underlying the conventional analysis techniques applied to the test results (data) should be known and incorporated in the planning and test analysis. The limitations of the technique for determining aquifer parameters are related to the correspondence between the field situation and the simplifying assumptions of the analysis method(s). Such limitations should be understood and considered during planning analysis and test-result reviews.

5.2. Methodology and Basic Issues

This section describes the basic methods for conducting slug, specific-capacity, step-drawdown, and constant-rate pumping tests. Example general procedures for conducting each of these aquifer test methods and special considerations are attached to this SOP. The general procedures should be modified as appropriate to address specific site conditions and requirements. These detailed project-specific procedures should be presented in the project work plans.

5.2.1. Slug Tests

A slug test is an aquifer test to determine hydraulic conductivity, in which the water level in a well is instantaneously changed by removing, adding, or displacing a known volume of water. The water-level response is monitored over a period of time in the slugged well. The water-level response is generally proportional to the hydraulic conductivity of the water-bearing unit.

A known volume of water can be removed relatively rapidly from the well with a submersible pump or bailer. Potable water can be added rapidly to a well by directly dumping from a container. Slug tests may also be initiated pneumatically by injecting a known volume of air into the well using an air compressor. However, the most common method used in environmental projects involves inserting and removing a solid slug (e.g., a solid cylindrical PVC blank), which instantaneously displaces the water level inside the well. The added or removed solid slug or water volume should be sufficient to create a measurable water-level displacement.

During testing, water levels may be measured with an electric tape if the wells recharge slowly. However, pressure transducers (with associated data loggers) are more commonly used to measure water levels because they can record a large number of measurements more rapidly. Many brands of transducer and data-logger packages have the ability to pre-program the measurement rate, obtaining frequent measurements during the initial portions of the test and less-frequent measurements near the end of the test as the water level slowly stabilizes. For convenience in performing the test, some data loggers can be programmed to store data only after a specified change in water level has taken place. Attachment 1 provides the general procedure for performing slug tests.

Slug tests are commonly used testing methods to determine the hydraulic conductivity of confined and unconfined aquifers. Slug tests are low-cost, relatively simple and rapid tests that are very useful in formations that do not have very high hydraulic conductivity. Usually, no water has to be handled and data analysis is straightforward. However, the test is limited to the immediate vicinity of the well, and the slug test results are heavily impacted by drilling-induced formation disturbances, well completion, completeness of well development, and well-screen fouling. The simplicity of the technique can also breed a certain casualness among those performing the tests and analyzing the test data.

Attention to detail regarding installing and developing monitoring wells—along with attention to detail during the design, implementation, and analysis of slug tests—can greatly improve the representativeness and accuracy of the results. Falling head tests (slug-in) should not be performed where the slug of water will flow into the unsaturated zone, and caution should be exercised in low-permeability formations where the well filter-pack permeability is much greater than that of the formation. In the latter case, the water slug may move up or down the filter pack rather than in or out of the formation, leading to erroneous results.

5.2.2 Specific Capacity Testing

Specific capacity tests are short-term, single-well pumping tests, generally performed to test well efficiency. The method consists of measuring the stabilized drawdown in the well while pumping at a uniform rate. The tests may be conducted in monitoring, extraction, and injection wells. Specific capacity tests can be conducted at the end of well development using the pump utilized for development. Specific capacity can also be determined for each pumping rate while conducting step drawdown tests. Specific capacity is typically expressed as the stabilized flow rate divided by the stabilized drawdown, with units of volume/length (e.g., gallons per minute / feet [gpm/ft]).

Attachment 2 provides the general procedure for performing specific capacity tests. While less accurate than long-term multiple-well pumping tests, specific capacity tests provide fast and easy-to-interpret data for estimating transmissivity of the water-bearing unit. The aquifer transmissivity is estimated from well specific capacity data. The simplifying assumptions of the Theis equation and application are never fully met in a specific capacity field-test situation. Generally, the values of transmissivity derived from specific capacity vary from those values determined from aquifer pumping tests using observation wells placed at a distance from the pumping well. These differences may be due to well construction, gravel pack, well development, partial penetration, well efficiency, or near-well aquifer conditions. Therefore, the transmissivity values derived from the specific capacity tests may be viewed as estimated values.

5.2.3 Step-Drawdown Tests

A step-drawdown test is conducted for the pumping well and is recommended before initiation of any constant-rate pumping test. The data provided by the step-drawdown test is used to evaluate well performance and to determine the optimum discharge for the subsequent constant-rate test. The step-drawdown test entails conducting three or more steps of increased discharge while monitoring water-level drawdown. Each step is conducted until the water-level drawdown shows signs of stabilization. This effectively produces successive stepped-drawdown curves. Aquifer testing may potentially be discontinued at a well after the step-drawdown pumping test if: 1) only a single-well pumping test is planned, and 2) the step-drawdown test provides the necessary data of a single-well pumping test. Specific capacity of the pumping well can be determined at each step to determine the optimum and sustainable pumping rate of the extraction well. Attachment 3 provides the general procedure for performing step-drawdown tests.

If drawdown is excessive during the initial pumping step, a decreasing discharge step test may be performed. Data analysis will be the same as for an increasing discharge step test.

5.2.4 Single or Multiple Well Constant-Rate Pumping Tests

A constant-rate pumping test involves pumping water (using a mechanical pump) from a well at a constant discharge, and monitoring the water-level drawdown in response to the pumping to determine the transmissivity and storage coefficient of the aquifer. Water-level recovery may also be monitored after the pumping is discontinued. When designed, conducted, and analyzed properly, the data and corresponding analysis results from pumping tests tend to be more reliable than from slug or specific capacity tests. Attachment 4 provides the general procedure for performing single or multiple well constant-rate pumping tests.

Water-level monitoring may be limited to the pumping well (single-well pumping test) or may include one or more nearby observation wells (multiple-well pumping test). For the single-well pumping test, the water-level drawdown and recovery are measured only in the pumping well. The storage coefficient of the aquifer cannot be determined from the pumping-well data.

The multiple-well test uses not only the pumping well but one or more observation (monitoring) wells at selected distances and locations relative to the pumping well. Water levels are monitored in the pumping and observation wells throughout the duration of the test. Observation-well selection should consider well-screen interval, depth and hydrostratigraphic zone of completion, and direction and distance from the pumping well.

5.3 Documentation

Documentation of aquifer test design, implementation, description and discussion of data-analysis techniques (including software), and analysis results should be placed in the project files and should include all field forms, notes, logs, plots or graphs, calculation sheets, and electronic or hard-copy data files.

5.4. Technical Review

Aquifer test procedures, data analysis, and results should undergo technical review. The technical reviewer should also provide review/oversight of the actual field implementation of the aquifer test(s). The technical reviewer should be an experienced senior geologist or hydrogeologist. At a minimum, the technical reviewer should be a person capable of designing and conducting the aquifer tests. However, the technical reviewer should not have developed or conducted the particular test to be reviewed. Individuals needing assistance in finding qualified technical reviewers may consult internal Trihydro technical listings for experts in aquifer testing.

The technical review, at a minimum, should consider and evaluate the following:

- Hydrogeologic setting (soil types and degree of stratification, confined or unconfined water-bearing zone).
- Appropriateness of the test method selected.
- Appropriateness and content of the test procedure (described in project work plans).
- Test duration.
- Pumping and observation well construction details and development.
- Selection and layout of the test equipment.
- Procedure execution.
- Quality of the data collected.
- Appropriateness of data-analysis method and data-analysis software.
- Validity and/or viability of any assumptions used in selecting test method, analysis method, and conducting field-data analysis.
- Completeness and technical viability of field-data analysis.
- Technical validity and supportability of analysis results.
- Documentation of results.

Questions raised during the technical review should be resolved between the reviewer and the staff conducting the aquifer tests before external (i.e., outside of Trihydro) use or submission of the results. The technical review comments and issues, and corresponding resolution, should be documented and filed with the project records. Such records should be maintained until project closeout.

ATTACHMENT 1
GENERAL PROCEDURE FOR PERFORMING SLUG TESTS

The following procedure should be used when performing slug tests. The approach covers both slug insertion (slug-in) and slug withdrawal (slug-out) portions of slug testing. In certain instances, only the slug-withdrawal test data are used for analysis. However, it is advisable to still conduct the slug-insertion test even if only using the slug-withdrawal test data for evaluating aquifer hydraulic conductivity. The slug-insertion test can provide information to make necessary adjustments to the withdrawal test in the field. This approach is readily adaptable for other slug-testing methods.

1. Select monitoring wells with known and adequate/appropriate construction for testing, and ensure that the wells to be tested are adequately developed before commencing testing activities. If more than one well is available, select the one that best represents the area or lithologic and hydrogeologic unit of concern.
2. Inspect the equipment to ensure that it is in good working order. Slug-test equipment will vary depending on the formation, other site conditions, the diameter and depth of the wells, and the number of the wells to be tested. To reduce slug-rod spinning, select a rope that will not twist when stretched while in tension.
3. Calibrate and test all measuring and testing equipment before use per manufacturer's specifications and appropriate project-specific requirements and procedures.
4. Decontaminate all downhole equipment per applicable Trihydro and project-specific requirements and procedures. If the contaminant histories of the wells to be tested are known or anticipated, the slug should be chemically compatible with the formation water, and tests should be performed starting with the least-contaminated well and ending with the most-contaminated well. Also, it is recommended to replace braided rope or line that has been submerged during slug testing of one well before moving on to another well. These practices will reduce the potential for cross-contamination between wells.
5. Visually inspect the wellhead for damage or obstructions that could hinder transducer or slug insertion or removal. Use a mirror or flashlight to inspect the well. If it is not vertically straight, install the transducer cable to one side of the well, insert the slug, and test for free movement.
6. Obtain a water-level depth measurement and sound the well bottom. If light non-aqueous-phase liquid (LNAPL) or dense non-aqueous-phase liquid (DNAPL) is expected, use an interface probe for monitoring. Compare the measured total depth to the well bottom with the well-construction diagram and information to determine if sediment is in the well bottom. It is important not to set the pressure transducer in the sediment. Temporarily install the pressure transducer in the well and connect it to the data logger. Read the depth before securing the transducer in the well. Install the pressure transducer in the water column to a depth that will not interfere with the insertion or withdrawal of the slug during testing, but also not exceed the maximum head limitation of the transducer. Secure the pressure transducer so that it will not move during the test.
7. Calculate the height of the water column in the well. The height of the water column should be sufficient to totally immerse the slug and also allow concurrent use of a pressure transducer or other measuring equipment during the testing.
8. Connect the pressure transducer to the data logger.

9. Obtain a barometric pressure measurement if testing (water-level recovery) is expected to take longer than 30 minutes or if weather conditions are changing rapidly. Station barometric pressure may be recorded from on-site equipment or obtained from a local weather station.
10. Turn on the pressure transducer and data logger and set the recording frequency (frequency that recorder stores data measured from the transducer and displays a reading) for pretest monitoring. Data loggers should be placed in a secure location to prevent tampering.
11. Measure the water level with an electric tape (or equivalent) and record along with the measurement time. Start pretest monitoring with the pressure transducer and data logger. In general, the total time should be roughly equal to or greater than twice the length of time expected to run the slug test.
12. Once the pre-test monitoring period is ended, re-measure the water level using the electric tape and record along with the measurement time.
13. Change the recording frequency on the data logger for the slug-in test. If the data logger is programmable to store specific changes in water levels (events), select an appropriate delta time for test recording. Lower the slug to just above the static water level. Concurrently start the data logger and lower the slug as quickly as possible to a depth below the static water level. Do not allow the slug to free-fall when lowering. Record the time of initiation of the slug on the appropriate form. The slug should be completely submerged. However, it is best to lower the slug only enough to make sure it is submerged and not more. This will reduce the chance of pinching the transducer cables, dragging the transducer, or sticking the slug.
14. Continue to monitor water-level decline with the pressure transducer and data logger, taking periodic water-level measurements with the electric tape. Data logger and tape readings should be conducted per the schedule before the test.
15. The slug-in test may be terminated once the water level has returned sufficiently to the pre-test static level. Once the slug-in test is terminated, take a physical water-level measurement with the electric tape. Record the measurement and time. Continue on to the slug-withdrawal ("slug-out") test.
16. The slug-withdrawal test should not be initiated until the water level has recovered sufficiently.
17. Re-measure the water level using the electric tape and record along with the time.
18. Change the recording frequency on the data logger to the appropriate frequency of data recording for the slug-withdrawal test (if the data logger is not programmed to store events only). The recording frequency may be modified based upon a review of the slug-in test data. Concurrently with starting the data logger, immediately raise the slug as quickly as possible such that the rod is completely out of the water column and above the static water level. If possible, remove the slug completely from the well to eliminate water dripping on the water column causing some deviations in the recorded readings. Record the test-initiation time.
19. Continue to monitor water-level rise with the pressure transducer and data logger, taking periodic water-level measurements with the electric tape.
20. The slug-out test may be terminated once the water level has returned sufficiently close to the pretest static level. Once the slug-out test is terminated, take a physical water-level measurement with the electric tape. Record the measurement and time.

21. The data should be reviewed in the field to help ensure test validity. Complete documentation per applicable Trihydro SOPs and project-specific requirements.
22. The slug-in and slug-out tests may be repeated as necessary and as appropriate.
23. Once all tests are satisfactorily completed for the well, all downhole equipment may be removed and decontaminated, and the wellhead secured.

ATTACHMENT 2
GENERAL PROCEDURE FOR PERFORMING SPECIFIC CAPACITY TESTS

This procedure provides general requirements for specific capacity tests. Newly installed wells to be tested for specific capacity should be developed before commencing testing activities. The specific capacity test may be conducted right after development, using the same submersible pump used to develop the well.

1. Select wells with adequate yield for testing. Wells that do not recharge sufficiently to maintain a stabilized water level during the lowest pump-discharge rates cannot be used for specific capacity tests. This can be determined by checking well-development records or purging records (for water sampling).
2. Inspect the equipment to ensure that it is in good working order. Specific-capacity test equipment may vary widely depending on the formation and site conditions, and the diameter and depth of the wells. A pump should be selected that has the required maximum capacity and is efficient for the full range of the planned extraction rates.
3. Calibrate and test all measuring and testing equipment before use per manufacturer's specifications and appropriate project-specific requirement and procedures.
4. Decontaminate all downhole equipment per Trihydro and project-specific requirements and procedures.
5. Visually inspect the wellhead for damage or obstructions that could hinder water-level recorder or pump insertion and removal.
6. Obtain a water-level depth measurement and sound the well bottom.
7. Install the mechanical pump in the well using the manufacturer's instructions. Place the pump in the well so that there is sufficient water above the pump intake during pumping. During testing, the drawdown should not be so great as to cause the pump to cavitate.
8. Obtain a barometric-pressure measurement if testing (water-level recovery) is expected to take longer than 30 minutes or if weather conditions are changing rapidly. Station barometric pressure may be recorded from on-site equipment or obtained from a local weather station.
9. Immediately before turning on the pump, physically measure the water level in the well. Start the mechanical pump and adjust the valve or flow regulator to maintain a constant discharge as determined from the well-development records. The discharge rate should be sufficient to calculate specific capacity and maintain a stabilized, sustainable drawdown.
10. Once pumping starts, physically measure the water-level decline with the electric well tape (or equivalent). Observe and record the wellhead flow-meter readings at intervals specified by the project work plans. Record these measurements and the time.
11. Once the drawdown appears to stabilize (i.e., the water level under pumping conditions is relatively stable for a sufficient time), continue pumping for a sufficient length of time. During this time period, continue to physically measure and record the water levels.
12. Once the specified time period has elapsed, take a final physical water-level measurement with the electric tape and shut the pump down (or increase the pumping rate to the next step). Record the measurement and time.

13. The data should be reviewed in the field to ensure that valid data have been collected. This includes verifying that discharge was maintained at a constant rate and that the drawdown stabilized. Complete all documentation as per applicable Trihydro SOPs and project-specific requirements.
14. The specific capacity tests may be repeated, as necessary, at different discharge rates.
15. Once all tests are satisfactorily completed for the well, all downhole equipment may be removed and decontaminated, and the wellhead secured.

ATTACHMENT 3
GENERAL PROCEDURE FOR PERFORMING STEP-DRAWDOWN TESTS

This procedure provides general requirements for step-drawdown tests. Step-drawdown testing should be conducted before other pumping tests. Newly installed wells should be developed before conducting step-drawdown tests. Generally, three pumping rates are selected for the test, based on estimates of the water-bearing formation yield. Sometimes more steps are added to the test based on specific field or project requirements.

1. Inspect the equipment to be used to ensure that it is in good working order. Equipment used for the step-drawdown testing will vary widely based upon site-specific conditions.
2. Calibrate and test all measuring and testing equipment before use per manufacturer's specifications and appropriate project-specific requirements and procedures.
3. Decontaminate all downhole equipment per applicable Trihydro and project-specific requirements and procedures.
4. Visually inspect the wellhead for damage or obstructions that could hinder water-level recorder or pump insertion and removal.
5. Obtain a water-level depth measurement and sound the well bottom with the electric tape.
6. Install the mechanical pump in the well using the manufacturer's instructions. The position of the pump intake inside the well should be based upon well construction and site-specific factors. Note the height of the water column from the static water level to the pump intake. Record all information. During testing, the drawdown should not be so great as to cause the pump to cavitate.
7. Connect the pressure transducer to the data logger. Lower the pressure transducer inside the pumping well to a depth below the bottom of the anticipated drawdown. The transducer should be installed at a level that: 1) eliminates effects from the pump intake, 2) is below the anticipated water level during maximum drawdown, and 3) does not exceed the maximum transducer head limitations. In addition, the transducer should be secured inside the pumping well in such a manner that the transducer will not be affected by turbulence from the pump. Record the transducer depth.
8. Turn on the pressure transducer and data logger, and set the recording frequency for pretest monitoring to that specified by the project work plans. Data loggers should be placed in a secure location to prevent tampering.
9. Obtain barometric-pressure measurements throughout the test. Station barometric pressure may be recorded from on-site equipment or obtained from a local weather station.
10. Physically measure the water level with the electric tape and record along with the time. Commence pretest monitoring with the pressure transducer and data logger. Generally, water levels are recorded for a period before the step-drawdown test that is at least twice as long as the time expected for the step-drawdown test and the recovery period. Record the information, including times of measurements.
11. Once the pre-test monitoring period is ended, re-measure the water level using the electric tape and record along with the time.
12. Change the recording frequency on the data logger to the appropriate frequency for step-drawdown data entry. Begin recording water-level measurements with pressure transducer and data logger for the initial pumping phase of the step-drawdown test. Start the mechanical pump and adjust the valve

or flow regulator to maintain the constant discharge rate. This rate will be the first step in the step-drawdown test. Record the start time of the step-drawdown test.

13. Continue to monitor water-level decline during the first step with the pressure transducer and data logger, taking periodic water-level measurements with the electric tape. Data logger and tape readings should be conducted per the predetermined schedule. As the first step continues, review the water-level data and, if necessary, adjust the recording frequency of the data logger. Observe and record the wellhead flow-meter readings.
14. Continue pumping and recording water levels and flow-meter readings in the first step until adequate data is acquired and the rate of water-level change becomes insignificant with time.
15. Once the first step is ended, measure the water level with the electric tape and record depth and time. Adjust the data logger as necessary (based upon review of data from the first step) for commencing the second step of the test.
16. Without turning the mechanical pump off, initiate the second step of the test by changing (increasing) the pumping rate with the valve or flow regulator to the rate specified.
17. Monitor the water levels and flow-meter readings and continue the second step.
18. Repeat the cycles of changing pumping rate and recording water depth as often as is required (for each step of the step-drawdown test).
19. Once the last step is completed, reset the data logger for the recovery period measurement duration and frequency. Obtain a water-level measurement with the electric well tape and record the measurement and time. Shut down the mechanical pump. Record the time that the pump was shut down.
20. Continue to measure and record the water-level recovery with the pressure transducer and data logger until the water level has recovered to at least 90 percent of the level expected from the pretest trends. Also, continue to take physical water-level measurements periodically during recovery. Once the recovery period is ended, take a final physical water-level measurement at the end of the test. Record the measurement and time.
21. The data should be reviewed in the field to help ensure the test validity. The field data review may also be used to determine the discharge rate to be used during a constant-rate pumping test. Complete all documentation as per applicable Trihydro SOPs and project-specific requirements.
22. Once the step-drawdown test is satisfactorily completed for the well, the equipment may be left in the well for subsequent constant-rate aquifer testing. If subsequent testing will not be conducted, downhole equipment may be removed and decontaminated and the wellhead secured.

ATTACHMENT 4
GENERAL PROCEDURE FOR PERFORMING SINGLE AND MULTIPLE WELL CONSTANT-RATE AQUIFER-PUMPING TESTS

This procedure provides general requirements for conducting single and multiple well constant-rate pumping tests. These procedures are written for a multiple-well pumping test. However, these procedures are directly applicable to single-well testing. The only difference for single-well tests is that water-level measurements are collected only from the pumping well.

1. Inspect the equipment to be used to ensure that it is in good working order. Equipment used for the pumping test will vary widely based upon site-specific conditions.
2. Calibrate and test all measuring and testing equipment before use, per manufacturer's specifications and appropriate project-specific requirements and procedures.
3. Decontaminate all downhole equipment as per applicable Trihydro and project-specific requirements and procedures. Equipment remaining inside the pumping well from the step-drawdown test to be used directly for the subsequent constant-rate pumping test does not need to be re-decontaminated.
4. Visually inspect the wellhead for damage or obstructions that could hinder water-level recorder or pump insertion and removal.
5. Obtain a depth to water-level measurement and sound the bottom of each well to be used with the electric tape.
6. If necessary, install the mechanical pump in the pumping well as per item number 6 in Attachment 3.
7. If a multiple well test is being conducted, connect the pressure transducers to their respective data loggers. Install the transducers inside the observation wells at this time. The transducers should be installed at a position inside each well that is below the anticipated water level during maximum drawdown, and that does not exceed the maximum head limitation. Set up another pressure transducer in an outlying well (outside of the suspected influence of the pumping well) to record station barometric effects, if required. If not already installed from the step-drawdown test, set the pressure transducer inside the pumping well as per item number 7 in Attachment 3.
8. Record the depth(s) of the transducer(s) below the water surface using the data logger.
9. Appropriately protect any transducer cables that run across traffic areas. Consider using in-well data recorders to eliminate long cables and road crossings. Data loggers should also be placed in a secure location to prevent tampering.
10. Turn on the pressure transducers and data loggers, set the recording frequencies for pretest monitoring to that specified by the project work plans. It is also important before initiating pretest monitoring for the pumping test to ensure that water levels from any previous step-drawdown testing have completely recovered.
11. Obtain barometric-pressure measurements throughout the test. Station barometric pressure may be recorded from on-site equipment or obtained from a local weather station.
12. Physically measure the water levels in the pumping and observation wells with the electric tape and record along with the time. Separate data sheets should be used for each well. Commence pretest monitoring with the pressure transducers and data loggers. The total length of time over which the pretest measurements are made should be the length of the pumping test and recovery period, if practicable. Test requirements and aquifer characteristics will dictate the length of pretest monitoring required. Record the information, including measurement times.

13. Once the pretest monitoring period is ended, re-measure the water levels in the wells using the electric tape and record along with the time.
14. Change the recording frequencies in the data loggers for the pumping test. Just before starting the pump, begin recording the pressure-transducer measurements.
15. Start the mechanical pump and adjust the valve or flow regulator to maintain a constant discharge rate as determined from the step-drawdown test. Record pump start time.
16. Continue to monitor water levels during pumping with the pressure transducers and data loggers, taking periodic water-level measurements in each of the wells with the electric tape. The water-level data should be evaluated during the test and, if necessary, the recording frequencies of the data loggers should be adjusted.
17. Observe and record the wellhead flow-meter readings.
18. The test duration should be based on expected aquifer response to pumping (non-leaky confined, leaky confined, unconfined with gravity drainage, etc.), review of field-generated drawdown versus time plots from the pumping and observation wells, and precipitation or other recharge events during the pumping period.
19. Once the pumping phase is completed, re-set the data loggers for the recovery period, recording duration and frequencies as specified in the project work plans. Obtain a water-level measurement in each of the wells with the electric well tape, and record the measurements and times. Shut down the mechanical pump. Record the time that the pump was shut down.
20. Continue to record the water-level recovery in the wells with the pressure transducers and data loggers until the water levels have recovered to within 90 percent of the level expected from the pretest trends. Also, continue to take physical water-level measurements periodically during recovery. Once the recovery period is ended, take a physical water-level measurement in each observation well. Record the measurements and times.
21. Additional depth to water measurements may be physically taken following complete well recovery in order to monitor post-test trends in water levels.
22. The data should be reviewed in the field to help ensure the test validity. Complete documentation as per applicable Trihydro SOPs and project-specific requirements.
23. Once the pump test is satisfactorily completed for the wells, downhole equipment may be removed and decontaminated and the wellheads secured.

ATTACHMENT 5
SPECIAL CONSIDERATIONS FOR SETTING UP AND PERFORMING SLUG AND AQUIFER PUMPING TESTS

The following special considerations may be useful when planning and executing slug and aquifer pumping tests.

1. A single ball valve or gate valve may not be adequate, for some pumping tests, to stabilize groundwater flow rates. Installing a flow-control system between the well and the discharge line or tank will greatly increase pumping-rate control. The flow-control system includes the following equipment (along the flow direction): (1) pressure gauge (for pump performance and to show cavitations); (2) check valve (to prevent groundwater backflow to the well); (3) first gate valve for main flow control; (4) flow diversion and sampling port (to divert initial turbid water before the totalizer); (5) rotameter (vertical flow meter) to visualize and adjust groundwater flow; (6) second gate valve to adjust and fine-tune flow; and (7) totalizer flow meter.
2. Much time may be saved if the data logger is programmed to store data only when there is a significant change in water level (such as 0.2 inches) with default storage each period of time (e.g., 5 minutes). Such a program will cover rapid changes that occur in seconds and slow changes that may take 5 or more minutes. Other advantages include the following:
    - Generation of a smaller data record (file)
    - No need to reprogram the logger between pretest, pumping test, and recovery test
    - No need to synchronize pumping with logging
    - Every detail will be recorded between and after testing

    At least two makers (In-Situ Inc. and Campbell Scientific, Inc.) have this option ("Event" programming) in the data logger. The "Event" program can also be used for long-term monitoring and testing.
3. Using a recording transducer, such as the In-Situ LevelTROLL® 700 or miniTROLL®, will eliminate the requirement for a data logger outside of the wellhead or transducer cables running across traffic areas. This will make it safer and practical to install the logger in the well and to secure the well box for a few days of testing. It will also allow monitoring more wells without the need to extend cables over traffic areas.
4. Using observation wells that contain some product will require protection for the transducer. In such wells, a soft-sealed latex type sheath filled with distilled water could be used to protect the transducer during use. An interface probe should still be used to periodically monitor product thickness in the well in addition to the total fluid head monitored with the transducer.
5. Sampling and recording changes in the groundwater-quality parameters may help determine the source of pumped groundwater, particularly if an aquitard is leaking different-quality water into the aquifer. In many cases, the aquifer may have different-quality water with depth that could be detected during pumping.

memorandum

To:	Trihydro Employees
From:	OSE
Date:	May 2, 2013
Re:	Standard Operating Procedure – Chain of Custody

This Standard Operating Procedure (SOP) is intended for the sole use of Trihydro Corporation (Trihydro) and its employees. This SOP cannot be copied or used by others without Trihydro's express written consent. This SOP may be modified when field or other conditions warrant.

1.0 INTRODUCTION

The purpose of this SOP is to provide the requirements for completing written chain-of-custody (CoC) documentation. This SOP applies to all Trihydro efforts where samples are transferred between parties, including to off-site testing facilities. The procedures described in this SOP are not required whenever the same individual and team are performing sampling and testing within the same work day and transfer to the analytical services provider is being documented by other means (e.g., sampling and then field screening in a mobile laboratory).

2.0 DEFINITIONS

Custody - The legal term used to define control and evidence of traceability of an environmental sample. A sample is considered to be in an individual's custody when it is in actual physical possession of the person, is in view of the person, is locked in a container controlled by the person, or has been placed into a designated secure area by the person.

Chain-of-custody form - A form used to document and track custody and transfers of a sample from collection to analysis or placement in a designated secure area within the testing facility (**Attachment A**).

Chain-of-custody continuation page - An additional page (or pages) may be added using the same CoC form. The continuation page contains information on additional samples contained within the same cooler and shipping container associated with the cooler and shipping container. Please mark page numbers on all pages (upper right side of form) if you are using more than one CoC form (**Attachment A**).

Custody Seal - Commercially available thin strips of adhesive paper with blank lines for the name of the person placing the seals, date, and time. Custody seals **(Attachment B**) are placed over the caps of sample containers and along the openings of shipping containers as a means to detect tampering before arrival at the testing facility. Custody seals should be provided by the laboratory to which the samples will be shipped.

1252 Commerce Drive | Laramie, WY 82070 | phone 307/745.7474 | fax 307/745.7729 | www.trihydro.com

3.0 RESPONSIBILITIES

The Field Team Leader (FTL) is responsible for maintaining, managing, and revising this SOP. Questions, comments, or suggestions regarding this SOP should be directed to the FTL.

Trihydro employees performing this task, or any portion thereof, are responsible for meeting the requirements of this SOP. Trihydro employees conducting technical review of task performance are also responsible for following appropriate portions of this SOP.

For those projects where the activities of this SOP are conducted, the project manager, or her/his designee, is responsible for checking that the activities are conducted in accordance with this and other appropriate SOPs. Project participants are responsible for documenting information with sufficient detail that the requirements of this SOP have been met. Such documentation shall be retained as project records.

4.0 CHAIN-OF-CUSTODY PROCEDURE

All CoC documentation must be completed in indelible ink (see example **Attachment C**). All corrections must be performed using standard single-line cross-out methods, and the initials of the individual making the change must be included beside the corrected entry.

4.1 Continuation Pages

Continuation pages (using the same CoC form) may be added for shipping containers and coolers with sufficient samples and sample containers. If a continuation page is used, total page numbers must be filled out at the top right of the page, and all samples entered onto a continuation page must be included in the same cooler and shipping container as those listed on the first page of the CoC form.

4.2 Header Information

- Each CoC form must be assigned a unique Reference Document Number—use the project and proposal number followed by a unique numeric sequence or current date (if only one cooler is sent per day). Continuation pages should contain the same Reference Document Number as the CoC form that they are associated with. The project team should maintain a log of CoC Reference Document Numbers.
- The page identifier and total page count section must be completed. Total pages include the CoC form and any attached continuation pages.
- The project number, name, and location information must be completed for all forms.
- If available, the laboratory Purchase Order Number should be included on the appropriate line.

- The name and phone number of the Project Contact should be included. The Project Contact should be a responsible individual that the laboratory may contact to address analytical issues--usually the analytical lead for the project.
- The shipment date should be provided on the appropriate line.
- If shipping by carrier, the waybill and air-bill number must be included. (Note: Carriers will not sign custody documents. Therefore, including the waybill and air-bill number on the CoC form is the only means of documenting the carrier transfer.)
- Laboratory Destination and Contact information should be provided.
- The Sampler(s) names should be legibly printed on the appropriate line. All persons whose initials appear on any of the sample containers should be included so that the laboratory has a means of cross-referencing containers.
- The "Send Report To" information should be completed. If multiple reports and locations are needed, the information should be provided on a separate page included with the CoC documentation.

4.3 Sample Information Section (Including on Continuation Page)

During sampling, each sample must be entered on the CoC form at the time of collection to document possession of the sample. The sampler must not wait until sampling is completed before entering samples on the CoC. An example of a completed sample information section on a CoC form is provided in **Attachment C**.

Completing the sample information section on the CoC form includes:

- Entering the sample identification number for each line. If there are multiple container types for a sample, use additional lines to indicate the needed information.
- Checking that the sample description matches the description on the sample label. The laboratory will use this information for cross-referencing.
- Providing the sample collection date and time. This information must be consistent on the sample label, field logbook, and log sheets.
- Indicating whether the sample is a grab or composite sample.
- Indicating the matrix of the sample. Use the matrix codes listed on the CoC form.
- Indicating the number of containers and the container type. If a sample has multiple container types, use multiple lines.
- Checking the appropriate preservative box for each line and container type.
- Completing the analysis-request boxes for each line and container type. The specific method number (e.g., EPA Method 8260C) and method name must be written.

- Indicating the turnaround time requested for each sample.
- Using the special instructions section to provide important information to the laboratory (e.g., samples that may require dilution or samples that will need to be composited by the laboratory). This section may also be used to inform the laboratory of additional information contained in attachments to the CoC documentation.
- Circling the appropriate quality control (QC) and data package level requested.

4.4 Custody-Transfer Section

The following items pertain to the custody-transfer process:

- The first "Relinquished By" space must be completed by the individual who will either transfer the samples or seal the shipping container.
- If the samples will be transferred to a courier, write the courier's name (i.e., company name) in the "Received By" box and enter the date and time the shipping container was closed.
- All other transfers must be performed in person, and the person relinquishing custody must witness the signing by the receiver.
- A copy of the CoC form and all associated continuation pages should be maintained in the project files.

5.0 CHAIN-OF-CUSTODY SEALS

The following sections outline the procedure for completing and attaching the custody seal. No other forms are required. An example of a completed custody seal is shown in **Attachment B**.

5.1 Completing the Custody Seal Information

All custody seals must be completed in indelible ink. All corrections must be made using standard single-line cross-out methods, and the initials of the individual making the change must be included beside the corrected entry.

Each custody seal attached must be completed by the person responsible for the sealing of the sample by writing the date and signing the custody seal with full signature. If a space is provided, the time should also be added.

5.2 Attaching the Custody Seals

Prior to shipping or courier delivery of sample coolers, signed custody seal should be affixed prior to taping/sealing of the container. Sample coolers and shipping containers should have two custody seals attached in such a manner that the seal extends lengthwise from the top edge of the lid to the side of the cooler and container. The packaging tape shall be affixed across the custody seal to secure the cooler for shipment.

6.0 INCOMPLETE CHAIN OF CUSTODY

Samples shipped under an incomplete CoC are not admissible in a legal court and also may not meet project objectives. Examples of incomplete custody include:

- Missing custody seals
- Broken custody seals
- Evidence of sample tampering
- Missing signatures (relinquishment/received) on the CoC
- Incomplete CoCs (incorrectly filled out, missing samples, missing documentation, incorrect information)

If the custody of the samples or the custody records (CoC forms or custody seals) were not complete, immediate action should be taken to complete the records. The preferred remedy is to obtain signatures from the sampling, shipping, or laboratory personnel in the form of an affidavit or confirmation confirming complete custody (**Attachment D**). If custody cannot be proven or if tampering was proven, actions should be taken, through validation or qualification, to mark that data as inadmissible in legal courts. Trihydro marks this data with an "X" flag in the database.

7.0 CHAIN-OF-CUSTODY FORM

A Trihydro CoC and Analytical Request Record form is included as **Attachment A**.

8.0 BIBLIOGRAPHY

Engineering/Remediation Resources Group, Inc. (ERRG). 2010a. Chain of Custody FS-003 Standard Operating Procedure.

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United States Army Corps of Engineers (USACE). 2001. "Requirements for the Preparation of Sampling and Analysis Plans, EM200-1-3."

United States Environmental Protection Agency (USEPA). 2008. "Test Methods for Evaluating Solid Waste; Physical/Chemical Methods, SW-846." Available from: http://www.epa.gov/epawaste/hazard/testmethods/sw846/online/index.htm.

ATTACHMENT A. TRIHYDRO CHAIN-OF-CUSTODY FORM

Trihydro CORPORATION

Trihydro Chain of Custody and Analytical Request Record

PLEASE PRINT; provide as much information as possible. Refer to corresponding notes on reverse side.

Page______ of ______

Company Name:	Project Name:	
Report Mail Address:	Contact Name (phone, email, etc.):	Sampler Name if other than Contact:
Invoice Address:	Invoice Contact & Phone #:	Purchase Order #: / Lab Quote #:

Report Required For:____________________

Special Report Formats –
NELAC A2LA Level IV
Other _See attached_
EDD/EDT ☐ Format_______

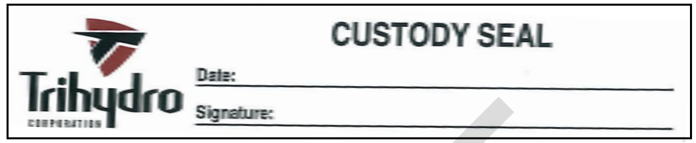
SAMPLE IDENTIFICATION (Name, Location, Interval, etc.)	Collection Date	Collection Time	MATRIX (Number of Containers; Sample Type: A W S V B O; Air, Water Soils/Solids, Vegetation, Bioassay Other)	ANALYSIS REQUESTED									SEE ATTACHED	Normal Turnaround (TAT)	RUSH Turnaround (TAT)	Comments:	LAB ID
1																	
2																	
3																	
4																	
5																	
6																	
7																	
8																	
9																	
10																	

Receipt Temp
__________ ° C
Cooler ID(s)
____
Custody Seal Y N
Intact Y N
Signature Y N
Match Y N

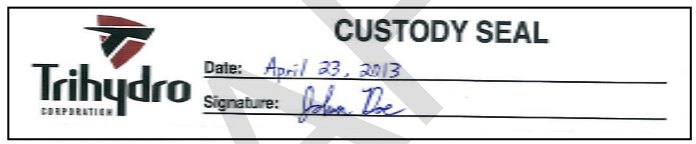
LABORATORY USE ONLY

Custody Record MUST be Signed	Relinquished by:	Date/Time:	Shipped by:	Received by:	Date/Time:
	Relinquished by:	Date/Time:	Shipped by:	Received by:	Date/Time:
	Sample Disposal:	Return to Client:	Lab Disposal:	LABORATORY USE ONLY Sample Type __________ # of fractions	

ATTACHMENT B. TRIHYDRO CHAIN-OF-CUSTODY SEALS


Trihydro CORPORATION
CUSTODY SEAL
Date:
Signature:

Blank Custody Seal


Trihydro CORPORATION
CUSTODY SEAL
Date: April 23, 2013
Signature: John Doe

Completed Custody Seal

ATTACHMENT C. COMPLETED CHAIN-OF-CUSTODY FORM

Trihydro Chain of Custody and Analytical Request Record

PLEASE PRINT; provide as much information as possible. Refer to corresponding notes on reverse side.

Page 1 of 1

Company Name: Trihydro	Project Name: Project X			
Report Mail Address: 1252 Commerce Drive, Laramie WY 82070	Contact Name (phone, email, etc): 307-745-7474	Sampler Name if other than Contact: John Doe		
Invoice Address: Address, City, State, Zip Code	Invoice Contact & Phone #: XXX-XXX-XXXX	Purchase Order #: XXXXXXXX	Lab Quote #: XXXXXX	

Report Required For: Client X

Special Report Formats – NELAC (circled) A2LA Level IV

Other See attached

EDD/EDT ☒ Format CSV

Receipt Temp 4.0 °C

Cooler ID(s) XXXXXX

Custody Seal Y (circled) N

Intact Y (circled) N

Signature Match Y (circled) N

ANALYSIS REQUESTED

#	SAMPLE IDENTIFICATION (Name, Location, Interval, etc)	Collection Date	Collection Time	MATRIX (Number of Containers / Sample Type: A W S V B O – Air, Water, Soils/Solids, Vegetation, Bioassay, Other)	VOCs (8260)	SVOCs (8270)	Metals (6010)							SEE ATTACHED	Normal Turnaround (TAT)	RUSH Turnaround (TAT)	Comments:	LABORATORY USE ONLY – LAB ID
1	Water Sample Name	04/23/2013	0840	1 W	X	X	X								X			ABCD-001
2	Soil Sample Name	04/23/2013	1452	2 S			X								X			ABCD-002
3	Trip Blank	04/23/2013	—	1 W	X										X			ABCD-003
4																		
5																		
6																		
7																		
8																		
9																		
10																		

Custody Record MUST be Signed	Relinquished by: John Doe	Date/Time: 04/23/2013	Shipped by:	Received by: Jane Doe	Date/Time: 04/24/2013
	Relinquished by: John Doe (signature)	Date/Time: 04/23/2013	Shipped by: UPS	Received by: Jane Doe (signature)	Date/Time: 04/24/2013
	Sample Disposal:	Return to Client:	Lab Disposal: X (circled)	LABORATORY USE ONLY Sample Type ________	# of fractions

ATTACHMENT D. CHAIN-OF-CUSTODY LETTER OF CONFIRMATION

Date

First Name Last Name
Trihydro Corporation (Or insert appropriate company name)
1252 Commerce Drive
Laramie, WY 82070

Letter of Confirmation

I, NAME, representing the CLIENT, LOCATION, and PROJECT NAME, do confirm the following information provided with data set LAB ID #. In addition, I do confirm that the SAMPLE TYPE(S) samples were provided to the laboratory in the proper, method-referenced, containers and were properly preserved (chemically and physically). Finally, samples were relinquished from my custody to INSERT CARRIER NAME on INSERT DATE at INSERT TIME.

The information identified in bold italics will be used to further clarify the CoC documentation.

_______Missing information here in either table form or paragraph_____.

NOTE: Delete blue highlighted text if all that was missing was a signature.

To the best of my knowledge, the above information is correct.

__________________________________ ______________________

NAME (in caps) DATE

This letter of confirmation is an amendment to the chain-of-custody accompanying the PROJECT NAME, LABORATORY data set LAB ID#.

Region 4 **U.S. Environmental Protection Agency** **Science and Ecosystem Support Division** **Athens, Georgia**

GUIDANCE

Title: **Design and Installation of Monitoring Wells**	
Effective Date: February 18, 2008	**Number:** SESDGUID-101-R0
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Revision History

This table shows changes to this controlled document over time. The most recent version is presented in the top row of the table. Previous versions of the document are maintained by the SESD Document Control Coordinator.

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SESDGUID-101-R0, *Design and Installation of Monitoring Wells*, Original Issue	February 18, 2008

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1 General Information

1.1 Purpose

This document describes general and specific procedures, methods and considerations to be used and observed when designing and installing permanent and temporary groundwater monitoring wells to be used for collection of groundwater samples.

1.2 Scope/Application

The procedures contained in this document are to be used by field personnel when designing, constructing and installing groundwater monitoring wells. On the occasion that SESD field personnel determine that any of the procedures described in this section are either inappropriate, inadequate or impractical and that another procedure must be used for any aspect of the design, construction and/or installation of a groundwater monitoring well, the variant procedure will be documented in the field log book, along with a description of the circumstances requiring it's use.

1.3 Documentation/Verification

This procedure was prepared by persons deemed technically competent by SESD management, based on their knowledge, skills and abilities and has been tested in practice and reviewed in print by a subject matter expert. The official copy of this procedure resides on the H: drive of the SESD local area network. The Document Control Coordinator is responsible for ensuring the most recent version of the procedure is placed on the H: drive and for maintaining records of review conducted prior to its issuance.

1.4 References

USEPA Region 4 Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (EISOPQAM), November 2001

USEPA. Safety, Health and Environmental Management Program Procedures and Policy Manual. Science and Ecosystem Support Division, Region 4, Athens, GA.

SESD Operating Procedure for Field Sampling Quality Control, SESDPROC-011-Most Recent Version

SESD Operating Procedure for Field Equipment Cleaning and Decontamination, SESDPROC-205- Most Recent Version

SESD Operating Procedure for Field Records and Documentation, SESDPROC-204-Most Recent Version

SESD Operating Procedure for Groundwater Sampling, SESDPROC-301- Most Recent Version

SESD Operating Procedure for Management of Investigation Derived Waste, SESDPROC-202- Most Recent Version

EPA/540/S-95/503, *Nonaqueous Phase Liquids Compatibility with Materials Used in Well Construction, Sampling, and Remediation*

ASTM standard D5092, *Design and Installation of Ground Water Monitoring Wells in Aquifers*

1.5 General Precautions

1.5.1 Safety

Proper safety precautions must be observed when constructing and installing groundwater monitoring wells. Refer to the SESD Safety, Health and Environmental Management Program Procedures and Policy (SHEMP) Manual and any pertinent site-specific Health and Safety Plans (HASPs) for guidelines on safety precautions. These guidelines should be used to complement the judgment of an experienced professional. When using this procedure, minimize exposure to potential health hazards through the use of protective clothing, eye wear and gloves. Address chemicals that pose specific toxicity or safety concerns and follow any other relevant requirements, as appropriate. Section 2.6, Safety Procedures for Drilling Activities, contains detailed and specific safety guidelines that must be followed by Branch personnel when conducting activities related to monitoring well construction and installation.

1.5.2 Procedural Precautions

The following precautions should be considered when constructing and installing groundwater monitoring wells.

- Special care must be taken to minimize or prevent inadvertent cross-contamination between borehole locations. Equipment, tools and well materials must be cleaned and/or decontaminated according to procedures found in SESD Operating Procedure for Field Equipment Cleaning and Decontamination, (SESDPROC-205).
- All field activities are documented in a bound logbook according to the procedures found in SESD Operating Procedure for Field Records and Documentation, (SESDPROC-204).

2 Permanent Monitoring Well Design Considerations

2.1 General

The design and installation of permanent monitoring wells involves drilling into various types of geologic formations that exhibit varying subsurface conditions. Designing and installing permanent monitoring wells in these geologic environments may require several different drilling methods and installation procedures. The selection of drilling methods and installation procedures should be based on field data collected during a hydrogeologic site investigation and/or a search of existing data. Each permanent monitoring well should be designed and installed to function properly throughout the duration of the monitoring program. When designing monitoring wells, the following should be considered:

- Short-and long-term objectives;
- Purpose of the well(s);
- Probable duration of the monitoring program;
- Contaminants likely to be monitored;
- Surface and subsurface geologic conditions;
- Properties of the aquifer(s) to be monitored;
- Well screen placement;
- General site conditions; and
- Potential site health and safety hazards.

In designing permanent monitoring wells, the most reliable, obtainable data should be utilized. Once the data have been assembled and the well design(s) completed, a drilling method(s) must be selected. The preferred drilling methods for installing monitoring wells are those that temporarily case the borehole during drilling and the construction of the well, e.g. hollow-stem augers and sonic methods. However, site conditions or project criteria may not allow using these methods. When this occurs, alternate methods should be selected that will achieve the project objectives. The following discussion of methods and procedures for designing and installing monitoring wells will cover the different aspects of selecting materials and methods, drilling boreholes, and installing monitoring devices.

2.2 Drilling Methods

The following drilling methods may be used to install environmental monitoring wells or collect samples under various subsurface conditions. In all cases the preferred methods are those that case the hole during drilling, i.e. Hollow Stem Augers (HSA) and sonic methods using an override system. Other methods may be used where specific subsurface or project criteria dictate.

2.2.1 Hollow Stem Auger (HSA)

This type of auger consists of a hollow, steel stem or shaft with a continuous, spiraled steel flight, welded onto the exterior. A hollow auger bit, generally with carbide teeth, disturbs soil material when rotated, whereupon the spiral flights transport the cuttings to the surface. This method is best suited in soils that have a tendency to collapse when disturbed. A monitoring well can be installed inside of hollow-stem augers with little or no concern for the caving potential of the soils. If caving sands exist during monitoring well installations, a drilling rig must be used that has enough power to extract the augers from the borehole without having to rotate them. A bottom plug, trap door, or pilot bit assembly can be used at the bottom of the augers to keep out most of the soils and/or water that have a tendency to enter the bottom of the augers during drilling. Potable water (analyzed for contaminants of concern) may be poured into the augers during drilling to equalize pressure so that the inflow of formation materials will be held to a minimum. Water-tight center bits are not acceptable because they create suction when extracted from the augers. This suction forces or pulls cuttings and formation materials into the augers, defeating the purpose of the center plug. Augering without a center plug or pilot bit assembly is permitted, provided that the soil plug, formed in the bottom of the augers, is removed before sampling or installing well casings. Removing the soil plug from the augers can be accomplished by drilling and washing out the plug using a rotary bit, or augering out the plug with a solid-stem auger bit sized to fit inside the hollow-stem auger. Bottom plugs can be used where no soil sampling is conducted during the drilling process. The bottom plug is wedged into the bottom of the auger bit and is knocked out at depth with drill pipe or the weight of the casing and screen assembly. The plug material should be compatible with the screen and casing materials. The use of wood bottom plugs is not acceptable. The type of bottom plug, trap door, or pilot bit assembly proposed for the drilling activity should be approved by a senior field geologist prior to drilling operations. Boreholes can be augered to depths of 150 feet or more (depending on the auger size), but generally boreholes are augered to depths less than 100 feet.

2.2.2 Solid Stem Auger

This type of auger consists of a sealed hollow or solid stem or shaft with a continuous spiraled steel flight welded on the outside of the stem. An auger bit connected to the bottom disturbs soil material when rotated and the helical flights transport cuttings to the surface. At the desired depth the entire auger string is removed to gain access to the bottom of the borehole. This auger method is used in cohesive and semi-cohesive soils that do not have a tendency to collapse when disturbed. Boreholes can be augered to depths of 200 feet or more (depending on the auger size), but generally boreholes are augered to depths less than 100 feet.

Both of the previously discussed auger methods can be used in unconsolidated soils and semi-consolidated (weathered rock) soils, but not in competent rock.

Each method can be employed without introducing foreign materials into the borehole such as water and drilling fluids, minimizing the potential for cross contamination. Minimizing the risk of cross contamination is one of the most important factors to consider when selecting the appropriate drilling method(s) for a project.

2.2.3 Sonic Methods

These methods generally alternately advance concentric hollow drill stems using rotation in conjunction with axial vibration of the drill stem. After each stage of drill stem advancement, the inner string is removed with a core of drill cuttings while the outer 'override' string remains to hold the borehole open. The cuttings can be removed nearly intact from the inner casing for examination of the stratigraphy prior to sampling or disposal. Because there are no auger flights to increase the borehole diameter, the quantity of cuttings removed from the hole is minimized as compared to hollow stem augering. With moderate rotation, smearing of the formation materials on the borehole walls is reduced as well. This drilling method is useful in a variety of materials, from flowing sands to heavily consolidated or indurated formations.

In flowing sands, the drill casings can be filled and/or pressurized with potable water to prevent excess entry of formation materials into the drill string. The same QA/QC requirements for sampling of material introduced to the borehole apply as in other drilling methods. Because the amount of water introduced into the borehole can be significant, an approximation of the water used in the drilling process should be logged for use in estimating appropriate well development withdrawal.

Sonic drilling allows a larger diameter temporary casing to be set into a confining layer while drilling proceeds into deeper aquifers. This temporary casing is then removed during the grouting operation. In many cases this will be acceptable technique. However, the level of contamination in the upper aquifer, the importance of the lower aquifers for drinking water uses, the permeability and continuity of the confining layer, and state regulations should be taken into account when specifying this practice as opposed to permanent outer casing placed into the confining unit. Note that when using the temporary casing practice, it is critical that grout be mixed and placed properly as specified elsewhere in this section.

Because the total borehole diameter in sonic drilling is only incrementally larger than the inner casing diameter, particular care should be taken that the well casing is placed in the center of the drill stem while placing the filter pack. Centralizers should be used in most cases to facilitate centering, particularly in the case of deep wells with PVC casing.

2.2.4 Rotary Methods

These methods consist of a drill pipe or drill stem coupled to a drilling bit that rotates and cuts through the soils. The cuttings produced from the rotation of the drilling bit are transported to the surface by drilling fluids which generally consist of water, drilling mud, or air. The water, drilling mud, or air are forced down through the drill pipe, and out through the bottom of the drilling bit. The cuttings are then lifted to the surface between the borehole wall and the drill pipe, (or within a concentric drill stem in reverse rotary). Except in the case of air rotary, the drilling fluid provides a hydrostatic pressure that reduces or prevents borehole collapse. When considering this method, it is important to evaluate the potential for contamination when fluids and/or air are introduced into the borehole.

Due to the introduction of the various circulating fluids, the use of rotary methods requires that the potential for contamination by these fluids be evaluated. Water and mud rotary methods present the possibility of trace contamination of halogenated compounds when municipal water supplies are used as a potable water source. Air rotary drilling can introduce contamination through the use of lubricants or entrained material in the air stream. Unless contaminated formations are cased off, the circulation of drilling fluids presents a danger of cross contamination between formations. In any of the rotary (or sonic) methods, care must be exercised in the selection and use of compounds to prevent galling of drill stem threads.

2.2.4.1 Water Rotary

When using water rotary, potable water (that has been analyzed for contaminants of concern) should be used. If potable water (or a higher quality water) is not available on-site, then potable water will have to be transported to the site or an alternative drilling method will have to be selected. Water does not clog the formation materials, but the suspended drilling fines can be carried into the formation, resulting in a very difficult to develop well. This method is most appropriate for setting isolation casing.

2.2.4.2 Air Rotary

Air rotary drilling uses air as a drilling fluid to entrain cuttings and carry them to the surface. High air velocities, and consequently large air volumes and compressor horsepower are required. “Down-the-hole” (DTH) percussion hammers driven by the air stream can be used with this method to rapidly penetrate bedrock materials. Where a casing through unconsolidated material is required to prevent borehole collapse, it can be driven in conjunction with advancement of the drill stem.

When using air rotary drilling in any zone of potential contamination, the cuttings exiting the borehole must be controlled. This can be done using the dual-tube reverse circulation method where cuttings are carried to the surface inside dual-wall drill pipe and separated with a cyclone separator. An air diverter with hose or pipe carrying cuttings to a waste container is also an acceptable alternative. Allowing cuttings to blow uncontrolled from the borehole is not acceptable.

When using air rotary, the issue of contaminants being introduced into the borehole by the air stream must be addressed. Screw compressor systems should have a coalescing filter system in good working order to capture excess entrained compressor oils. The lubricant to be used with DTH hammers as well as thread lubricants to be used on drill stem should be evaluated for their potential impact on analytical samples.

2.2.4.3 Mud Rotary

Mud rotary is an undesirable drilling method because contamination can be introduced into the borehole from the constituents in the drilling mud, cross contamination can occur along the borehole column, and it is difficult to remove the drilling mud from the borehole after drilling and during well development. The drilling mud can also carry contaminates from a contaminated zone to an uncontaminated zone thereby cross-contaminating the borehole. If mud rotary is selected, only potable water and pure (no additives) bentonite drilling muds should be used. All materials used should have adequate documentation as to manufacturer's recommendations and product constituents. QA/QC samples of drilling muds and potable water should be sampled at a point of discharge from the circulation system to assure that pumps and piping systems are not contributing cross-contamination from previous use.

2.2.5 Other Methods

Other methods such as the cable-tool method, jetting method, and boring (bucket auger) method are available. If these and/or other methods are selected for monitoring well installations, they should be approved by a senior field geologist before field work is initiated.

2.3 Borehole Construction

2.3.1 Annular Space

The borehole or hollow stem auger should be of sufficient diameter so that well construction can proceed without major difficulties. For open boreholes, the annular space should be approximately 2" to allow the uniform deposition of well materials around the screen and riser, and to allow the passage of tremie pipes and well materials without unduly disturbing the borehole wall. For example, a 2" nominal diameter (nom.) casing would require a 6" inside diameter (ID) borehole.

In hollow stem augers and sonic method drill casing, the ID should be of sufficient size to allow the passage of the tremie pipe to be used for well grout placement, as well as free passage of filter sands or bentonite pellets dropped through the auger or casing. In general, 4-1/4" ID should be the minimum size used for placement of 2" nom. casing and 8-1/4" ID for 4" nom. casing. Larger augers should be used where installation difficulties due to geologic conditions or greater depths are anticipated, e.g. larger augers might be required to place a bentonite pellet seal through a long water column.

2.3.2 Over-drilling the Borehole

Sometimes it is necessary to over-drill the borehole in anticipation of material entering the augers during center bit removal or knocking out of the bottom plug. Normally, 3 to 5 feet is sufficient for over-drilling. The borehole can also be over-drilled to allow for an extra space or a "sump" area below the well screen. This "sump" area provides a space to attach a 5 or 10 foot section of well casing to the bottom of the well screen. The extra space or "sump" below the well screen serves as a catch basin or storage area for sediment that flows into the well and drops out of suspension. These "sumps" are added to the well screens when the wells are screened in aquifers that are naturally turbid and will not yield clear formation water (free of visible sediment) even after extensive development. The sediment can then be periodically pumped out of the "sump" preventing the well screen from clogging or "silting up". If the borehole is inadvertently drilled deeper than desired, it can be backfilled to the design depth with bentonite pellets, chips, or the filter sand that is to be used for the filter pack.

2.3.3 Filter Pack Placement

When placing the filter pack into the borehole, a minimum of 6-inches of the filter pack material should be placed under the bottom of the well screen to provide a firm base. Also, the filter pack should extend a minimum of 2-feet above the top of the well screen to allow for settling and to isolate the screened interval from the grouting material. In open boreholes, the filter pack should be placed by the tremie or positive displacement method. Placing the filter pack by pouring the sand into an open drill stem is acceptable with the use hollow stem augers, and other methods where the borehole is temporarily cased down to the filter pack.

2.3.4 Filter Pack Seal – Bentonite Pellet Seal (Plug)

Bentonite pellets consist of ground, dried bentonite compacted into pellets available in several sizes. Bentonite pellets are compressed to a bulk density of 70-80 lbs/cu.ft. and hydrate to a 30% min. solids material. Where neat cement grouts are to be used, the placement of a bentonite pellet seal above the filter pack is mandatory to prevent the possibility of grout infiltration into the screened interval prior to setting. Bentonite chips or other sealing products should not be substituted in this application. Where bentonite grouts are to be used, the placement of a bentonite pellet seal is optional, but desirable.

Since bentonite pellets begin hydrating rapidly, they can be very difficult to place properly. They are generally placed by pouring slowly into open boreholes, hollow stem augers or sonic drill pipe. In some cases, pellets are placed by tremie pipe and flushed into place with potable water. A tamper can be used to ensure that the material is being placed properly and to rapidly break up any pellet bridging that occurs.

Pellet seals should be designed for a two-foot thickness of dry pellets above the filter pack. Hydration may extend the height of the seal. Where neat cement grouts are to be used, the pellets should be hydrated for eight hours, or the manufacturer's recommended hydration time, whichever is greater. Where the water table is temporarily below the pellet seal, potable (or higher quality) water should be added repeatedly to hydrate the pellets prior to grouting.

2.3.5 Grouting the Annular Space

The annular space between the casing and the borehole wall should be filled with either a 30% solids bentonite grout, a neat cement grout, or a cement/bentonite grout. Each type of grout selected should be evaluated as to its intended use and integrity. Bentonite grouts are preferred unless the application dictates the use of another material.

Bentonite grout shall be a 30% solids pure bentonite grout. Drilling muds are not acceptable for grouting. The grout should be placed into the borehole, by the tremie method, from the top of the bentonite seal to within 2-feet of the ground surface or below the frost line, whichever is the greater depth. The bentonite pellet seal or filter pack should not be disturbed during grout placement, either by the use of a side discharge port on the tremie tube, or by maintaining clearance between the bottom of the tremie tube and the bentonite seal or filter pack. The grout should be allowed to cure for a minimum of 24 hours before the concrete surface pad is installed. The preferred method of achieving proper solids content is by measurement of ingredients per the manufacturer's specifications during mixing with a final check by grout balance after mixing. Bentonite grouts should have a minimum density of 10 lbs/gal to ensure proper gelling and low permeability. The density of the first batch of grout should be measured while mixing to verify proper measurement of ingredients. In addition, the grouting operation should not cease until the bentonite grout flowing out of the borehole has a minimum density of 10 lbs/gal. Estimating the grout density is not acceptable.

Cement grouts are generally dictated where a high level of dissolved solids or a particular dissolved constituent would prevent proper gelling of a bentonite grout. Neat cement grouts (cement without additives) should be mixed using 6 gallons of water per 94-lb bag of Type 1 Portland cement to a density of 15lbs/gal. The addition of bentonite (5 to 10 percent) to the cement grout can be used to delay the "setting" time and may not be needed in all applications. The specific mixtures and other types of cement and/or grout proposed should be evaluated on a case by case basis by a senior field geologist.

2.3.6 Above Ground Riser Pipe and Outer Casing

The well casing, when installed and grouted, should extend above the ground surface a minimum of 2.5 feet. A vent hole should be drilled into the top of the well casing cap to permit pressure equalization, if applicable. An outer protective casing should be installed into the borehole after the annular grout has cured for at least 24 hours. The outer protective casing should be of steel construction with a hinged, locking cap. Generally, outer protective casings used over 2-inch well casings are 4 inches square by 5 feet long. Similarly, protective casings used over 4-inch well casings are 6 inches square and 5 feet long. Other types of protective casing including those constructed of pipe are also acceptable. All protective casings should have sufficient clearance around the inner well casings, so that the outer protective casings will not come into contact with the inner well casings after installation. The protective casings should have a weep hole to allow drainage of accumulated rain or spilled purge water. The weep hole should be approximately 1/4-inch in diameter and drilled into the protective casings just above the top of the concrete surface pad to prevent water from standing inside of the protective casings. Protective casings made of aluminum or other soft metals are normally not acceptable because they are not strong enough to resist tampering. Aluminum protective casing may be used in very corrosive environments such as coastal areas.

Prior to installing the protective casing, the bentonite grout in the borehole annulus is excavated to a depth of approximately two feet. The protective casing is installed by pouring concrete into the borehole on top of the grout. The protective casing is then pushed into the wet concrete and borehole a minimum of 2 feet. Extra concrete may be needed to fill the inside of the protective casing so that the level of the concrete inside of the protective casing is at or above the level of the surface pad. In areas where frost heave of the surface pad is possible, the protective casing should first be pressed into the top surface of the bentonite grout seal and concrete poured around the protective casing. A granular material such as sand or gravel can then be used to fill the space between the riser and protective casing. The use of granular material instead of concrete between the protective casing and riser will also facilitate the future conversion of the well to a flush-mount finish, if required. The protective casing should extend above the ground surface to a height so that the top of the inner well casing is exposed when the protective casing is opened. At each site, all locks on the outer protective casings should be keyed alike.

2.3.7 Concrete Surface Pad

A concrete surface pad should be installed around each well at the same time as the outer protective casing is being installed. The surface pad should be formed around the well casing. Concrete should be placed into the pad forms and into the borehole (on top of the grout) in one operation making a contiguous unit. The size of the concrete surface pad is dependent on the well casing size. If the well casing is 2 inches in diameter, the pad should be 3 feet x 3 feet x 4 inches. If the well casing is 4 inches in diameter, the pad should be 4 feet x 4 feet x 6 inches. Round concrete surface pads are also acceptable. The finished pad should be slightly sloped so that drainage will flow away from the protective casing and off of the pad. A minimum of one inch of the finished pad should be below grade to prevent washing and undermining by soil erosion.

2.3.8 Surface Protection – Bumper Guards

If the monitoring wells are located in a high traffic area, a minimum of three bumper guards consisting of steel pipes 3 to 4 inches in diameter and a minimum 5-foot length should be installed. These bumper guards should be installed to a minimum depth of 2 feet below the ground surface in a concrete footing and extend a minimum of 3 feet above ground surface. Concrete should also be placed into the steel pipe to provide additional strength. Substantial steel rails and/or other steel materials can be used in place of steel pipe. Welding bars between the bumper posts can provide additional strength and protection in high traffic areas, but the protective bumpers should not be connected to the protective casing.

2.4 Construction Techniques

2.4.1 Well Installation

The borehole should be bored, drilled, or augered as close to vertical as possible, and checked with a plumb bob or level. Deviation from plumb should be within 1° per 50ft of depth. Slanted boreholes are undesirable and should be noted in the boring logs and final construction logs. The depth and volume of the borehole, including the over-drilling if applicable, should have been calculated and the appropriate materials procured prior to drilling activities.

The well casings should be secured to the well screen by flush-jointed threads and placed into the borehole and plumbed by the use of centralizers and/or a plumb bob and level. Another method of placing the well screen and casings into the borehole and plumbing them at the same time is to suspend the string of well screen and casings in the borehole by means of a hoist on the drill rig. This wireline method is especially useful if the borehole is deep and a long string of well screen and casings have to be set and plumbed.

No lubricating oils or grease should be used on casing threads. No glue of any type should be used to secure casing joints. Teflon "O" rings can also be used to insure a tight fit and minimize leakage; however, "O" rings made of other materials are not acceptable if the well is going to be sampled for organic compound analyses.

Before the well screen and casings are placed on the bottom of the borehole, at least 6 inches of filter material should be placed at the bottom of the borehole to serve as a firm footing. The string of well screen and casings should then be placed into the borehole and plumbed. Centralizers can be used to plumb a well, but centralizers should be placed so that the placement of the filter pack, bentonite pellet seal, and annular grout will not be hindered. Centralizers placed in the wrong locations can cause bridging during material placement. Monitoring wells less than 50 feet deep generally do not need centralizers. If centralizers are used they should be placed below the well screen and above the bentonite pellet seal. The specific placement intervals should be decided based on site conditions.

When installing the well screen and casings through hollow-stem augers, the augers should be slowly extracted as the filter pack, bentonite pellet seal, and grout are tremied and/or poured into place. The gradual extraction of the augers will allow the materials being placed in the augers to flow out of the bottom of the augers into the borehole. If the augers are not gradually extracted, the materials (sand, pellets, etc.) will accumulate at the bottom of the augers causing potential bridging problems.

After the string of well screen and casing is plumb, the filter pack material should then be placed around the well screen to the designated depth. With cased drilling methods, the sand should be poured into the casing or augers until the lower portion is filled. The casing or augers are then withdrawn, allowing the sand to flow into the evacuated space. With hollow stem augers, sand should always fill the augers 6-12 inches, maintained by pouring the sand while checking the level with a weighted tag line. The filter pack sand in open boreholes should be installed by tremie methods, using water to wash the sand through the pipe to the point of placement.

After the filter pack has been installed, the bentonite pellet seal (if used) should be placed directly on top of the filter pack to an unhydrated thickness of two feet. When installing the seal for use with ~~neat~~ cement grouts, the bentonite pellet seal should be allowed to hydrate a minimum of eight hours or the manufacturer's recommended hydration time, whichever is longer.

After the pellet seal has hydrated for the specified time, the grout should then be pumped by the tremie method into the annular space around the casings. The grout should be allowed to set for a minimum of 24 hours before the surface pad and protective casing are installed.

After the surface pad and protective casing are installed, bumper guards should be installed (if needed). The bumper guards should be placed around the concrete surface pad in a configuration that provides maximum protection to the well. Each piece of steel pipe or approved material should be installed into an 8-to 10-inch diameter hole, to a minimum depth of 2 feet below ground surface, and filled with concrete. As previously stated, the bumper guard should extend above the ground surface a minimum of 3 feet. The total length of each bumper guard should be a minimum of 5 feet.

After the wells have been installed, the outer protective casing should be painted with a highly visible paint. The wells should be permanently marked with the well number, date installed, site name, elevation, etc., either on the cover or an appropriate place that will not be easily damaged and/or vandalized.

If the monitoring wells are installed in a high traffic area such as a parking lot, in a residential yard, or along the side of a road it may be desirable to finish the wells to the ground surface and install water-tight flush mounted traffic and/or man-hole covers. Flush mounted traffic and man-hole covers are designed to extend from the ground surface down into the concrete plug around the well casing. Although flush mounted covers may vary in design, they should have seals that make the unit water-tight when closed and secured. The flush mounted covers should be installed slightly above grade to minimize standing water and promote runoff. Permanent identification markings should be placed on the covers or in the concrete plug around the cover. Expansive sealing plugs should be used to cap the well riser to prevent infiltration of any water that might enter the flush cover.

2.4.2 Double-Cased Wells

Double-cased wells should be constructed when there is reason to believe that interconnection of two aquifers by well construction may cause cross-contamination or when flowing sands make it impossible to install a monitoring well using conventional methods. A highly contaminated surface soil zone may also be cased off so that drilling may continue below the casing with reduced danger of cross contamination. A pilot borehole should be bored through the overburden and/or the contaminated zone into the clay confining layer or bedrock. An outer casing (sometimes called surface or pilot casings) should then be placed into the borehole and sealed with grout. The borehole and outer casing should extend into tight clay a minimum of two feet and into competent bedrock a minimum of 1 foot. The total depths into the clay or bedrock will vary, depending on the plasticity of the clay and the extent of weathering and\or fracturing of the bedrock. The final depths should be approved by a senior field geologist. The size of the outer casing should be of sufficient inside diameter to contain the inner casing, and the 2-inch minimum annular space. In addition, the borehole should be of sufficient size to contain the outer casing and the 2-inch minimum outer annular space, if applicable.

The outer casing should be grouted by the tremie, displacement, grout shoe, or Halliburton method from the bottom to the ground surface. The grout should be pumped into the annular space between the outer casing and the borehole wall. A minimum of 24 hours should be allowed for the grout plug (seal) to cure before attempting to drill through it. The grout mixture used to seal the outer annular space should be either a neat cement, cement/bentonite, cement/sand, or a 30% solids bentonite grout. However, the seal or plug at the bottom of the borehole and outer casing should consist of a Type I portland cement/bentonite or cement/sand mixture. The use of a pure bentonite grout for a bottom plug or seal is not acceptable, because the bentonite grout cures to a gel-like material, and is not rigid enough to withstand the stresses of drilling. When drilling through the seal, care should be taken to avoid cracking, shattering, or washing out the seal. If caving conditions exist so that the outer casing cannot be sufficiently sealed by grouting, the outer casing should be driven into place and a grout seal placed in the bottom of the casing.

2.4.2.1 Bedrock Wells

The installation of monitoring wells into bedrock can be accomplished in two ways:

1. The first method is to drill or bore a pilot borehole through the soil overburden into the bedrock. An outer casing is then installed into the borehole by setting it into the bedrock, and grouting it into place as described in the previous section. After the grout has set, the borehole can then be advanced through the grout seal into the bedrock. The preferred method of advancing the borehole into the bedrock is rock coring. Rock coring makes a smooth, round hole through the seal and into the bedrock without cracking and/or shattering the seal. Roller cone bits are used in soft bedrock, but extreme caution should be taken when using a roller cone bit to advance through the grout seal in the bottom of the borehole because excessive water and "down" pressure can cause cracking, eroding (washing), and/or shattering of the seal. Low volume air hammers may be used to advance the borehole, but they have a tendency to shatter the seal because of the hammering action. If the structural integrity of the grout seal is in question, a pressure test can be utilized to check for leaks. A visual test can also be made by examining the cement/concrete core that is collected when the seal is cored with a diamond coring bit. If the seal leaks (detected by pressure testing) and/ or the core is cracked or shattered, or if no core is recovered because of washing, excessive down pressure, etc., the seal is not acceptable. The concern over the structural integrity of the grout seal applies to all double cased wells. Any proposed method of double casing and/or seal testing will be evaluated on its own merits, and will have to be approved by a senior field geologist before and during drilling activities, if applicable. When the drilling is complete, the finished well will consist of an open borehole from the ground surface to the bottom of the well. There is no inner casing, and the outer surface casing, installed down into bedrock, extends above the ground surface, and also serves as the outer protective casing. If the protective casing becomes cracked or is sheared off at the ground surface, the well is open to direct contamination from the ground surface and will have to be repaired immediately or abandoned. Another limitation to the open rock well is that the entire bedrock interval serves as the monitoring zone. In this situation, it is very difficult or even impossible to monitor a specific zone, because the contaminants being monitored could be diluted to the extent of being non-detectable. The installation of open bedrock wells is generally not acceptable in the Superfund and RCRA programs, because of the uncontrolled monitoring intervals. However, some site conditions might exist, especially in cavernous limestone areas (karst topography) or in areas of highly fractured bedrock, where the installation of the filter pack and its structural integrity are questionable. Under these conditions the design of an open bedrock well may be warranted.

2. The second method of installing a monitoring well into bedrock is to install the outer surface casing and drill the borehole (by an approved method) into bedrock, and then install an inner casing and well screen with the filter pack, bentonite seal, and annular grout. The well is completed with a surface protective casing and concrete pad. This well installation method gives the flexibility of isolating the monitoring zone(s) and minimizing inter-aquifer flow. In addition, it gives structural integrity to the well, especially in unstable areas (steeply dipping shales, etc.) where the bedrock has a tendency to shift or move when disturbed. Omitting the filter pack around the well screen is a general practice in some open rock borehole installations, especially in drinking water and irrigation wells. However, without the filter pack to protect the screened interval, sediment particles from the well installation and/or from the monitoring zone could clog the well screen and/or fill the screened portion of the well rendering it inoperable. Also, the filter pack serves as a barrier between the bentonite seal and the screened interval. Rubber inflatable packers have been used to place the bentonite seal when the filter pack is omitted, but the packers have to remain in the well permanently and, over a period of time, will decompose and possibly contribute contaminants to the monitoring zone.

2.5 Well Construction Materials

2.5.1 Introduction

Well construction materials are chosen based on the goals and objectives of the proposed monitoring program and the geologic conditions at the site(s). In this section, the different types of available materials will be discussed.

2.5.2 Well Screen and Casing Materials

When selecting the materials for well construction, the prime concern should be to select materials that will not contribute foreign constituents, or remove contaminants of concern from the ground water. If the monitoring program is designed to analyze for organic compounds, stainless steel materials are the preferred choice. If the monitoring program calls for the analyses of only inorganic compounds or the contaminants or formation are highly corrosive, then rigid PVC materials meeting National Sanitary Foundation (NSF) Standard 14 type WC (Well Casing) are acceptable. PVC materials may be acceptable for monitoring identified organic compounds in a soluble aqueous phase where incompatibilities are known to not exist. EPA document EPA/540/S-95/503, *Nonaqueous Phase Liquids Compatibility with Materials Used in Well Construction, Sampling, and Remediation* (http://www.epa.gov/ada/-download/issue/napl.pdf) should be used for guidance in this area and in the use of PVC with non-aqueous phase liquids (NAPLs). Another concern is to select materials that will be rugged enough to endure the entire monitoring period. Site conditions will generally dictate the type of materials that can be used. A preliminary field investigation should be conducted to determine the geologic conditions, so that the most suitable materials can be selected. The best grade or highest quality material for that particular application should be selected. Each manufacturer can supply the qualitative data for each grade of material that is being considered. All materials selected for monitoring well installation should be evaluated and approved by a senior field geologist prior to field activities.

Well screen and casing materials generally used in monitoring well construction on RCRA and Superfund sites are listed in order of preference:

1. Stainless Steel (304 or 316)
2. Rigid PVC meeting NSF Standard 14 (type WC)
3. Other (where applicable)

There are other materials used for well screens and casings such as black iron, carbon steel, galvanized steel, and fiberglass, but these materials are not recommended for use in long term monitoring programs at hazardous waste sites, because of their low resistance to chemical attack and potential constituent contribution to the ground water. In cases where a driven casing is used, or a high strength outer casing is needed, carbon steel may be acceptable in non-corrosive aquifers. This outer casing should have threaded connections. Welding casing is not an acceptable practice unless all relevant safety issues have been adequately addressed.

The minimum nominal casing size for most permanent monitoring wells will be 2". Where a complete program of installation, monitoring, and abandonment is being designed, smaller wells may be installed if suitable purging and sampling equipment for the smaller diameter wells can be specified and obtained. The length of well screens in permanent monitoring wells should be long enough to effectively monitor the interval or zone of interest. However, well screens designed for long term monitoring purposes should normally not be less than 5 feet in length. Well screens less than 5 feet long are generally only used in temporary monitoring wells where ground water samples are collected for screening purposes.

2.5.3 Filter Pack Materials

The filter pack materials should consist of clean, rounded to well-rounded, hard, insoluble particles of siliceous composition. The required grain-size distribution or particle sizes of the filter pack materials should be selected based upon a sieve analysis conducted on the soil samples collected from the aquifer materials and/or the formation(s) to be monitored. Filter pack materials should not be accepted unless proper documentation can be furnished as to the composition, grain-size distribution, cleaning procedure, and chemical analysis. If a data search reveals that there is enough existing data to adequately design the well screen and filter pack, then it may not be necessary to conduct a sieve analysis on the formation materials to be monitored. However, all data and design proposals will be evaluated and approved by a senior staff geologist before field activities begin.

2.5.4 Filter Pack and Well Screen Design

The majority of monitoring wells are installed in shallow ground water aquifers that consist of silts, clays, and sands in various combinations. These shallow aquifers are not generally characteristic of aquifers used for drinking water. Therefore, modifications to the procedures used for the design of water well filter packs may be required. In cases where insufficient experience exists with local or similar materials, the filter pack and well screen design should be based on the results of a sieve analysis conducted on soil samples collected from the aquifer or the formation(s) that will be monitored.

In formations consisting primarily of fines (silts and clays), the procedures for water well screen design may result in requirements for filter packs and screen slot sizes that are not available. In those cases the selection of 0.010" screen slots with a 20-40 sand filter pack, or 0.005" screen slots with 100 sand filter pack for very fine formations, will be acceptable practice. Table 6.6.1 provides size specifications for the selection of sand packs for fine formation materials. ASTM standard D5092, *Design and Installation of Ground Water Monitoring Wells in*

Aquifers, may be consulted for further guidance on specifications for sand appropriate for these applications.

Table 6.6.1
Sand Pack Specifications

Screen Opening (in)	Sand Pack Mesh Name	1% Passing Size (d-1) (in)	10% Passing Size (d-10) (in)	30% Passing Size (d-30) (in)	Derived 60% Passing Size (d-60) (in)	Range for Uniformity Coefficient
0.005-0.006	100	.0035 - .0047	.0055 - .0067	.0067 - .0083	.0085 - .0134	1.3 - 2.0
0.010"	20-40	.0098 - .0138	.0157 - .0197	.0197 -.0236	.020 - .0315	1.1 - 1.6

The following procedure should be used in coarser grained formations:

The data from the sieve analysis are plotted on a grain-size distribution graph, and a grain-size distribution curve is generated. From this grain-size distribution curve, the uniformity coefficient (Cu) of the aquifer material is determined. The Cu is the ratio of the 60 percent finer material (d60) to the 10 percent finer material (d10)

$$Cu = (d60/d10)$$

The Cu ratio is a way of grading or rating the uniformity of grain size. For example, a Cu of unity means that the individual grain sizes of the material are nearly all the same, while a Cu with a large number indicates a large range of particle sizes. As a general rule, a Cu of 2.5 or less should be used in designing the filter pack and well screen.

Before designing the filter pack and well screen, the following factors should be considered:

1. Select the well screen slot openings that will retain 90 percent of the filter pack material.

2. The filter pack material should be of the size that minimizes head losses through the pack and also prevents excessive sediment (sand, silt, clay) movement into the well.

3. A filter material of varying grain sizes is not acceptable because the smaller particles fill the spaces between the larger particles thereby reducing the void spaces and increasing resistance to flow. Therefore, filter material of the same grain size and well rounded is preferred.

4. The filter pack design is based on the gradation of the finest aquifer materials being analyzed.

Steps to design a filter pack in aquifers:

1. Construct a grain-size distribution curve, on a grain-size distribution graph, from the sieve analysis of the aquifer materials. The filter pack design (as stated above) is based on the gradation of the finest aquifer materials.

2. Multiply the d30 size from the grain-size distribution graph by a factor of four to nine (Pack-Aquifer ratio). A factor of four is used if the formation is fine-grained and uniform (Cu is less than 3), six if it is coarse-grained and non-uniform, and up to nine if it is highly non-uniform and contains silt. Head losses through filter packs increase as the Pack-Aquifer (P-A) ratios decrease. In order to design a fairly stable filter pack with a minimum head loss, the d30 size should be multiplied by a factor of four.

3. Plot the point from step 2 on the d30 abscissa of a grain-size distribution graph and draw a smooth curve with a uniformity coefficient of approximately 2.5.

4. A curve for the permissible limits of the filter pack is drawn plus or minus 8 per cent of the desired curve with the Cu of 2.5.

5. Select the slot openings for the well screen that will retain 90 per cent or more of the filter pack material.

The specific steps and procedures for sieve analysis and filter pack design can be found in soil mechanics, ground water, and water well design books. The staff geologists and/or engineers should be responsible for the correct design of the monitoring wells and should be able to perform the design procedures.

2.6 Safety Procedures for Drilling Activities

A site health and safety plan should be developed and approved by the Branch Safety Officer or designee prior to any drilling activities, and should be followed during all drilling activities. The driller or designated safety person should be responsible for the safety of the drilling team performing the drilling activities. All personnel conducting drilling activities should be qualified in proper drilling and safety procedures. Before any drilling activity is initiated, utilities should be marked or cleared by the appropriate state or municipal utility protection organization. In developed areas, additional measures should be taken to locate utilities not covered by the utility protection program. Before operating the drill rig, a pilot hole should be dug (with hand equipment) to a depth of three feet to check for undetected utilities or buried objects. Proceed with caution until a safe depth is reached where utilities normally would not be buried. The following safety requirements should be adhered to while performing drilling activities:

1. All drilling personnel should wear safety hats, safety glasses, and steel toed boots. Ear plugs are required and will be provided by the safety officer or driller.

2. Work gloves (cotton, leather, etc.) should be worn when working around or while handling drilling equipment.

3. All personnel directly involved with the drilling rig(s) should know where the kill switch(s) is located in case of emergencies.

4. All personnel should stay clear of the drill rods or augers while in motion, and should not grab or attempt to attach a tool to the drill rods or augers until they have completely stopped rotating. Rod wipers, rather than gloves or bare hands should be used to remove mud, or other material, from drill stem as it is withdrawn from the borehole.

5. Do not hold drill rods or any part of the safety hammer assembly while taking standard penetration tests or while the hammer is being operated.

6. Do not lean against the drill rig or place hands on or near moving parts at the rear of the rig while it is operating.

7. Keep the drilling area clear of any excess debris, tools, or drilling equipment.

8. The driller will direct all drilling activities. No work on the rig or work on the drill site will be conducted outside of the driller's direction. Overall drill site activities will be in consultation with the site geologist or engineer, if present.

9. Each drill rig will have a first-aid kit and a fire extinguisher located on the rig in a location quickly accessible for emergencies. All drilling personnel will be familiarized with their location.

10. Work clothes will be firm fitting, but comfortable and free of straps, loose ends, strings etc., that might catch on some moving part of the drill rig.

11. Rings, watches, or other jewelry will not be worn while working around the drill rig.

12. The drill rig should not be operated within a minimum distance of 20 feet of overhead electrical power lines and/or buried utilities that might cause a safety hazard. In addition, the drill rig should not be operated while there is lightening in the area of the drilling site. If an electrical storm moves in during drilling activities, the area will be vacated until it is safe to return.

2.7 Well Development

A newly completed monitoring well should not be developed for at least 24 hours after the surface pad and outer protective casing are installed. This will allow sufficient time for the well materials to cure before development procedures are initiated. The main purpose of developing new monitoring wells is to remove the residual materials remaining in the wells after installation has been completed, and to try to re-establish the natural hydraulic flow conditions of the formations which may have been disturbed by well construction, around the immediate vicinity of each well. A new monitoring well should be developed until the column of water in the well is free of visible sediment, and the pH, temperature, turbidity, and specific conductivity have stabilized. In most cases the above requirements can be satisfied; however, in some cases the pH, temperature, and specific conductivity may stabilize but the water remains turbid. In this case the well may still contain well construction materials, such as drilling mud in the form of a mud cake and/or formation soils that have not been washed out of the borehole. Excessive or thick drilling mud can not be flushed out of a borehole with one or two well volumes of flushing. Continuous flushing over a period of several days may be necessary to complete the well development. If the well is pumped to dryness or near dryness, the water table should be allowed to sufficiently recover (to the static water level) before the next development period is initiated. Caution should be taken when using high rate pumps and/or large volume air compressors during well development because excessive high rate pumping and high air pressures can damage or destroy the well screen and filter pack. The onsite geologist should make the decision as to the development completion of each well. All field decisions should be documented in the field log book.

The following development procedures, listed in approximate increasing order of the energy applied to the formation materials, are generally used to develop wells:

1. Bailing
2. Pumping/overpumping
3. Surging
4. Backwashing ("rawhiding")
5. Jetting
6. Compressed air (with appropriate filtering): airlift pumping and air surging

These development procedures can be used, individually or in combination, in order to achieve the most effective well development. In most cases, over-pumping and surging will adequately develop the well without imparting undue forces on the formation or well materials. Except when compressed air is being used for well development, sampling can be initiated as soon as the ground water has re-equilibrated, is free of visible sediment, and the water quality parameters have stabilized. Since site conditions vary, even between wells, a general rule-of-thumb is to wait 24 hours after development to sample a new monitoring well. Wells developed with stressful measures may require as long as a 7-day interval before sampling. In particular, air surge developed wells require 48 hours or longer after development so that the formation can dispel the compressed air and re-stabilize to pre-well construction conditions. Because of the danger of introducing contaminants with the airstream, the possibility of entraining air in the aquifer, and the violent forces imparted to the formation, air surging is the least desired method of development and should only be used where there is a specific need for the procedure. Air-lift pumping is permissible where an eductor pipe is used and several well volumes of water are removed from the well by other by pumping means after air-lift pumping. The selected development method(s) should be approved by a senior field geologist before any well installation activities are initiated.

2.8 Well Decommisioning (Abandonment)

When a decision is made to decommission (abandon) a monitoring well, the borehole should be sealed in such a manner that the well can not act as a conduit for migration of contaminants from the ground surface to the water table or between aquifers. To properly decommission a well, the preferred method is to completely remove the well casing and screen from the borehole, clean out the borehole, and backfill with a cement or bentonite grout, neat cement, or concrete. In order to comply with state well decommissioning requirements, the appropriate state agency should be notified (if applicable) of monitoring well decommissioning. However, some state requirements are not explicit, so a technically sound well abandonment method should be designed based on the site geology, well casing materials, and general condition of the well(s).

2.8.1 Decommissioning Procedures

As previously stated the preferred method should be to completely remove the well casing and screen from the borehole. This may be accomplished by augering with a hollow-stem auger over the well casing down to the bottom of the borehole, thereby removing the grout and filter pack materials from the hole. The well casing should then be removed from the hole with the drill rig. The clean borehole can then be backfilled with the appropriate grout material. The backfill material should be placed into the borehole from the bottom to the top by pressure grouting with the positive displacement method (tremie method). This abandonment method can be accomplished on small diameter (1-inch to 4-inch) wells without too much difficulty. With wells having 6-inch or larger diameters, the use of hollow-stem augers for casing removal is very difficult or almost impossible. Instead of trying to ream the borehole with a hollow-stem auger, it is more practical to force a drill stem with a tapered wedge assembly or a solid-stem auger into the well casing and extract it out of the borehole. Wells with little or no grouted annular space and/or sound well casings can be removed in this manner. However, old wells with badly corroded casings and/or thickly grouted annular space have a tendency to twist and/or break-off in the borehole. When this occurs, the well will have to be grouted with the remaining casing left in the borehole. The preferred method in this case should be to pressure grout the borehole by placing the tremie tube to the bottom of the well casing, which will be the well screen or the bottom sump area below the well screen. The pressurized grout will be forced out through the well screen into the filter material and up the inside of the well casing sealing holes and breaks that are present.

A PVC well casing may be more difficult to remove from the borehole than a metal casing, because of its brittleness. If the PVC well casing breaks during removal, the borehole should be cleaned out by using a drag bit or roller cone bit with the wet rotary method to grind the casing into small cuttings that will be flushed out of the borehole by water or drilling mud. Another method is to use a solid-stem auger with a carbide tooth pilot bit to grind the PVC casing into small cuttings that will be brought to the surface on the rotating flights. After the casing materials have been removed from the borehole, the borehole should be cleaned out and pressure grouted with the approved grouting materials.

Where state regulations and conditions permit, it may be permissible to grout the casing in place. This decision should be based on confidence in the original well construction practice, protection of drinking water aquifers, and anticipated future property uses. The pad should be demolished and the area around the casing excavated. The casing should be sawn off at a depth of three feet below ground surface. The screen and riser should be tremie grouted with a 30% solids bentonite grout in the saturated zone. The remaining riser may be grouted with a cement grout for long term resistance to dessication.

3 Temporary Monitoring Well Installation

3.1 Introduction

Five types of temporary monitoring well installation techniques have been demonstrated as acceptable. The type selected for a particular site is dependent upon site conditions. The project leader and site geologist should be prepared to test temporary well installations on site and select the best solution. Temporary wells are cost effective, may be installed quickly, and provide a synoptic picture of ground water quality.

Temporary monitoring well locations are not permanently marked, nor are their elevations normally determined. Sand pack materials may or may not be used, but typically there is no bentonite seal, grout, surface completion, or extensive development (as it normally applies to permanent monitoring wells). Temporary wells are generally installed, purged, sampled, removed, and backfilled in a matter of hours.

Due to the nature of construction, turbidity levels may initially be high. However, these levels may be reduced by low flow purging and sampling techniques as described in Section 7.2.4.

Temporary wells may be left overnight, for sampling the following day, but the well must be secured, both against tampering and against the fall hazard of the open annulus. If the well is not sampled immediately after construction, the well should be purged prior to sampling as specified in SESD Operating Procedure for Groundwater Sampling, SESDPROC-301.

3.2 Data Limitation

Temporary wells described in this section are best used for delineation of contaminant plumes at a point in time, and for some site screening purposes. They are not intended to replace permanent monitoring wells. Temporary wells can be used in conjunction with a mobile laboratory, where quick analytical results can be used to delineate contaminant plumes.

3.3 Temporary Well Materials

Materials used in construction of temporary monitoring wells are the same standard materials used in the construction of permanent monitoring wells. Sand used for the filter pack (if any) should be as specified in Section 2.5.3, Filter Pack Materials. The well screen and casing should be stainless steel for ruggedness and suitability for steam cleaning and solvent rinsing. Other materials may be acceptable, on a case by case basis. Some commercially available temporary well materials, pre-packed riser, screen and filter pack assemblies are available commercially; however, these pre-assembled materials cannot be cleaned. Appropriate QA/QC must be performed to assure there will be no introduction of contamination.

3.4 Temporary Monitoring Well Borehole Construction

Borehole construction for temporary wells is as specified in Section 2.3, using a drill rig. Alternatively, boreholes may be constructed using hand augers or portable powered augers (generally limited to depths of ten feet or less). If a drill rig is used to advance the borehole, the augers must be pulled back the length of the well screen (or removed completely) prior to sampling. When hand augers are used, the borehole is advanced to the desired depth (or to the point where borehole collapse occurs). In situations where borehole collapse occurs, the auger bucket is typically left in the hole at the point of collapse while the temporary well is assembled. When the well is completely assembled, a final auger bucket of material is quickly removed and the well is immediately inserted into the borehole, pushing, as needed, to achieve maximum penetration into the saturated materials.

3.5 Temporary Monitoring Well Types

Five types of monitoring wells which have been shown to be acceptable are presented in the order of increasing difficulty to install and increasing cost:

3.5.1 No Filter Pack

This is the most common temporary well and is very effective in many situations. After the borehole is completed, the casing and screen are simply inserted. This is the least expensive and fastest well to install. This type of well is extremely sensitive to turbidity fluctuations because there is no filter pack. Care should be taken to not disturb the casing during purging and sampling.

3.5.2 Inner Filter Pack

This type differs from the "No Filter Pack" well in that a filter pack is placed inside the screen to a level approximately 6 inches above the well screen. This ensures that all water within the casing has passed through the filter pack. For this type well to function properly, the static water level must be at least 6-12 inches above the filter pack. The screen slots may plug in some clayey environments with this construction method and others that use sand only inside the well screen.

3.5.3 Traditional Filter Pack

For this type of well, the screen and casing are inserted into the borehole, and the sand is poured into the annular space surrounding the screen and casing. Occasionally, it may be difficult to effectively place a filter pack around shallow open boreholes, due to collapse. This method requires more sand than the "inner filter pack" well, increasing material costs. As the filter pack is placed, it mixes with the muddy water in the borehole, which may increase the amount of time needed to purge the well to an acceptable level of turbidity.

3.5.4 Double Filter Pack

The borehole is advanced to the desired depth. As with the "inner filter pack" the well screen is filled with filter pack material and the well screen and casing inserted until the top of the filter pack is at least 6 inches below the water table. Filter pack material is poured into the annular space around the well screen. This type temporary well construction can be effective in aquifers where fine silts or clays predominate. This construction technique takes longer to implement and uses more filter pack material than others previously discussed.

3.5.5 Well-in-a-Well

The borehole is advanced to the desired depth. At this point, a 1-inch well screen and sufficient riser is inserted into a 2-inch well screen with sufficient riser, and centered. Filter pack material is then placed into the annular space surrounding the 1-inch well screen, to approximately 6 inches above the screen. The well is then inserted into the borehole.

This system requires twice as much well screen and riser, with attendant increases in assembly and installation time. The increased amount of well construction materials results in a corresponding increase in decontamination time and costs. The use of pre-packed well screens in this application will require rinse blanks of each batch of screens. Pre-pack Screen assemblies can not be decontaminated for reuse.

3.6 Decommissioning

Temporary well boreholes must be decommissioned after sampling and removal of the screen and riser. Backfilling the holes with cuttings may be acceptable practice for shallow holes in uniform materials with expected low contamination levels. Use of cuttings would not be an acceptable practice if waste materials were encountered or a confining layer was breached. Likewise, where the borehole is adjacent to, or downgradient of contaminated areas, the loose backfilled material could create a highly permeable conduit for contaminant migration. If the borehole will not be backfilled with the soil cuttings for this or other reasons, then SESD Operating Procedure for Management of Investigation Derived Waste, SESDPROC-202, should be referenced regarding disposal of the cuttings as IDW.

4 Temporary Monitoring Well Installation Using the Geoprobe® Screen Point 15/16 Groundwater Sampler

4.1 Introduction

The Geoprobe® Screen Point 15/16 Groundwater Sampler is a discrete interval ground water sampling device that can be pushed to pre-selected sampling depths in saturated, unconsolidated materials. Once the target depth has been reached, the screen is opened and groundwater can be sampled as a temporary monitoring well, which yields a representative, uncompromised sample from that depth. Using knock-out plugs, this method also allows for grouting of the push hole during sample tool retrieval.

The Screen Point® 15 sampler consist of four parts (drive point, screen, sampler sheath and drive head), with an assembled length of 52 inches (1321 mm) and a maximum OD of 1.5 inches (38 mm). When opened, it has an exposed screen length of 41 inches (1041 mm). It is typically pushed using 1.25-inch probe rod. The Screen Point® 16 consists of the same parts and works in the same fashion, the only differences being larger diameter and its use with 1.5" rods.

4.1.1 Assembly of Screen Point® 15/16 Groundwater Sampler

1. Install O-ring on expendable point and firmly seat in the angled end of the sampler sheath.

2. Place a grout plug in the lower end of the screen section. Grout plug material should be chosen with consideration for site specific Data Quality Objectives (DQOs).

3. When using stainless steel screen, place another O-ring* in the groove on the upper end of the screen and slide it into the sampler sheath.

4. Place an O-ring* on the bottom of the drive head and thread into the top of the sampler sheath.

5. The Screen Point® 15/16 Groundwater Sampler is now assembled and ready to push for sample collection.

   * It should be noted that O-ring use in steps 3 and 4 are optional.

4.1.2 Installation of Screen Point® 15/16 Groundwater Sampler

1. Attach drive cap to top of sampler and slowly drive it into the ground. Raise the hammer assembly, remove the drive cap and place an O-ring* in the top groove of the drive head. Add a probe rod and continue to push the rod string.

2. Continue to add probe rods until the desired sampling depth is reached.

3. When the desired sampling depth is reached, re-position the probe derrick and position either the casing puller assembly or the rod grip puller over the top of the top probe rod.

4. Thread a screen push adapter on an extension rod and attach sufficient additional extension rods to reach the top of the Screen Point® 15/16 sampler. Add an extension handle to the top of the string of extension rods and run this into the probe rod, resting the screen push adapter on top of the sampler.

5. To expose the screened portion of the sampler, exert downward pressure on the sampler, using the extension rod and push adapter, while pulling the probe rod upward. To expose the entire open portion of the screen, pull the probe rod upward approximately 41 inches.

6. At this point, the Screen Point® 15/16 Groundwater Sampler has been installed as a temporary well and may be sampled using appropriate ground water sampling methodology. If waters levels are less than approximately 25 feet, EIB personnel typically use a peristaltic pump, utilizing low-flow methods, to collect ground water samples from these installations. If water levels are greater than 25 feet, a manual bladder pump, a micro bailer, or other method may have to be utilized to collect the sample (SESD Operating Procedure for Groundwater Sampling, SESDPROC-301-R0) provides detailed descriptions of these techniques and methods).

4.1.3 Special Considerations for Screen Point® 15/16 Installations

<u>Decommissioning (Abandonment)</u>

In many applications, it may be appropriate to grout the abandoned probe hole where a Screen Point® 15/16 sampler was installed. This probe hole decommissioning can be accomplished through two methods which are determined by location and contamination risk. In certain non-critical areas, boreholes may be decommissioned by filling the saturated zone with bentonite pellets and grouting the vadose zone with neat cement poured from the surface or Bentonite pellets properly hydrated in place. Probe holes in areas where poor borehole sealing could present a risk of contaminant migration should be decommissioned by pressure grouting through the probe rod during sampler retrieval. To accomplish this, the grout plug is knocked out of the bottom of the screen using a grout plug push adapter and a grout nozzle is fed through the probe rod, extending just below the bottom of the screen. As the probe rod and sampler are pulled, grout is injected in the open hole below the screen at a rate that just fills the open hole created by the pull. Alternatively, the screen can generally be pulled and the hole re-probed with a tool string to be used for through-the-rod grouting.

Screen Material Selection

Screen selection is also a consideration in sampling with the Screen Point® 15/16 sampler. The screens are available in two materials, stainless steel and PVC. Because of stainless steel's durability, ability to be cleaned and re-used, and overall inertness and compatibility with most contaminants, it is the material typically used during EIB investigations.

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MONITOR WELL
INSTALLATION PROCEDURES

Rev. #: 1

Rev Date: 7/8/11

Pre-packed Screen Monitoring Well Installation Procedures

Prior to commencing work, all underground utilities will be located by the Mississippi One Call Center, by field personnel with appropriate devices, and/or by a private utility locator. Also, consistent with ARCADIS subsurface drilling policies, soil probing will be attempted to feet below ground surface at or adjacent to the intended locations where drilling/soil borings will take place.

Direct-push drilling is the preferred technique for subsurface sampling because it minimizes the generation of soil cuttings and the introduction of foreign fluids into the probehole. Direct-push techniques are also known to cause less disturbance to the natural formations. A pre-packed screen is an assembly consisting of an inner slotted screen surrounded by a wire mesh sleeve that acts as a support for filter media. Because the filter media is placed around the screen at the surface, pre-packed screens allow more control over the filter pack grain size and eliminate bridging of the filter media. Use of pre-packed screens may make it possible to use finer grained filter pack sand than is used for conventional well filter pack, providing less turbid samples.

I. Temporary Monitoring Well Installation using Pre-Packed Screens

The prepacked screens are constructed in 3- to 5-foot length sections, which have an outside diameter of about 1.5 to 2.0 inches and an inside diameter of 0.75 to 1.0 inch. The screen length will be determined in the field, but will not exceed 10 feet in length. The inner component of the prepacked screens consists of a flush-threaded, 0.5-inch Schedule 40 polyvinyl chloride (PVC) with 0.01-inch slots. The outer component of the screen is stainless steel wire mesh with a pore size of 0.011 inch. The space between the inner slotted pipe and outer wire mesh is filled with 20/40 silica sand.

The specific procedure for installing direct-push pre-packed screen monitoring wells is as follows. Equivalent pre-packed screen materials can also be used.

- The installation begins by advancing a 2.25-inch outside diameter probe rods to depth with a direct-push machine.

- Pre-packed screens are then assembled and installed through the 1.5-inch inside diameter of the probe rods using corresponding 0.75-inch Schedule 40 PVC riser.

- The pre-pack tool string is attached to an expendable anchor point with a locking connector that is threaded to the bottom of the leading screen. Once the connector is locked onto the anchor point, the rod string is slowly retracted until the lower end of the rods is approximately 3 feet above the top prepack. A threaded bottom plug with an expendable point is another way to set the well.

- A minimum 2-foot sand barrier will be installed above the top prepack to avoid contaminating the well screens with bentonite or cement during installation (if the wells are converted to permanent wells). If the formation is stable and does not collapse around the riser as the rod string is retracted, environmental grade 20/40 mesh sand may be installed through the probe rods to provide the minimum 2-foot barrier.

Groundwater samples can be collected with a check valve assembly (with 3/8-inch outside diameter poly tubing), a stainless steel mini-bailer assembly, or a peristaltic pump when appropriate. Groundwater samples collected using pre-packed screens should be considered screening-level data, suitable for obtaining a general understanding of groundwater quality.

II. Conversion of Temporary to Permanent Monitoring Wells

The following steps may be followed to convert a temporary well to a permanent well:

- Granular bentonite or bentonite slurry will be installed in the annulus to form a well seal. A high-pressure grout pump may be used as a tremie cement/bentonite slurry to fill the well annulus.

- The grout mixture should be installed with a tremie tube from the bottom up to accomplish a tight seal without voids.

- These wells will be allowed to equilibrate overnight and groundwater measurements will be collected to determine groundwater flow direction.

Wells will be completed with a flush-mount (curb box) cover when installed in areas exposed to vehicle access or in residential areas. In areas not exposed to vehicle access, a vented protective steel casing will be located over the riser casing extending at least 1.5 feet below grade and 2 to 3 feet above grade secured by a neat concrete seal. The concrete seal will be flush with the ground surface and will extend approximately 1.5 feet below grade and laterally at least 1 foot in all directions from the protective casing and will slope gently to drain water away from the well. Monitoring wells will be labeled with the appropriate designation both on the inner and outer well casings.

The supervising geologist will specify the monitoring well designs to the drilling contractor before installation.

The supervising geologist is responsible for recording the exact construction details as relayed by the drilling contractor and actual measurements. Both the supervising geologist and drilling contractor are responsible for tabulating all materials used, such as casing footage and screen or bags of bentonite, cement, and sand.

III. Conversion of Temporary to Double-Cased Permanent Monitoring Wells

Double-cased monitoring wells will be installed to assess groundwater where the borings penetrate soil and/or groundwater zones potentially containing elevated levels of constituents of interest. An outer casing will be used to minimize the potential for the drilling process to draw or carry contamination down. Hollow-stem auger drilling methods or a direct push drill rig with the ability to advance a longer isolation casing will be used to install the wells.

The specific procedure for installing double-cased direct push monitoring wells is as follows. Equivalent direct-push techniques can also be used.

§ The borehole for the outer casing will be advanced with a large-diameter hollow-stem auger or direct-push device to the required depth. Soil will be continuously sampled using a 2-inch diameter split-spoon sampler and visually classified by the supervising scientist.

§ Then, a large-diameter PVC outer casing will be installed through the hollow-stem augers or direct-push device. To complete the installation, the outer casing will be hydraulically pushed approximately 1 foot beyond the bottom of the boring. The annular space of the borehole will then be filled with a cement/bentonite grout mixture using a tremie pipe installed to the bottom of the borehole.

§ The cement/bentonite grout in the annulus will be allowed to cure for at least 24 hours before the boring is advanced.

§ After the grout has cured for a minimum of 24 hours, the boring will be advanced through the outer casing using a smaller-diameter hollow-stem auger or direct-push device to the required depth.

§ During advancement of the boring, soil will be continuously sampled with a 2-inch diameter split-spoon sampler, or 4-foot Macrocore sampler, and will be visually classified by the supervising scientist.

The direct-push well will be installed in accordance with the procedures described in Section I.

Wells will be completed with a flush-mount (curb box) cover when installed in areas exposed to vehicle access or in residential areas. In areas not exposed to vehicle access, a vented protective steel casing will be located over the riser casing extending at least 1.5 feet below grade and 2 to 3 feet above grade secured by a neat concrete seal. The concrete seal will be flush with the ground surface and will extend approximately 1.5 feet below grade and laterally at least 1 foot in all directions from the protective casing and will slope gently to drain water away from the well. Monitoring wells will be labeled with the appropriate designation on the outer well casing.

The supervising geologist will specify the monitoring well designs to the drilling contractor before installation.

The supervising geologist is responsible for recording the exact construction details as relayed by the drilling contractor and actual measurements. Both the supervising geologist and drilling contractor are responsible for tabulating all materials used, such as casing footage and screen or bags of bentonite, cement, and sand.

IV. Development

Development will not be performed within 24 hours of the monitoring well installation. Development will be accomplished by surging and evacuating water by slow pumping. As an alternative to surging and pumping, shallow overburden wells may be developed by using a new, disposable hand bailer to entrain the water and fine-grained solids in and around the well screen and remove these materials. Each well will be developed until turbidity is reduced to 10 nephelometric turbidity units (NTUs) or less. In the event that the wells cannot be developed to 10 NTUs, development will proceed until three consecutive measurements of pH, conductivity, and temperature (taken at 5-minute intervals) agree within 10 percent.

Materials for well development include:

- Appropriate health and safety equipment;
- Appropriate cleaning equipment;
- Bottom-loading bailer;
- Polypropylene rope;
- Plastic sheeting;
- pH, conductivity, and temperature meters;
- Nephelometric turbidity meter;

- Graduated buckets;
- Disposable gloves;
- Drums to collect purge fluids;
- Pump/tubing/foot valve/surge block; and
- Generator.

The procedure for developing a well using the pumping method is outlined below:

When developing a well using the pumping method, new cleaned polypropylene tubing equipped with a foot valve and surge block will be extended to the screened portion of the well. The diameter of the surge block will be within 0.5 inch of the well diameter. The tubing will be connected to a hydrolift-type pumping system that allows up and down movement of the surge block. The tubing will also be manually lifted and lowered within the screened interval. The pumping rate will be about two times the anticipated well purging rate. Surging will be repeated as many times as necessary within the well screen interval until the groundwater is relatively clear. Any tubing will be disposed of between wells; clean, new tubing will be used at each well.

Detailed procedures for groundwater well development are as follows:

1. Use appropriate safety equipment.
2. All equipment entering each monitoring well will be cleaned as specified in Attachment 10.
3. Attach appropriate pump and lower tubing into well.
4. Turn on pump. If well runs dry, shut off pump and allow to recover.
5. Surging by raising and lowering the tubing in the well will be performed several times to pull in fine-grained materials.
6. Steps 4 and 5 will be repeated until groundwater is relatively silt free.
7. Step 6 will be repeated until entire well screen has been developed.

V. Survey

A field survey control program will be conducted using standard instrument survey techniques to document the well location, as well as the ground, inner casing, and outer casing elevations, to the North American Vertical Datum of 1988.

VI. Equipment Cleaning

Downhole equipment will be cleaned with high-pressure steam cleaning equipment using a tap water source. Downhole equipment will be cleaned prior to use on the Site, between each monitoring well location, and at the completion of the drilling prior to leaving the Site as discussed in Attachment 12.

Traditional Groundwater Monitoring Well Installation and Development Procedures

Prior to commencing work, all underground utilities will be located by the Mississippi One Call Center, by field personnel with appropriate devices, and/or by a private utility locator. Also, consistent with best management practices, soil probing will be attempted to 5 feet below ground surface at or adjacent to the intended locations where drilling/soil borings will take place.

I. Monitoring Wells in Overburden

Monitoring wells will be installed by placing the screen and casing assembly with bottom cap into the auger string once the screen interval has been selected. At that time, a washed silica sand pack will be placed in the annular space opposite the screen to 1 to 2 feet above the top of the screen. A graded filter sand pack appropriate to the size of the screened soil interval will be used. The upper 0.5 foot of the sand pack will consist of #00 morie sand to impede bentonite infiltrating into the sand pack. Hydrated bentonite will be added to the annulus between the casing and the borehole wall for at least 2 feet. A cement/bentonite grout will then be added above the bentonite during the extraction of the augers to ground surface. For each 94-pound bag of cement, 6 to 7 gallons of water and approximately 7 pounds of granular or powdered bentonite will be added to make the grout mixture. During placement of sand and bentonite, frequent measurements will be made to check the height of the sand pack and thickness of bentonite by a weighted tape measure.

Monitoring wells will be constructed of 2-inch polyvinyl chloride well screen and riser. The well screen will be installed from approximately 2 feet above the water table to just above the anticipated aquitard depth with a maximum screen length of 15 feet. During advancement of the boring, soil will be continuously sampled with a 2-inch diameter split-spoon sampler, or 4-foot Macrocore sampler, and will be visually classified by the supervising scientist.

Wells will be completed with a flush-mount (curb box) cover when installed in areas exposed to vehicle access or in residential areas. In areas not exposed to vehicle access, a vented protective steel casing will be located over the riser casing extending at least 1.5 feet below grade and 2 to 3 feet above grade secured by a neat concrete seal. The concrete seal will be flush with the ground surface and will extend approximately 1.5 feet below grade and laterally at least 1 foot in all directions from the protective casing and will slope gently to drain water away from the well. Monitoring wells will be labeled with the appropriate designation both on the inner and outer well casings. A typical overburden monitoring well detail is shown on Figures 5-1 and 5-2.

The supervising geologist will specify the monitoring well designs to the drilling contractor before installation.

The supervising geologist is responsible for recording the exact construction details as relayed by the drilling contractor and actual measurements. Both the supervising geologist and drilling contractor are responsible for tabulating all materials used, such as casing footage and screen or bags of bentonite, cement, and sand.

II. Development

All monitoring wells will be developed of fine-grained materials that may have collected in the sand filter pack placed around the screen during installation. Development will not be performed within 24 hours of the monitoring well installation of protective casing and concrete pad. Development will be accomplished by surging and evacuating water by slow pumping. As an alternative to surging and pumping, shallow overburden wells may be developed by using a new, disposable hand bailer to entrain the water and fine-grained solids in and around the well screen and remove these materials. Each well will be developed until turbidity is reduced to 10 nephelometric turbidity units (NTUs) or less. In the event that the wells cannot be developed to 10 NTUs, development will proceed until three consecutive measurements of pH, conductivity, and temperature (taken at 5-minute intervals) agree within 10 percent.

Materials for well development include:

- Appropriate health and safety equipment;
- Appropriate cleaning equipment;
- Bottom-loading bailer;
- Polypropylene rope;
- Plastic sheeting;
- pH, conductivity, and temperature meters;
- Nephelometric turbidity meter;
- Graduated buckets;
- Disposable gloves;
- Drums to collect purge fluids;
- Pump/tubing/foot valve/surge block; and
- Generator.

The procedure for developing a well using the pumping method is outlined below:

When developing a well using the pumping method, new cleaned polypropylene tubing equipped with a foot valve and surge block will be extended to the screened portion of the well. The diameter of the surge block will be within 0.5 inch of the well diameter. The tubing will be connected to a hydrolift-type pumping system that allows up and down movement of the surge block. The tubing will also be manually lifted and lowered within the screened interval. The pumping rate will be about two times the anticipated well purging rate. Surging will be repeated as many times as necessary within the well screen interval until the groundwater is relatively clear. Any tubing will be disposed of between wells; clean, new tubing will be used at each well.

Detailed procedures for groundwater well development are as follows:

1. Use appropriate safety equipment.

2. All equipment entering each monitoring well will be cleaned as specified in Attachment 12.

3. Attach appropriate pump and lower tubing into well.

4. Turn on pump. If well runs dry, shut off pump and allow to recover.

5. Surging by raising and lowering the tubing in the well will be performed several times to pull in fine-grained materials.

6. Steps 4 and 5 will be repeated until groundwater is relatively silt free.

7. Step 6 will be repeated until entire well screen has been developed.

memorandum

To: Trihydro Employees
From: OSE
Date: May 31, 2018
Re: Standard Operating Procedure – Rock Coring
(Author: Tom Nissen)

1.0 INTRODUCTION

This standard operating procedure (SOP) provides the standard practice for subsurface rock coring while drilling. The SOP includes the minimum recommended steps and quality checks that employees and subcontractors are to follow when performing the subject task.

This SOP may also contain guidance for other recommended or suggested practice that is based upon collective professional experience. Recommended practice goes beyond the minimum requirements of the SOP, and should be implemented when appropriate.

2.0 SCOPE

This SOP describes standards for collecting subsurface rock cores while drilling, and describes how such coring will be conducted and documented for Trihydro projects. Proper collection procedures are necessary to ensure rock-core quality and integrity.

This SOP addresses technical requirements and required documentation. Additional project-specific requirements for subsurface rock coring while drilling may be developed, as necessary, to supplement this procedure.

3.0 DEFINITIONS

The following definitions apply to collecting subsurface rock cores while drilling and are used in this SOP:

Photo 1: Cores

Borehole - Any hole drilled into the subsurface for the purpose of identifying lithology, collecting samples, and/or installing monitoring wells.

Core - A cylindrical sample of rock obtained using a core sampler (Photo 1).

Coring - The process of recovering cylindrical cores of subsurface rock by means of rotating a hollow steel tube (core barrel) equipped with a coring bit.

Photo 2: Core barrels

Core Barrels - Hollow tubes of steel used to collect cores of drilled rock (Photo 2).

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Core Bit - A drill bit with surface-set or impregnated diamonds in tungsten carbide inserts mounted on a cylindrical housing (Photo 3). The core bit is designed to cut the core as the drill string is rotated and the borehole is advanced.

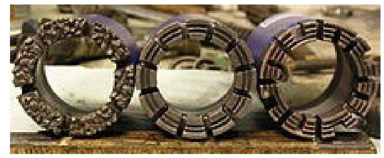

Photo 3: Core bits

Core Boxes - Durable, waxed cardboard or wooden boxes with partitioned compartments for storing core samples (Photo 4).

Photo 4: Core box

Core Care - Requirements for the handling, packaging, shipping, and storage of rock core. The different levels or types of core care include:

- **Critical Care** - Used for samples that are fragile or fluid- or temperature-sensitive
- **Routine Care** - Used for non-sensitive, nonfragile samples for general visual identification, or samples that will not deteriorate before laboratory testing
- **Soil-like Care** - Used for samples so poorly consolidated that soil sampling techniques must be employed to obtain intact pieces of core
- **Special Care** - Used for fluid-sensitive samples and those that will be tested and analyzed

Photo 5: Drill rods

Drill Rod - Hollow steel tubes that are connected to the drill bit or core barrel and to the rotary head of the drilling machine (Photo 5).

Rock Quality Designation (RQD) - RQD is the percentage of the length of each core run that consists of pieces of core that are unbroken and longer than 4 inches (100 millimeters [mm]), or judged to have been unbroken before drilling and longer than 4 inches (100 mm), when measured along the central axis of the core. The lengths of the pieces that exceed (or are judged to have exceeded before drilling) 4 inches (100 mm) are summed, and the total is divided by the length of the core run. The RQD classifications of rock quality are 0-25% Very Poor, 25-50% Poor, 50-75% Fair, 75-90% Good, and 90-100% Excellent.

4.0 RESPONSIBILITIES

Questions, comments, or suggestions regarding this SOP should be sent to the Project Manager (PM) and or Field Teal Lead (FTL). Trihydro employees performing this task, or any portion thereof, are responsible for meeting the requirements of this SOP. For those projects where the activities of this SOP are conducted, the PM, or designee, is responsible for ensuring that those activities are conducted in accordance with this and other appropriate procedures. Project participants are responsible for demonstrating through appropriate documentation (i.e., calculations, reports, etc.) that the requirements of this SOP have been met. Such documentation shall be retained as project records.

5.0 PROCEDURE

Rock cores are cylindrical samples of the subsurface materials at a site. The samples are generally used to document the subsurface geological, physical, and engineering conditions for use in site environmental characterization and as-built construction of engineered structures. Adherence to proper subsurface rock-coring procedures is necessary to ensure the quality and integrity of the cores. This SOP should be used in conjunction with project-specific work plans when conducting rock-coring projects. The project work plans should include the following information:

- Rock coring objectives
- Type of drilling and specific coring methods to be employed to obtain the rock cores
- Locations of borings and target horizons or depths from which rock cores are to be obtained
- Types of analysis (chemical and physical) to be performed on the rock core samples
- Specific rock coring, handling, preservation, and storage requirements
- Specific quality-assurance / quality-control (QA/QC) procedures
- Specific health and safety information
- Decontamination protocols
- Drill cutting, water, and fluid-disposal requirements
- Any additional project- or site-specific information pertinent to the investigation.

5.1 General Coring Considerations

The procedures described in this SOP should be used in conjunction with the SOP for the specific drilling method to be used at the site. Drilling method SOPs include, but may not be limited to, specific drilling requirements, site clearance, site preparation, and health and safety requirements. Consequently, this SOP, the SOP for the specific drilling method, and the project work plans should be reviewed together before starting drilling and rock coring tasks.

5.2 General Operational Requirements

The following operational requirements pertain to all environmental coring projects.

- Perform site inspections to determine boring locations.
- Survey and mark underground utilities near the drill site following the Excavation-Site Clearance SOP (Trihydro 2014).
- Check the site for overhead obstructions or hazards (e.g., power lines) before raising the drill-rig mast.

- Calibrate field analytical and health and safety monitoring equipment according to the instrument manufacturer's specifications. Calibration results must be recorded on the appropriate form(s) as specified by the project work plan or health and safety plan (HASP).
- Wear the appropriate personal protective equipment (PPE) as specified in the project work plan or HASP. Minimum PPE will typically include hardhat, safety glasses, gloves, steel-toed boots, hearing protection, and coveralls.
- During drilling, monitor vapors in the breathing zone according to the project work plan and HASP.
- Appropriately preserve, package, handle, and ship rock samples for chemical analysis in accordance with this SOP and applicable project-specific procedures. The samples shall also be maintained under custody. If possible, attempts should be made to ship samples for chemical analysis on the date they are collected.
- Document rock coring and sampling on the appropriate form(s).
- Boreholes shall be properly sealed and abandoned in accordance with the project work plan.

5.3 Selection of Rock Coring Devices, Diameters, and Lengths

Rock-core diameter, core barrel design, and coring methods have a direct bearing on the core quality and should be selected carefully. Information on the selection of core barrel diameters and design and coring methods can be found in ASTM Method D 2113.

Larger-diameter cores are obtained in delicate formations. Larger-diameter core barrels can reduce shearing stresses and thus reduce mechanical breakage. Smaller-diameter cores reduce the amount of drilled rock and thus increase drilling speed. The most commonly used core size, and generally the minimum size for site investigations, is "N" series.

Commonly used core barrels include the following:

Single-tube Core Barrel (Photo 6). The core is subjected to drill fluid circulation over the entire length, subjecting the core to possible erosion. The core also rotates in the barrel and is subject to breakage.

Double-tube Core Barrel (Photo 7). Contains an inner barrel that protects the core from contact with the drilling fluid along the length but not at the end. Washing erosion is reduced with this design and recovery in weaker zones is enhanced. The inner barrel is solid or split for core protection and can accept liners.


Photo 6: Single-tube core barrel

Photo 7: Double-tube core barrel


Photo 8: Triple-tube core barrel

Triple-tube Core Barrel (Photo 8). A double tube barrel equipped with a solid or split liner.

Wire-line Core Barrel (Photo 9). Essentially a double tube core barrel inserted and removed from within the drill rod by a wire line. The application of this core barrel is for deep-rock coring where the drill rods are not removed between coring runs, or where the drill rod is used to stabilize the borehole.

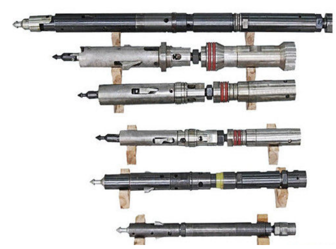
Photo 9: Wire-line core barrel

Double tube core barrels are the most commonly used. Core barrels are available in 5- and 10-foot lengths. Ten-foot core runs are generally made under good (RQD greater than 75 percent) rock-quality conditions. Five-foot core barrel lengths are used in soft, friable, and highly-fractured formations to improve core quality and recovery.

5.4 Selection of Drilling Methods, Fluids, and Casing Equipment

Coring is performed using various rotary drilling machines using a circulating fluid to remove cuttings. The drilling machines can be skid, track, or truck mounted. Rock coring can be vertical or angled. The drilling and coring methods should be selected based upon site conditions and sampling requirements. Those individuals needing assistance in planning coring activities may seek local (i.e., within Trihydro) experienced senior geologists and hydrogeologists or may consult internal Trihydro technical listings for experts in drilling and rock coring.

Drilling methods used for rock coring are typically limited to mud- and air-rotary techniques. Mud-rotary methods use water or water-based drilling fluid with or without additives; effective in a wide range of conditions, above and below the water table. Air-rotary methods use air as the circulating fluid with or without additives; selected for water-sensitive soils (e.g., swelling clays), low density or collapsible soils, vadose-zone coring, and fractured and porous formations where water-based drilling fluids are not acceptable.

Drilling fluids used in rock coring operations need to be considered. The primary functions of the drilling fluid are to:

- Remove drill cuttings.
- Stabilize the borehole.
- Cool and lubricate the bit.
- Control fluid loss.
- Drop cuttings into a settling pit.
- Facilitate logging of the borehole.
- Suspend cuttings in the borehole during coring.

No single drilling fluid may serve all of these functions, but an acceptable mixture can be developed for a particular site and formation to optimize core quality and recovery. Casing use in the borehole may be necessary to stabilize the overlying formation, bridge voids, seal out groundwater, and prevent cross-contamination. A wire-line drilling and coring process may also be used to stabilize the borehole.

5.5 Basic Rock Coring Procedure

Driller anticipated procedures may include (Acker 1974):

1. Setting up the drill rig and platform.
2. Setting up the mud tank or pit to collect drill cuttings, or, for air-based circulation systems, set up the dust collector or cyclone separator.
3. Drilling and casing the overburden or setting hollow-stem augers
4. Establishing a datum for measuring borehole depth (top of drill platform, stake in ground, etc.). The hole depth is determined by keeping track of the length of rod/bit assemblies and comparing the position relative to the established datum.
5. Assembling the core barrel according to manufacturer's instructions.
6. Inspecting the core barrel for wear, dents, galls, and clearances.
7. Cleaning and decontaminating the core barrel, inner tube, drill rods, and any tools to be used down hole or to handle the cores.
8. Inserting the inner tube of the core barrel.

9. Attaching the lead drill rod and core rod (with core barrel) to the drill mechanism through the spindle or below the drill head.
10. Activating the drilling-fluid circulation system.
11. Starting drill-head rotation, and drilling to the required depth while maintaining appropriate fluid circulation so that drill cuttings are removed from the borehole. Fluid circulation should not be at a rate where erosion of the core occurs. Drilling speed should also be appropriate for the material to be cored.
12. Stopping rotation and down-force pressure when the required depth is reached, slightly raising the core barrel off the hole bottom, and continuing fluid circulation until cuttings are removed from the borehole annulus.
13. Stopping fluid circulation and advancing the core barrel to the hole bottom to measure hole depth.
14. Raising the drill rod and removing the core barrel and core from the borehole (if not using a wire line).
15. Disassembling the core barrel and removing the core.
16. Checking the core barrel for wear or damage.
17. Reassembling the core barrel and drill rod and returning them to the borehole. The use of two core barrels can greatly speed up the coring operations. When one core barrel is in use the other can be cleaned and reassembled.
18. Repeating the rock coring procedure. Drilling depth is increased by adding drill-rod sections to the top of the previously advanced drill-rod column.

The rock core shall be recovered continuously from the borehole. If core recovery drops below an acceptable level, the drilling procedure should be modified to increase recovery to the extent feasible by adjusting the drilling revolutions per minute (RPM), down-feed pressure, or drilling fluid type. The type and size of core barrel and bit used may be changed until core recovery is improved to a level acceptable to the project geologist. Mechanical breaks in the core should be minimized as much as possible. In many instances, 100 percent recovery of core is not possible and significant intervals of no recovery occur during coring. This may be due to a variety of factors related to the formations encountered and drilling and coring methods used. If problems with core recovery occur, the rig geologist should consult with the driller to determine if core recovery can be improved and what actions should be taken to improve recovery. If it is determined that recovery cannot be improved with any corrective action, the coring may continue after consultation with the PM, or designee. The corresponding decision(s) and rationale to continue coring should be documented on the appropriate forms and records, according to project-specific requirements (Acker 1974).

Once the total depth of the borehole is reached and the coring is completed, the borehole should be abandoned according to applicable Trihydro technical SOPs and the project work plans.

5.6 Rock Core Environmental Sampling

Once the cores have been recovered, they can be field-screened with an organic vapor meter and samples removed, packaged, and shipped to a laboratory for chemical analysis. The project work plans should specify the sample selection and analysis protocols to be followed.

5.7 Core Handling, Care, Preservation, Packaging, and Storage

The handling, initial logging, preservation, shipping, and storage of cores are described in ASTM Method D 5079. The following tasks should be completed for core samples requiring routine care:

1. Remove the core from the core barrel with a minimum of disturbance.
2. Mark the top and bottom of the core with a felt-tip or other permanent marker.
3. Photograph the core in color and with a color strip-chart in the picture for reference.
4. Perform initial core logging, including identification of the borehole and personnel, equipment used, datum, coring depth, contact depths, and any information required or useful for the detailed logging.
5. Place the core in rigid wooden or waxed boxes with appropriate partitions). Mark the top and bottom and core depths inside the box. Orient the core segments to their original relative positions by fitting tops and bottoms of adjacent core segments together to the extent feasible. Once the core is oriented to the extent feasible, mark entire length of cores with adjacent felt-tip markers of two different colors to preserve their relative positions. Optionally, place the core in loose-fitting polyethylene sleeves following marking.
6. Add core blocks/spacers (Photo 10) for intervals of no recovery; add packing to the core box and seal.
7. Mark both the top and one edge of the core box with the following information: company name, project name, drill-hole number or location, core box number in sequence down the hole, and depths from a specified datum to the top and bottom of the core.

Photo 10: Core blocks/spacers

8. Handle the core boxes gently and transport them by company vehicles, if possible, to avoid core damage. Protect the core from excess heat and freezing during transportation.
9. Store the core in an environment that will not cause alteration of physical properties and structure.
10. Catalog the core and maintain a record of the core, including company and project name, drill hole number and location, orientation of the borehole, elevation of the datum, dates of coring, core box

number and depth intervals, date and name of the person doing the initial logging, boring log, and photographs of the core.

5.8 Technical Review

All subsurface rock-coring plans and results should undergo technical review. The technical reviewer should be an experienced senior geologist or hydrogeologist. At a minimum, the technical reviewer should be a person capable of planning and supervising rock-coring programs. The technical reviewer should not have developed or conducted the work to be reviewed. Individuals needing assistance in finding qualified technical reviewers may consult internal Trihydro technical listings for experts in drilling and rock coring.

The technical review, at a minimum, should consider and evaluate the following items:

- Purpose and scope of the rock-coring program
- Site lithology and stratigraphy
- Depth to groundwater
- Existing site environmental data
- Selected drilling and rock-coring method
- Sampling methodology and any special requirements
- Core handling and storage procedures
- QA/QC procedures
- Equipment-decontamination procedures
- Issues or events regarding limited recovery during coring activities

Any issues raised during the technical review shall be resolved between the reviewer and the staff preparing the work plan or conducting the subsurface rock coring before external (i.e., outside of Trihydro) submission of plans or results. The technical review comments and issues, and corresponding resolution, shall be documented and filed with the project records. Such records should be maintained until project closeout.

5.0 REFERENCES

Acker III, W.L. 1974. "Basic Procedures for Soil Sampling and Core Drilling." Acker Drilling Company, Inc. Scranton, Pennsylvania.

ASTM D 2113-99. 2018a. "Standard Practice for Rock Core Drilling and Sampling Rock for Site Investigation." Available from: https://www.astm.org/Standards/D2113.htm.

ASTM D 5079-02. 2018b. "Standard Practices for Preserving and Transporting Rock Core Samples." Available from: https://www.astm.org/Standards/D5079.htm.

Trihydro Corporation (Trihydro). 2014. Standard Operating Procedure – Excavation-Site Clearance. February 20, 2014. Available from: https://home.trihydro.com/prj/Documents/UndergroundUtilityLocation_SOP%20(2).pdf.

QAQ-CSO-P00

Trihydro
CORPORATION

memorandum

To:	Trihydro Employees
From:	OSE
Date:	May 15, 2013
Re:	Standard Operating Procedure – Equipment Decontamination

1.0 INTRODUCTION

The purpose of this Standard Operating Procedure (SOP) is to establish procedures for decontaminating non-disposable equipment to prevent cross contamination.

2.0 DECONTAMINATION PROCEDURES

Non-disposable sampling equipment should be decontaminated before use and between sampling locations. Equipment will also be decontaminated if the equipment contacts potentially contaminated surfaces. The decontamination method will vary depending on the equipment type. Procedures for decontaminating tools and non-disposable sampling equipment are provided below.

Step 1: Establish a decontamination area. If decontaminating large equipment, a temporary decontamination pad will be established with appropriate drainage to collect decontamination and rinse water without running off the decontamination pad. This will help to prevent the potential release of impacted materials. Large equipment may be decontaminated using a steam or pressure washer on a decontamination pad. Small tools may be decontaminated using decontamination buckets or drums. Water will be prevented from running off the decontamination pad.

Step 2: Fill an adequately sized, clean bucket/drum with tap water and non-phosphate detergent. Fill a second bucket/drum with clean tap water. Fill a third bucket/drum with clean distilled or deionized water.

Step 3: Submerge the tools into the series of buckets starting with the soapy wash. Using a scrub brush, scrub sediment from the tools. Rinse by submerging the equipment into the tap and distilled/deionized water buckets.

Step 4: Dispose of decontamination rinse water in a client-approved decontamination area or store it in approved containers for disposal at an approved off-site disposal facility.

QAQ-CSO-P00

memorandum

To:	Trihydro Employees
From:	OSE
Date:	August 30, 2012
Re:	Standard Operating Procedure – Field Documentation Author: Nella Dagnillo

1.0 PURPOSE, SCOPE, AND RESPONSIBILITIES

This standard operating procedure (SOP) describes requirements associated with documenting field investigation and remediation activities. The procedures apply to field logbooks, sample labels, and chain-of custody documentation.

The Operational and Service Excellence (OSE) Business Unit is responsible for SOP maintenance, management, and revisions. Trihydro employees performing tasks within this SOP are responsible for meeting SOP requirements. For projects where activities within this SOP are necessary, the project manager (or designee) is responsible for ensuring that those activities are conducted in accordance with this and other SOPs. Project team members are responsible for documenting procedural information in sufficient detail (i.e., calculations, field notes, reports, etc.) and reporting these changes to OSE. Such documentation will be included as a component of project records.

2.0 PROCEDURES

Proper field documentation is a crucial part of the field investigation and remediation process. Documentation should be maintained to trace the possession and handling of samples from the time of collection through submittal to the laboratory, to allow sampling locations to be located in the future, to record sampling methods and equipment, and to identify field personnel responsibilities. Field documentation procedures are important from both the technical and legal perspective.

The following sections describe the procedures for field documentation. This SOP provides general guidance that can be adapted to site-specific procedures. Contact the Project Manager to tailor the procedure based on the specific project. Additional, site-specific documentation may be found in sampling and analysis plans, quality-assurance project plans, and work plans.

2.1 Field Logbook

Field team members conducting sampling activities shall maintain a field logbook and/or field forms to document activities conducted by the field team each day. Any corrective actions or alterations of the prescribed preparation and/or sampling procedures will also be noted. Entries on all forms and logbooks should be made in indelible ink. A single stroke should be used to cross out incorrect information and initialed by the sampler. A single stroke with the field personnel's initials shall be used to manage unused space left on a page. A new day's entry shall start with a new page in the logbook. Field logbooks will be maintained in accordance with the procedures listed in Section 2.4.

Sections of the applicable field forms should be filled out by members of the sampling team. Documentation will include the date of sampling, sample location, and sample identification. The sample-location coordinates obtained from the hand-held GPS will also be included on the field sampling forms, when applicable. Any corrective actions or alterations of the prescribed preparation and/or sampling procedures will also be noted. Entries on all forms and logbooks should be made in indelible ink. A single stroke should be used to cross out incorrect information and initialed by the sampler.

Photographs will be used to substantiate and augment the field notes. Photographs will be numbered and recorded in the logbook or Photograph Log Form.

At a minimum, the following information shall be recorded in the field logbook:

- Name and location of the site
- Date(s) of sample collection events
- Name and affiliation of sampling personnel
- Name of field team members and responsibilities (if others)
- Daily time of arrival to the site
- Daily weather conditions
- Pertinent field observations
- Daily summary of field activities
- Daily summary of equipment-preparation procedures (notation of equipment calibration and maintenance), if appropriate
- Time of sample collection for each sample
- Sample locations and types of samples collected and sample-identification numbers
- Sample-collection depths, if applicable
- Sample description, if applicable
- Project quality-control samples (i.e., Field Duplicate Samples, Matrix Spike Samples, Field Blank Samples, Equipment Blank Samples, Trip Blank Samples) collected with each location or sampling event
- Any corrective actions or alterations of the prescribed preparation and/or sampling procedures
- Physical description and sketch/photograph of the sample-collection location(s)
- A Global Position System (GPS) reference to the collected data, if applicable
- Record of daily phone calls and/or contact with individuals at the site
- Management or disposal of investigation-derived wastes

If field forms are also used in conjunction with the field logbook, specific details that are recorded on the field forms will not be duplicated within the field logbook.

2.2 Sample Labels

Sample labels should include:

- The unique sample-identification number
- Sample location
- Parameter sampled
- Date and time sampled
- Sampler's initials
- Preservative used (if applicable)
- Site name or location
- Bottle types

If possible, sample containers should be pre-labeled with as much of this information pior to departing for the field. Any remaining information (such as sample time) should be filled out immediately prior to/during sample collection.

2.3 Chain-of-Custody Documentation

The chain-of-custody (CoC) form is intended to be a legal record of possession of samples for laboratory analysis. The CoC form will be created during pre-job preparations. The CoC form will be provided to the field-sampling personnel prior to sampling activities and should accompany the sample bottles through transport to the field site. The CoC form should be completed by the field-sampling personnel at the time of sample collection and should bear the name of the person responsible for the secure and appropriate handling of the samples.

The Field Team Lead (FTL) should maintain the CoC form during sample-collection activities. Care should be taken during the CoC process so that the samples listed on the CoC form match what is provided in the cooler. Additionally, one individual CoC form shall be completed per sample cooler submitted and all samples need to be accounted for during storage. The minimum information required for CoC documentation includes:

- Name and location of the site
- Name and affiliation of the sampling personnel
- Sample-identification number
- Matrix and type of sample collected (grab or composite)

- Number of containers per sample
- Preservatives or fixatives used
- Date and time of samples collected
- Parameters to be analyzed
- Identification of couriers
- Identification of laboratory
- Custody seal numbers, if applicable

When completing CoC forms, field personnel shall properly relinquish the samples to the chosen courier.

2.4 Field Records Management

Field records must be managed according to the Quality Management System manual/Quality Assurance Project Plan (QAPP), SAP, and/or Work Plan. In addition to the original CoC form that accompanies each sample shipment, a copy of each CoC form must be provided to the master project files. A working copy of the CoC form shall be retained in working files in the field-sampling work area for reference. The FTL will maintain a list of people requiring courtesy copies of the CoC form. Courtesy copies may be distributed by either hard copy (mail) or electronic copy (e-mail) and shall be distributed the next working day after sample collection.

The receiving laboratory may provide a completed copy of the CoC form as part of data deliverables or as part of routine sample-receipt notification (usually by e-mail). A copy released as part of data deliverables will become part of the project files. Any electronic copy may be printed and retained as a working copy in the field-sampling work area for reference.

Field logbooks shall have a unique identifier and shall have pre-numbered pages. Logbooks carried into the field shall have completed pages copied to project files on a daily basis to minimize potential data loss caused by accidental loss or destruction. Copies shall be reviewed for legibility prior to storing electronically. Refer to Section 2.1, “Field Logbook,” for additional logbook details.

2.5 Photographs

Photographs will be used to substantiate and augment the field notes. For each photograph taken, the following items should be recorded in the field logbook and/or field form:

- Photographer’s name or initials
- Date and time of photograph
- General direction or orientation of the photograph (e.g., view toward the west or east)
- Brief description of the subject and fieldwork shown in the photograph

- For digital photographs, the sequential number of the photograph, file name, and file location
- For photographs, the sequential number of the photograph or specific file name

Follow these best practices when submitting photographs for the project notes:

- If you take photographs of sample characteristics and routine sampling activities, include a scale in the image and avoid using telephoto or wide-angle shots.
- If photographing a borehole location or a pole-mounted transformer, include a background object to show the location.
- Avoid photographing only a hole in the ground or a transformer showing only the sky.

Photographs will be numbered and a description of each will be recorded in the photograph log form (if applicable). After completing field-sampling events, the FTL should submit all photographs for development and subsequent storage in the project files.

3.0 REFERENCES

Office of Environment and Research. 2009. *Tennessee Valley Authority (TVA) Standard Operating Procedure.*

United States Environmental Protection Agency (USEPA). 1991. *Guidance for Performing Preliminary Assessments Under CERCLA. Office of Solid Waste and Emergency Response.* Directive 9345.0-01A, 1991. http://www.epa.gov/superfund/sites/npl/hrsres/#PA%20Guidance.

USEPA. *Region 4, Logbook Operating Procedure*. Document #SESDPROC-010-R3, November 2007.

QAQ-CSO-P00

Trihydro CORPORATION

memorandum

To:	Trihydro Employees
From:	OSE
Date:	January 23, 2013
Re:	Standard Operating Procedure – Field Equipment Calibration – PID and Multi-Gas Detector Author: Craig Carlson

1.0 INTRODUCTION

The purpose of this Standard Operating Procedure (SOP) is to establish procedures for the inspection, maintenance, and calibration of field equipment to ensure that environmental assessments are consistently performed. Personnel using field equipment will properly calibrate equipment with sufficient frequency to yield valid, reproducible field data. Personnel shall identify equipment malfunctions and implement corrective action if equipment malfunctions occur. Equipment that cannot be repaired will be removed from service and replaced with operable field equipment.

2.0 CALIBRATION PROCEDURES

Field personnel will inspect and calibrate equipment at the start of each field day. Instrument calibration may be checked anytime during the field day if unexpected or unexplained readings are obtained. The instrument will be re-calibrated, if necessary. For instruments and equipment that are calibrated on an operational basis, calibration generally consists of measuring instrumental response to standards of known composition and concentration and may include preparing a standard response curve for the compound or parameter at different concentrations. Calibration records will be maintained on calibration logs or in a field logbook following instrument calibration.

3.0 PORTABLE TOTAL ORGANIC VAPOR MONITOR (PHOTOIONIZATION DETECTOR)/MULTI-GAS DETECTOR

Organic vapor monitors are used to monitor ambient-air quality (breathing space) for the presence of volatile organic vapors. Instruments commonly used include photoionization detectors (PIDs), and multi-gas detectors. Inspection, maintenance, and calibration procedures will be implemented as detailed below and per the manufacturers recommendations.

Step 1	Inspect the equipment to ensure that all contents are clean and accounted for (additional serviceable alkaline batteries, expendable hydrophobic filters, 20-micron water vapor filter, threaded sampling tip, and operator's manual). Inspect the calibration-gas cylinder(s) and safety valve for adequate gas supply and serviceability. If something is missing or defective, notify the Project Manager. Test the equipment by turning it on and exposing the probe to a source and check for a response prior to initiating the calibration process.

Step 2	Allow the instrument to reach ambient temperature prior to use.
Step 3	Calibrate the instrument according to the manufacturer's specifications. Calibration includes a two-point process using "fresh air" and the standard reference gas. Use a 100 parts-per-million (ppm) isobutylene gas as the calibration standard for the PID. Use a span gas as the calibration standard for a multi-gas meter.
Step 4	Record the manufacturer's serial number or use other means to uniquely identify calibrated equipment on the calibration log and/or in the field logbook. Also document the calibration standards, lot number, expiration date, and the calibration results (final reading).
Step 5	Document that calibration was conducted, including the time and the instrument involved, in the field notebook or on a calibration log.
Step 6	If a suspicious or unexpected reading is collected, verify calibration by testing the equipment using the calibration standard.
Step 7	If the equipment fails calibration or becomes inoperable during use, perform the following troubleshooting steps: • Replace the alkaline batteries. • Ensure that the "Fresh Air" calibration was performed in "fresh air" • Replace isobutylene or span-gas calibration gas cartridge. • Clean the lamp per the Operator's manual or call for service if the procedure is unable to be performed.
Step 8	If the equipment cannot be restored to operable use and cannot be recalibrated, remove it from service and segregate to prevent inadvertent use. Note the problem in the field notebook or equipment-calibration sheet and order replacement equipment.

QAQ-CSO-P00

memorandum

To:	Trihydro Employees
From:	OSE
Date:	May 2019
Re:	Standard Operating Procedure – Field Measurement of Residual Radiation Author: Michelle Harper

1.0 INTRODUCTION

The objective of this technical standard operating procedure (SOP) is to define the techniques and the requirements for the detection of residual radiation in the areas where work is to be performed. Operational Unit 1 (OU-1), Area 1 and Area 2 are the primary areas that have been radiologically impacted. However, radiological surveys will be performed in other areas to verify that they have not been cross contaminated.

2.0 BACKGROUND

2.1 Definitions

MicroR detector– A portable, hand-held scintillation counter that measures gamma radiation in air. Although measurements are typically made about one meter above the ground surface, sodium iodide scintillation detectors can also be used to qualitatively measure radiation emitted from in-situ soil, soil samples, and soil cores. In this instance the detectors will be held about 0.5 to 1 inch above the samples. When used to evaluate soil activity, measurements will be compared against background count rates for the same material taken in a consistent manner (i.e., 0.5 to 1 inch above soil material). Background is established by taking measurements in an area that has exposure rates that are relatively low and uniform. The background reference area should be in an area that has not been impacted by radiologically impacted material (RIM).

Dual Phosphor Alpha Beta Scintillator – A portable, hand-held field radiation survey instrument that detects both alpha and beta emissions.

2.2 Discussion

Radiation screening of in-situ soil, soil samples and soil core samples is necessary because of the prior disposal of RIM at the West Lake Landfill. Radiation measurement data will be used pursuant to health and safety monitoring requirements detailed in the Radiation Safety Plan (RSP) to determine if radiation exposure rates for field personnel in a work area is acceptable or if additional personal protective equipment or exposure limitations are necessary for field personnel. In addition to health and safety monitoring, radiation monitoring will be used to screen surface and subsurface soil and sediment samples for levels above background.

Two types of instruments will be used to measure residual radiation: the MicroR gamma detector and the dual phosphor alpha/beta detector.

2.2.1 MicroR Operation

The MicroR detector is a sodium iodide scintillation meter used to measure low levels of gamma radiation. Although sodium iodide detectors can be set up to operate as a single channel analyzer, thereby reporting a specific radionuclide, the instruments for this project will be set up to report all gamma emissions, irrespective of radionuclide. The instrument has a speaker which provides an audible measure of the radiation emitted, as an audible click. The rate at which the clicks occur allows real-time monitoring of the strength of the radiation sources. Readout is generally in terms of microroentgens per hour (µR/hr).

2.2.2 Dual Phosphor Alpha Beta Scintillation Operation

For this project a Ludlum 43-93 Dual Phosphor alpha/beta scintillation detector paired with a Ludlum 2360 or equivalent will be primarily used to detect alpha/beta emissions.

Although these detectors can detect alpha emissions, alpha particles generally have a range of about an inch or less in air. Alpha/beta detectors are generally calibrated to the alpha emissions of Th-230 or Pu-239 and the beta emissions of C-14, Tc-99 and Sr-90. Beta efficiency varies with energy such that 4 pi efficiency ranges from about 10 percent to 40 percent for beta particles with average energies of 50 to 550 kiloelectron volts (keV), respectively. If the instrument has a speaker, the pulses also give an audible click. The readout is displayed are counts per minute (cpm). Alpha/beta probes are commonly used with a variety of different hand held scalers/ratemeters for contamination measurements.

3.0 RESPONSIBILITIES

Field Team Leader – The field team leader (FTL) is responsible for ensuring that field personnel conduct field activities in accordance with this SOP, Field Sampling Plan (FSP), and the RSP.

Site Health and Safety Officer – The person who will use field screening instruments to monitor all field activities for VOCs, combustible gases, etc. and ensure workers are using safe work practices.

Radiation Controls Supervisor – The person who oversees radiation survey activities, confirms background levels, and provides field direction when background levels are exceeded per the Health and Safety Plan.

Health Physics Technician – The person who performs and documents the radiation survey activities under the direction of the Radiation Controls Supervisor and provides health physics oversight of the field activities when required.

4.0 REQUIRED EQUIPMENT

- Ludlum Model 19 Micro R Instrument (or equivalent)
- Ludlum Model 43-93 Dual Phosphor Alpha/Beta Scintillation Detector (or equivalent)
- Site-specific plans (i.e., FSP, WP)
- Health and safety plan (HASP)
- Field logbook
- Waterproof black ink pen
- Personal protective clothing and equipment

5.0 DETERMINATION OF BACKGROUND

As set forth in the HASP (health and safety plan monitoring and action levels) and for the selection of soil sample intervals, background radiation levels for various media will be established prior to soil sampling. Because radiation levels vary based on composition of the media and multimedia that will effect radiation measurements at the site, the following background radiation levels will be developed initially at the site.

- Unconsolidated soil
- Bedrock

Additional media may be added as it is encountered in the field. Background of these media will be established using the following procedure.

1. Ensure each instrument is functioning properly and source check readings are acceptable per requirements of Ameriphysics SOP RCP-4.3, *Survey Instrument Procedure* prior to instrument use each day.
2. Demarcate background radiation SAMPLE AREA for each media with wooden Stakes. Minimum requirements for the background SAMPLE AREA is as follows:
   a. 20 square feet of surface area
   b. made up of 80% intended media
   c. area does not consist of imported fill or debris
   d. area has no history of RIM
3. Obtain and Record GPS coordinates of SAMPLE AREA
4. Using appropriate radiation instrument (Micro R Meter Model 19, Dual Phosphor Alpha/Beta Detector Model 43-93) collect 10 gamma, alpha, and beta measurement about 0.5 to 1 inch above the media, equally distributed throughout the SAMPLE AREA. Measurement count times will be determined by the Radiation Controls Supervisor.

5. Record the ten radiation measurements in log book along with a map/GPS coordinates for each measurement, as appropriate.
6. Once the background survey is completed, source response checks shall be performed for each instrument used to ensure the instruments have been functioning properly throughout the survey.
7. Discuss readings with site Radiation Controls Supervisor for review and receive approval of background radiation levels.
8. The Radiation Controls Supervisor will provide approved background radiation levels for the media to Trihydro and its subcontractors. This will include background levels, mean, and standard deviation.
9. The SHSO will record the Radiation Controls Supervisor's recommendations and discuss the background action level with all field personnel as part of safety briefings.
10. Following establishment of, and periodical renewal of background readings throughout project, background radiation levels will be discussed during project meetings and daily tailgate safety meetings.

6.0 PROCEDURES

6.1 MicroR Detector

Instrument Daily Response Check for Gamma Scan

1. Ensure each instrument is functioning properly and source check readings are acceptable per requirements of Ameriphysics SOP RCP-4.3, *Survey Instrument Procedure* prior to instrument use each day.

Surface Soils and Soil Sample Gamma Scan

1. Beginning at the highest scale, proceed to lower scales until a reading is encountered (setting the instrument selector switch to the most sensitive range of the instrument). Holding the probe approximately 1 inch from the surface soil sample, move the detector slowly (about 1 inch per second) over the core and/or sample being evaluated.
2. Do not let the probe touch anything and try to maintain a constant distance.
3. Record the measurements in log book along with a map/GPS coordinates for each measurement, as appropriate.
4. Areas that register more than background levels may be considered contaminated and the Radiation Controls Supervisor should be consulted.
5. Once the survey is completed, post survey response checks shall be performed for each instrument used to ensure the instruments have been functioning properly throughout the survey.

6.2 Dual Phosphor Alpha/Beta Scintillation Detector

Instrument Daily Response Check for Alpha/Beta Scan

1. Ensure each instrument is functioning properly and source check readings are acceptable per requirements of Ameriphysics SOP RCP-4.3, *Survey Instrument Procedure* prior to instrument use each day.

Soils and Soil Sample Alpha/Beta Scan

1. Set the instrument selector switch to the most sensitive range of the instrument.
2. Holding the probe approximately 0.5 or less from the sample and move the probe slowly (about 1 inch per second). (Note: Alpha emissions are reliably detectable only with the detector as close as practicable to the item being surveyed.
3. Do not let the probe touch anything and try to maintain a constant distance.
4. At the ten locations of the highest gamma readings, scan 1-2 meters around each location and obtain a 1-minute field measurement at the highest location in each scan area. Additional readings may be taken based on the discretion of the technician.
5. Record the measurements in log book along with a map/GPS coordinates for each measurement, as appropriate.
6. Areas that register more than background level may be considered contaminated and the Radiation Controls Supervisor should be consulted.
7. Once the survey is completed, post response checks shall be performed for each instrument used to ensure the instruments have been functioning properly throughout the survey.

Surface Contamination Scanning

In addition, every sample, piece of equipment, and container of material used at the site and/or that leaves the site will be surveyed and results will be used to document that residual total and removable surface contamination are compliant with criteria contained in 10 CFR 835.

TABLE 1. SURFACE CONTAMINATION VALUES[1] IN DPM/100 CM[2]

Radionuclides	Removable 2, 4	Total (Fixed + Removable) 2, 3
U-nat, U-235, U-238, and associated decay products	1,000[7]	5,000[7]
Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129	20	500
Th-nat, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133	200	1,000
Beta-gamma emitters (nuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above [5]	1,000	5,000
Tritium and STCs [6]	10,000	See Footnote 6

1. The values in this appendix, with the exception noted in footnote 6 below, apply to radioactive contamination deposited on, but not incorporated into the interior or matrix of, the contaminated item. Where surface contamination by both alpha- and beta-gamma-emitting nuclides exists, the limits established for alpha- and beta-gamma-emitting nuclides apply independently.
2. As used in this table, disintegrations per minute (dpm) means the rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.
3. The levels may be averaged over one square meter provided the maximum surface activity in any area of 100 cm^2 is less than three times the value specified. For purposes of averaging, any square meter of surface shall be considered to be above the surface contamination value if: (1) from measurements of a representative number of sections it is determined that the average contamination level exceeds the applicable value; or (2) it is determined that the sum of the activity of all isolated spots or particles in any 100 cm^2 area exceeds three times the applicable value.
4. The amount of removable radioactive material per 100 cm^2 of surface area should be determined by swiping the area with dry filter or soft absorbent paper, applying moderate pressure, and then assessing the amount of radioactive material on the swipe with an appropriate instrument of known efficiency. (Note — The use of dry material may not be appropriate for tritium.) When removable contamination on objects of surface area less than 100 cm^2 is determined, the activity per unit area shall be based on the actual area and the entire surface shall be wiped. It is not necessary to use swiping techniques to measure removable contamination levels if direct scan surveys indicate that the total residual surface contamination levels are within the limits for removable contamination.
5. This category of radionuclides includes mixed fission products, including the Sr-90 which is present in them. It does not apply to Sr-90 which has been separated from the other fission products or mixtures where the Sr-90 has been enriched.
6. Tritium contamination may diffuse into the volume or matrix of materials. Evaluation of Surface contamination shall consider the extent to which such contamination may migrate to the surface in order to ensure the surface contamination value provided in this appendix is not exceeded. Once this contamination migrates to the surface, it may be removable, not fixed; therefore, a “Total” value does not apply. In certain cases, a “Total” value of 10,000 dpm/100 cm^2 may be applicable either to metals, of the types which form insoluble special tritium compounds that have been exposed to tritium; or to bulk materials to which particles of insoluble special tritium compound are fixed to a surface.
7. These limits only apply to the alpha emitters within the respective decay series.

7.0 RESTRICTIONS/LIMITATIONS

Dual Phosphor detectors are principally used for the detection of presence of radionuclides above background and are not used for quantitative measurements. They are prone to breaking if the thin Mylar window is punctured. This can easily occur if the window comes in contact with a variety of objects (such as a blade of grass, paper clip, nail, and paint flecks). Once the window is broken the instrument ceases to operate and must be taken out of service and returned for repair and possibly sent for recalibration.

8.0 REFERENCES

Ameriphysics SOP RCP-4.3, *Survey Instrument Procedure.*

Integrated Environmental Management, Inc., 1998, *Measuring Radioactivity.*

Title 10, Code of Federal Regulations, Part 835, Occupational Radiation Protection.

DOE Order 426.2, Personnel Selection, Training, Qualification, and Certification Requirements for DOE Nuclear Facilities, 21 April 2010.

DOE Standard 1107-97 with Change 1 dated November 2007, Knowledge, Skills, and Abilities for Key Radiation Protection Positions.

Ludlum Measurements, Inc. Operators Manuals for Model 2360 Survey Meter with Model 43-93 Alpha/Beta Scintillator Detector.

Ludlum Measurements, Inc. Operators Manuals for Model 19.

memorandum

To:	Trihydro Employees
From:	OSE
Date:	August 1, 2011
Re:	Standard Operating Procedure – Fluid-Level Measurement

1.0 PURPOSE, SCOPE, AND RESPONSIBILITIES

This standard operating procedure (SOP) is intended to provide methods for taking fluid-level measurements prior to sample collection, and to determine groundwater elevations and hydrocarbon thicknesses for use in hydrogeologic and environmental investigations. Measurements should be made using a water-level meter or oil-water interface probe if free product is suspected or known to be present at the site. This SOP is applicable to Trihydro projects where groundwater samples are collected from monitoring wells and where no project- and program-specific procedure is in place. Detailed safety procedures are included in the site-specific health and safety plan (HASP) and job safety analyses (JSAs). The project manager should be contacted for additional health and safety information.

This SOP is intended for the sole use of Trihydro Corporation and its employees. This SOP cannot be copied or used by others without the express written consent of Trihydro. In Trihydro's sole discretion, this SOP may be modified when field or other conditions warrant.

The Operational and Service Excellence (OSE) Business Unit is responsible for SOP maintenance, management, and revisions. Trihydro employees performing tasks within this SOP are responsible for meeting SOP requirements. For projects where activities within this SOP are necessary, the project manager (or designee) is responsible for ensuring that those activities are conducted in accordance with this and other SOPs. Project team members are responsible for documenting procedural information in sufficient detail (i.e., calculations, field notes, reports, etc.) and reporting these changes to OSE. Such documentation will be included as a component of project records.

2.0 PLANNING AND PROCEDURES

Several tasks should be conducted prior to and during fluid-level measurement activities.

2.1 Office Preparation

The following task should be performed in the office and field prior to measuring fluid levels.

- Review available background information (i.e., geologic maps, hydrogeologic maps, previous fluid-level data, and site-specific planning documents) to determine the extent of the measurement effort and the type of fluid-level measurement equipment and supplies required. Previous fluid-level measurements can be extremely helpful in identifying wells that may contain free product and in determining the length of the measurement device required at the site.

- Determine previous fluid-level depths for each well to be sampled in order to have a basis for determining change since the last measurement event. For example, if the groundwater level measured in a well has increased by 2 feet since the last recorded level and all other water depths on site have increased by 2 feet, there is a good chance that the field technician made an error in reading the water-level tape, in which case the measurement should be repeated to confirm the potentially erroneous reading.
- Obtain necessary fluid-level measurement equipment; ensure that equipment is in proper working condition. Ensure that batteries are fresh or that additional batteries are taken in the field, if needed.
- Prepare a field schedule and discuss responsibilities with associated field personnel, the client, and/or regulatory agencies, if applicable.
- If using a dedicated field form for recording fluid levels (other than a site logbook or other water sampling form), complete as much of the fluid-level form as possible prior to commencing field activities.

2.2 Field Preparation

Once in the field, the following pre-sampling tasks should be completed:

1. At the start of the sampling event, visit all wells to be sampled to determine if they are fitted with air-tight compression caps. Document those wells that do have compression caps for future use.
2. Open each well and loosen or remove the compression cap (if present), which will allow for venting in cases where static water levels are higher than screened intervals, so that accurate water levels can be obtained. (If potentially harmful vapors exceed action levels, move away from the well. The project-specific HASP includes action levels and the associated amount of time to stay a safe distance away while the well off-gases.)
3. Inspect and decontaminate all necessary sampling equipment.

2.3 Equipment

The following equipment is recommended for obtaining fluid-level measurements. Fluid-level measurement equipment will be based on specific site data requirements, accessibility, well construction, and depth to water. A suggested base equipment list for groundwater sampling activities is included below.

- Fluid-level meters: electronic water-level meter or oil/water interface probe
- Well keys

- Bolt cutters and spare locks
- 4-gas monitor
- Logbook
- Fluid-level data sheets
- Required personal protective equipment (PPE), listed in site-specific HASP
- Spare batteries
- Decontamination solutions: distilled water (DI) and non-phosphate detergent (Alconox, Liqui-Nox, Simple Green, or similar).
- Brushes, buckets, and physical decontamination supplies
- Calculator
- Wrist watch (with digital display)

The procedures for fluid-level measurements vary, depending upon the type of equipment used (electronic water-level meter or oil/water interface probe). Specific procedures for operating different pieces of equipment should be obtained from the individual equipment operation manuals provided by the manufacturer or rental company. The procedures for measuring fluid levels using an electronic water-level meter or an oil/water interface probe are described in Sections 2.4 and 2.5, respectively.

2.4 Electronic Water-Level Meter Procedure

The following steps describe a generalized procedure for measuring fluid levels in wells using an electronic water-level meter. Refer to manufacturer recommendations for specific equipment setup and operational procedures.

1. Decontaminate equipment.
2. Start water-level measurements at the least contaminated or up-gradient well, if known.
3. Unlock, open, and screen the well for organic vapors/LEL using a 4-gas meter, or other appropriate monitoring devices as specified in the HASP. (Note: Wells should be unlocked and opened before attempting to measure a fluid level if the well casing is fitted with an air-tight compression cap). If potentially harmful vapors exceed action levels, move away from the well. The project-specific HASP includes action levels and the associated amount of time to stay a safe distance away while the well off-gases.)
4. Check the water-level meter alarm button to ensure the meter will sound properly, and make sure the bottom of the probe is free of debris.
5. Lower the water-level probe slowly into the well until the meter sounds.

6. Once the probe is situated at the level where the water-level meter sounds, indicating the presence of water, raise and lower the probe across the fluid-level interval several times to check that the depth reading can be continuously repeated.
7. Note the measurement on the tape when the meter sounds. Fluid-level depth measurements should be recorded to 0.01-foot accuracy. (The measurement point should be marked where the well casing was surveyed. If the casing survey point is not marked, use the north side of the innermost well casing that is reachable.)
8. Remove the probe from the well.
9. Mark the fluid-level measurement reading in a logbook or on a field data sheet along with any notes, such as the measurement point on the well casing, if no survey mark was noted.
10. Replace well cap and lock well.
11. Decontaminate the tape.

4.0 GLOSSARY: ACRONYMS, ABBREVIATIONS, AND DEFINITIONS

HASP - Health and Safety Plan: includes a complete list of project personal protective equipment requirements, evacuation routes, medical services, and other pertinent health and safety information

OSE - Operational and Service Excellence Business Unit: Trihydro's designated authority for facilitating standard operating procedure reviews

PID - Photoionization Detector: a type of gas detector used to measure volatile organic compounds

PPE - Personal Protective Equipment: minimum-required site-safety equipment; a full list is included in the site-specific HASP

SOP - Standard Operating Procedure: procedure to be followed when performing a routine task

5.0 REFERENCES

U.S. Army Corps of Engineers. 2001. Requirements for the Preparation of Sampling and Analysis Plans, Appendix C, Section C.2, EM200-1-3. Washington, DC.

U.S. Environmental Protection Agency. 2011. Terms of Environment. Available from: (http://www.epa.gov/OCEPATERMS/).

U.S. Environmental Protection Agency. 2007. Guidance for Preparing Standard Operating Procedures. EPA QA/G-6. Accessed April 1, 2011. Available from: (http://www.epa.gov/quality/qs-docs/g6-final.pdf).

Trihydro CORPORATION

memorandum

To:	Trihydro Employees
From:	Jim Vanderweide and Brian Robeson
Date:	June 4, 2019
Re:	Standard Operating Procedure – GPS Use for Field-Data Collection

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1.0 INTRODUCTION

The purpose of this Standard Operating Procedure (SOP) is to establish procedures for global-positioning system (GPS) use for field-data collection.

2.0 PROCEDURES

The procedures for collecting GPS data using the two most-common software programs are described below.

2.1 Field Work – TerraSync Software

TerraSync will run on any tablet or handheld device with the following operating systems:

- Windows XP
- Windows Vista
- Windows 7
- Windows 8
- Windows Mobile 5.0 or later
- Windows Embedded Handheld 6.5 Professional

[TerraSync Software Mapping and GIS (Trimble 2014)]

Start of Fieldwork

1. Turn on the GPS unit.
2. Open TerraSync by tapping the GNSS button on the lower-right part of the screen.
3. Connect to the GPS antenna by tapping the GNSS button on the upper-right portion of the Setup Page.

Data Capture

1. Change to the **Data Page** and create a new file using an appropriate data dictionary. TerraSync will default to the most-recently used data dictionary.
2. The **Create** sub-page contains a list of features available to map. Select a feature from the list and tap **Create**.
3. Enter the attributes for the feature and record the location by tapping **Log**. Tapping **Done** stores the feature and returns you to the list of available features.
4. Switch to the **Map Page** to see the newly created feature as confirmation of successful data collection.

Map Use

1. Select the **Map Page** to view the map.
2. To change what data are displayed, tap the **Layers** button followed by **Background Layers**. Use the check boxes to turn layers on/off.
3. Map-interaction tools (pan, zoom, select, measure) are available from the drop-down menu below Map.
4. Navigation targets are set by tapping on a feature and then tapping **Options**>**Set Nav Target**. Switch to the **Navigation Page** to navigate.

Navigation

1. Set the navigation target on the **Map** or **Data** pages.
2. Switch to the **Navigation Page**.
3. Follow the arrow to your location (straight line direction).

End of Fieldwork

1. Close the data file.
2. Disconnect from the GPS antenna.
3. Exit TerraSync.
4. Turn off the GPS unit.

2.2 Office Work – TerraSync Software

Transfer GPS data to the appropriate project folder on the M:\ drive and notify the GIS Team so it can be moved to the GIS\GPSData folder.

Required Software

- Windows Mobile Device Center (only if running Windows 7 on your office computer and Windows Mobile or Windows Embedded on the field device)
  - http://www.microsoft.com/en-us/download/details.aspx?id=3182
- Trimble Data-Transfer Utility
  - http://www.trimble.com/datatransfer.shtml
  - Do not install land survey devices!
  - The Data-Transfer Utility is part of Pathfinder Office, so there is no need to install if Pathfinder is already installed.

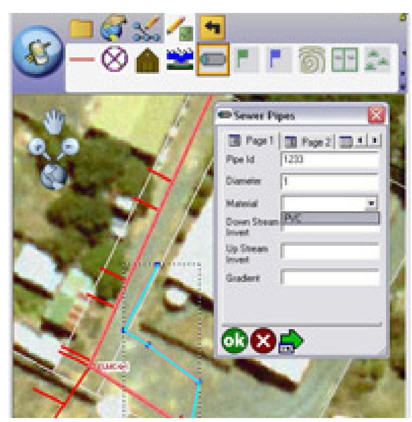
Data Transfer

1. Connect the USB cable to the GPS and computer.
2. Windows Mobile Device Center will launch automatically.
   a. Choose **Connect without setting up your device**.
3. Open the **Data-Transfer Utility** from the Start>All Programs menu or from within Pathfinder Office.
   a. The device will need to be **GIS Datalogger on Windows Mobile**.
   b. Choose to **Receive** data from the GPS.
   c. **Add** data file.
   d. The data files that have not been transferred will be highlighted.
   e. Select a destination for the files and click **OK**.
   f. Click **Transfer All** to receive data from the GPS.

2.3 Fieldwork – ArcPad Software

ArcPad will run on any tablet or handheld device with the following operating systems:

- Windows XP
- Windows Vista
- Windows 7
- Windows 8
- Windows Mobile 5.0 or later



ArcPad Data Collection Software (esri 2014)

Start of Fieldwork

1. Turn on the device.
2. Open your ArcPad project-specific map by tapping the **ArcPad** shortcut icon on the desktop.
3. Connect to the GPS antenna by tapping the **GPS Active** icon on the **Main Tools** tab.

Data Capture

1. Change to the **Quick Capture** tab.
2. The **Quick Capture** tab contains a list of features available to map. Select a feature from the list to open the attribute form begin recording the location.
3. Enter the attributes for the feature. Tapping **OK** stores the feature and returns you to the list of available features.
4. The new feature appears on the map.

Map Use

1. Select the **Browse Tools** tab to interact with the map.
2. Many map-interaction tools (pan, zoom, select, measure, identify) are available.

Navigation

1. From the **Browse Tools** tab, tap the drop-down menu below **Identify**.
2. Choose **Go To**.
3. Tap the map to select a navigation destination.
4. The destination is displayed with a Mark label.
5. Use the **GPS Position Window** (**Main Tools** tab) to view the Distance and Bearing from your current location to your selected destination.
6. To clear the selected destination, tap the Clear Selected tool on the **Browse Tools** tab.

End of Fieldwork

1. **Save** the map (**Main Tools** tab).
2. Disconnect from the GPS antenna.
3. Exit ArcPad.
4. Turn off the device.

2.4 Office Work – ArcPad Software

Transfer GPS data to the appropriate project folder on the M:\ drive and notify the Geospatial Information Systems (GIS) Team so it can be moved to the GIS\GPSData folder.

Required Software

- Windows Mobile Device Center (only if running Windows 7 on your office computer and Windows Mobile on the field device)
  - http://www.microsoft.com/en-us/download/details.aspx?id=3182

Data Transfer

1. Connect the USB cable to the GPS and computer. Alternatively, connect via Wi-Fi or Bluetooth.
2. Windows Mobile Device Center will launch automatically.
   a. Choose **Connect without setting up your device**.
3. Open Windows Explorer
   a. Browse to your field-data collection folder (C:\<your project name>)
   b. Copy the entire folder.
   c. Paste the entire folder in the appropriate project folder on the M:\ drive.

U.S. ENVIRONMENTAL PROTECTION AGENCY
REGION I

LOW STRESS (low flow) PURGING AND SAMPLING PROCEDURE FOR THE COLLECTION OF GROUNDWATER SAMPLES FROM MONITORING WELLS

Quality Assurance Unit
U.S. Environmental Protection Agency – Region 1
11 Technology Drive
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The controlled version of this document is the electronic version viewed on-line only. If this is a printed copy of the document, it is an uncontrolled version and may or may not be the version currently in use.

Prepared by: Charles Porfert 1/19/10
(Charles Porfert, Quality Assurance Unit) Date

Approved by: Gerard Sotolongo 1-19-10
(Gerard Sotolongo, Quality Assurance Unit) Date

Revision Page

Date	Rev #	Summary of changes	Sections
7/30/96	2	Finalized	
01/19/10	3	Updated	All sections

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USE OF TERMS

Equipment blank: The equipment blank shall include the pump and the pump's tubing. If tubing is dedicated to the well, the equipment blank needs only to include the pump in subsequent sampling rounds. If the pump and tubing are dedicated to the well, the equipment blank is collected prior to its placement in the well. If the pump and tubing will be used to sample multiple wells, the equipment blank is normally collected after sampling from contaminated wells and not after background wells.

Field duplicates: Field duplicates are collected to determine precision of the sampling procedure. For this procedure, collect duplicate for each analyte group in consecutive order (VOC original, VOC duplicate, SVOC original, SVOC duplicate, etc.).

Indicator field parameters: This SOP uses field measurements of turbidity, dissolved oxygen, specific conductance, temperature, pH, and oxidation/reduction potential (ORP) as indicators of when purging operations are sufficient and sample collection may begin.

Matrix Spike/Matrix Spike Duplicates: Used by the laboratory in its quality assurance program. Consult the laboratory for the sample volume to be collected.

Poteniometric Surface: The level to which water rises in a tightly cased well constructed in a confined aquifer. In an unconfined aquifer, the potentiometric surface is the water table.

QAPP: Quality Assurance Project Plan

SAP: Sampling and Analysis Plan

SOP: Standard operating procedure

Stabilization: A condition that is achieved when all indicator field parameter measurements are sufficiently stable (as described in the "Monitoring Indicator Field Parameters" section) to allow sample collection to begin.

Temperature blank: A temperature blank is added to each sample cooler. The blank is measured upon receipt at the laboratory to assess whether the samples were properly cooled during transit.

Trip blank (VOCs): Trip blank is a sample of analyte-free water taken to the sampling site and returned to the laboratory. The trip blanks (one pair) are added to each sample cooler that contains VOC samples.

SCOPE & APPLICATION

The goal of this groundwater sampling procedure is to collect water samples that reflect the total mobile organic and inorganic loads (dissolved and colloidal sized fractions) transported through the subsurface under ambient flow conditions, with minimal physical and chemical alterations from sampling operations. This standard operating procedure (SOP) for collecting groundwater samples will help ensure that the project's data quality objectives (DQOs) are met under certain low-flow conditions.

The SOP emphasizes the need to minimize hydraulic stress at the well-aquifer interface by maintaining low water-level drawdowns, and by using low pumping rates during purging and sampling operations. Indicator field parameters (e.g., dissolved oxygen, pH, etc.) are monitored during purging in order to determine when sample collection may begin. Samples properly collected using this SOP are suitable for analysis of groundwater contaminants (volatile and semi-volatile organic analytes, dissolved gases, pesticides, PCBs, metals and other inorganics), or naturally occurring analytes. This SOP is based on Puls, and Barcelona (1996).

This procedure is designed for monitoring wells with an inside diameter (1.5-inches or greater) that can accommodate a positive lift pump with a screen length or open interval ten feet or less and with a water level above the top of the screen or open interval (Hereafter, the "screen or open interval" will be referred to only as "screen interval"). This SOP is not applicable to other well-sampling conditions.

While the use of dedicated sampling equipment is not mandatory, dedicated pumps and tubing can reduce sampling costs significantly by streamlining sampling activities and thereby reducing the overall field costs.

The goal of this procedure is to emphasize the need for consistency in deploying and operating equipment while purging and sampling monitoring wells during each sampling event. This will help to minimize sampling variability.

This procedure describes a general framework for groundwater sampling. Other site specific information (hydrogeological context, conceptual site model (CSM), DQOs, etc.) coupled with systematic planning must be added to the procedure in order to develop an appropriate site specific SAP/QAPP. In addition, the site specific SAP/QAPP must identify the specific equipment that will be used to collect the groundwater samples.

This procedure does not address the collection of water or free product samples from wells containing free phase LNAPLs and/or DNAPLs (light or dense non-aqueous phase liquids). For this type of situation, the reader may wish to check: Cohen, and Mercer (1993) or other pertinent documents.

This SOP is to be used when collecting groundwater samples from monitoring wells at all Superfund, Federal Facility and RCRA sites in Region 1 under the conditions described herein. Request for modification of this SOP, in order to better address specific situations at individual wells, must include adequate technical justification for proposed changes. <u>All changes and modifications must be approved and included in a revised SAP/QAPP before implementation in field.</u>

BACKGROUND FOR IMPLEMENTATION

It is expected that the monitoring well screen has been properly located (both laterally and vertically) to intercept existing contaminant plume(s) or along flow paths of potential contaminant migration. Problems with inappropriate monitoring well placement or faulty/improper well installation cannot be overcome by even the best water sampling procedures. This SOP presumes that the analytes of interest are moving (or will potentially move) primarily through the more permeable zones intercepted by the screen interval.

Proper well construction, development, and operation and maintenance cannot be overemphasized. The use of installation techniques that are appropriate to the hydrogeologic setting of the site often prevent "problem well" situations from occurring. During well development, or redevelopment, tests should be conducted to determine the hydraulic characteristics of the monitoring well. The data can then be used to set the purging/sampling rate, and provide a baseline for evaluating changes in well performance and the potential need for well rehabilitation. Note: if this installation data or well history (construction and sampling) is not available or discoverable, for all wells to be sampled, efforts to build a sampling history should commence with the next sampling event.

The pump intake should be located within the screen interval and at a depth that will remain under water at all times. It is recommended that the intake depth and pumping rate remain the same for all sampling events. The mid-point or the lowest historical midpoint of the saturated screen length is often used as the location of the pump intake. For new wells, or for wells without pump intake depth information, the site's SAP/QAPP must provide clear reasons and instructions on how the pump intake depth(s) will be selected, and reason(s) for the depth(s) selected. If the depths to top and bottom of the well screen are not known, the SAP/QAPP will need to describe how the sampling depth will be determined and how the data can be used.

Stabilization of indicator field parameters is used to indicate that conditions are suitable for sampling to begin. Achievement of turbidity levels of less than 5 NTU, and stable drawdowns of less than 0.3 feet, while desirable, are not mandatory. Sample collection may still take place provided the indicator field parameter criteria in this procedure are met. If after 2 hours of purging indicator field parameters have not stabilized, one of three optional courses of action may be taken: a) continue purging until stabilization is achieved, b) discontinue purging, do not collect any samples, and record in log book that stabilization could not be achieved (documentation must describe attempts to achieve stabilization), c) discontinue purging, collect samples and provide full explanation of attempts to achieve stabilization (note: there is a risk that the analytical data obtained, especially metals and strongly hydrophobic organic analytes, may reflect a sampling bias and therefore, the data may not meet the data quality objectives of the sampling event).

It is recommended that low-flow sampling be conducted when the air temperature is above 32°F (0°C). If the procedure is used below 32°F, special precautions will need to be taken to prevent the groundwater from freezing in the equipment. Because sampling during freezing temperatures may adversely impact the data quality objectives, the need for water sample collection during months when these conditions are likely to occur should be evaluated during site planning and special sampling measures may need to be developed. Ice formation in the flow-through-cell will cause the monitoring probes to act erratically. A transparent flow-through-cell needs to be used to observe if ice is forming in the cell. If ice starts to form on the other pieces of the sampling equipment, additional problems may occur.

HEALTH & SAFETY

When working on-site, comply with all applicable OSHA requirements and the site's health/safety procedures. All proper personal protection clothing and equipment are to be worn. Some samples may contain biological and chemical hazards. These samples should be handled with suitable protection to skin, eyes, etc.

CAUTIONS

The following cautions need to be considered when planning to collect groundwater samples when the below conditions occur.

If the groundwater degasses during purging of the monitoring well, dissolved gases and VOCs will be lost. When this happens, the groundwater data for dissolved gases (e.g., methane, ethene, ethane, dissolved oxygen, etc.) and VOCs will need to be qualified. Some conditions that can promote degassing are the use of a vacuum pump (e.g., peristaltic pumps), changes in aperture along the sampling tubing, and squeezing/pinching the pump's tubing which results in a pressure change.

When collecting the samples for dissolved gases and VOCs analyses, avoid aerating the groundwater in the pump's tubing. This can cause loss of the dissolved gases and VOCs in the groundwater. Having the pump's tubing completely filled prior to sampling will avoid this problem when using a centrifugal pump or peristaltic pump.

Direct sun light and hot ambient air temperatures may cause the groundwater in the tubing and flow-through-cell to heat up. This may cause the groundwater to degas which will result in loss of VOCs and dissolved gases. When sampling under these conditions, the sampler will need to shade the equipment from the sunlight (e.g., umbrella, tent, etc.). If possible, sampling on hot days, or during the hottest time of the day, should be avoided. The tubing exiting the monitoring well should be kept as short as possible to avoid the sun light or ambient air from heating up the groundwater.

Thermal currents in the monitoring well may cause vertical mixing of water in the well bore. When the air temperature is colder than the groundwater temperature, it can cool the top of the water column. Colder water which is denser than warm water sinks to the bottom of the well and the warmer water at the bottom of the well rises, setting up a convention cell. "During low-flow sampling, the pumped water may be a mixture of convecting water from within the well casing and aquifer water moving inward through the screen. This mixing of water during low-flow sampling can substantially increase equilibration times, can cause false stabilization of indicator parameters, can give false indication of redox state, and can provide biological data that are not representative of the aquifer conditions" (Vroblesky 2007).

Failure to calibrate or perform proper maintenance on the sampling equipment and measurement instruments (e.g., dissolved oxygen meter, etc.) can result in faulty data being collected.

Interferences may result from using contaminated equipment, cleaning materials, sample containers, or uncontrolled ambient/surrounding air conditions (e.g., truck/vehicle exhaust nearby).

Cross contamination problems can be eliminated or minimized through the use of dedicated sampling equipment and/or proper planning to avoid ambient air interferences. Note that the use of dedicated sampling equipment can also significantly reduce the time needed to complete each sampling event, will promote consistency in the sampling, and may reduce sampling bias by having the pump's intake at a constant depth.

Clean and decontaminate all sampling equipment prior to use. All sampling equipment needs to be routinely checked to be free from contaminants and equipment blanks collected to ensure that the equipment is free of contaminants. Check the previous equipment blank data for the site (if they exist) to determine if the previous cleaning procedure removed the contaminants. If contaminants were detected and they are a concern, then a more vigorous cleaning procedure will be needed.

PERSONNEL QUALIFICATIONS

All field samplers working at sites containing hazardous waste must meet the requirements of the OSHA regulations. OSHA regulations may require the sampler to take the 40 hour OSHA health and safety training course and a refresher course prior to engaging in any field activities, depending upon the site and field conditions.

The field samplers must be trained prior to the use of the sampling equipment, field instruments, and procedures. Training is to be conducted by an experienced sampler before initiating any sampling procedure.

The entire sampling team needs to read, and be familiar with, the site Health and Safety Plan, all relevant SOPs, and SAP/QAPP (and the most recent amendments) before going onsite for the sampling event. It is recommended that the field sampling leader attest to the understanding of these site documents and that it is recorded.

EQUIPMENT AND SUPPLIES

A. Informational materials for sampling event

A copy of the current Health and Safety Plan, SAP/QAPP, monitoring well construction data, location map(s), field data from last sampling event, manuals for sampling, and the monitoring instruments' operation, maintenance, and calibration manuals should be brought to the site.

B. Well keys.

C. Extraction device

Adjustable rate, submersible pumps (e.g., centrifugal, bladder, etc.) which are constructed of stainless steel or Teflon are preferred. Note: if extraction devices constructed of other materials are to be used, adequate information must be provided to show that the substituted materials do not leach contaminants nor cause interferences to the analytical procedures to be used. Acceptance of these materials must be obtained before the sampling event.

If bladder pumps are selected for the collection of VOCs and dissolved gases, the pump setting should be set so that one pulse will deliver a water volume that is sufficient to fill a 40 mL VOC vial. This is not mandatory, but is considered a "best practice". For the proper operation, the bladder pump will need a minimum amount of water above the pump; consult the manufacturer for the recommended submergence. The pump's recommended submergence value should be determined during the planning stage, since it may influence well construction and placement of dedicated pumps where water-level fluctuations are significant.

Adjustable rate, peristaltic pumps (suction) are to be used with caution when collecting samples for VOCs and dissolved gases (e.g., methane, carbon dioxide, etc.) analyses. Additional information on the use of peristaltic pumps can be found in Appendix A. If peristaltic pumps are used, the inside diameter of the rotor head tubing needs to match the inside diameter of the tubing installed in the monitoring well.

Inertial pumping devices (motor driven or manual) are not recommended. These devices frequently cause greater disturbance during purging and sampling, and are less easily controlled than submersible pumps (potentially increasing turbidity and sampling variability, etc.). This can lead to sampling results that are adversely affected by purging and sampling operations, and a higher degree of data variability.

D. Tubing

Teflon or Teflon-lined polyethylene tubing are preferred when sampling is to include VOCs, SVOCs, pesticides, PCBs and inorganics. Note: if tubing constructed of other materials is to be used, adequate information must be provided to show that the substituted materials do not leach contaminants nor cause interferences to the analytical procedures to be used. Acceptance of these materials must be obtained before the sampling event.

PVC, polypropylene or polyethylene tubing may be used when collecting samples for metal and other inorganics analyses.

The use of 1/4 inch or 3/8 inch (inside diameter) tubing is recommended. This will help ensure that the tubing remains liquid filled when operating at very low pumping rates when using centrifugal and peristaltic pumps.

Silastic tubing should be used for the section around the rotor head of a peristaltic pump. It should be less than a foot in length. The inside diameter of the tubing used at the pump rotor head must be the same as the inside diameter of tubing placed in the well. A tubing connector is used to connect the pump rotor head tubing to the well tubing. Alternatively, the two pieces of tubing can be connected to each other by placing the one end of the tubing inside the end of the other tubing. The tubing must not be reused.

E. The water level measuring device

Electronic "tape", pressure transducer, water level sounder/level indicator, etc. should be capable of measuring to 0.01 foot accuracy. Recording pressure transducers, mounted above the pump, are especially helpful in tracking water levels during pumping operations, but their use must include check measurements with a water level "tape" at the start and end of each sampling event.

F. Flow measurement supplies

Graduated cylinder (size according to flow rate) and stopwatch usually will suffice.

Large graduated bucket used to record total water purged from the well.

G. Interface probe

To be used to check on the presence of free phase liquids (LNAPL, or DNAPL) before purging begins (as needed).

H. Power source (generator, nitrogen tank, battery, etc.)

When a gasoline generator is used, locate it downwind and at least 30 feet from the well so that the exhaust fumes do not contaminate samples.

I. Indicator field parameter monitoring instruments

Use of a multi-parameter instrument capable of measuring pH, oxidation/reduction potential (ORP), dissolved oxygen (DO), specific conductance, temperature, and coupled with a flow-through-cell is required when measuring all indicator field parameters, except turbidity. Turbidity is collected using a separate instrument. Record equipment/instrument identification (manufacturer, and model number).

Transparent, small volume flow-through-cells (e.g., 250 mLs or less) are preferred. This allows observation of air bubbles and sediment buildup in the cell, which can interfere with the operation of the monitoring instrument probes, to be easily detected. A small volume cell facilitates rapid turnover of water in the cell between measurements of the indicator field parameters.

It is recommended to use a flow-through-cell and monitoring probes from the same manufacturer and model to avoid incompatibility between the probes and flow-through-cell.

Turbidity samples are collected before the flow-through-cell. A "T" connector coupled with a valve is connected between the pump's tubing and flow-through-cell. When a turbidity measurement is required, the valve is opened to allow the groundwater to flow into a container. The valve is closed and the container sample is then placed in the turbidimeter.

Standards are necessary to perform field calibration of instruments. A minimum of two standards are needed to bracket the instrument measurement range for all parameters except ORP which use a Zobell solution as a standard. For dissolved oxygen, a wet sponge used for the 100% saturation and a zero dissolved oxygen solution are used for the calibration.

Barometer (used in the calibration of the Dissolved Oxygen probe) and the conversion formula to convert the barometric pressure into the units of measure used by the Dissolved Oxygen meter are needed.

J. Decontamination supplies

Includes (for example) non-phosphate detergent, distilled/deionized water, isopropyl alcohol, etc.

K. Record keeping supplies

Logbook(s), well purging forms, chain-of-custody forms, field instrument calibration forms, etc.

L. Sample bottles

M. Sample preservation supplies (as required by the analytical methods)

N. Sample tags or labels

O. PID or FID instrument

If appropriate, to detect VOCs for health and safety purposes, and provide qualitative field evaluations.

P. Miscellaneous Equipment

Equipment to keep the sampling apparatus shaded in the summer (e.g., umbrella) and from freezing in the winter. If the pump's tubing is allowed to heat up in the warm weather, the cold groundwater may degas as it is warmed in the tubing.

EQUIPMENT/INSTRUMENT CALIBRATION

Prior to the sampling event, perform maintenance checks on the equipment and instruments according to the manufacturer's manual and/or applicable SOP. This will ensure that the equipment/instruments are working properly before they are used in the field.

Prior to sampling, the monitoring instruments must be calibrated and the calibration documented. The instruments are calibrated using U.S Environmental Protection Agency Region 1 *Calibration of Field Instruments (temperature, pH, dissolved oxygen, conductivity/specific conductance, oxidation/reduction [ORP], and turbidity),* January 19, 2010, or latest version or from one of the methods listed in 40CFR136, 40CFR141 and SW-846.

The instruments shall be calibrated at the beginning of each day. If the field measurement falls outside the calibration range, the instrument must be re-calibrated so that all measurements fall within the calibration range. At the end of each day, a calibration check is performed to verify that instruments remained in calibration throughout the day. This check is performed while the instrument is in measurement mode, not calibration mode. If the field instruments are being used to monitor the natural attenuation parameters, then a calibration check at mid-day is highly recommended to ensure that the instruments did not drift out of calibration. Note: during the day if the instrument reads zero or a negative number for dissolved oxygen, pH, specific conductance, or turbidity (negative value only), this indicates that the instrument drifted out of calibration or the instrument is malfunctioning. If this situation occurs the data from this instrument will need to be qualified or rejected.

PRELIMINARY SITE ACTIVITIES (as applicable)

Check the well for security (damage, evidence of tampering, missing lock, etc.) and record pertinent observations (include photograph as warranted).

If needed lay out sheet of clean polyethylene for monitoring and sampling equipment, unless equipment is elevated above the ground (e.g., on a table, etc.).

Remove well cap and if appropriate measure VOCs at the rim of the well with a PID or FID instrument and record reading in field logbook or on the well purge form.

If the well casing does not have an established reference point (usually a V-cut or indelible mark in the well casing), make one. Describe its location and record the date of the mark in the logbook (consider a photographic record as well). All water level measurements must be recorded relative to this reference point (and the altitude of this point should be determined using techniques that are appropriate to site's DQOs.

If water-table or potentiometric surface map(s) are to be constructed for the sampling event, perform synoptic water level measurement round (in the shortest possible time) before any purging and sampling activities begin. If possible, measure water level depth (to 0.01 ft.) and total well depth (to 0.1 ft.) the day before sampling begins, in order to allow for re-settlement of any particulates in the water column. This is especially important for those wells that have not been recently sampled because sediment buildup in the well may require the well to be redeveloped. If measurement of total well depth is not made the day before, it should be measured after sampling of the well is complete. All measurements must be taken from the established referenced point. Care should be taken to minimize water column disturbance.

Check newly constructed wells for the presence of LNAPLs or DNAPLs before the initial sampling round. If none are encountered, subsequent check measurements with an interface probe may not be necessary unless analytical data or field analysis signal a worsening situation. This SOP cannot be used in the presence of LNAPLs or DNAPLs. If NAPLs are present, the project team must decide upon an alternate sampling method. All project modifications must be approved and documented prior to implementation.

If available check intake depth and drawdown information from previous sampling event(s) for each well. Duplicate, to the extent practicable, the intake depth and extraction rate (use final pump dial setting information) from previous event(s). If changes are made in the intake depth or extraction rate(s) used during previous sampling event(s), for either portable or dedicated extraction devices, record new values, and explain reasons for the changes in the field logbook.

PURGING AND SAMPLING PROCEDURE

Purging and sampling wells in order of increasing chemical concentrations (known or anticipated) are preferred.

The use of dedicated pumps is recommended to minimize artificial mobilization and entrainment of particulates each time the well is sampled. Note that the use of dedicated sampling equipment can also significantly reduce the time needed to complete each sampling event, will promote consistency in the sampling, and may reduce sampling bias by having the pump's intake at a constant depth.

A. Initial Water Level

Measure the water level in the well before installing the pump if a non-dedicated pump is being used. The initial water level is recorded on the purge form or in the field logbook.

B. Install Pump

Lower pump, safety cable, tubing and electrical lines slowly (to minimize disturbance) into the well to the appropriate depth (may not be the mid-point of the screen/open interval). The Sampling and Analysis Plan/Quality Assurance Project Plan should specify the sampling depth (used previously), or provide criteria for selection of intake depth for each new well. If possible keep the pump intake at least two feet above the bottom of the well, to minimize mobilization of particulates present in the bottom of the well.

Pump tubing lengths, above the top of well casing should be kept as short as possible to minimize heating the groundwater in the tubing by exposure to sun light and ambient air temperatures. Heating may cause the groundwater to degas, which is unacceptable for the collection of samples for VOC and dissolved gases analyses.

C. Measure Water Level

Before starting pump, measure water level. Install recording pressure transducer, if used to track drawdowns, to initialize starting condition.

D. Purge Well

From the time the pump starts purging and until the time the samples are collected, the purged water is discharged into a graduated bucket to determine the total volume of groundwater purged. This information is recorded on the purge form or in the field logbook.

Start the pump at low speed and slowly increase the speed until discharge occurs. Check water level. Check equipment for water leaks and if present fix or replace the affected equipment. Try to match pumping rate used during previous sampling event(s). Otherwise, adjust pump speed until there is little or no water level drawdown. If the minimal drawdown that can be achieved exceeds 0.3 feet, but remains stable, continue purging.

Monitor and record the water level and pumping rate every five minutes (or as appropriate) during purging. Record any pumping rate adjustments (both time and flow rate). Pumping rates should, as needed, be reduced to the minimum capabilities of the pump to ensure stabilization of the water level. Adjustments are best made in the first fifteen minutes of pumping in order to help minimize purging time. During pump start-up, drawdown may exceed the 0.3 feet target and then "recover" somewhat as pump flow adjustments are made. Purge volume calculations should utilize stabilized drawdown value, not the initial drawdown. If the initial water level is above the top of the screen do not allow the water level to fall into the well screen. The final purge volume must be greater than the stabilized drawdown volume plus the pump's tubing volume. If the drawdown has exceeded 0.3 feet and stabilizes, calculate the volume of water between the initial water level and the stabilized water level. Add the volume of the water which occupies the pump's tubing to this calculation. This combined volume of water needs to be purged from the well after the water level has stabilized before samples are collected.

Avoid the use of constriction devices on the tubing to decrease the flow rate because the constrictor will cause a pressure difference in the water column. This will cause the groundwater to degas and result in a loss of VOCs and dissolved gasses in the groundwater samples.

Note: the flow rate used to achieve a stable pumping level should remain constant while monitoring the indicator parameters for stabilization and while collecting the samples.

Wells with low recharge rates may require the use of special pumps capable of attaining very low pumping rates (e.g., bladder, peristaltic), and/or the use of dedicated equipment. For new monitoring wells, or wells where the following situation has not occurred before, if the recovery rate to the well is less than 50 mL/min., or the well is being essentially dewatered during purging, the well should be sampled as soon as the water level has recovered sufficiently to collect the volume needed for all anticipated samples. The project manager or field team leader will need to make the decision when samples should be collected, how the sample is to be collected, and the reasons recorded on the purge form or in the field logbook. A water level measurement needs to be performed and recorded before samples are collected. If the project manager decides to collect the samples using the pump, it is best during this recovery period that the pump intake tubing not be removed, since this will aggravate any turbidity problems. Samples in this specific situation may be collected without stabilization of indicator field parameters. Note that field conditions and efforts to overcome problematic situations must be recorded in order to support field decisions to deviate from normal procedures described in this SOP. If this type of problematic situation persists in a well, then water sample collection should be changed to a passive or no-purge method, if consistent with the site's DQOs, or have a new well installed.

E. Monitor Indicator Field Parameters

After the water level has stabilized, connect the "T" connector with a valve and the flow-through-cell to monitor the indicator field parameters. If excessive turbidity is anticipated or encountered with the pump startup, the well may be purged for a while without connecting up the flow-through-cell, in order to minimize particulate buildup in the cell (This is a judgment call made by the sampler). Water level drawdown measurements should be made as usual. If possible, the pump may be installed the day before purging to allow particulates that were disturbed during pump insertion to settle.

During well purging, monitor indicator field parameters (turbidity, temperature, specific conductance, pH, ORP, DO) at a frequency of five minute intervals or greater. The pump's flow rate must be able to "turn over" at least one flow-through-cell volume between measurements (for a 250 mL flow-through-cell with a flow rate of 50 mLs/min., the monitoring frequency would be every five minutes; for a 500 mL flow-through-cell it would be every ten minutes). If the cell volume cannot be replaced in the five minute interval, then the time between measurements must be increased accordingly. Note: during the early phase of purging emphasis should be put on minimizing and stabilizing pumping stress, and recording those adjustments followed by stabilization of indicator parameters. Purging is considered complete and sampling may begin when all the above indicator field parameters have stabilized. Stabilization is considered to be achieved when three consecutive readings are within the following limits:

Turbidity (10% for values greater than 5 NTU; if three Turbidity values are less than 5 NTU, consider the values as stabilized),
Dissolved Oxygen (10% for values greater than 0.5 mg/L, if three Dissolved Oxygen values are less than 0.5 mg/L, consider the values as stabilized),
Specific Conductance (3%),
Temperature (3%),
pH (± 0.1 unit),
Oxidation/Reduction Potential (±10 millivolts).

All measurements, except turbidity, must be obtained using a flow-through-cell. Samples for turbidity measurements are obtained before water enters the flow-through-cell. Transparent flow-through-cells are preferred, because they allow field personnel to watch for particulate build-up within the cell. This build-up may affect indicator field parameter values measured within the cell. If the cell needs to be cleaned during purging operations, continue pumping and disconnect cell for cleaning, then reconnect after cleaning and continue monitoring activities. Record start and stop times and give a brief description of cleaning activities.

The flow-through-cell must be designed in a way that prevents gas bubble entrapment in the cell. Placing the flow-through-cell at a 45 degree angle with the port facing upward can help remove bubbles from the flow-through-cell (see Appendix B Low-Flow Setup Diagram). All during the measurement process, the flow-through-cell must remain free of any gas bubbles. Otherwise, the monitoring probes may act erratically. When the pump is turned off or cycling on/off (when using a bladder pump), water in the cell must not drain out. Monitoring probes must remain submerged in water at all times.

F. Collect Water Samples

When samples are collected for laboratory analyses, the pump's tubing is disconnected from the "T" connector with a valve and the flow-through-cell. The samples are collected directly from the pump's tubing. Samples must not be collected from the flow-through-cell or from the "T" connector with a valve.

VOC samples are normally collected first and directly into pre-preserved sample containers. However, this may not be the case for all sampling locations; the SAP/QAPP should list the order in which the samples are to be collected based on the project's objective(s). Fill all sample containers by allowing the pump discharge to flow gently down the inside of the container with minimal turbulence.

If the pump's flow rate is too high to collect the VOC/dissolved gases samples, collect the other samples first. Lower the pump's flow rate to a reasonable rate and collect the VOC/dissolved gases samples and record the new flow rate.

During purging and sampling, the centrifugal/peristaltic pump tubing must remain filled with water to avoid aeration of the groundwater. It is recommended that 1/4 inch or 3/8 inch (inside diameter) tubing be used to help insure that the sample tubing remains water filled. If the pump tubing is not completely filled to the sampling point, use the following procedure to collect samples: collect non-VOC/dissolved gases samples first, then increase flow rate slightly until the water completely fills the tubing, collect the VOC/dissolved gases samples, and record new drawdown depth and flow rate.

For bladder pumps that will be used to collect VOC or dissolved gas samples, it is recommended that the pump be set to deliver long pulses of water so that one pulse will fill a 40 mL VOC vial.

Use pre-preserved sample containers or add preservative, as required by analytical methods, to the samples immediately after they are collected. Check the analytical methods (e.g. EPA SW-846, 40 CFR 136, water supply, etc.) for additional information on preservation.

If determination of filtered metal concentrations is a sampling objective, collect filtered water samples using the same low flow procedures. The use of an in-line filter (transparent housing preferred) is required, and the filter size (0.45 μm is commonly used) should be based on the sampling objective. Pre-rinse the filter with groundwater prior to sample collection. Make sure the filter is free of air bubbles before samples are collected. Preserve the filtered water sample immediately. Note: filtered water samples are not an acceptable substitute for unfiltered samples when the monitoring objective is to obtain chemical concentrations of total mobile contaminants in groundwater for human health or ecological risk calculations.

Label each sample as collected. Samples requiring cooling will be placed into a cooler with ice or refrigerant for delivery to the laboratory. Metal samples after acidification to a pH less than 2 do not need to be cooled.

G. Post Sampling Activities

If a recording pressure transducer is used to track drawdown, re-measure water level with tape.

After collection of samples, the pump tubing may be dedicated to the well for re-sampling (by hanging the tubing inside the well), decontaminated, or properly discarded.

Before securing the well, measure and record the well depth (to 0.1 ft.), if not measured the day before purging began. Note: measurement of total well depth annually is usually sufficient after the initial low stress sampling event. However, a greater frequency may be needed if the well has a "silting" problem or if confirmation of well identity is needed.

Secure the well.

DECONTAMINATION

Decontaminate sampling equipment prior to use in the first well and then following sampling of each well. Pumps should not be removed between purging and sampling operations. The pump, tubing, support cable and electrical wires which were in contact with the well should be decontaminated by one of the procedures listed below.

The use of dedicated pumps and tubing will reduce the amount of time spent on decontamination of the equipment. If dedicated pumps and tubing are used, only the initial sampling event will require decontamination of the pump and tubing.

Note if the previous equipment blank data showed that contaminant(s) were present after using the below procedure or the one described in the SAP/QAPP, a more vigorous procedure may be needed.

<u>Procedure 1</u>

Decontaminating solutions can be pumped from either buckets or short PVC casing sections through the pump and tubing. The pump may be disassembled and flushed with the decontaminating solutions. It is recommended that detergent and alcohol be used sparingly in the decontamination process and water flushing steps be extended to ensure that any sediment trapped in the pump is removed. The pump exterior and electrical wires must be rinsed with the decontaminating solutions, as well. The procedure is as follows:

Flush the equipment/pump with potable water.

Flush with non-phosphate detergent solution. If the solution is recycled, the solution must be changed periodically.

Flush with potable or distilled/deionized water to remove all of the detergent solution. If the water is recycled, the water must be changed periodically.

Optional - flush with isopropyl alcohol (pesticide grade; must be free of ketones {e.g., acetone}) or with methanol. This step may be required if the well is highly contaminated or if the equipment blank data from the previous sampling event show that the level of contaminants is significant.

Flush with distilled/deionized water. This step must remove all traces of alcohol (if used) from the equipment. The final water rinse must not be recycled.

<u>Procedure 2</u>

Steam clean the outside of the submersible pump.

Pump hot potable water from the steam cleaner through the inside of the pump. This can be accomplished by placing the pump inside a three or four inch diameter PVC pipe with end cap. Hot water from the steam cleaner jet will be directed inside the PVC pipe and the pump exterior will be cleaned. The hot water from the steam cleaner will then be pumped from the PVC pipe through the pump and collected into another container. Note: additives or solutions should not be added to the steam cleaner.

Pump non-phosphate detergent solution through the inside of the pump. If the solution is recycled, the solution must be changed periodically.

Pump potable water through the inside of the pump to remove all of the detergent solution. If the solution is recycled, the solution must be changed periodically.

Pump distilled/deionized water through the pump. The final water rinse must not be recycled.

FIELD QUALITY CONTROL

Quality control samples are required to verify that the sample collection and handling process has not compromised the quality of the groundwater samples. All field quality control samples must be prepared the same as regular investigation samples with regard to sample volume, containers, and preservation. Quality control samples include field duplicates, equipment blanks, matrix spike/matrix spike duplicates, trip blanks (VOCs), and temperature blanks.

FIELD LOGBOOK

A field log shall be kept to document all groundwater field monitoring activities (see Appendix C, example table), and record the following for each well:

Site name, municipality, state.

Well identifier, latitude-longitude or state grid coordinates.

Measuring point description (e.g., north side of PVC pipe).

Well depth, and measurement technique.

Well screen length.

Pump depth.

Static water level depth, date, time and measurement technique.

Presence and thickness of immiscible liquid (NAPL) layers and detection method.

Pumping rate, drawdown, indicator parameters values, calculated or measured total volume pumped, and clock time of each set of measurements.

Type of tubing used and its length.

Type of pump used.

Clock time of start and end of purging and sampling activity.

Types of sample bottles used and sample identification numbers.

Preservatives used.

Parameters requested for analyses.

Field observations during sampling event.

Name of sample collector(s).

Weather conditions, including approximate ambient air temperature.

QA/QC data for field instruments.

Any problems encountered should be highlighted.

Description of all sampling/monitoring equipment used, including trade names, model number, instrument identification number, diameters, material composition, etc.

DATA REPORT

Data reports are to include laboratory analytical results, QA/QC information, field indicator parameters measured during purging, field instrument calibration information, and whatever other field logbook information is needed to allow for a full evaluation of data usability.

Note: the use of trade, product, or firm names in this sampling procedure is for descriptive purposes only and does not constitute endorsement by the U.S. EPA.

REFERENCES

Cohen, R.M. and J.W. Mercer, 1993, *DNAPL Site Evaluation*; C.K. Smoley (CRC Press), Boca Raton, Florida.

Robert W. Puls and Michael J. Barcelona, *Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures*, April 1996 (EPA/540/S-95/504).

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U.S Environmental Protection Agency, EPA SW-846.

U.S Environmental Protection Agency, 40 CFR 136.

U.S Environmental Protection Agency, 40 CFR 141.

Vroblesky, Don A., Clifton C. Casey, and Mark A. Lowery, Summer 2007, Influence of Dissolved Oxygen Convection on Well Sampling, *Ground Water Monitoring & Remediation* 27, no. 3: 49-58.

APPENDIX A
PERISTALTIC PUMPS

Before selecting a peristaltic pump to collect groundwater samples for VOCs and/or dissolved gases (e.g., methane, carbon dioxide, etc.) consideration should be given to the following:

- The decision of whether or not to use a peristaltic pump is dependent on the intended use of the data.
- If the additional sampling error that may be introduced by this device is NOT of concern for the VOC/dissolved gases data's intended use, then this device may be acceptable.
- If minor differences in the groundwater concentrations could effect the decision, such as to continue or terminate groundwater cleanup or whether the cleanup goals have been reached, then this device should NOT be used for VOC/dissolved gases sampling. In these cases, centrifugal or bladder pumps are a better choice for more accurate results.

EPA and USGS have documented their concerns with the use of the peristaltic pumps to collect water sample in the below documents.

- "Suction Pumps are not recommended because they may cause degassing, pH modification, and loss of volatile compounds" *A Compendium of Superfund Field Operations Methods*, EPA/540/P-87/001, December 1987.
- "The agency does not recommend the use of peristaltic pumps to sample ground water particularly for volatile organic analytes" *RCRA Ground-Water Monitoring Draft Technical Guidance*, EPA Office of Solid Waste, November 1992.
- "The peristaltic pump is limited to shallow applications and can cause degassing resulting in alteration of pH, alkalinity, and volatiles loss", *Low-flow (Minimal drawdown) Ground-Water Sampling Procedures*, by Robert Puls & Michael Barcelona, April 1996, EPA/540/S-95/504.
- "Suction-lift pumps, such as peristaltic pumps, can operate at a very low pumping rate; however, using negative pressure to lift the sample can result in the loss of volatile analytes", USGS Book 9 Techniques of Water-Resources Investigation, Chapter A4. (Version 2.0, 9/2006).

APPENDIX B

SUMMARY OF SAMPLING INSTRUCTIONS

These instructions are for using an adjustable rate, submersible pump or a peristaltic pump with the pump's intake placed at the midpoint of a 10 foot or less well screen or an open interval. The water level in the monitoring well is above the top of the well screen or open interval, the ambient temperature is above 32°F, and the equipment is not dedicated. Field instruments are already calibrated. The equipment is setup according to the diagram at the end of these instructions.

1. Review well installation information. Record well depth, length of screen or open interval, and depth to top of the well screen. Determine the pump's intake depth (e.g., mid-point of screen/open interval).

2. On the day of sampling, check security of the well casing, perform any safety checks needed for the site, lay out a sheet of polyethylene around the well (if necessary), and setup the equipment. If necessary a canopy or an equivalent item can be setup to shade the pump's tubing and flow-through-cell from the sun light to prevent the sun light from heating the groundwater.

3. Check well casing for a reference mark. If missing, make a reference mark. Measure the water level (initial) to 0.01 ft. and record this information.

4. Install the pump's intake to the appropriate depth (e.g., midpoint) of the well screen or open interval. Do not turn-on the pump at this time.

5. Measure water level and record this information.

6. Turn-on the pump and discharge the groundwater into a graduated waste bucket. Slowly increase the flow rate until the water level starts to drop. Reduce the flow rate slightly so the water level stabilizes. Record the pump's settings. Calculate the flow rate using a graduated container and a stop watch. Record the flow rate. Do not let the water level drop below the top of the well screen.

If the groundwater is highly turbid or colored, continue to discharge the water into the bucket until the water clears (visual observation); this usually takes a few minutes. The turbid or colored water is usually from the well being disturbed during the pump installation. If the water does not clear, then you need to make a choice whether to continue purging the well (hoping that it will clear after a reasonable time) or continue to the next step. Note, it is sometimes helpful to install the pump the day before the sampling event so that the disturbed materials in the well can settle out.

If the water level drops to the top of the well screen during the purging of the well, stop purging the well, and do the following:

> Wait for the well to recharge to a sufficient volume so samples can be collected. This may take awhile (pump maybe removed from well, if turbidity is not a problem). The project manager will need to make the decision when samples should be collected and the reasons recorded in the site's log book. A water level measurement needs to be performed and recorded before samples are collected. When samples are being collected, the water level must not drop below the top of the screen or open interval. Collect the samples from the pump's tubing. Always collect the VOCs and dissolved gases samples first. Normally, the samples requiring a small volume are collected before the large volume samples are collected just in case there is not sufficient water in the well to fill all the sample containers. All samples must be collected, preserved, and stored according to the analytical method. Remove the pump from the well and decontaminate the sampling equipment.

If the water level has dropped 0.3 feet or less from the initial water level (water level measure before the pump was installed); proceed to Step 7. If the water level has dropped more than 0.3 feet, calculate the volume of water between the initial water level and the stabilized water level. Add the volume of the water which occupies the pump's tubing to this calculation. This combined volume of water needs to be purged from the well after the water level has stabilized before samples are be collected.

7. Attach the pump's tubing to the "T" connector with a valve (or a three-way stop cock). The pump's tubing from the well casing to the "T" connector must be as short as possible to prevent the groundwater in the tubing from heating up from the sun light or from the ambient air. Attach a short piece of tubing to the other end of the end of the "T" connector to serve as a sampling port for the turbidity samples. Attach the remaining end of the "T" connector to a short piece of tubing and connect the tubing to the flow-through-cell bottom port. To the top port, attach a small piece of tubing to direct the water into a calibrated waste bucket. Fill the cell with the groundwater and remove all gas bubbles from the cell. Position the flow-through-cell in such a way that if gas bubbles enter the cell they can easily exit the cell. If the ports are on the same side of the cell and the cell is cylindrical shape, the cell can be placed at a 45-degree angle with the ports facing upwards; this position should keep any gas bubbles entering the cell away from the monitoring probes and allow the gas bubbles to exit the cell easily (see Low-Flow Setup Diagram). Note,

make sure there are no gas bubbles caught in the probes' protective guard; you may need to shake the cell to remove these bubbles.

8. Turn-on the monitoring probes and turbidity meter.

9. Record the temperature, pH, dissolved oxygen, specific conductance, and oxidation/reduction potential measurements. Open the valve on the "T" connector to collect a sample for the turbidity measurement, close the valve, do the measurement, and record this measurement. Calculate the pump's flow rate from the water exiting the flow-through-cell using a graduated container and a stop watch, and record the measurement. Measure and record the water level. Check flow-through-cell for gas bubbles and sediment; if present, remove them.

10. Repeat Step 9 every 5 minutes or as appropriate until monitoring parameters stabilized. Note at least one flow-through-cell volume must be exchanged between readings. If not, the time interval between readings will need to be increased. Stabilization is achieved when three consecutive measurements are within the following limits:

Turbidity (10% for values greater than 5 NTUs; if three Turbidity values are less than 5 NTUs, consider the values as stabilized),
Dissolved Oxygen (10% for values greater than 0.5 mg/L, if three Dissolved Oxygen values are less than 0.5 mg/L, consider the values as stabilized),
Specific Conductance (3%),
Temperature (3%),
pH (± 0.1 unit),
Oxidation/Reduction Potential (±10 millivolts).

If these stabilization requirements do not stabilize in a reasonable time, the probes may have been coated from the materials in the groundwater, from a buildup of sediment in the flow-through-cell, or a gas bubble is lodged in the probe. The cell and the probes will need to be cleaned. Turn-off the probes (not the pump), disconnect the cell from the "T" connector and continue to purge the well. Disassemble the cell, remove the sediment, and clean the probes according to the manufacturer's instructions. Reassemble the cell and connect the cell to the "T" connector. Remove all gas bubbles from the cell, turn-on the probes, and continue the measurements. Record that the time the cell was cleaned.

11. When it is time to collect the groundwater samples, turn-off the monitoring probes, and disconnect the pump's tubing from the "T" connector. If you are using a centrifugal or peristaltic pump check the pump's tubing to determine if the tubing is completely filled with water (no air space).

All samples must be collected and preserved according to the analytical method. VOCs and dissolved gases samples are normally collected first and directly into pre-preserved sample containers. However, this may not be the case for all sampling locations; the SAP/QAPP should list the order in which the samples are to be collected based on the project's objective(s). Fill all sample containers by allowing the pump discharge to flow gently down the inside of the container with minimal turbulence.

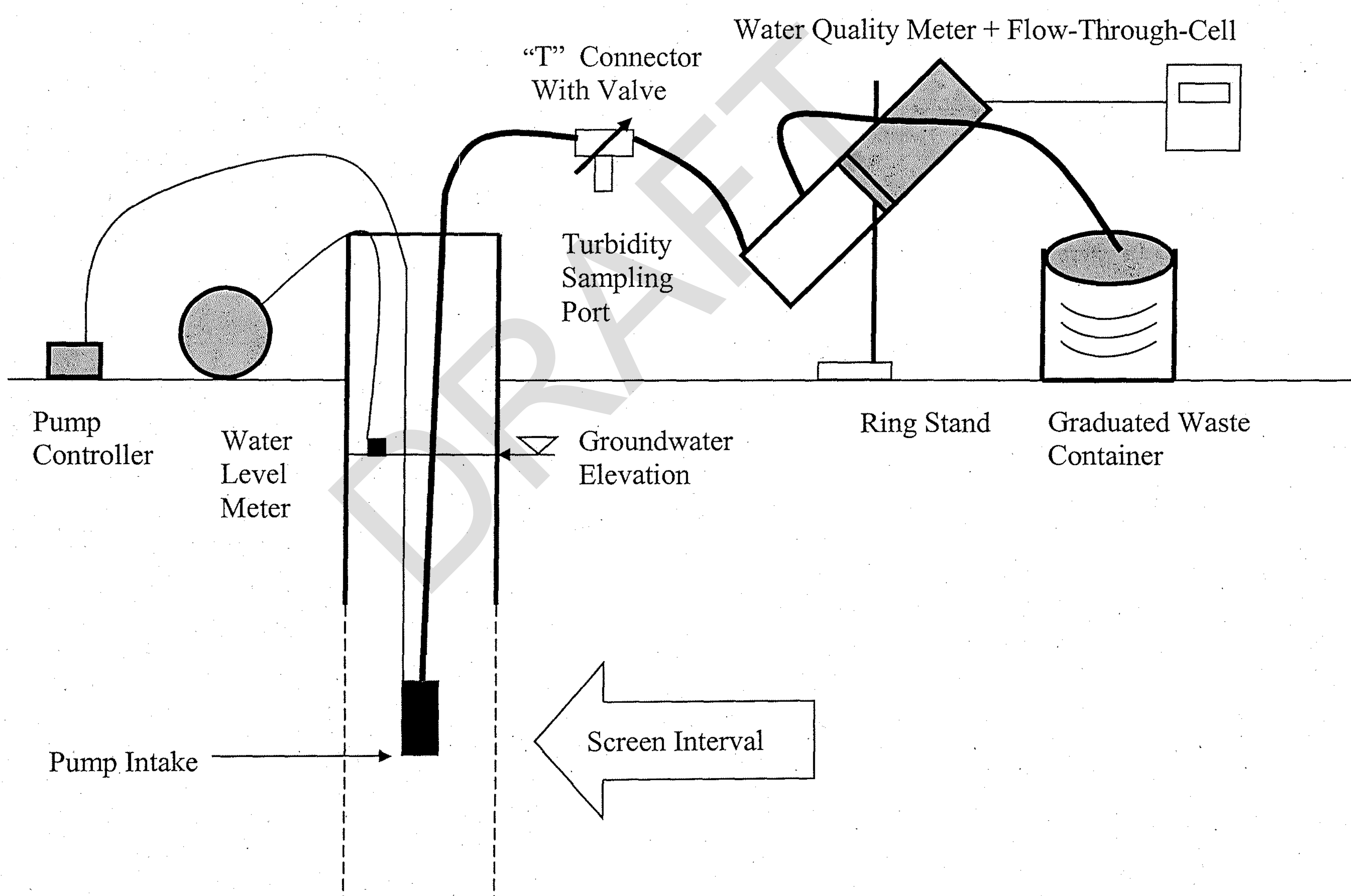
If the pump's tubing is not completely filled with water and the samples are being collected for VOCs and/or dissolved gases analyses using a centrifugal or peristaltic pump, do the following:

> All samples must be collected and preserved according to the analytical method. The VOCs and the dissolved gases (e.g., methane, ethane, ethene, and carbon dioxide) samples are collected last. When it becomes time to collect these samples increase the pump's flow rate until the tubing is completely filled. Collect the samples and record the new flow rate.

12. Store the samples according to the analytical method.

13. Record the total purged volume (graduated waste bucket). Remove the pump from the well and decontaminate the sampling equipment.

Low-Flow Setup Diagram



APPENDIX C
EXAMPLE (Minimum Requirements)
WELL PURGING-FIELD WATER QUALITY MEASUREMENTS FORM

Location (Site/Facility Name)______________________________
Well Number_________________Date_______________________
Field Personnel____
Sampling Organization___________________________________
Identify MP____

Depth to ________/________ of screen
(below MP) top bottom
Pump Intake at (ft. below MP)__________
Purging Device; (pump type)__________
Total Volume Purged __________

Clock Time 24 HR	Water Depth below MP ft	Pump Dial[1]	Purge Rate ml/min	Cum. Volume Purged liters	Temp. °C	Spec. Cond.[2] µS/cm	pH	ORP[3] mv	DO mg/L	Turb-idity NTU	Comments
Stabilization Criteria					3%	3%	±0.1	± 10 mv	10%	10%	

1. Pump dial setting (for example: hertz, cycles/min, etc).
2. µSiemens per cm(same as µmhos/cm)at 25°C.
3. Oxidation reduction potential (ORP)

memorandum

To: Trihydro Employees
From: Operational & Service Excellence
Date: June 2019
Re: Standard Operating Procedure – Packaging and Shipping of Nonhazardous Substances to Laboratories for Analyses (Authors: Charlie Ballek and Christina Hiegel)

1.0 PURPOSE

The purpose of this standard operating procedure (SOP) is to provide general instructions for the packaging and shipping of nonhazardous substances or samples for physical, chemical, and radiological analysis. Nonhazardous samples are those that do not meet the hazardous materials classifications provided in Title 49 Code of Federal Regulations (49 CFR) Parts 107 through 178, including materials designated by the Department of Transportation (DOT) as Class 9 materials, and materials that represent Reportable Quantities (hazardous substances) (**Attachment A**) (NEU 2013).

Soil, air, and aqueous samples generally do not meet any of the DOT's hazardous materials classifications. However, samples for which screening has shown a potential hazard sufficient to meet a DOT classification (**Attachment A)**, or that are derived from a source known or suspected to meet a DOT classification, must be packaged and shipped in accordance with the applicable DOT and International Air Transport Association (IATA) requirements.

2.0 RESPONSIBILITIES

Trihydro employees that package or ship nonhazardous samples are responsible for meeting these SOP requirements. Trihydro employees reviewing task performance are also responsible for following appropriate portions of this SOP. For projects involving package or shipping, the Project Manager or designee is responsible for ensuring that those activities are conducted per this and other appropriate SOPs. Project-team members are responsible for documenting information in sufficient detail to provide objective documentation (e.g., shipping documentation) that the requirements of this SOP have been met. Such documentation shall be retained in the project records.

3.0 PROCEDURE

If samples are not immediately shipped, store samples at 4 ± 2 degrees Celsius (ºC) in a secure location until the shipment day. The basic packaging and shipping procedures (DOT 2009) (IATA 2009) are provided below.

Packaging

- Ensure that the cooler is labeled or marked “For Samples Only.”
- Use tape to seal off the cooler drain on the inside and outside to prevent leakage.
- Place packing material on the inside bottom of the shipping cooler to provide a soft impact surface.
- Place an inner protective liner (if available) inside the cooler. Open and fold the sides down so it will remain open while the samples are inserted.
- Starting with the largest glass containers, wrap each container with sufficient bubble wrap to minimize the potential for container breakage.
- Place each sample bottle in a resealable-plastic bag to: a) prevent inadvertent exposure of the labels to melted ice, and b) contain the sample and minimize cross-contamination if the bottle is broken during shipment. To help keep the samples cool enough, do not “double bag” the sample bottles.
- Pack the largest glass containers in the cooler bottom, placing packing material between each of the containers to avoid breakage.
- Line each cooler with a large plastic bag and add bagged ice across the top of the samples.
- If a temperature blank was provided by the laboratory or if one was prepared for the cooler, place it in a location that will receive the same contact with ice as the samples.
- When sufficiently full, seal the inner protective plastic bag (when available) using a zip tie or by twisting and tying the excess material, and place additional packing material on top of the bag to minimize shifting of containers during shipment. “Test shake” the cooler to feel for shifting, and add more packing material if contents are not packed to prevent moving.
- Tape a resealable-plastic bag to the inside cooler lid, place the completed chain-of-custody form inside the bag, and seal the bag.
- Securely tape the shipping cooler shut using packing tape, duct tape, or other tear-resistant adhesive strips. Taping should be performed to ensure the lid cannot open during transport.
- Immediately before shipping, place custody seals on two separate sides of the cooler lid to provide evidence that the cooler has not been opened before receipt by the intended recipient.

Labeling

- A “This Side Up” arrow label must be placed on all sides of the cooler.
- If the contents are fragile, use a “Fragile” label to indicate handling requirements (**Attachment B**).
- Label “Nonhazardous Waste” to indicate the contents’ hazardous materials classification (**Attachment B**).
- If the contents need to stay cold, use the appropriate “Keep Refrigerated” label (**Attachment B**).
- Provide the name and address of the receiver and shipper on the cooler top.

Shipping Documentation
A cooler-shipment checklist should be completed and kept in the project file. Example checklists are provided in **Attachment C**.

Declared Value Limits
FedEx and United Parcel Service (UPS) limit their liability for lost shipments at a $100 value at no cost to Trihydro. Do not declare shipment values above $100 when shipping samples (e.g., soil, groundwater, etc.).

4.0 REFERENCES

International Air Transport Association (IATA). 2009. IATA Dangerous Goods Regulations Manual, current edition.

Northeastern University (NEU). 2013. Hazardous Materials Definition. Available from: http://www.ehs.neu.edu/hazardous_material/hazardous_material/.

United States Department of Transportation (DOT). 2009. U.S. DOT Regulations, 49 CFR Part 107-178.

United States Environmental Protection Agency (USEPA). 2011. Contract Laboratory Program (CLP) Guidance for Field Samplers. Available from: http://www.epa.gov/superfund/programs/clp/guidance.htm#sample

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ATTACHMENT A
Department of Transportation (DOT) Hazardous Materials Classifications

There are nine classes of hazardous materials:

Class 1: Explosives	1.1: Mass explosion hazard 1.2: Projectile hazard 1.3: Minor blast / projectile / fire 1.4: Minor blast 1.5: Insensitive explosives 1.6: Very insensitive explosives
Class 2: Compressed Gases	2.1: Flammable gases 2.2: Non-flammable compressed gases 2.3: Poisonous gases
Class 3: Flammable Liquids	3.1: Flammable (flash point below 141°) 3.2: Combustible (flash point from 141° to 200°)
Class 4: Flammable Solids	4.1: Flammable solids 4.2: Spontaneously combustible 4.3: Dangerous when wet
Class 5: Oxidizers and Organic Peroxides	5.1: Oxidizer 5.2: Organic peroxide
Class 6: Toxic Materials	6.1: Poisonous materials 6.2: Infectious agents
Class 7: Radioactive Material	7.1: Radioactive I 7.2: Radioactive II 7.3: Radioactive III
Class 8: Corrosive Material	8.1: Destruction of the human skin 8.2: Corrodes steel at minimum 0.25 inches per year
Class 9: Miscellaneous	A material that presents a hazard during shipment but does not meet the definition of the other classes

ATTACHMENT B
Cooler-Shipment Label Examples

ATTACHMENT C
Cooler-Shipment Checklist Examples

Example C-1: Packing Sample Container Checklist (USEPA 2011)

Packing Sample Container	Yes	No	Comments
1. Did you follow all state, federal, Department of Transportation (DOT), and International Air Transportation Association (IATA) regulations governing the packaging of environmental and hazardous samples?			
2. Were all Contract Laboratory Program (CLP) Sample numbers, Sample Management Office (SMO)-assigned CLP Case numbers, analyses, labels, tags, and custody seals attached to the correct sample containers?			
3. Is modified analysis indicated if requested?			
4. Was an inventory conducted of CLP Sample numbers, SMO-assigned CLP Case numbers, analyses, and containers, and verified against the traffic report / Chain of Custody (TR/CoC) records?			
5. Were the correct number and type of performance evaluation (PE) and quality-control (QC) samples collected?			
6. Were all sample containers sealed in clear plastic bags with the sample label and tag visible through the packaging?			
7. Were all soil/sediment samples known or suspected to contain dioxin securely enclosed in metal cans (e.g., paint cans) with the lids sealed?			
8. Was suitable absorbent packing material placed around the sample bottles or containers?			
9. Were the outsides of metal containers labeled properly with the CLP Sample number, SMO-assigned CLP Case number, and the analysis of the sample inside?			

ATTACHMENT C (cont'd)
Example C-2: Shipping Container Checklist (USEPA 2011)

Packing Shipping Container	Yes	No	Comments
1. Are shipping containers (e.g., clean waterproof metal or hard plastic ice chest or cooler) in good condition?			
2. Were all non-applicable labels from previous shipments removed from the container?			
3. Were inside and outside drain plugs closed and covered with suitable tape (e.g., duct tape)?			
4. Was the inside of the cooler lined with plastic (e.g., large heavy-duty garbage bag)?			
5. Was the lined cooler packed with noncombustible absorbent packing material?			
6. Were sample containers placed in the cooler in an upright position not touching one another?			
7. Was a sample shipping cooler temperature blank included in the cooler?			
8. Did the documentation in the cooler only address the samples in that cooler?			
9. Was the site name absent from all documentation? Under no circumstances should the site name appear on any documentation being sent to the laboratory, unless the laboratory is a Regional USEPA laboratory.			
10. Was there sufficient packing material around and in between the sample bottles and cans to avoid breakage during transport?			
11. If required, was double-bagged ice placed on top and around sample bottles to keep the samples cold at 4°C (± 2°C)? Do not pack loose ice into the cooler.			
12. Was the top of the plastic liner fastened and secured with tape?			
13. Was a completed CoC seal (if required) placed around the fastened plastic liner top?			
14. Were all sample documents enclosed within the cooler (e.g., CoC record and cooler return instructions) in a waterproof plastic bag?			
15. Was the plastic bag containing the documentation taped to the underside of the cooler lid?			
16. Were cooler-return instructions and air bills taped to the underside of the cooler lid?			
17. Was the return address of the cooler written with permanent ink on the underside of the cooler lid?			
18. Was tape placed around the outside of the entire cooler and over the hinges?			
19. Were the completed custody seals placed over the top edge of the cooler so the cooler cannot be opened without breaking the seals?			
20. Was the return address label attached to the top left corner of the cooler lid?			
21. Were instructional labels attached to the top of the cooler, as necessary (e.g., "This End Up," "Do Not Tamper With," or "Environmental Laboratory Samples")?			
22. If shipping samples containing methanol as a preservative (e.g., samples to be analyzed by SW-846 Method 5035A), was a label used to indicate methanol, the United Nations (UN) identification number for methanol (UN 1230), and Limited Quantity?			

Commented [MH1]: Even if limited quanity, these should ship Haz Mat and require shipping labels. FYI.

ATTACHMENT C (cont'd)

Example C-3: Shipping and Reporting Contract Laboratory Program (CLP) Samples Checklist (USEPA 2011)

Shipping CLP Samples	Yes	No	Comments:
1. Did you follow all state, federal, Department of Transportation (DOT), and International Air Transportation Association (IATA) regulations governing the shipment of environmental and hazardous samples?			
2. Was a separate air bill filled out for each cooler being shipped?			
3. Was the air bill filled out completely, including correct laboratory name, address, and telephone number, identification of recipient as "Sample Custodian," and appropriate delivery option (e.g., overnight or Saturday)?			
4. Was the completed air bill attached to cooler top with the correct laboratory address?			
5. If more than one cooler was being shipped to the same laboratory, were they marked as "1 of 2," "2 of 2," etc.?			
6. Were the samples being shipped "overnight" through a qualified commercial carrier?			
Reporting CLP Samples	**Yes**	**No**	**Comments:**
1. Did you contact the Regional Sample Control Center Coordinator (RSCC) (or designee) or the CLP Sample Management Office (SMO) on the same day the samples were shipped?			
2. If the samples were shipped after 5:00 PM Eastern Time (ET), were they reported to the RSCC (or designee) or to SMO by 8:00 AM ET the following business day?			
3. Did you notify the RSCC (or designee) or SMO so that SMO will receive the delivery information by 3:00 PM ET on Friday for sample shipments that will be delivered to the laboratory on Saturday?			
4. Did you provide the RSCC (or designee) or SMO with: □ Your name, phone number, and Region number □ Case Number of the project □ Modified Analysis Number, if requested □ Exact number of samples, matrix(ces), concentration(s), and type of analysis □ Laboratory(ies) to which the samples were shipped □ Carrier name and air bill number □ Date of shipment □ Date of next shipment □ Any other information pertinent to the shipment			

memorandum

To:	Trihydro Employees
From:	Operational & Service Excellence
Date:	June 2019
Re:	Standard Operating Procedure – Packaging and Shipping of Nonhazardous Substances to Laboratories for Analyses (Authors: Charlie Ballek and Christina Hiegel)

1.0 PURPOSE

The purpose of this standard operating procedure (SOP) is to provide general instructions for the packaging and shipping of nonhazardous substances or samples for physical, chemical, and radiological analysis. Nonhazardous samples are those that do not meet the hazardous materials classifications provided in Title 49 Code of Federal Regulations (49 CFR) Parts 107 through 178, including materials designated by the Department of Transportation (DOT) as Class 9 materials, and materials that represent Reportable Quantities (hazardous substances) (**Attachment A**) (NEU 2013).

Soil, air, and aqueous samples generally do not meet any of the DOT's hazardous materials classifications. However, samples for which screening has shown a potential hazard sufficient to meet a DOT classification (**Attachment A)**, or that are derived from a source known or suspected to meet a DOT classification, must be packaged and shipped in accordance with the applicable DOT and International Air Transport Association (IATA) requirements.

2.0 RESPONSIBILITIES

Trihydro employees that package or ship nonhazardous samples are responsible for meeting these SOP requirements. Trihydro employees reviewing task performance are also responsible for following appropriate portions of this SOP. For projects involving package or shipping, the Project Manager or designee is responsible for ensuring that those activities are conducted per this and other appropriate SOPs. Project-team members are responsible for documenting information in sufficient detail to provide objective documentation (e.g., shipping documentation) that the requirements of this SOP have been met. Such documentation shall be retained in the project records.

3.0 PROCEDURE

If samples are not immediately shipped, store samples at 4 ± 2 degrees Celsius (°C) in a secure location until the shipment day. The basic packaging and shipping procedures (DOT 2009) (IATA 2009) are provided below.

Packaging

- Ensure that the cooler is labeled or marked "For Samples Only."
- Use tape to seal off the cooler drain on the inside and outside to prevent leakage.
- Place packing material on the inside bottom of the shipping cooler to provide a soft impact surface.
- Place an inner protective liner (if available) inside the cooler. Open and fold the sides down so it will remain open while the samples are inserted.
- Starting with the largest glass containers, wrap each container with sufficient bubble wrap to minimize the potential for container breakage.
- Place each sample bottle in a resealable-plastic bag to: a) prevent inadvertent exposure of the labels to melted ice, and b) contain the sample and minimize cross-contamination if the bottle is broken during shipment. To help keep the samples cool enough, do not "double bag" the sample bottles.
- Pack the largest glass containers in the cooler bottom, placing packing material between each of the containers to avoid breakage.
- Line each cooler with a large plastic bag and add bagged ice across the top of the samples.
- If a temperature blank was provided by the laboratory or if one was prepared for the cooler, place it in a location that will receive the same contact with ice as the samples.
- When sufficiently full, seal the inner protective plastic bag (when available) using a zip tie or by twisting and tying the excess material, and place additional packing material on top of the bag to minimize shifting of containers during shipment. "Test shake" the cooler to feel for shifting, and add more packing material if contents are not packed to prevent moving.
- Tape a resealable-plastic bag to the inside cooler lid, place the completed chain-of-custody form inside the bag, and seal the bag.
- Securely tape the shipping cooler shut using packing tape, duct tape, or other tear-resistant adhesive strips. Taping should be performed to ensure the lid cannot open during transport.
- Immediately before shipping, place custody seals on two separate sides of the cooler lid to provide evidence that the cooler has not been opened before receipt by the intended recipient.

Labeling

- A "This Side Up" arrow label must be placed on all sides of the cooler.
- If the contents are fragile, use a "Fragile" label to indicate handling requirements (**Attachment B**).
- Label "Nonhazardous Waste" to indicate the contents' hazardous materials classification (**Attachment B**).
- If the contents need to stay cold, use the appropriate "Keep Refrigerated" label (**Attachment B**).
- Provide the name and address of the receiver and shipper on the cooler top.

Shipping Documentation
A cooler-shipment checklist should be completed and kept in the project file. Example checklists are provided in **Attachment C**.

Declared Value Limits
FedEx and United Parcel Service (UPS) limit their liability for lost shipments at a $100 value at no cost to Trihydro. Do not declare shipment values above $100 when shipping samples (e.g., soil, groundwater, etc.).

4.0 REFERENCES

International Air Transport Association (IATA). 2009. IATA Dangerous Goods Regulations Manual, current edition.

Northeastern University (NEU). 2013. Hazardous Materials Definition. Available from: http://www.ehs.neu.edu/hazardous_material/hazardous_material/.

United States Department of Transportation (DOT). 2009. U.S. DOT Regulations, 49 CFR Part 107-178.

United States Environmental Protection Agency (USEPA). 2011. Contract Laboratory Program (CLP) Guidance for Field Samplers. Available from: http://www.epa.gov/superfund/programs/clp/guidance.htm#sample

QAQ-CSO-P00

ATTACHMENT A
Department of Transportation (DOT) Hazardous Materials Classifications

There are nine classes of hazardous materials:

Class 1: Explosives	1.1: Mass explosion hazard 1.2: Projectile hazard 1.3: Minor blast / projectile / fire 1.4: Minor blast 1.5: Insensitive explosives 1.6: Very insensitive explosives
Class 2: Compressed Gases	2.1: Flammable gases 2.2: Non-flammable compressed gases 2.3: Poisonous gases
Class 3: Flammable Liquids	3.1: Flammable (flash point below 141°) 3.2: Combustible (flash point from 141° to 200°)
Class 4: Flammable Solids	4.1: Flammable solids 4.2: Spontaneously combustible 4.3: Dangerous when wet
Class 5: Oxidizers and Organic Peroxides	5.1: Oxidizer 5.2: Organic peroxide
Class 6: Toxic Materials	6.1: Poisonous materials 6.2: Infectious agents
Class 7: Radioactive Material	7.1: Radioactive I 7.2: Radioactive II 7.3: Radioactive III
Class 8: Corrosive Material	8.1: Destruction of the human skin 8.2: Corrodes steel at minimum 0.25 inches per year
Class 9: Miscellaneous	A material that presents a hazard during shipment but does not meet the definition of the other classes

ATTACHMENT B
Cooler-Shipment Label Examples

ATTACHMENT C
Cooler-Shipment Checklist Examples

Example C-1: Packing Sample Container Checklist (USEPA 2011)

Packing Sample Container	Yes	No	Comments
1. Did you follow all state, federal, Department of Transportation (DOT), and International Air Transportation Association (IATA) regulations governing the packaging of environmental and hazardous samples?			
2. Were all Contract Laboratory Program (CLP) Sample numbers, Sample Management Office (SMO)-assigned CLP Case numbers, analyses, labels, tags, and custody seals attached to the correct sample containers?			
3. Is modified analysis indicated if requested?			
4. Was an inventory conducted of CLP Sample numbers, SMO-assigned CLP Case numbers, analyses, and containers, and verified against the traffic report / Chain of Custody (TR/CoC) records?			
5. Were the correct number and type of performance evaluation (PE) and quality-control (QC) samples collected?			
6. Were all sample containers sealed in clear plastic bags with the sample label and tag visible through the packaging?			
7. Were all soil/sediment samples known or suspected to contain dioxin securely enclosed in metal cans (e.g., paint cans) with the lids sealed?			
8. Was suitable absorbent packing material placed around the sample bottles or containers?			
9. Were the outsides of metal containers labeled properly with the CLP Sample number, SMO-assigned CLP Case number, and the analysis of the sample inside?			

ATTACHMENT C (cont'd)
Example C-2: Shipping Container Checklist (USEPA 2011)

Packing Shipping Container	Yes	No	Comments
1. Are shipping containers (e.g., clean waterproof metal or hard plastic ice chest or cooler) in good condition?			
2. Were all non-applicable labels from previous shipments removed from the container?			
3. Were inside and outside drain plugs closed and covered with suitable tape (e.g., duct tape)?			
4. Was the inside of the cooler lined with plastic (e.g., large heavy-duty garbage bag)?			
5. Was the lined cooler packed with noncombustible absorbent packing material?			
6. Were sample containers placed in the cooler in an upright position not touching one another?			
7. Was a sample shipping cooler temperature blank included in the cooler?			
8. Did the documentation in the cooler only address the samples in that cooler?			
9. Was the site name absent from all documentation? Under no circumstances should the site name appear on any documentation being sent to the laboratory, unless the laboratory is a Regional USEPA laboratory.			
10. Was there sufficient packing material around and in between the sample bottles and cans to avoid breakage during transport?			
11. If required, was double-bagged ice placed on top and around sample bottles to keep the samples cold at 4°C (± 2°C)? Do not pack loose ice into the cooler.			
12. Was the top of the plastic liner fastened and secured with tape?			
13. Was a completed CoC seal (if required) placed around the fastened plastic liner top?			
14. Were all sample documents enclosed within the cooler (e.g., CoC record and cooler return instructions) in a waterproof plastic bag?			
15. Was the plastic bag containing the documentation taped to the underside of the cooler lid?			
16. Were cooler-return instructions and air bills taped to the underside of the cooler lid?			
17. Was the return address of the cooler written with permanent ink on the underside of the cooler lid?			
18. Was tape placed around the outside of the entire cooler and over the hinges?			
19. Were the completed custody seals placed over the top edge of the cooler so the cooler cannot be opened without breaking the seals?			
20. Was the return address label attached to the top left corner of the cooler lid?			
21. Were instructional labels attached to the top of the cooler, as necessary (e.g., "This End Up," "Do Not Tamper With," or "Environmental Laboratory Samples")?			
22. If shipping samples containing methanol as a preservative (e.g., samples to be analyzed by SW-846 Method 5035A), was a label used to indicate methanol, the United Nations (UN) identification number for methanol (UN 1230), and Limited Quantity?			

ATTACHMENT C (cont'd)

Example C-3: Shipping and Reporting Contract Laboratory Program (CLP) Samples Checklist (USEPA 2011)

Shipping CLP Samples	Yes	No	Comments:
1. Did you follow all state, federal, Department of Transportation (DOT), and International Air Transportation Association (IATA) regulations governing the shipment of environmental and hazardous samples?			
2. Was a separate air bill filled out for each cooler being shipped?			
3. Was the air bill filled out completely, including correct laboratory name, address, and telephone number, identification of recipient as "Sample Custodian," and appropriate delivery option (e.g., overnight or Saturday)?			
4. Was the completed air bill attached to cooler top with the correct laboratory address?			
5. If more than one cooler was being shipped to the same laboratory, were they marked as "1 of 2," "2 of 2," etc.?			
6. Were the samples being shipped "overnight" through a qualified commercial carrier?			
Reporting CLP Samples	**Yes**	**No**	**Comments:**
1. Did you contact the Regional Sample Control Center Coordinator (RSCC) (or designee) or the CLP Sample Management Office (SMO) on the same day the samples were shipped?			
2. If the samples were shipped after 5:00 PM Eastern Time (ET), were they reported to the RSCC (or designee) or to SMO by 8:00 AM ET the following business day?			
3. Did you notify the RSCC (or designee) or SMO so that SMO will receive the delivery information by 3:00 PM ET on Friday for sample shipments that will be delivered to the laboratory on Saturday?			
4. Did you provide the RSCC (or designee) or SMO with: □ Your name, phone number, and Region number □ Case Number of the project □ Modified Analysis Number, if requested □ Exact number of samples, matrix(ces), concentration(s), and type of analysis □ Laboratory(ies) to which the samples were shipped □ Carrier name and air bill number □ Date of shipment □ Date of next shipment □ Any other information pertinent to the shipment			

Trihydro CORPORATION

memorandum

To:	Trihydro Employees
From:	OSE
Date:	June 2019
Re:	Standard Operating Procedure – Packaging and Shipping of Department of Transportation (DOT) and International Air Transport Association (IATA)Hazardous Substances

1.0 PURPOSE

The purpose of this standard operating procedure (SOP) is to provide general instructions for packaging and shipping Department of Transportation (DOT) and International Air Transport Association (IATA) hazardous samples, including Class 9 "environmentally hazardous substances." The primary use of this SOP is for transporting samples collected on site to be sent off site for physical, chemical, biological (infectious substance), and radiological analysis.

2.0 SCOPE

This SOP applies to packaging and shipping of DOT hazardous samples. Samples must be packaged and shipped as hazardous materials (HAZMAT) if they meet any of the hazard class definitions in Title 49 Code of Federal Regulations (49 CFR) (see Section 3.0 below) (DOT 2009). Improperly shipping HAZMAT, including willful misrepresentation, is a violation of federal law and is punishable by fines and possible imprisonment of guilty parties (IATA 2009). It is also a violation of Trihydro policy and can result in disciplinary action up to and including termination of employment.

3.0 HAZARDOUS MATERIAL CLASSIFICATIONS

Under the United Nations (UN) system for classification, identification, and hazardous-materials ranking, all hazardous substances are divided into nine general classes according to their physical, chemical, and nuclear properties as follows (IATA 2016):

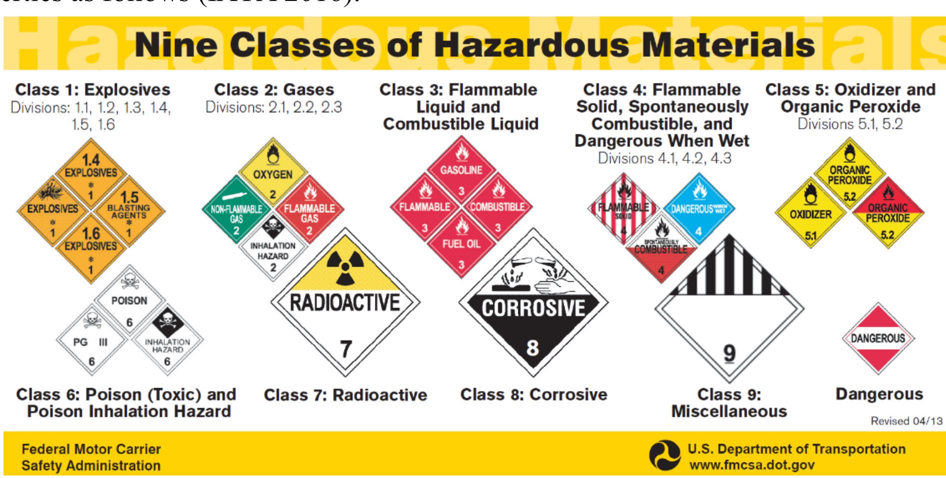

Figure 1: Classes of Hazardous Materials

There are nine classes of hazardous materials:

Class 1: Explosives	1.1: Mass explosion hazard 1.2: Projectile hazard 1.3: Minor blast / projectile / fire 1.4: Minor blast 1.5: Insensitive explosives 1.6: Very insensitive explosives
Class 2: Compressed Gases	2.1: Flammable gases 2.2: Non-flammable compressed gases 2.3: Poisonous gases
Class 3: Flammable Liquids	3.1: Flammable (flash point below 141°) 3.2: Combustible (flash point from 141° to 200°)
Class 4: Flammable Solids	4.1: Flammable solids 4.2: Spontaneously combustible 4.3: Dangerous when wet
Class 5: Oxidizers and Organic Peroxides	5.1: Oxidizer 5.2: Organic peroxide
Class 6: Toxic Materials	6.1: Poisonous materials 6.2: Infectious agents
Class 7: Radioactive Material	7.1: Radioactive I 7.2: Radioactive II 7.3: Radioactive III
Class 8: Corrosive Material	8.1: Destruction of the human skin 8.2: Corrodes steel at minimum 0.25 inches per year
Class 9: Miscellaneous	A material that presents a hazard during shipment but does not meet the definition of the other classes

4.0 RESPONSIBILITIES AND TRAINING REQUIREMENTS

The major responsibilities of HAZMAT shippers include (FMCSA 2014):

- Determining whether a material meets the definition of a HAZMAT.
- Providing appropriate containers/labeling information (e.g., proper shipping name, class, identification number, hazard-warning label, packaging, and marking).
- Attending training as required (DOT/IATA).
- Providing emergency-response information and telephone numbers.
- Following incident-reporting procedures.

Any employee involved in shipping HAZMAT is defined as a "HAZMAT employee" by DOT. HAZMAT employees must receive initial training before transporting hazardous materials and retrained at least every 3 years (DOT 2009) and every 2 years for IATA (IATA 2016). For projects requiring HAZMAT transportation, the Project Manager, Field Team Lead (FTL), or designee, is responsible for ensuring that employees are properly trained and comply with DOT/IATA regulations.

5.0 PROCEDURE

The basic packaging and shipping procedures include (USGPO 2016):

- Determining the traits of the material to be shipped and comparing them to the specific hazard class definitions in the appropriate regulations. If the material falls within one or more hazard class definitions, it is deemed "hazardous."
- Selecting the accurate shipping name and packing group combination, and preparing the package according to the prescribed requirements for quantity limitations, authorized packaging, marking, labeling, and documentation.
- If shipping multiple inner packages and each item meets a separate hazard class definition, consulting the "Separation and Segregation" table in the appropriate regulations for guidance on packaging and preparing as an over-pack with individual marking and labeling on the outer packaging.
- If shipping multiple inner packages that meet the same hazard class(es) but represent both solid and liquid matrices, preparing as an over-pack with individual marking and labeling on the outer packaging.
- If shipping HAZMAT that meets more than one hazard class definition, check the hazard precedence table in the appropriate regulations to determine primary and subsidiary classes.

5.1 Additional Inner Packaging General Requirements

According to the United States Government Publishing Office (USGPO), the following additional inner-packaging requirements must be met:

- Place each sample container into a resealable-plastic bag.
- Fold over and tape the bag seal onto the sample jar to prevent the closure from unsealing.
- Wrap the bagged sample container with bubble wrap or other packing material to prevent breakage against the sides of the primary receptacle, and place it into the primary receptacle.
- Seal the primary receptacle and label it with the sample-identification number and any hazard information.
- Specific inner packaging requirements will be determined based on the type of materials shipped in accordance with DOT and IATA regulations.

5.2 Additional Outer-Packaging Requirements

According to the USGPO (2016), the following additional outer-packaging requirements must be met:

- Samples that qualify as Excepted Quantities or Limited Quantities do not require the use of UN specification packaging and may be shipped in sturdy coolers, pails, or any packaging that meets general packaging requirements.
- Samples that do not qualify as Excepted Quantities or Limited Quantities require UN specification outer packaging. For such samples that also require cooling to meet sample-preservation requirements, UN-specification coolers are available from several packaging vendors.
- If using a cooler of any kind, ensure that it is marked or labeled "For Samples Only," then seal off the cooler drain on the inside and outside with tape to prevent leakage.
- Place cushioning and absorbent material on the bottom of the outer packaging to provide a soft impact surface.
- Place a 55-gallon or equivalent plastic bag into the container to minimize possibility of leakage during transit.
- Wrap glass inner packaging with sufficient bubble wrap to ensure the best chance to prevent container breakage.
- Pack the largest inner packaging in the bottom of the container with cushioning material between each to avoid breakage from bumping.
- Line each cooler with a large plastic bag and add bagged ice across the top of the samples.
- When sufficiently full, seal the plastic bag that lines the outer packaging, and place additional cushioning material on top of the bag to minimize shifting of contents during shipment.
- Tape a resealable-plastic bag to the inside of the container lid, place the completed chain-of-custody document inside, and seal the bag shut.
- Tape the outer packaging closed using packing tape, duct tape, or other tear-resistant adhesive strips.
- Place a custody seal on two separate portions of the outer packaging to provide evidence that the lid remains sealed during transit.
- Specific outer packaging requirements to be determined based on the type of materials that will be shipped in accordance with DOT and IATA regulations.

5.3. Marking and Labeling

The DOT (USGPO 2016) and IATA (2009) marking and labeling requirements include:

Photo 2: Hazardous material labels examples

- If the package contains any liquids, orientation arrows must be applied to two opposite faces of the package (front and back or both ends).
- The proper shipping name, UN number, and all other required markings, as well as the appropriate hazard class label, must be placed on the same face of the package near each other.
- Consignor and consignee information should appear on some face of the package in addition to appearing on the shipping papers that are enclosed in a pouch attached to the package.

5.4 Shipping Documentation

The DOT (USGPO 2016) and IATA (2009) shipping documentation requirements are outlined below.

- If a sturdy cooler is used, whether UN-specification or not, complete a Cooler Shipment Checklist and keep it in the project file; an example checklist is shown on Attachment 1.
- A Shipper's Declaration for Dangerous Goods (Attachment 2) must be completed, inserted into an adhesive pouch, and attached to the package in close proximity to the proper shipping name and hazard class label. Only properly trained personnel can prepare and sign off on shipping documentation.
- Many carriers require a typed or computer-generated form.
- If the form has an area specifically designated for a "24-Hour Emergency Response" telephone number, insert "800-XXX-XXXX" into that space. If it does not, write "24-Hour Emergency Response Telephone Number: 800-XXX-XXXX" in the "Additional Handling Information" section of the form. Immediately following the telephone number, write the three-digit Emergency Response Guidebook page number that corresponds to the HAZMAT being shipped.
- The trained shipper must sign the certification on the form.

5.5 Declared Value Limits

FedEx and United Parcel Service (UPS) limit their liability for lost shipments to $100 value at no cost to Trihydro. Do not declare shipment values beyond $100 when shipping samples (e.g., soil, groundwater, etc.).

6.0 REFERENCES

Federal Motor Carrier Safety Administration (FMCSA). 2014. How to Comply with Federal Hazardous Materials Regulations. Available from: https://www.fmcsa.dot.gov/regulations/hazardous-materials/how-comply-federal-hazardous-materials-regulations.

International Air Transport Association (IATA). 2009. IATA Dangerous Goods Regulations Manual.

IATA. 2016. Hazard Labels. Available from: http://www.iata.org/publications/dgr/Pages/hazard-labels.aspx.

United States Department of Transportation (DOT). 2009. The Transportation of Hazardous Materials: Insurance, Security, and Safety Costs. Available from: https://www.transportation.gov/sites/dot.gov/files/docs/The%20Transportation%20of%20Hazardous%20Materials%20-%20Insurance%2C%20Security%2C%20and%20Safety%20Costs%20--%20Dec%202009.pdf.

United States Government Publishing Office (USGPO). 2016. Electronic Code of Federal Regulations, Title 49, Subtitle B, Chapter I, Subchapter C, Part 178 178. Available from: http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title49/49cfr178_main_02.tpl.

QAQ-CSO-P00

ATTACHMENT 1

EXAMPLE COOLER SHIPMENT CHECKLIST

Check the appropriate boxes
Y = Yes; N = No; N/A = Not Applicable

If any checks are entered in the **NO** box make all necessary corrections before allowing shipment to be released.

Item	Shipping Document Questions	Y	N	N/A
1.	Is the Shipping Date entered? (4.4.(1)(a))			
2.	Is the Shipping Document Number entered? (4.4(1)(a))			
3.	Is the full name and address of the Consignor entered? (4.8(1)(a))			
4.	Is the full name and Address of the Consignee entered? (4.8(1)(b))			
5.	Is the Name of the Initial Carrier entered? (4.8(1)(c))			
6.	Is the Unit Number of the Railway Vehicle entered? Rail Only 4.8(1)(d))			
7.	For shipments including Dangerous and Non Dangerous Goods, are the Dangerous Goods correctly highlighted? (Under a separate Heading of Dangerous Goods, Highlighted in a different colour or an X in a DG/MG column opposite the shipping name) (4.6(b))			
8.	Is each item of dangerous goods entered in the following order? a) The full Shipping Name. (4.8(1)(e)(i))			
	b) The primary classification (4.8(1)(e)(ii))			
	c) For class 1 only the compatibility group (4.8(1)(e)(iii))			
	d) Every susidiary class in parentheses (4.8(1)(e)(iv))			
	e) The product identification number (4.8(1)(e)(v)			
	f) The letter "E" if applicable (4.8(1)(e)(vi))			
	g) The packing group (4.8(1)(e)(vii))			
9.	Are the words "SPECIAL COMMODITY" used if by rail and special provision 102 applied? (4.8(1)(f)			
10.	Is the flash point for all class three items entered, if by ship? (4.8(1)(g))			
11.	If subject to Schedule XII requirements do the words "Summary Emergency Response Plan" or "ERP", the plan reference Number and the plan telephone number appear? (4.8(1)(h))			
12.	Does the number of packages and containers for each item appear? (4.8(1)(i))			
13.	Is the total gross mass or volume of each item listed? (4.8(1)(i))			

Available from:
http://www.bing.com/images/search?q=Shipping+Checklist&view=detailv2&&id=8A53E3674456E22E18071A203515FC36FF14E5F6&selectedIndex=4&ccid=uelLwGJL&simid=607997100325208931&thid=OIP.Mb9e94bc0624b76bf75f19fd10d5dfb49o0&ajaxhist=0.

ATTACHMENT 2

SHIPPERS DECLARATION FOR DANGEROUS GOODS

memorandum

To:	Trihydro Employees
From:	OSE
Date:	June 2019
Re:	Standard Operating Procedure – Packaging and Shipping of Department of Transportation (DOT) and International Air Transport Association (IATA)Hazardous Substances

1.0 PURPOSE

The purpose of this standard operating procedure (SOP) is to provide general instructions for packaging and shipping Department of Transportation (DOT) and International Air Transport Association (IATA) hazardous samples, including Class 9 "environmentally hazardous substances." The primary use of this SOP is for transporting samples collected on site to be sent off site for physical, chemical, biological (infectious substance), and radiological analysis.

2.0 SCOPE

This SOP applies to packaging and shipping of DOT hazardous samples. Samples must be packaged and shipped as hazardous materials (HAZMAT) if they meet any of the hazard class definitions in Title 49 Code of Federal Regulations (49 CFR) (see Section 3.0 below) (DOT 2009). Improperly shipping HAZMAT, including willful misrepresentation, is a violation of federal law and is punishable by fines and possible imprisonment of guilty parties (IATA 2009). It is also a violation of Trihydro policy and can result in disciplinary action up to and including termination of employment.

3.0 HAZARDOUS MATERIAL CLASSIFICATIONS

Under the United Nations (UN) system for classification, identification, and hazardous-materials ranking, all hazardous substances are divided into nine general classes according to their physical, chemical, and nuclear properties as follows (IATA 2016):

Figure 1: [Classes of Hazardous Materials]

There are nine classes of hazardous materials:

Class 1: Explosives	1.1: Mass explosion hazard 1.2: Projectile hazard 1.3: Minor blast / projectile / fire 1.4: Minor blast 1.5: Insensitive explosives 1.6: Very insensitive explosives
Class 2: Compressed Gases	2.1: Flammable gases 2.2: Non-flammable compressed gases 2.3: Poisonous gases
Class 3: Flammable Liquids	3.1: Flammable (flash point below 141°) 3.2: Combustible (flash point from 141° to 200°)
Class 4: Flammable Solids	4.1: Flammable solids 4.2: Spontaneously combustible 4.3: Dangerous when wet
Class 5: Oxidizers and Organic Peroxides	5.1: Oxidizer 5.2: Organic peroxide
Class 6: Toxic Materials	6.1: Poisonous materials 6.2: Infectious agents
Class 7: Radioactive Material	7.1: Radioactive I 7.2: Radioactive II 7.3: Radioactive III
Class 8: Corrosive Material	8.1: Destruction of the human skin 8.2: Corrodes steel at minimum 0.25 inches per year
Class 9: Miscellaneous	A material that presents a hazard during shipment but does not meet the definition of the other classes

4.0 RESPONSIBILITIES AND TRAINING REQUIREMENTS

The major responsibilities of HAZMAT shippers include (FMCSA 2014):

- Determining whether a material meets the definition of a HAZMAT.
- Providing appropriate containers/labeling information (e.g., proper shipping name, class, identification number, hazard-warning label, packaging, and marking).
- Attending training as required (DOT/IATA).
- Providing emergency-response information and telephone numbers.
- Following incident-reporting procedures.

Any employee involved in shipping HAZMAT is defined as a "HAZMAT employee" by DOT. HAZMAT employees must receive initial training before transporting hazardous materials and retrained at least every 3 years (DOT 2009) and every 2 years for IATA (IATA 2016). For projects requiring HAZMAT transportation, the Project Manager, Field Team Lead (FTL), or designee, is responsible for ensuring that employees are properly trained and comply with DOT/IATA regulations.

5.0 PROCEDURE

The basic packaging and shipping procedures include (USGPO 2016):

- Determining the traits of the material to be shipped and comparing them to the specific hazard class definitions in the appropriate regulations. If the material falls within one or more hazard class definitions, it is deemed "hazardous."
- Selecting the accurate shipping name and packing group combination, and preparing the package according to the prescribed requirements for quantity limitations, authorized packaging, marking, labeling, and documentation.
- If shipping multiple inner packages and each item meets a separate hazard class definition, consulting the "Separation and Segregation" table in the appropriate regulations for guidance on packaging and preparing as an over-pack with individual marking and labeling on the outer packaging.
- If shipping multiple inner packages that meet the same hazard class(es) but represent both solid and liquid matrices, preparing as an over-pack with individual marking and labeling on the outer packaging.
- If shipping HAZMAT that meets more than one hazard class definition, check the hazard precedence table in the appropriate regulations to determine primary and subsidiary classes.

5.1 Additional Inner Packaging General Requirements

According to the United States Government Publishing Office (USGPO), the following additional inner-packaging requirements must be met:

- Place each sample container into a resealable-plastic bag.
- Fold over and tape the bag seal onto the sample jar to prevent the closure from unsealing.
- Wrap the bagged sample container with bubble wrap or other packing material to prevent breakage against the sides of the primary receptacle, and place it into the primary receptacle.
- Seal the primary receptacle and label it with the sample-identification number and any hazard information.
- Specific inner packaging requirements will be determined based on the type of materials shipped in accordance with DOT and IATA regulations.

5.2 Additional Outer-Packaging Requirements

According to the USGPO (2016), the following additional outer-packaging requirements must be met:

- Samples that qualify as Excepted Quantities or Limited Quantities do not require the use of UN specification packaging and may be shipped in sturdy coolers, pails, or any packaging that meets general packaging requirements.
- Samples that do not qualify as Excepted Quantities or Limited Quantities require UN specification outer packaging. For such samples that also require cooling to meet sample-preservation requirements, UN-specification coolers are available from several packaging vendors.
- If using a cooler of any kind, ensure that it is marked or labeled "For Samples Only," then seal off the cooler drain on the inside and outside with tape to prevent leakage.
- Place cushioning and absorbent material on the bottom of the outer packaging to provide a soft impact surface.
- Place a 55-gallon or equivalent plastic bag into the container to minimize possibility of leakage during transit.
- Wrap glass inner packaging with sufficient bubble wrap to ensure the best chance to prevent container breakage.
- Pack the largest inner packaging in the bottom of the container with cushioning material between each to avoid breakage from bumping.
- Line each cooler with a large plastic bag and add bagged ice across the top of the samples.
- When sufficiently full, seal the plastic bag that lines the outer packaging, and place additional cushioning material on top of the bag to minimize shifting of contents during shipment.
- Tape a resealable-plastic bag to the inside of the container lid, place the completed chain-of-custody document inside, and seal the bag shut.
- Tape the outer packaging closed using packing tape, duct tape, or other tear-resistant adhesive strips.
- Place a custody seal on two separate portions of the outer packaging to provide evidence that the lid remains sealed during transit.
- Specific outer packaging requirements to be determined based on the type of materials that will be shipped in accordance with DOT and IATA regulations.

5.3. Marking and Labeling

Photo 2: Hazardous material labels examples

The DOT (USGPO 2016) and IATA (2009) marking and labeling requirements include:

- If the package contains any liquids, orientation arrows must be applied to two opposite faces of the package (front and back or both ends).
- The proper shipping name, UN number, and all other required markings, as well as the appropriate hazard class label, must be placed on the same face of the package near each other.
- Consignor and consignee information should appear on some face of the package in addition to appearing on the shipping papers that are enclosed in a pouch attached to the package.

5.4 Shipping Documentation

The DOT (USGPO 2016) and IATA (2009) shipping documentation requirements are outlined below.

- If a sturdy cooler is used, whether UN-specification or not, complete a Cooler Shipment Checklist and keep it in the project file; an example checklist is shown on Attachment 1.
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- The trained shipper must sign the certification on the form.

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FedEx and United Parcel Service (UPS) limit their liability for lost shipments to $100 value at no cost to Trihydro. Do not declare shipment values beyond $100 when shipping samples (e.g., soil, groundwater, etc.).

6.0 REFERENCES

Federal Motor Carrier Safety Administration (FMCSA). 2014. How to Comply with Federal Hazardous Materials Regulations. Available from: https://www.fmcsa.dot.gov/regulations/hazardous-materials/how-comply-federal-hazardous-materials-regulations.

International Air Transport Association (IATA). 2009. IATA Dangerous Goods Regulations Manual.

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United States Department of Transportation (DOT). 2009. The Transportation of Hazardous Materials: Insurance, Security, and Safety Costs. Available from: https://www.transportation.gov/sites/dot.gov/files/docs/The%20Transportation%20of%20Hazardous%20Materials%20-%20Insurance%2C%20Security%2C%20and%20Safety%20Costs%20--%20Dec%202009.pdf.

United States Government Publishing Office (USGPO). 2016. Electronic Code of Federal Regulations, Title 49, Subtitle B, Chapter I, Subchapter C, Part 178 178. Available from: http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title49/49cfr178_main_02.tpl.

QAQ-CSO-P00

ATTACHMENT 1

EXAMPLE COOLER SHIPMENT CHECKLIST

Check the appropriate boxes Y = Yes; N = No; N/A = Not Applicable	If any checks are entered in the **NO** box make all necessary corrections before allowing shipment to be released.			
Item	**Shipping Document Questions**	**Y**	**N**	**N/A**
1.	Is the Shipping Date entered? (4.4.(1)(a))			
2.	Is the Shipping Document Number entered? (4.4(1)(a))			
3.	Is the full name and address of the Consignor entered? (4.8(1)(a))			
4.	Is the full name and Address of the Consignee entered? (4.8(1)(b))			
5.	Is the Name of the Initial Carrier entered? (4.8(1)(c))			
6.	Is the Unit Number of the Railway Vehicle entered? Rail Only 4.8(1)(d))			
7.	For shipments including Dangerous and Non Dangerous Goods, are the Dangerous Goods correctly highlighted? (Under a separate Heading of Dangerous Goods, Highlighted in a different colour or an X in a DG/MG column opposite the shipping name) (4.6(b))			
8.	Is each item of dangerous goods entered in the following order? a) The full Shipping Name. (4.8(1)(e)(i))			
	b) The primary classification (4.8(1)(e)(ii))			
	c) For class 1 only the compatibility group (4.8(1)(e)(iii))			
	d) Every susidiary class in parentheses (4.8(1)(e)(iv))			
	e) The product identification number (4.8(1)(e)(v)			
	f) The letter "E" if applicable (4.8(1)(e)(vi))			
	g) The packing group (4.8(1)(e)(vii))			
9.	Are the words "SPECIAL COMMODITY" used if by rail and special provision 102 applied? (4.8(1)(f)			
10.	Is the flash point for all class three items entered, if by ship? (4.8(1)(g))			
11.	If subject to Schedule XII requirements do the words "Summary Emergency Response Plan" or "ERP", the plan reference Number and the plan telephone number appear? (4.8(1)(h))			
12.	Does the number of packages and containers for each item appear? (4.8(1)(i))			
13.	Is the total gross mass or volume of each item listed? (4.8(1)(i))			

Available from:
http://www.bing.com/images/search?q=Shipping+Checklist&view=detailv2&&id=8A53E3674456E22E18071A203515FC36FF14E5F6&selectedIndex=4&ccid=uelLwGJL&simid=607997100325208931&thid=OIP.Mb9e94bc0624b76bf75f19fd10d5dfb49o0&ajaxhist=0.

ATTACHMENT 2

SHIPPERS DECLARATION FOR DANGEROUS GOODS

SHIPPER'S DECLARATION FOR DANGEROUS GOODS

IATA

Shipper	Air Waybill No. Page of Pages Shipper's Reference No. (optional)
Consignee	
Two completed and signed copies of this Declaration must be handed to the operator.	**WARNING** **Failure to comply in all respects with the applicable Dangerous Goods Regulations may be in breach of the applicable law, subject to legal penalties.**
TRANSPORT DETAILS This shipment is within the limitations prescribed for: ☐ PASSENGER AND CARGO AIRCRAFT ☐ CARGO AIRCRAFT ONLY Airport of Departure (optional): Airport of Destination (optional):	Shipment type: *(delete non-applicable)* ☐ NON-RADIOACTIVE RADIOACTIVE ☐

NATURE AND QUANTITY OF DANGEROUS GOODS

UN Number or Identification Number, Proper Shipping Name, Class or Division (subsidiary hazard), Packing Group (if required) and all other required information.

Additional Handling Information

I hereby declare that the contents of this consignment are fully and accurately described above by the proper shipping name, and are classified, packaged marked and labelled/placarded, and are in all respects in proper condition for transport according to applicable international and national governmental regulations. I declare that all of the applicable air transport requirements have been met.	Name of Signatory Date Signature *(See warning above)*

TABLE OF CONTENTS

Revision History

Version History

Date	Document Version	Document Revision History	Document Author/Reviser
12/21/15	0	Document Creation	Elizabeth Gillenwalters

Approvals

Date	Document Version	Approver Name and Title	Approver Signature
12/21/15	0	Tom Hansen, President	

1. PURPOSE

This procedure provides the implementing instructions necessary to comply with requirements specified in Ameriphysics' Radiological Control Procedure Manual, Section 4.3, *Survey Instruments*.

2. REFERENCED DOCUMENTS

- RCF 4-4 Instrument Validation Checklist
- RCF 4-5 Scalar Instrument Set-up
- RCF 4-6 Daily Instrument Response Check
- RCF 4-7 Non-Scalar Instrument Set-up and Daily Response Check
- RCF 4-8 Gas Flow Instrument Set-up
- RCF 4-9 Gas Flow Instrument Daily Response Check
- Survey instrument calibration certificates

3. RESPONSIBILITIES

3.1 Radiation Safety Officer

1. Maintain survey instrument inventory.

3.2 Project Manager

1. Selection of proper survey instruments during pre-project assessment.
2. Maintenance of project records.
3. Review of all completed forms.
4. Ensure all employees using survey instruments have been provided satisfactory training.

3.3 Technicians

1. Perform instrument validation, set-up and daily response checks in accordance with this procedure.
2. Accurate completion of applicable forms.

4. INSTRUMENT VALIDATION

Each survey instrument selected shall be checked out of the corporate office. The check-out sheet should include the check-out date, initials of responsible party, and indication of where the project will be taken. Check-in shall occur once the instrument is returned to the corporate office.

Prior to mobilization to a project location, each instrument should be investigated for proper working condition and documentation made on Form RCF 4-4 for each instrument.

5. SCALAR INSTRUMENT SET-UP

- This applies to all instruments used to measure activity, i.e. units of cpm.
- Scalar instrument set-up must be completed for each project location prior to the first use of the instrument.
- A separate form RCF 4-5 should be completed for each survey instrument/probe combination to be used, as well as each radiation type to be measured, i.e. alpha, beta, gamma.

1. Inspect the instrument, detector, and cables for signs of obvious damage; check (as applicable) batteries, mechanical zero, electrical zero, high voltage, and threshold setting.
2. Obtain and complete form RCF 4-5.
3. Complete date, time, and project number.
4. Enter instrument model, serial number, and calibration due date.
5. Enter detector model, serial number, and calibration due date.
6. Enter calibration source isotope, serial number and source activity in decays per minute (dpm).
7. Ensure the survey instrument is in an area of low background radiation. Refer to manufacturers specifications or instrument Ameriphysics' Instrument Quick Reference Sheets for typical instrument background.

5.1. Beta/Gamma Instrument Background Determination

1. Obtain 10 one-minute background (BKG) counts. Record the 10 measurements in the BKD Count Rate column.

2. Calculate BKD Count Rate Mean value using the following equation and enter in the appropriate space:

$$\frac{\sum BKD\ Count\ Rate}{10}$$

3. Determine the BKD range using the following equations and enter in the appropriate space:

$$Minimum = B_R \times 0.80$$

$$Maximum = B_R \times 1.20$$

5.2. Alpha Instrument Background Determination

1. Obtain 10 one-minute background counts. Record the 10 measurements in the BKD Count Rate column.
2. Calculate BKD Count Rate Mean value using the following equation and enter in the appropriate space:

$$\frac{\sum BKD\ Count\ Rate}{10}$$

3. Determine the BKD range using the manufacturer's specifications and enter in the appropriate space. Background range information can be found on Ameriphysics' Instrument Quick Reference Sheets or manufacturer's product manuals.

5.3. Source Count Determination

1. Obtain 10 one-minute source (SRC) counts. Record the 10 measurements in the Gross SRC Count Rate column.
2. Calculate the SRC Net Count Rate using the following equation and enter the values in the Net Count Rate column:

$$Gross\ SRC\ Count\ Rate - BKD\ Count\ Rate\ Mean$$

3. Calculate SRC Net Count Rate Mean value using the following equation and enter in the appropriate space:

$$\frac{\sum Net\ Count\ Rate}{10}$$

4. Determine the SRC Net range using the following equations and enter in the appropriate space:

$$Minimum = S_R \times 0.80$$

$$Maximum = S_R \times 1.20$$

5. The form must be signed by the Ameriphysics team member performing the survey instrument set up.
6. Completed forms RCF 4-5 shall be reviewed by the Radiation Control Supervisor or Project Manager.

6. SCALAR INSTRUMENT DAILY RESPONSE CHECK

- A separate form RCF 4-6 should be completed for each survey instrument/probe combination to be used.
- A daily response check should be performed prior to the first use of the survey instrument.

1. Inspect the instrument, detector, and cables for signs of obvious damage; check (as applicable) batteries, mechanical zero, electrical zero, high voltage, and threshold setting.
2. Obtain and complete form RCF 4-6.
3. Enter instrument, detector, source, and range information from form RCF 4-5.
4. Enter page number in the format Page 2, Page 3, etc.
5. Enter high voltage. This information can be found on the instrument calibration certificate.
6. Enter current date and time.
7. Obtain a single one-minute background count and enter into the appropriate column.
8. Obtain a single one-minute gross source count and enter into the appropriate column.
9. Calculate the Net Count Rate using the following equation and enter on the form:

$$Net\ Count\ Rate = Gross\ Count\ Rate - Background\ Count\ Rate$$

10. Compare the Background Count Rate to the Background Range.
11. Compare the Net Count Rate to the Net Count Range.
12. If the Background Count Rate and Net Count Rate fall within their respective ranges, Ameriphysics team member initials are placed to verify completion of daily response check.
13. If the Background Count Rate and Net Count Rate do not fall within their respective ranges, remove the instrument from service and notify the Radiation Control Supervisor or the Project Manager. Refer to Section 11.

14. Enter any comments relevant to the daily response check, if applicable.
15. Project Manager or Radiation Control Supervisor shall review form RCF 4-6 and sign before moving to project files.

7. GAS FLOW INSTRUMENT SET UP

- Instrument set-up must be completed for each project location prior to the first use of the instrument.
- A separate form RCF 4-8 should be completed for each survey instrument/probe combination to be used, as well as each radiation type to be measured, i.e. alpha, beta, gamma.

1. Inspect the instrument, detector, and cables for signs of obvious damage; check (as applicable) batteries, mechanical zero, electrical zero, high voltage, and threshold setting.
2. Obtain and complete form RCF 4-8.
3. Complete date, time, and project number.
4. Enter instrument model, serial number, and calibration due date.
5. Enter detector model, serial number, and calibration due date.
6. Enter calibration source isotope, serial number and source activity in decays per minute (dpm).
7. Enter the instrument efficiency for the calibration source isotope in the appropriate space. This information is found on the survey instrument calibration certificate. The Project Manager will determine if the use of 2 Pi or 4 Pi efficiency is required.
8. Calculate the Expected Count Rate in counts per minute (cpm) using the following equation and enter the value in the appropriate space:

$$Instrument\ Efficiency\ \times Source\ Activity$$

9. Determine the Expected Count Rate Range using the following equations and enter in the appropriate space:

$$Minimum = \ Expected\ Count\ Rate\ \times 0.80$$

$$Maximum = \ Expected\ Count\ Rate\ \times 1.20$$

10. Determine the gas inlet and exit flows using a flow meter (rotometer or equivalent). Record the flow rates in the appropriate spaces.
11. If the inlet and exit gas flow rates do not agree within 10%, remove the instrument from service and refer to Section 11.
12. Ensure the survey instrument is in an area of low background radiation. Refer to manufacturers specifications or instrument Ameriphysics' Instrument Quick Reference Sheets for typical instrument background.
13. Refer to Sections 5.1, 5.2, and 5.3, as appropriate, for background determination and source count determination.
14. Compare each Net SRC Count Rate and the Net SRC Count Rate Mean with the Expected Count Rate Range. If the Net values and Net SRC Count Rate Mean area within Expected Count Rate range, enter "True" in the appropriate space(s) and proceed with use. Otherwise enter "False" in the appropriate space(s) and refer to Section 11 for instructions on how to proceed.
15. The form must be signed by the Ameriphysics team member performing the survey instrument set up.
16. Completed forms shall be reviewed by the Radiation Control Supervisor or Project Manager.

8. GAS FLOW DAILY RESPONSE CHECK

- A separate form RCF 4-9 should be completed for each survey instrument/probe combination to be used.
- A daily response check should be performed prior to the first use of the survey instrument.

1. Inspect the instrument, detector, and cables for signs of obvious damage; check (as applicable) batteries, mechanical zero, electrical zero, high voltage, and threshold setting.
2. Obtain and complete form RCF 4-9.
3. Enter instrument, detector, source, and range information from form RCF 4-8.
4. Enter page number in the format Page 2, Page 3, etc.
5. Enter high voltage. This information can be found on the instrument calibration certificate.
6. Enter current date and time.

7. Obtain a single background count and enter into the appropriate column.
8. Obtain a single gross source count and enter into the appropriate column.
9. Calculate the Net Count Rate using the following equation and enter on the form:

$$Net\ Count\ Rate = Gross\ Count\ Rate - Background\ Count\ Rate$$

10. Compare the Background Count Rate to the Background Range.
11. Compare the Net Count Rate to the Net Count Range.
12. If the Background Count Rate and Net Count Rate fall within their respective ranges, enter "yes" in the "Acceptable for Use" column.
13. If the Background Count Rate and Net Count Rate do not fall within their respective ranges, perform the following:
- Check the gas tank pressure and regulator settings to ensure they are acceptable.
- Check all fittings to ensure they are tight and not leaking
- Wait 10 minutes and repeat the background and source check counts
14. If the Background Count Rate and Net Count Rate fall within their respective ranges, enter "yes" in the "Acceptable for Use" column.
15. If the Background Count Rate and Net Count Rate remain outside their respective ranges, enter "no" in the "Acceptable for Use" column and remove the instrument from service and notify the Radiation Control Supervisor or the Project Manager. Refer to Section 11.
16. Enter any comments relevant to the daily response check, if applicable.
17. Ameriphysics team member initials must be completed to verify daily response check. Initials indicate that the Count Rates fell within their respective ranges and the instrument is satisfactory for service.
18. Project Manager or Radiation Control Supervisor shall review form RCF 4-9 and sign before moving to project files.

9. NON-SCALAR INSTRUMENT SET-UP

- This applies to all instruments used to measure dose rate in units of mR/hr or activity in cpm that do not have a scaler function (i.e., friskers), as applicable.

- A separate form RCF 4-7 should be completed for each survey instrument/probe combination to be used.
- Non-scalar instrument set-up must be completed for each project location prior to the first use of the instrument.

1. Inspect the instrument, detector, and cables for signs of obvious damage; check (as applicable) batteries, mechanical zero, electrical zero, high voltage, and threshold setting.
2. Obtain and complete form RCF 4-7.
3. Enter instrument model, serial number, and calibration due date.
4. Enter detector model, serial number, and calibration due date, if applicable.
5. Enter calibration source isotope, serial number and source activity.
6. Enter project number and page number.
7. Enter the date and time of the initial reading and enter on the first line.
8. Ensure the survey instrument is in an area of low background. Refer to manufacturers specifications or instrument Ameriphysics' Instrument Quick Reference Sheets for typical instrument background.
9. Obtain a single background measurement and record in mR/hr or cpm, as applicable.
10. Determine the background range using the following equations and enter in the appropriate space:

$$Minimum = Background\ Rate \times 0.80$$

$$Maximum = Background\ Rate \times 1.20$$

11. Obtain a single gross source count utilizing the check source and record in mR/hr or cpm.
12. Calculate the Net Rate using the following equation and enter the values in the Net Rate column:

$$Net\ Rate = Gross\ Source\ Rate - Background\ Rate$$

13. Determine the net rate range using the following equations and enter in the appropriate space:

$$Minimum = Net\ Rate \times 0.80$$

$$Maximum = Net\ Rate \times 1.20$$

14. For the initial reading, leave the "Acceptable for Use" and "Initials" columns blank and enter "Initial Reading" in the Comments Section.

15. The Ameriphysics team member performing the initial survey instrument set-up should print their name and date at the bottom of the form.
16. Completed forms RCF 4-7 shall be reviewed by the Radiation Control Supervisor or Project Manager.

10. NON-SCALAR INSTRUMENT DAILY RESPONSE CHECK

- A daily response check should be performed prior to the first use of the survey instrument.

1. Inspect the instrument, detector, and cables for signs of obvious damage; check (as applicable) batteries, mechanical zero, electrical zero, high voltage, and threshold setting.
2. Enter current date and time.
3. Obtain a single Background Rate.
4. Obtain a single Gross Source Rate measurement.
5. Calculate the Net Rate using the following equation and enter on the form:

$$Net\ Rate\ = Gross\ Rate - Background\ Rate$$

6. Compare the Background Rate to the Background Range.
7. Compare the calculated Net Rate to the Net Rate Range.
8. If the Background Count Rate and Net Count Rate fall within their respective ranges, enter "yes" in the "Acceptable for Use" column.
9. If the Background Count Rate and Net Count Rate do not fall within their respective ranges, enter "no" in the "Acceptable for Use" column and remove the instrument from service and notify the Radiation Control Supervisor or the Project Manager.
10. Enter any comments relevant to the daily response check, if applicable.
11. Ameriphysics team member initials must be completed to verify daily response check.
12. Project Manager or Radiation Control Supervisor shall review form RCF 4-7 and sign before moving to project files.

11. FAILURE PROTOCOL

1. If response check result is outside of allowable range OR if the physical checks performed above are unsatisfactory:

- Tag instrument out of service
- Notify PM or Radiation Control Supervisor.
- Investigate all surveys performed with the instrument since the last satisfactory response check.

Note: If an instrument has failed because it fell out of the background tolerances, the PM or RCS may determine that the instrument is still operable and the failure is only due to background fluctuations. In this case, the instrument may be returned to service without performing steps 2 and 3 below.

2. Perform instrument validation and complete form RCF 4-4. Follow instructions on form RCF 4-4 for placing the instrument back in service or removing from service due to continued failures.
3. If instrument is placed back into service, check for variations in background radiation.
   a. If the background falls within the previously established background range, re-perform the daily check and record on RCF 4-6 or RCF 4-9, as appropriate.
   b. If the background no longer falls within the background range:
      i. Move the survey instrument to an area of background radiation within the previously established range OR
      ii. Re-perform survey instrument setup according to the appropriate section above.

12. DOCUMENT CONTROL

Document control shall be performed in accordance with QAM Section 6, *Document Control*.

Trihydro CORPORATION

memorandum

To: Trihydro Employees
From: OSE
Date: May 29, 2015
Re: Standard Operating Procedure – Slug Testing (Author: Brian Smith)

1.0 INTRODUCTION

The purpose of this Standard Operating Procedure (SOP) is to establish procedures for determining the horizontal hydraulic conductivity of distinct geologic horizons under in-situ conditions. Hydraulic conductivity (K) is an important parameter for modeling groundwater flow in an aquifer. SOPs should be varied based on site conditions, equipment limitations, or client contract requirements.

A slug test involves the instantaneous injection or withdrawal of a volume or slug of water or solid cylinder of known volume. This is accomplished by displacing a known volume of water from a well and measuring the artificial fluctuation of the groundwater level. The primary advantages of using slug tests to estimate hydraulic conductivities are numerous. First, estimates can be made in-situ, thereby avoiding errors incurred in laboratory testing of disturbed soil samples. Second, tests can be performed quickly at relatively low costs because pumping and observation wells are not required. And lastly, the hydraulic conductivity of small discrete portions of an aquifer can be estimated (e.g., sand layers in clay) (EPA 1994).

2.0 EQUIPMENT HANDLING

Limitations of slug testing include: 1) only the hydraulic conductivity of the area immediately surrounding the well is estimated, which may not be representative of the average area hydraulic conductivity; and 2) the storage coefficient (S) usually cannot be determined by this method (EPA 1994).

Equipment that comes in contact with the well should be decontaminated and tested before starting field activities. Refer to the Equipment Decontamination SOP and the site-specific work plan for decontamination procedures. The following equipment is needed to perform slug tests (EPA 1994):

- Tape measure (subdivided into tenths of feet)
- Water-pressure transducer
- Electric water-level indicator
- Weighted tapes
- Steel tape (subdivided into tenths of feet)
- Electronic data-logger (if the transducer method is used)

- Stainless steel or PVC slug of a known volume
- Watch or stopwatch with second hand
- Semi-log graph paper (if required)
- Waterproof ink pen and logbook
- Thermometer
- Appropriate references and calculator
- Electrical duct tape
- Compact portable computer or equivalent with applicable software (transducer-specific or Excel) installed on the hard disk

3.0 TESTING PROCEDURES

When working with potential hazardous materials, follow United States Environmental Protection Agency (EPA), Occupational Safety and Health Administration (OSHA), and corporate health and safety procedures. Use the following procedures to collect and report slug-test data using the Slug-Test Data Form (Attachment A); modify procedures to reflect site-specific conditions as necessary (EPA 1994; Trihydro 2011):

1. Verify that the test wells have been adequately developed before testing.
2. Inspect the slug-test equipment before testing. Equipment should be in good working order and should be decontaminated before use to reduce the potential for cross-contamination between wells. New braided rope or string should be used at each test well location.
3. Calibrate and test all measuring equipment before use.
4. Visually inspect the well condition for damage or obstructions that could hinder the transducer or slug insertion and removal.
5. Measure the depth-to-water (DTW) and total depth (TD) of the test well with a water-level meter. Compare the measured TD with the well-construction log to determine if sediment has accumulated at the bottom of the well.
6. Connect the pressure transducer to the data cable and install it in the well. The transducer should be installed in the water column to a depth that will not interfere with the insertion and removal of the slug and does not exceed the maximum head limitation of the transducer. Secure the pressure transducer to avoid movement during testing.
7. Calculate the height of the water column in the well and confirm that it is sufficient to completely submerge the slug and allow for adequate testing.

8. If not using a vented transducer, record a barometric pressure reading. Barometric pressure readings can be obtained from on-site equipment or from a local weather station.
9. Set the recording time intervals of the transducer and re-measure the DTW measurement and start time for the pre-test monitoring. Commence pre-test monitoring with the transducers for a total time roughly equal to or greater than twice the anticipated length of the slug test.
10. If monitoring for atmospheric or precipitation effects, obtain another DTW and estimate end of test time following the pre-test monitoring.
11. Change the recording frequency of the transducers for the slug-in test. Lower the slug into the well to a depth just above the water level. Begin recording measurements with the transducer and lower the slug just below the static water level so it is completely submerged. The slug should not be lowered to the bottom of the well because this may interfere with the transducer. Do not allow the slug to free-fall and minimize splashing the water surface. Record the start time of the slug-in test.
12. Monitor the water-level decline with the transducer and take periodic DTW measurements with the water-level meter or IP digital-sensing meter. The hand measurements should be conducted in accordance with the pre-test schedule.
13. The slug-in test will be terminated once the water level has returned to 90% of the pre-test level measurement. Once the water level has returned to the acceptable level, record a DTW measurement and time with the water-level meter and stop the transducer recording. The slug-in test is now complete.
14. Prepare for the slug-out test by recording a DTW measurement and time with the water-level meter or IP.
15. Based on the results of the slug-in test data, the recording frequency of the transducer may need to be modified. Begin recording measurements with the transducer and immediately raise the slug completely out of the water column and above the static-water level. If possible, completely remove the slug from the well casing to avoid dripping water into the water column. Record the start time of the slug-out test.
16. Monitor the water-level rise with the transducer and take periodic DTW measurements with the water-level meter or IP. The hand measurements should be conducted in accordance with the pre-test schedule.
17. The slug-out test will be terminated once the water level has returned to 90% of the pre-test level measurement. Once the water level has returned to the acceptable level, record a DTW measurement and time with the water-level meter or IP and stop the transducer recording. The slug-out test is now complete.
18. Review and verify the data for completeness. The slug-in and slug-out tests may be repeated as necessary and appropriate.

19. Remove and decontaminate all down-well equipment following completion of the slug test and secure the wellhead.

This process will be repeated at each tested well.

4.0 CALCULATIONS

Note: Various calculation methods are available. Use the appropriate method based on the specific aquifer you are testing.

The EPA recommends the Hvorslev piezometer-recovery interpretation. The Hvorslev method is the simplest form of analysis and assumes a homogenous, isotropic medium in which soil and water are incompressible.

The expression for hydraulic conductivity (K) is (EPA 1994):

$$K = \frac{r^2 \ln\left(\frac{L}{R}\right)}{2LT_0}$$

Where:

- ***K*** = hydraulic conductivity (ft/sec)
- ***r*** = radius of well casing (ft)
- ***L*** = length of open screen (or borehole) (ft)
- ***R*** = filter pack (borehole) radius (ft)
- T_0 = Basic Time Lag (sec); value of t on semi-logarithmic plot of H-h/H-H_0 vs. t, where H-h/H-H = 0.370
- ***H*** = initial water level before removal of slug
- ***H0*** = water level at t = 0
- ***h*** = recorded water level at t > 0

The Bouwer and Rice method is also commonly used to calculate hydraulic conductivity in unconfined aquifers, but is more complex. This method is based on the steady state Theim equation and also uses methods of curve matching, based upon test response and aquifer material. This method applies to both confined and unconfined aquifers and was developed from bail-down test data (Fetter 1994).

$$K = \frac{{r_c}^2 \ln(R_e/r_w)}{2L} \frac{1}{t} \ln\left(\frac{h_0}{h}\right)$$

Where:

- K = hydraulic conductivity (ft/sec)
- r_c = radius of well casing (ft)
- r_w = radius of the well
- R = radius of gravel envelope (ft)
- L = length of open screen (or borehole) (ft)
- L^e = length of the screen
- R_e = effective radial distance over which head is dissipated (ft)
- t = time since $H = H_o$(sec)
- H = initial water level before removal of slug
- $H0$ = water level at t = 0
- h = recorded water level at $t > 0$

5.0 QUALITY ASSURANCE / QUALITY CONTROL (QA/QC)

The following general QA/QC procedures apply:

1. Data must be documented on standard chain-of-custody records, field-data sheets, or in personal/site logbooks.
2. Instrumentation must be operated in accordance with operating instructions as supplied by the manufacturer unless otherwise specified in the work plan. Equipment checkout and calibration activities must occur before sampling/operation, and they must be documented.
3. Each well should be tested at least twice to compare results.

6.0 GENERAL COMMENTS

Slug tests provide several advantages over pumping tests, a main one being cost and disposal of potentially contaminated water. Many data points can be tested and re-tested for aquifer parameters at a much lower cost. Slug tests generally are more suitable for lower-permeability formations where low-volume pumping tests can be problematic. Because slug tests generally reflect conditions near the well, the results can be influenced by near-well conditions (e.g., gravel pack materials, degree of well development, well-skin effects). Many different analysis methods exist and are proven accurate; the user should seek out and understand which methods are applicable to the test and conditions present.

7.0 REFERENCES

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United States Environmental Protection Agency (USEPA). 1994. Tank Sampling SOP#: 2010, 11/16/94, Rev# 0.0. Available from: http://loostrom.com/kosov/separatasidor/usepatanksampling.pdf.

QAQ-CSO-P00

ATTACHMENT A. SLUG-TEST DATA FORM

DATE:

SITE ID: ________________________ SLUG VOLUME (ft^3):

LOCATION ID: _________________ LOGGER:

TEST METHOD: __ SLUG INJECTION __ SLUG WITHDRAWAL COMMENTS:

Time Beginning of Test #1

Time End of Test #1

Time Beginning of Test #2

Time End of Test #2

ELAPSED TIME (MIN)	DEPTH TO WATER (FT)	ELAPSED TIME (MIN)	DEPTH TO WATER (FT)

memorandum

To: Trihydro Employees
From: OSE
Date: March 26, 2013
Re: Standard Operating Procedure – Field Screening of Soil Samples Using a PID

1.0 INTRODUCTION

The purpose of this Standard Operating Procedure (SOP) is to establish procedures for conducting field screening of soil samples. Field screening of soil samples involves the qualitative and quantitative field assessment of various indicators of potential contamination. Field-screening procedures employed will include scanning the soil core and measurement of sample headspace for total organic vapors (TOV) using a photoionization detector (PID) and observing visual/olfactory indicators.

The PID uses an ultraviolet light source to ionize components of an incoming source. The ionization potential of the light source relative to the target compound governs the instrument sensitivity. Select a bulb having an ionization potential (commonly 8.4, 9.5, 10.2, and 11.7 electron volts [eV]) that is approximately equal to or greater than the target compounds. The PID will commonly detect compounds having ionization potentials up to 0.3 eV greater than the bulb value.

Use a PID when the presence of carbon-based volatile organic compounds is suspected to be present. Target compounds include hydrocarbons (e.g., benzene, toluene, etc.), halocarbons (e.g., carbon tetrachloride, vinyl chloride, Freon, etc.), solvents (e.g., tetrachloroethylene, trichloroethylene, etc.), and oxygenates (e.g., acetone, MTBE, etc.) that volatilize in air. PID readings are not recommended for saturated soils because groundwater constituents can cause anomalously high TOV readings if groundwater is impacted, and the presence of liquid could affect the soil-to-gaseous phase volatilization rate.

2.0 PROCEDURES

Soil field-screening procedures are listed below:

Step 1: Immediately after exposing the soil core, collect approximately 100 grams of soil from each sampling interval using a clean, decontaminated stainless-steel safety knife or spatula. **Do not use a fixed open-bladed knife for this task of the other field-screening tasks described in the steps below. Only safety knives can be used for Trihydro work. Use the proper hand protection for this task and the other field-screening tasks described in the steps below.**

Step 2: Place the soil sample in a resealable plastic bag (e.g., one quart) and seal the bag. Place the sealed container in a covered area (not in direct sunlight) to allow organic constituents to volatilize to the headspace.

Step 3: Insert the PID probe tip into the resealable plastic bag. Avoid contacting the soil or any fluids that may have collected in the sample container with the probe tip.

Step 4: Allow the instrument to stabilize, usually within 5 seconds of exposure to the headspace gas, and note the highest measured instrument reading. Record the reading in field notes.

If there are erratic readings (e.g., due to high TOV or moisture), obtain additional readings to obtain a representative headspace measurement.

Step 5: Allow the instrument to "zero out" before taking a measurement for subsequent samples or re-measuring a sample.

Step 6: Note the presence of any visual indicators of contamination (e.g., staining, discoloration, and/or sheen). Note the presence of any phase-separated liquids. Document the observations in field notes.

Step 7: Note and characterize the presence of any unusual odors in the working space over the sample. Describe odors in generic terms such as "gasoline-like," "musty," "sweet," "pungent," etc.

QAQ-CSO-P00

memorandum

To: Trihydro Employees
From: Paul Klemperer
Date: May 2019
Re: Standard Operating Procedure – Surveying

1.0 NOTEKEEPING

1.1 General

Field survey notes are the record of work done in the field. They contain the complete graphic, tabular or written (or combination thereof) survey records which depict each step of the survey. Field survey notes should be recorded on suitable forms, special notebooks or in digital format. They should enable knowledgeable persons to interpret and use the survey and its results, and to retrace the footsteps of the surveyor.

Field notes are not an accessory to the survey; they are an integral part of the survey. A survey is never completed until field notes are submitted, checked, and filed. Field notes are important because:

1. Field notes perpetuate a survey even when stakes have rotted and monuments are obliterated. Good field notes make it possible to re-establish lost monuments or other measured data. Conversely, incomplete, illegible or incorrect field notes cause the time and money invested in the survey to have been wasted.
2. Field notes of boundary or right-of-way surveys, together with diaries and survey crew reports, are important documentation in potential court cases arising between Trihydro and landowners or contractors.
3. Field notes are the means of communication between field and office personnel. The office personnel should be able to understand and process the data without needing additional explanations.

In view of the importance of the field notes, the duties of notekeeping should always be assigned to a knowledgeable member of the crew. The notekeeper should have a thorough understanding of the purpose of the survey and the operations.

1.2 Types of Notes

There are four basic types of notes currently used: sketch, tabular, modular, and electronic. A given survey may be recorded by a single type or combination of these four types.

1. **Sketch and/or Description Notes** - The main purpose of sketch notes is to clarify information shown in other types of notes, as described in #3 and #4, and to prevent misinterpretation thereof. Sketches increase the efficiency with which notes are taken and subsequently interpreted in the office. Description notes are a written narration of the survey procedure and of the measurement to clarify

information shown in other types of notes, as described in #3 and #4. Whenever the field crew observes a noteworthy circumstance, it should also be recorded in writing.

2. **Tabular Notes** - Tabular notes are records of measurements referenced to survey stations or topographic features. Tabular notes may or may not require the use of a sketch, but one should make an effort to include one. The advantage of this type of note taking is that it does not depend on electronic devices. That is also the main disadvantage in that the transportability of data is limited.

3. **Modular Notes** (Preprinted Forms) - Modular notes are those in which original raw values are entered on special forms. The forms are generally designed as a "trade off" between ease in recording notes in the field and computer input needs. In some cases, computer operators are trained to input into the computer directly from the modular form. In other cases, the field information is transferred manually to special forms.

   - The advantages of modular notes are:
     - Notes are neater and easier to interpret because entries are made in predetermined places and in predetermined order.
     - Field data is generally more complete because spaces are provided for recording each required raw value. If a space remains empty, it may indicate that data is missing.
     - The problem of arrangement and balancing a variety of information on a given page is eliminated.
     - It is easier to train members of the crew to become competent notekeepers.
   - The disadvantages of modular notes are:
     - Modular notes are usually in a loose leaf unbound format. This presents two problems. The first is that it is more difficult to organize, store, and preserve single forms. The second is a legal issue of the opportunity to alter and replace an original page with another one.

4. **Electronic Notes** (Data Collection) - A data collector is a device on which traditional survey data may be recorded electronically. This data is usually horizontal angle, zenith angle, slope distance and descriptive survey data such as feature identification or comments.

   A system of codes needs to be developed that will identify topographic and terrain features, such as a road, stream, tree, power pole, etc. Codes are also needed for computer drafting instructions, such as the start of a linear feature and the placement of topographic feature. Note sheets with point number, feature code, specific description and an occasional sketch, for unusually hard to define situations, could save a return trip to the field.

   A systematic method of data collection should be established so that the surface can be adequately covered. The collection method should also have built in checks to prevent features from not being accounted for or unintentionally measured again.

The editing of the original electronic file should be avoided. If the collection system does not automatically preserve the raw data file, a copy should be made so that edits and revisions are made on the copy.

- The advantages of electronic notes are:
  - No reading or recording mistakes. Measurement data is transferred automatically from the instrument to the data collector.
  - No computer input (typing) errors because there is no need to convert field notes into digital form.
  - Data can be processed in significantly less time, and therefore, at less cost.
- The disadvantages of electronic notes are:
  - Data could be accidentally erased due to hardware problems or carelessness.
  - Most data collectors do not allow sketch and diagram input. Sketches have to be made separately and must be associated with the data.
  - The legal status of electronic notes as original unedited notes is yet to be determined by the court. This is critical, especially in right-of-way and other boundary surveys.

It is worthwhile noting that electronic notes are subject to code and description input errors.

1.1.3 Arrangement of Notes

1.1.3.1 Title Page

A title page is the orientation, index, table of contents, and summary information for a set of field notes. It should include information that will aid someone searching for specific survey information. By the time a survey project is completed, there may be numerous books and forms filed. Digging through the survey records can be time consuming and expensive, particularly with those not involved with the actual survey. The title page should facilitate the information recovery process.

1.1.3.2 Header Information

The header information serves as an identifier that associates the notes with a survey project. It is usually entered at the top of the note page and should be completely filled in for each page. The header information shall include project name and appropriate designation, location of the survey, date, time, weather conditions, instrument (type and number), crew members and their individual duties.

1.1.3.3 Record Information

Record information is survey-related information that is not measured in the field, but retrieved from files, usually at the survey planning stage. For example, coordinates, control stations, curve data, point descriptions, computed bearings, etc. are all record information. Record information comes from such sources as control survey maps, filed survey notes, construction plans, government data sheets, etc.

Most of the record information should be assembled prior to the field survey. Where practical, the source or authority should be cited for the acceptance and use of any found point.

Record information includes calculated data results from mathematical manipulation of record or measured values. Whenever a calculated value is shown, also show the record or measured values which are the basis of the calculation.

1.1.3.4 Observations and Measurements

On most modular note forms, measurements are the only required field entries, except for perimeter information and point names. These values represent the heart of the survey. Record each required field value in its proper place.

Explanatory notes, such as unusual weather conditions, problems with equipment, etc., aid in the interpretation and analysis of the reliability of portions of a survey.

Those entries which are recorded at the time observations are made, are original entries. Entries which are transcribed to the formal note form from memory or from any other written source are not original entries. Field notes with original entries will stand up in court and will assure maximum accuracy. After-the-fact entries are suspect and more likely to be erroneous.

Some guidelines to follow when recording measurements are:

1. Always record the full raw value as called out by the instrument operator. Do not set the instrument to compute reduced measurements. Do not record only the sums or the differences or the mean of a series of raw values. Also, do not record only "corrected" sums, differences or means.
2. Record significant figures only and clearly indicate the decimal portion of a measured value.
3. Do not erase any observation. If a blunder is made in recording a "call out", or if an observation is rejected, draw a slash through the entry without destroying the legibility of the erroneous entry. Erasures diminish, and often destroy, the credibility of field notes.
4. Do not discard a page with erroneous records. To void a page, draw a diagonal across the page and write the word “VOID” in large letters.
5. Write clear and legible notes. A professional looking set of notes is likely to be of professional quality.

1.1.3.5 Descriptions

A survey point description is a (written, sketched, or written and sketched) recording of the general and exact horizontal (and vertical) location, datum, and the particular physical characteristics of a point which enable its recovery and the differentiation of that point from any other point.

There are several basic elements which, when included in the description, will aid in its identification. These elements are:

- Name of point.
- Physical description of monument, including size, appearance, materials, specific marks, and condition.
- Angles and/or distances to, and descriptions of, reference marks.
- General location and directions to its immediate vicinity.
- Citation of document or filed original field notes which first described point.

1.1.3.6 Suggestions for Recording Notes

- Make notes dark enough to be reproducible.
- Use standard abbreviations and symbols.
- Be consistent in style and lettering. Write tabulated figures inside and off column rulings. Align decimal points and digits vertically.
- Do not crowd information to a point where numbers or letters are hard to distinguish or some information is covered. Do not try to economize on paper. Do not write in margins of notes.
- Use drafting aids to produce neat drawing.
- Draw sketches to approximate scale. Exaggerate details on a separate diagram if clarity is thereby improved.
- Orient sketches and entries according to standard mapping procedure.
- Draw framework of sketch before measurements begin.

2.0 PRELIMINARY SURVEYS

Surveying activities for an engineering project consist of research, reconnaissance, control, and mapping of the project area. A preliminary survey consists of all survey activity connected with the gathering of data and establishment of survey control systems through the reconnaissance and design phases of a project development.

The results of the preliminary survey are the basis for the design, detailed plans, and cost estimate of the project. Since every engineering facility can be located and designed with different variations, the preliminary survey usually covers a larger area than necessary for the particular facility.

2.1 Research

The primary source of information is the county recorder's office. These records, generally in easy form to follow, are based strictly on land transfer documents. Additional valuable information can be obtained from the county or municipal engineer's office, clerk of courts, Department of Transportation, Department of Environmental Protection, etc.

Quite often, contracts for deeds, surface rights, leases, and other documents of a temporary nature are not filed, and occupation or use of the land may not be reflected in the county records. In such cases, an actual interview with whoever is occupying the land or person listed as agent for the owner should be conducted.

Determining land use and ownership along roads under the jurisdiction of a County or Municipality, within the state, is generally not required unless, the Department will be acquiring the Right-of-Way on behalf of the County or Municipality.

If entry to private property is required, a letter should be prepared for each landowner (see example in survey directory). Where absentee ownership is involved, the letters should be sent out well in advance of actual survey operations.

2.2 Reconnaissance and Gathering Data

As soon as practical after approval of the project, notification to landowner, and receipt of authority to proceed, the representative surveyor should visit the job site and determine the type of control that is needed and, in general, how the survey will be conducted.

Data Required - Pertinent information and data on the area involved should be gathered and compiled to aid in some of the decisions to be made. Such information could include:

- 7 ½ minute quadrangle maps, and County maps.
- Previous construction plans, listings of highway control, etc.
- Utility permit listings.
- Benchmark control maps and listings (and their sources).
- Horizontal control (and their sources).
- Photo mosaics.

Available Information - The most important objective of the reconnaissance is to determine what control is available, its suitability for the survey and what additional control will be required. Some of the questions to be asked are:

- How was the existing control established and to what accuracy?
- Is the existing control in the proper location?
- Will it suit all of the survey needs for the project, i.e. construction control, etc.?
- Is it properly monumented?
- Will a new control network be required?

2.3 Horizontal Control

All projects shall be based on an approved coordinate system. Wherever practical, that system should be the relevant State Plane Coordinate System. Local (arbitrary) grids may be used on small, isolated projects where it is impractical to tie to the established control network. With the availability of GPS technology, there is little justification for local grids, since control can be extended to virtually anywhere.

Control points in preliminary surveys are defined as permanently monumented points from which additional control can be established. Therefore, the establishment of control monuments through the project area is an extremely critical step. All subsequent phases of the project development, as well as future projects, will rely on these control points. Inaccurate or inadequate control can cause unnecessary and costly delays in the project.

2.3.1 Base Control

After thorough research of all control information, the extent of horizontal control required will be determined. If sufficient government or DOT established control is found within the project area, there should be no need for a new control network survey. If any of the found points to be used as base control were established by other surveys, their validity should be checked thoroughly. If, after such review, they are determined to be of questionable positional accuracy, they should be reconnected to the government control or a new control survey considered.

The base control should be established by GPS techniques. Traversing can also be used for setting control points when GPS is unavailable or for short ties between GPS points. The use of traversing for base control should be discouraged.

The distance between control points should be limited to no more than one half kilometer (one quarter mile). This limitation arises from the control requirements of subsequent activities, such as photogrammetry, supplemental topography surveys, and construction staking.

2.3.2 Supplemental Control

Accurate positional determination of such items as property corners, right-of-way markers, bridge ends, headwalls or other identifiable fixed objects can serve many purposes. For example:

- Such points can serve as supplemental control points for the data gathering process.
- The coordinate location of such objects establishes their positional relationship with all elements of the existing highway facility including centerlines.
- Such points are aids in correlation of old and new surveys.

2.4 Vertical Control

A consistent elevation datum is required through the project area. Unless authorized and documented otherwise, that datum will be NAVD 88. The normal procedure is to establish the control monuments as the primary bench line for the project. Supplementary vertical control, such as construction benchmarks, right-of-way markers or other monumented points to be used during the course of the project, would then be set from the primary bench line.

2.4.1 Base Control

The primary level line should be of second order accuracy, unless specified otherwise.

A three wire circuit between (NGS) benchmarks is the most efficient method of establishing vertical control on project control points. Satisfactory results may also be obtained by double turning points or double height of instrument circuits.

In some areas, discrepancies in the (NGS) benchmarks may be found. The level line should be extended to other (NGS) benchmarks until tolerances are met, or return level runs to the original benchmark. The former is the preferred method because it provides an extra check on the elevations.

2.4.2 Supplemental Control

The supplemental vertical control provides easy to reach benchmarks through the project area and, therefore, it should be established as accurately and efficiently as possible. Level circuits between control monuments should be used to establish the elevation of such benchmarks. Tolerance in closure should be third order. If a different tolerance is specified, Federal Geodetic Control Committee (FGCC) standards and specifications should be followed to meet this requirement.

2.5 Alignment – Highway Survey

2.5.1 Computing Existing Alignment

Most highway projects involve construction along or over existing alignment. In order to accurately locate the right-of-way, centerline and other features of the existing facility, right-of-way markers, bridge ends and other identifiable points should be accurately tied to the control network. These points should be surveyed from the control points with the same accuracy as prescribed for supplemental control.

After coordinate positions of the points surveyed have been computed, the existing centerline and right-of-way can be computed. As a result of the new measurements and design, new centerline stationing and curve data will be required. Generally, it is not practical to compute equations between the old and new stationing and the old stationing should only be used to identify the monumented points.

2.5.2 Establish Centerline

If required, the new computed tangents and curve points may be set from control points. In some cases, it may be more practical to stake a computed reference line or reference points for the points on tangent (POT), points of curve (PC) and points of tangency (PT).

If field cross sections are to be taken, it may be necessary to establish the centerline on the ground. Points which fall on roadways, cultivated fields, or other lands subject to disturbance should be referenced with at least 3 well placed ties.

2.5.3 Profiles

Profile elevations are taken on baseline stations to aid the engineer in establishing a grade line to fit field conditions. The profile and preliminary grade line also serve as reference elevations for cross sections and the soils profiles.

Profiles should be taken by differential leveling circuits beginning and ending on the previously established benchmarks. Heights of instruments and turning point elevations should be carried to the nearest 0.005 meter (0.016 foot). Profile elevations should be recorded to the nearest 0.01 meter (0.03 foot), unless they are on pavement, curbs, structures or other fixed objects that would require less tolerance in determination of the final grade line.

Profiles of grade line controlling features, such as crossroads, drainage, utility lines, irrigation works, railroads or other grade influencing features should be taken far enough on either side of the centerline to clearly define the grade lines of those features.

2.5.4 Cross Sections

Cross sectioning should not be started until the preliminary alignment and profiles have been approved.

The photogrammetric process may be used (UAV- Unmanned Aerial Vehicle) to obtain terrain cross sections. There are some occasions, however, that will require field checking of photogrammetric sections, such as, if the terrain extends outside of covered areas or if the ground is not visible due to obstructions.

In most projects, cross sections at all 20 meter stations should be sufficient. Closer spacing may be required for street sections, uneven terrain or in areas where there are special drainage problems. The general criteria for taking extra cross sections should be determined prior to commencement of the work.

Cross sections should be taken far enough on either side of the centerline to assure that all of the proposed construction zone will be included.
In general, skewed sections for drainage pipes or other special sections not required for earthwork computation should be recorded separately or clearly marked as not for use in earthwork computations.

2.6 Topographic Data

Topography for the preliminary survey is defined as all man-made or physical objects in or adjacent to a highway corridor or project area that would normally be shown on plans. The survey should include such items as existing fencing, roads, buildings, power lines, land features, waterways, railroads, pipes, utilities, etc. If the plan sheets are to be made from aerial photography, much of the information listed below can be identified and located by annotation of enlarged aerial photos. When the plans are to be developed solely from field notes and electronic data collection, the following is a list of minimum requirements for location and identification of topographic features.

1. **FENCES** Include the fence type and location of existing gates.
2. **UTILITIES**

   A. Gas and Petroleum Pipelines

   - Identify the location of the centerline crossing by station or surveyed coordinates at both rights-of-way.
   - Location of vents (if cased).
   - Location of bends.
   - Location of meter vaults and valve pits.
   - Depth of the line.

   B. Water and Sewer Lines

   - Identify the location of the centerline crossing or, in case of parallel lines, the actual distance from the centerline.
   - Location of manholes, valve boxes, meter pits, crosses and tees and bends.
   - Elevation on top of the waterline, sewer invert elevation, and manhole ring elevations.
   - Location of fire hydrants and curb stops.

C. Power Lines

- Location of supporting structures on each side of the centerline with the elevation of the neutral or lowest conductor at the centerline crossing point.
- Location of each pole and pole lines, including their alignment on either side of the corridor.
- Location of poles on parallel lines that may require relocation, location of guys, stubs and anchors for overhead lines.
- In cases of buried power, location of cables, pull boxes, transformer pads and notation of whether direct burial or conduit.
- Identification of the type and owner of the power utility.

D. Telephone Lines

- Denote direct burial or conduit run (number of conduits).
- Location of pedestal loop boxes.
- Location of manhole and sizes.
- Location of each pole and pole lines, including elevation, centerline crossing station and distance from centerline.
- Identification of the type and owner of the telephone utility.

3. **BUILDINGS**

- All buildings should be shown with dimensions and type of construction, as well as appurtenances.

4. **DRAINAGE COURSES**

- Show irrigation ditches, rivers, creeks, canals, and streams, giving the direction of flow.

5. **DRAINAGE STRUCTURES**

- Describe bridges, pipes, inlets, manholes, and culverts in place on the existing roads, indicating their dimensions, type of facility and general condition.

6. **RAILROADS**

- Mainline station and milepost at survey centerline crossing.
- Existing right-of-way.
- Rail profile 60 meters (200 feet) each side of the centerline crossing point.
- Switch points within 60 meters (200 feet) of the centerline crossing point.
- Signal and communication line locations.

- Any structures or other features relevant to the railroad.

2.7 Right-of-Way

Wherever new right-of-way may be acquired, it is necessary to tie property corners to either the centerline or control points. Sufficient land ties must be made to accurately define the centerline with respect to property ownership or other boundaries, such as corporate limits, subdivisions, or county lines. For detailed specifics of the required fieldwork, it will be necessary to reference the specific DOT Manual, Preparation of ROW Documents.

3.0 CONSTRUCTION SURVEYS

Construction surveys provide the horizontal and vertical layout for every key component of a construction project. They involve horizontal and vertical control and the placement of stakes to establish a framework for the construction site. From this control, lines and grades are established by means of stakes and strings. The contractor uses these stakes and strings to place supplemental stakes that may be necessary to guide the construction activities. In summary, construction surveying is the process of drawing the design plans on the actual construction site at the designated location and at a scale of 1:1.

Construction surveying techniques are also used for verifying the location and quantities of completed work (as-built).

Traditionally a "station/offset" method was used for establishing construction control. The introduction of computers, total stations and GPS in surveying have revolutionized the way construction surveys are done now. Construction surveys are now based on the three dimensional (X,Y,Z) coordinate system with which the design was made. From the three dimensional coordinates, angles and distances are computed to facilitate radial stakeout. Radial stakeout data can be downloaded into many total stations or electronic data collectors. This data guides the surveyor to the location of the points to be staked out. Three dimensional coordinates of the construction plan can also be downloaded into a GPS receiver and used in a real time kinematics mode to stake out the site.

3.1 Horizontal Control

The construction phase of most projects requires a relatively dense network of horizontal control monuments. The horizontal control network will normally consist of basic control monuments that were established during a preliminary survey and of additional control monuments established specifically for construction control.

Project control, consisting of centerline or centerline references, may be set by GPS or by traditional traversing.

3.1.1 Traverse Style Base Control

A traverse style control system is a control scheme that traverses between two terminal points. In construction surveys of highways, this type of control is set in the immediate vicinity along the construction site. The traverse points can be surveyed either by GPS or by a total station. Traverse style control monumentation may be the preferred control system for several reasons:

1. Points can be set where they will not be disturbed by construction activities.
2. Monuments can be used for both horizontal and vertical control, which makes use of total station capabilities.
3. Monuments can be set at optimum spacing for the staking accuracies required and the type of equipment being used.
4. The same monument would be used for setting all phases of the construction, including restoration of stakes obliterated during construction.
5. Distance, direction and elevation calculations can be made from any control point to any desired construction stake. This calculation can be done in the office, before leaving for the field, or by calculating inverses in the field with hand-held calculators.
6. Traverse control points must have 3 reference points (ties) for use in locating or relocating points in the field. Unstable reference points (regulatory sign posts, etc.) should not be utilized. Trees or building corners must include a height measured above ground level to the point.

3.1.2 Supplemental Control Monuments

Supplemental control is the establishment of extendible control monuments from the base (traverse) control at locations that will aid either the data gathering process or the construction staking. With proper planning, much of the supplemental control may have been included in the base control or the control completed for the preliminary survey operations. A thorough review of construction plans and staking requirements will generally indicate where additional control may be required. Interchanges, structures or other complex facilities will generally require monuments in unforeseen locations. Some basic suggestions for establishing additional supplemental control monuments are:

1. Set monuments by closed traverse between the highest order base control economically available. Never use previously set, unchecked points to set other control or construction stakes.
2. Set points where they can be used for setting all phases of construction staking.
3. Set points where they are accessible by vehicle, if possible. A vehicle can often be used to protect the instrument person from wind, and hand carrying equipment to inaccessible points is time consuming.
4. Generally, try to pick point locations where the instrument is above all stages of the work. This is particularly advantageous for structures.
5. Flag and protect points so they are easy to find and will not be disturbed by equipment.

6. Generally, space control points on both sides of the road to assure that any required staking point will be within approximately 200 meters (650 feet) from a control point.

Staking from Supplemental Control
There are two basic staking methods used from supplemental control points; namely, "direct" or "traverse". The direct method is the most common and advantageous with modern surveying equipment.

Direct staking from supplemental control is called "radial" staking. This system involves the use of inverse calculations that yield azimuth and distance and, where required, transfer elevation from the control monument to a construction stake. If several stakes are being set from one control point, the back sight setting should be rechecked.

Traverse staking is accomplished by running a line through the points to be staked, and setting the points as the line is run. Control points on the traverse line are established from the supplemental control point by direct ties. It is often advantageous to set PC's, PT's, and PI's from control points and then traverse the centerline or offset line before setting station marks.

3.1.3 Secondary Control
Secondary control, such as right-of-way, centerline references and pipe or structure reference points, can be set from supplemental control by either direct or traverse staking.

3.1.4 Centerline Control
This type of control uses the centerline (or a similar construction layout line) as the principal control line for a project. Since centerline stakes are usually destroyed by construction, strategic points must be referenced outside the construction limits. The reference points provide the horizontal control during the construction period.

Some advantages of the centerline method are:

1. Straightforward and easily understood.
2. Familiar to construction personnel.
3. Provides actual on-the-ground checks of the centerline. Also provides easy on-the- ground checks for critical clearance points.
4. Requires less computations.

Some disadvantages of the centerline method are:

1. The principal control line (centerline) is usually destroyed by construction work.

2. Intermediate steps of establishing each centerline station point must be set and occupied to set each construction control stake.
3. Adapts poorly to steep terrain and often requires more brush cutting.
4. The Survey is never "closed", unless the ends of the project are tied to base control stations. Positional accuracy is difficult to determine.

3.1.5 Alignment Control

The new alignment should be reset from the strongest ties or reference monuments available. When a base traverse is used for development of the project, all critical alignment points should be set directly from the base traverse monuments. In any event, those alignment control points should be set only from control monuments that were originally installed in accordance with criteria for extendible points. Also, each alignment control point should be set using the same criteria. Tacked hubs, nails and shiners or other types of semi-permanent station markers appropriate for the soil or type of surface should be used.

3.1.6 Reference Points

The cost and time required for resetting stakes, or for setting new lines of construction control stakes can be reduced if easy to use reference markers are set before construction is started. The prime considerations for reference points are that they too will not be destroyed and that they can be used without special survey equipment to accurately place the required control stakes.

Whenever feasible, reference points should be set on the right-of-way line because they have the best likelihood of remaining undisturbed. If the road or other terrain features will interfere with the line of sight between reference points, additional sight only references may be required.

3.1.7 Control Stakeout Methods

Once the alignment control is set, several optional methods for setting the intermediate station points are available. The option selected by the surveyor should be based on personnel, available equipment, terrain and safety.

Traverse Method - The traditional system of instrument setups at control points and sighting on line or turning appropriate angles to set station points. The main advantage of this method is that it provides on-the-ground and visual checks of the centerline. However, it is more time consuming and less accurate than using the supplemental control method.

Supplemental Control Method - (Centerline Stations) The setting of intermediate station points from strategically placed extendible control monuments. Some of the advantages of this method are:

1. Any section of the project can be set at any time.

2. Once methods are developed, it is generally faster and can be done with as few as two people. Three crew members are generally the most efficient, as rod people can move ahead while the new angle is being turned and the other rod person is painting or completing installation of the set station mark.
3. Generally provides the best setup and sighting conditions.
4. Points can be accurately re-established to their original position at any stage of the construction.
5. Coordinate calculations for curves can be pre-figured in the office and tabulated for simple reference in the field.

The main disadvantage is the lower level of accuracy obtained as compared to the higher levels obtained using GPS.

Real Time GPS Method - GPS surveying provides the most efficient method for setting the centerline and additional reference points. A base GPS receiver and a (one or several) roving receiver are used for this purpose. Numerical and graphical instructions displayed on the roving receiver direct the surveyor to the desired point. The real time kinematics GPS method is based on the following procedure:

- The three dimensional coordinates of all the points to be staked out are stored in the roving receiver.
- A base station is set up on a known point.
- The rover and the base station receivers are initialized to establish a relative position between them.
- The rover and the base receivers communicate measurements via a radio (usually FM) frequency.
- Since the coordinates of the rover are measured and updated continuously, it is relatively easy to compute the direction and distance to the construction stake to be staked out. This information is then displayed and made available to the surveyor.

The main advantages of the real time GPS method are:

1. One base receiver can serve many rovers simultaneously. This makes this method very efficient.
2. Less control is needed for the project because line-of-sight does not have to be maintained. The only limitation is the range of the radio communication between the rover and the base.
3. It is very easy to reset any destroyed point.

3.2 Vertical Control

Vertical control is an important part of all projects. A relatively dense network of vertical control (benchmarks) must be established for most projects prior to construction staking operations. Such vertical control is seldom accomplished in one survey, but is a culmination of several vertical surveys beginning with the base vertical survey to establish the vertical datum on all major control monuments.

The most important aspect of the various stages of vertical control is that the same datum be used from preliminary surveys through design and final construction control.

Ideally, most of the project control benchmarks have been established during the preliminary stage of the project development or the preliminary survey. This existing network is then densified by closed loop vertical surveys throughout the preliminary and construction period. Prior to beginning establishment of construction control benchmarks, several steps should be taken.

1. **Check monuments** - If there has been a long delay between the time the base vertical survey was conducted and the completion of the design plans, the condition of the base monuments should be field checked. Each monument should be checked for possible disturbance or settlement, and whether it is in satisfactory condition. Benchmarks that are to be used in the project should also be reflagged for easy location.
2. **Plan benchmark locations** - Design plans should be thoroughly reviewed and a set of plans marked up with the approximate location of existing benchmarks and locations where construction control benchmarks will be required. Such planning can save considerable field time and assure that required benchmarks will be established at their optimum location on a timely basis. Construction plan sheets must contain a minimum of one benchmark.
3. **Plan BM establishment** - The planning process should determine which bench-lines should be established for the initial grade staking (normally earthwork on mainlines and service roads), final grade staking, structure staking and vertical control monumentation. Each benchline should be planned to reduce the difficulty and length of level runs required to establish the subsequent benchmarks.

3.2.1 Bench Mark Spacing

The required density of benchmarks will depend on terrain, vegetation and type of construction. They should be of sufficient density to decrease survey time for subsequent leveling requirements. The advantage of density must be weighed against the greater initial cost for establishing extra benchmarks. The following are suggested spacing for benchmarks on a typical construction project:

1. A secondary line of semi-permanent benchmarks along one right-of-way line spaced at 300 meters (or approximately 1,000 feet) or less horizontal distance, the primary line being the permanent base control monuments. In heavy construction or rough terrain, a benchline may be required on both right-of-way lines.
2. Successive benchmarks should not be separated (vertically) by more than two "turns" or 7 meters (or approximately 24 feet) in elevation. Relative elevation and ease of access to bench marks is more important than the horizontal distance between them.
3. Bridge sites and major drainage sites should have at least two benchmarks placed outside the area to be disturbed.

4. At interchanges, two benchmarks should be established for each quadrant in addition to those required for the structure(s).

3.2.2 Bench Mark Location

Benchmarks should be placed in locations suitable for the intended purpose and permanence. Utility poles, ornamental trees, or fire hydrants should be avoided.

Permanent benchmarks - Benchmarks that are to remain as reliable elevation references over a period of years, or even for extended construction duration, such as major structures, should generally meet the following criteria:

1. Place in stable, undisturbed original ground.
2. Establish on abutments or wing walls of older existing structures that have become stabilized.
3. Locate near "join" lines of cross streets, intersection of sidewalks and existing facilities outside of the construction area.
4. Select locations with locally level terrain. A benchmark on top of a high slope is not as desirable as one lower on the slope, provided all other criteria can be met. Quite often, the positions of horizontal (traverse) points are not compatible with project use of benchmarks, but are compatible with other considerations. In such instances, benchmarks in more usable locations should be established from the traverse control.
5. Utilize baseline monuments when practical.
6. Benchmarks destroyed during construction activities must be replaced to ensure a minimum of one benchmark per thousand feet.

Temporary Benchmarks - Less permanent benchmarks may be required for a limited use period for a specific survey operation, i.e., slope staking. Such stakes are called temporary benchmarks and they are not perpetuated after construction. Temporary benchmarks are usually marked with wooden stakes.

3.2.3 Marking Bench Marks

The density of benchmarks in the project area can be a source of confusion and possible error through misidentification. It is important that each be uniquely identifiable by name, number, or location and marked with the appropriate identification code. During periods of use, a flagged or painted lath can aid the rod person in the speedy location of the benchmark. Care should be used not to deface private property or structures that will remain after construction.

3.2.4 Leveling Accuracies

The elevation of all permanent benchmarks should be determined to third order accuracy.

Temporary benchmark accuracy should be consistent with the type of construction for which they will be used.

3.3 Earthwork Staking

3.3.1 Cross Sections and Slope Staking (Grading)

Design quantities are calculated from field cross sections, from cross sections derived through the photogrammetric process, or from electronically collected data. Normally the staked location and elevation should agree fairly closely with the plotted location and elevation. Discrepancies of up to 0.3 meters (1 foot) in distance or less than 0.1 meters (0.3 feet) in elevation would not be a reason for complete reacquisition of cross sections. If the plotted and staked locations disagree, the staked position, as reflected in the staking notes, would be used for final quantities.

Some surveyors have found it advantageous to add at least one line of grade control stakes as the roadway sections near completion. A control line of centerline, median ditch, or roadway shoulder stakes is run and grade stakes set to aid the contractor in the final stages of the earthwork prior to staking for finished grades. This not only works toward a better end product, but also expedites the finish grading.

Marking Slope Stakes

It is extremely important that the information shown on construction stakes is concise, legible and clearly understood by the contractor. Since a contractor may have projects in any part of the State, consistency among the various survey crews is a great aid to the contractor's understanding of the information being conveyed. The required information should be neatly written on a stake that has been painted and set.

Slope Staking with a Total Station

The use of a three dimensional coordinate system for the design makes staking with total station or GPS a valuable option for slope staking, particularly in rough terrain.

The first requirement for "radial" slope staking is that two control points be available for all slope staking. A second requirement is that the instrument be within 300 meters (1,000 feet) of the furthest slope stake to be set and the control point ("back azimuth").

In order to establish the horizontal position of each slope stake, the instrument should be set over a control point, back sighting another with the calculated "back azimuth" set on the horizontal circle. Turn the calculated "forward azimuth" to the slope stake being set. Alternatively, the slope stake may be set by setting the back sight to zero degrees and turning the angle calculated from the difference in azimuths between the back sight and the slope stake. The rod person should be directed on the line-of-sight to the calculated distance of the slope stake.

Determination of the ground elevation of the staking point.
One of the following methods can be used for determining the ground elevation of the staking point:

Relative elevation without HI or HR - Determination of relative elevation (DE) where the height of the rod or the prism (HR) is set to be equal to the height of the instrument (HI). In this case, the elevation differences or the vertical component of the slope distance is due only to the elevation changes in the topography. OR

DE = the vertical component of the slope distance

Relative elevation with HI and HR - When the height of the rod must be changed for visibility or other reasons, the height of the rod and the height of the instrument have to be recorded. In this case:

DE = the vertical component of the slope distance + HR - HI.

3.3.2 Borrow Areas

Determination of volumes removed from borrow areas involves a comparison of "before" and "after" elevations. For large or extremely rough borrow areas, or in areas that may require more than one stage or type of removed material, photogrammetric methods are generally the most efficient methods. Field cross sectioning, especially the real time kinematics GPS method, can be also be used for this purpose.

Photogrammetric Borrow - UAV photos taken at various stages of material removal provide positive proof of the quantities of material removed. Reliable quantity determination by aerial photography requires that the area is photographed prior to any material being removed and after each stage for which quantities will be computed. It is also important that the "model" control be targeted for each photographic flight. If the elevation of a targeted point was changed between flights, a new ground elevation will be required for that point.

Pit layouts and special needs should be reviewed with the photogrammetry and survey representatives prior to setting up the survey.

Field Cross-Sections - A total station can be used to establish the baseline, turn the right angles from the established station points, measure offset distance and determine elevations by trigonometric calculations. Ground elevations may be calculated by any of the recommended methods.

Additionally, total station instruments with electronic data collectors are capable of computing coordinate and elevation information of any target point. When baselines are tangent (straight) lines, it is possible to orient the total station relative to the baseline for stationing and offset. The stationing at the total station defines the northerly coordinate value, while the offset at the total station is the easterly coordinate value. An orientation of 0 degrees on the horizontal circle should be set parallel to the baseline in the ascending stationing direction of the baseline. Station and offset values of the target point should be then computed and displayed directly on the total station. By determining the height of the instrument and subtracting the target (rod) height, the ground elevation should be displayed.

The instrument operator can direct the rod person to stay on the cross section. Offset distances and elevations of topographic features are read directly. The ground point station, offset, and elevation may be either manually recorded in traditional cross section type notes, on forms or recorded digitally in an electronic data collector. Some advanced total stations come with programs or processes that can automatically determine the instrument's random setup location from measurements to control in both the horizontal and vertical components automatically. These methods can greatly increase the productivity of field crews in severely sloping terrain or even in areas when offsets exceed 30 meters (100 feet) or taping offsets are difficult due to elevation differences, between the instrument and the rod person.

Salient points and ground slope break line data may be recorded in total station data collectors, downloaded into computers and processed into digital terrain models from which cross sections may be interpolated and plotted. Very accurate volumes may be calculated by comparing grid files of the original ground with that of the excavation or fill.

Real Time GPS - GPS in real time kinematics mode is the fastest ground based method for determining volumes of borrow areas. A grid of X,Y coordinate values can be downloaded into a roving receiver to direct its operator to measurement points. Additional salient points or break line data can also be recorded. One base station can serve many rovers, which makes this method very efficient.

3.3.3 Structure Staking

Major Structure Staking

Stakes set to control the location and elevation of structures serve several purposes:

- They ensure that the contractor has the information needed to construct a structure to the lines and grades shown in the plans and are compatible with the adjacent roadway.
- They provide the contractor with accessible and understandable reference points and working lines to line up with, or measure from, without the use of sophisticated surveying equipment.

Field Notes - Separate field notes should be set up for each major structure and maintained on a daily basis when work is being done on the structure. Information for setting up staking diagrams and sketches should be obtained from the detail sheets in the plans. Separate pages should be used to show the overall staking system and detail drawings of the various structural components. Do not try to crowd too much information onto one page.

Coordinate Control - Most highway and other construction projects are presently designed using a horizontal and vertical coordinate control system. The structure design may or may not have been laid out under the same coordinate system. If not, the structural layout should be converted to the roadway coordinate system for staking purposes. Such conversion is a comparatively simple office procedure using two common coordinate positions from each of the two systems. Use of the roadway coordinate system will ensure that the roadway and structural components will fit in the completed facility. It also simplifies on the job calculations and provides a more exact method of establishing or restoring control references.

Reference Markers - All reference markers should be iron pins or tacked hubs set to line and grade as accurately as practicable. Although certain tolerances do exist between the various components of a structure, those tolerances should be preserved, as much as practicable, for subsequent measurements.

In general, all major working lines for abutments, footings, columns and centerline should be referenced with two intersecting lines of stakes. At least the two stakes nearest the component should be on line with, and at a set distance from, the component. Outer stakes may be set for line only. All reference markers should be double guarded and lathed on line where required for "eyeball" sight in. Each guard stake should be marked to identify the station and/or offset from the component. If the stake controls elevation, the cut, fill or flow line information should be included.

Where many stakes or much information is required, a stake numbering system can be used and each marker identified on the guard stake by number only. A listing of each marker would then be furnished to the contractor.

Special Items - Separate pages in the structure field notes should be maintained for such pay items as excavation, back fill material, rip rap, wire mesh, etc., in order to compute and document quantities.

Minor Structure Staking

Minor structures consist of reinforced concrete boxes, reinforced concrete pipe and corrugated metal or plastic pipe installations. The same general procedures for staking and documentation of the various pay items apply as described previously for major structures.

Staking Notes - Staking notes are generally set up in the office from the plans as amended by the revised pipe list.

Excavation and Backfill - Most pipe or box installations require several types of excavation and backfill. During the staking processes, cross sections of sufficient width on either side of the installation should be taken to establish natural ground. The cross sections should be taken at sufficient distance beyond each end of the pipe to encompass the excavation anticipated.

Reference Markers - Reference markers may be either iron pins or tacked hubs. Except on approach pipe or other small installations, the ends of the installation should be referenced both on centerline and by fixture end offsets. The offset markers should be set 3 meters (5 to 10 feet) or more from centerline.

Elevations should be taken on each marker and the offset distance, cut to flow line, type, size of pipe and designation of flared end, if applicable, are marked on the guard stakes.

A centerline marker should be set at 1 to 3 meters (3 to 10 feet) out from each pipe end with additional centerline markers set a sufficient measured distance to provide line of sight and distance reference in any area that will not be disturbed by construction. The terrain may dictate other reference marker layout. Information on the guard stake for the nearest to pipe reference marker should include station and offset distance on the backside and on the front side, size of pipe (if flared end is required), length of pipe, cut or fill to flow line, and grade per foot.

3.3.7 Curb and Gutter Staking

Tacked hubs should be set for radius points and as offsets from back of curb. The offset is normally 0.6 meters (2 feet) or a distance dictated by the contractor's operation. Offset stakes set outside the right-of-way must be approved in writing by the adjacent property owner. Guard stakes should show the station on the back side and offset distance and cut or fill to top of curb on the road side. Again, depending on the contractor's equipment and operation, the distance between offset stakes may vary from 5 to 30 meters (16 to 100 feet).

4.0 BOUNDARY SURVEYS

Following is a Scope of Work for typical boundary surveys:

1. Field verify or establish a legal property description of the site parcel as shown on a preliminary site map. This will include placing or replacing property corners as necessary, and updating associated corner records if necessary.
2. The Surveyor shall obtain and/or verify requisite information and data from public records including deeds, surveys of record, corner records, ROW maps, easements of record, etc., necessary for a complete site survey. On a large project, we have found it beneficial to enlist a Title Company to provide a Title Commitment for the property. A Title Commitment collects all the easements and encumbrances in one document, and a Title company typically can do this more efficiently than we can. If underground utilities are to be identified, an underground locating company will be utilized.
3. Provide a reproducible, black and white, hard copy of a Record of Survey, with a Professional Land Surveyor’s Stamp. The Stamp shall be a wet stamp with original signature and date. The survey will be recorded at the appropriate County Clerk and Recorder’s office, with signature or title blocks as required for the particular County the work will be performed in. The Record of Survey shall be drawn at an engineering scale (1”=20’, 50’, 100’ etc.) as appropriate to fit the size of the required hard copy. The survey map is typically printed in a 24” x 36” format and shall include at a minimum the mapping features listed below:

a. Property corners identified with local or state plane coordinates, property lines with bearings and distances and property lines of adjacent property owners, location of relevant fence lines within 10’ of the property lines.

b. Existing city, county or state ROW lines on all streets and roadways servicing or adjoining the site.

c. Legal description of the property.

d. Basis of bearings identified, a description of the coordinate system used, State Plane Zone identified and the state plane adjustment factor for this location, vertical datum identified if appropriate, north arrow and graphic bar scale, map key, line or curve tables as appropriate.

e. Landowner identification and address.

APPENDIX B

EXAMPLE FIELD FORMS

TRIHYDRO CORPORATION — Air Monitoring Record

ACCEPTABLE CONDITIONS	Oxygen 19.5% <0 <23.5%	Flammability <10% LEL	Carbon Monoxide CO <35ppm	Hydrogen Sulfide H S <10ppm	Other (specify) <PEL	Other (specify) <PEL
PRE-ENTRY Person:						
Time: Person:						
Time: Person:						
Time: Person:						
Time: Person:						
Time: Person:						
Time: Person:						
Time: Person:						
Time: Person:						
Time: Person:						
Time: Person:						
Time: Person:						
Time: Person:						
Time: Person:						
Time: Person:						

DRAFT

WORK COMPLETION

☐ Return space to original condition ☐ Submit form to supervisor

Close out time

Close out date

Signature

COMMENTS

Please let us know if you had any problems with the procedure or equipment, or if you have any suggestions.

DATE: ____________________
PROJECT NAME: ____________________
PROJECT NUMBER: ____________________
EVENT: ____________________
CALIBRATOR: ____________________

FID / PID METER CALIBRATION FORM

MAKE: ____________________
MODEL: ____________________
SERIAL NUMBER: ____________________
CALIBRATION GAS SERIAL NUMBER: ____________________

	PID:	FID:
STANDARD CONCENTRATION (C_{std}):	10 ppm isobutylene or 100 ppm isobutylene	10 ppm isobutylene or 100 ppm isobutylene
CALIBRATION READING (C_{act}):		
PERCENT RECOVERY (%R):		
ACCEPTANCE CRITERIA FOR %R:	90-100%	90-100%

$\%R = (C_{act} / C_{std}) \times 100$

COMMENTS: ____________________

4-GAS METER CALIBRATION FORM

MAKE: ____________________
MODEL: ____________________
SERIAL NUMBER: ____________________
CALIBRATION GAS SERIAL NUMBER: ____________________

	0xygen	LEL:	CO:	H2S:
STANDARD CONCENTRATION (C_{std}):	0.18	0.50	50 ppm	10 ppm
CALIBRATION READING (C_{act}):				
PERCENT RECOVERY (%R):				
ACCEPTANCE CRITERIA FOR %R:	90-100%	90-100%		

$\%R = (C_{act} / C_{std}) \times 100$

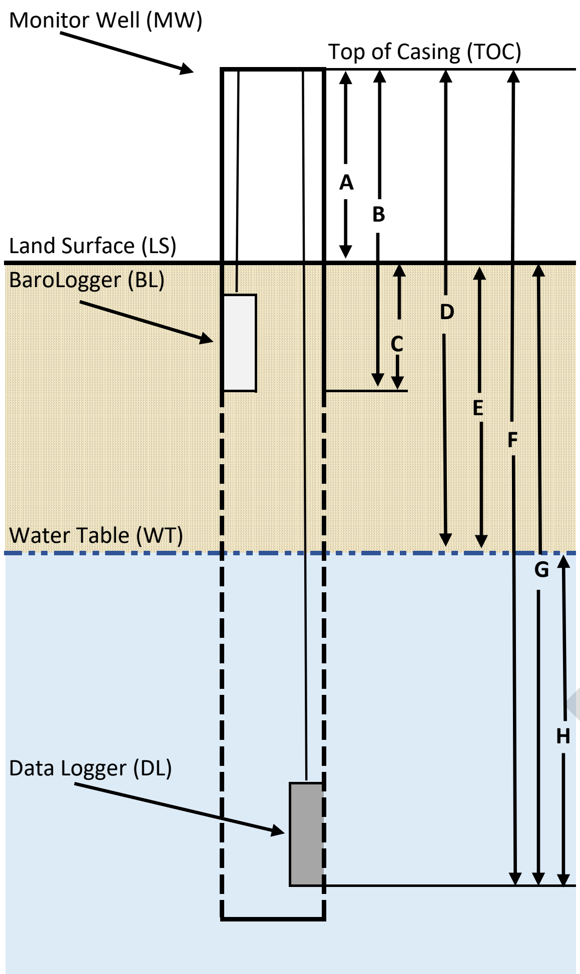
COMMENTS: ____________________

DATA LOGGER DEPLOYMENT FORM

Project Number ____________________ **Date** ____________________

Project Name Mattawoman Energy Center **Personnel** ____________________

Project Location 14175 Brandywine Road, Brandywine, MD **Task** ____________________



DEPLOYMENT DATA	Units	Location #1 MW-6	Location #2 MW-7	Location #3 MW-8	Location #4 MW-9
TOC Elevation	ft MSL/NGVD				
LS Elevation	ft MSL/NGVD {TOC - A}				
A - MW Stickup	ft				
B - Depth of BL	ft, btoc				
C- Depth of BL	ft, bls {B - A}				
D - Depth of WT	ft, btoc				
E - Depth of WT	ft, bls {D - A}				
F - Depth of DL	ft, btoc				
G - Depth of DL	ft, bls {F - A}				
H_m - Height of WC	ft {F - G}				
DL Reading	ft				
BL Reading	ft				
H_L - Height of WC	ft {DL-BL}				

Notes: Set the data and barometric logger to record/report in feet
Check the initial barometric pressure readings with Thomas Stone High School station (~ 5 mile S/SW)

Source: Trihydro 2015

Initials & Date: ____________________

Trihydro
CORPORATION

Site: ____

Personnel: ____

Well ID	Date	Time	Depth to Water (ft)	Depth to Water Previous Event (ft)	Total Depth (ft)	Total Depth Previous Event (ft)	Notes

	FIELD SCREENING LOG	Date	Field Book #
		Sampler Names:	

Project Location:	**Project No.**	**Page __1_ of ___**
Field Task:		
Comments:		

Field Sample ID	Field Sample Depth (feet bgs)	PID Result (ppmv)	Location ID	Sample Time	Sample Date

Sample Types

Samplers: ______________________________ Date: ____________

Groundwater Sampling Form

Facility: ______________________ Sample Point ID: ______________________

Location: ______________________ Sampler(s): ______________________

Sample Matrix: ______________________ ______________________

Top of Casing (ft, msl) ______________________

PURGE INFORMATION

Method of Well Purge: ______________________ Dedicated Equipment: Yes ______ No ______

Date/Time Initiated: ______________________ Casing Diameter (inches): ______________________

Initial Water Level (ft): ______________________ One Borehole volume (gal): ______________________

Initial Water Level Previous Event (ft): ______________ One Borehole Volume Previous Even (gal): ______________

Ground Water Elevation (ft, msl): ______________ Total Volume Purged (mL) ______________________

Ground Water Elevation Previous Event (ft, msl): ________ Purged Dry? Yes ______ No ______

Well Total Depth (ft): ______________________ Water Level after Purge (ft) ______________________

Well Total Depth Previous Event (ft): ______________ Date/Time Completed: ______________________

Purge Data: Discharge: ________ sec Refill: ________ sec Pressure: ________ psi

Measure Field pH, Temp, Specific Conductance, Diss O_2, and Oxidation-Reduction Potential using flow-through cell.

Average Purge Rate: ________ mL/Min

Time	Cumulative Volume (mL)	Purge Rate (mL/min)	Temp (ºC)	pH (std units)	Spec. Cond. (µS = µmhos/cm)	Turbidity (NTU)	Dissolved O_2 (mg/L)	ORP (mV)	Notes

Trihydro CORPORATION

FIELD INFORMATION LOG Part 2

SAMPLING INFORMATION

Sample Point ID: ______________________

Sampling Method: ______________________ Dedicated: Yes ________ No ________

Water Level @ Sampling (ft) ________________ Well Collection Sequence #: ________ of ________

Parameters: Annual: ____ Semi-Annual _____ Quarterly: ____ Monthly: ____ Other: _____

SAMPLE DATA:

Time	Sample Rate (mL/min)	Temp (ºC)	pH (std units)	Spec. Cond. (µS = µmhos/cm)	Turbidity (NTU)	Dissolved O_2 (mg/L)	ORP (mV)	Notes

INSTRUMENT CALIBRATION DATA

	Purging Event: Start of Day	Purging Event: End of Day		Sampling Event: Start of Day	Sampling Event: End of Day	
Start of day: (Date/Time) ________						
End of day: (Date/Time) ________						
Turbidity Meter: ________						
Turb Meter S/N: ________						
pH/Sp. Cond. Meter: ________						
pH/Sp. Cond. Meter S/N ________						
ORP/Diss O_2 Meter: ________						
ORP/Diss 0_2 Meter S/N ________						

Other Calibration: ______________________

GENERAL INFORMATION

Weather Conditions @ Sampling: ______________________

Sample Characteristics: ______________________

COMMENTS AND OBSERVATIONS

Well Closed and Locked? Y / N Full Suite Collected? Y / N # Bottles Collected: ________

____

____

____

Date: ____________ By: ________________ Title: ________________

Company: ________________

Trihydro CORPORATION

Lithology Log Sheet 1 of ___

Project Name	Project Number	Borehole ID

Drilling Company	Driller	Ground Elevation	Total Drilled Depth

Drilling Equipment	Drilling Method	Borehole Diameter	Date/Time Drilling Started	Date/Time Stopped

Type of Sampling Device	Water Level (ft bgs)
	Final

PID (make, model, serial no.)	Geologist	Checked by/Date

Location Description (include sketch in field logbook)	Weather Conditions (temp., clear, rain, wind)

Depth	Interval	Recovery	Blow Counts	Description (USCS, Munsell color, grain size, SECONDARY, PRIMARY, tertiary, (stiffness of clay or density of sand), (moisture), detail (sorting, angularity, minerology, bedding, plasticity, consistency, etc., as applicable)	Water Content	% Gravel	% Sand	% Fines	PID (ppm)	Remarks (Include all sample types & depth, odor, vapor measurements, times, etc.)
0										
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

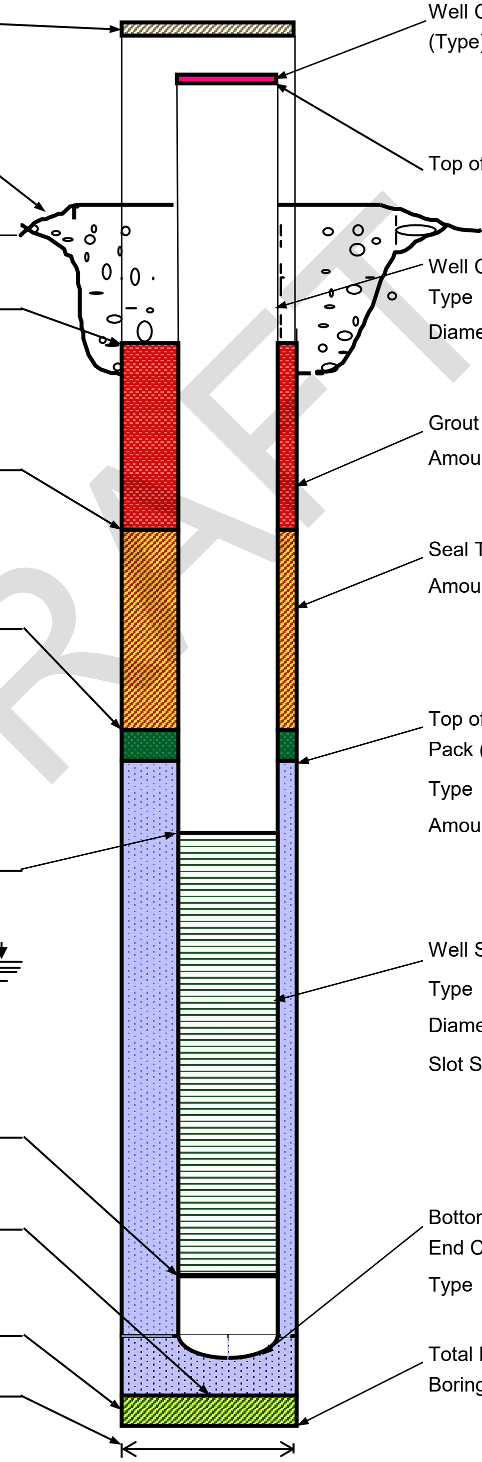
WELL CONSTRUCTION DETAIL

WELL ID: ____________

Project Name: ____________ **Project No:** ________ **Boring No.** ________ **Drilling Contractor:** ________

Site: ____________ **Datum:** ________ **Method:** ________ **Date Installed:** ________

Notes: ____



Locking Protective Casing

Concrete Surface Seal ____________

Ground Surface Elevation ____________

Top of Grout (ft. bgs) ____________

Top of Seal (ft. bgs) ____________

Top of Secondary Filter Pack (ft. bgs) ____________

Type ____________

Amount (bags) ____________

Top of Well Screen (ft. bgs) ____________

Groundwater (Static) ____________

Depth (ft. TOC) ____________

Date Measured ____________

Bottom of Well Screen (ft. bgs) ____________

Bottom of Filter Pack (ft. bgs) ____________

Bottom Seal Thickness (ft.) ____________

Borehole Diameter (in) ____________

Well Cap (Type) ____________

Top of Well Casing ____________

Well Casing

Type ____________

Diameter (in.) ____________

Grout Type ____________

Amount (bags) ____________

Seal Type ____________

Amount (bags) ____________

Top of Primary Filter Pack (ft. bgs) ____________

Type ____________

Amount (bags) ____________

Well Screen

Type ____________

Diameter (in.) ____________

Slot Size (in.) ____________

Bottom of End Cap (ft. bgs) ____________

Type ____________

Total Depth of Boring (ft. bgs) ____________

MONITORING WELL DEVELOPMENT LOG

Trihydro CORPORATION

Page ________ of ________
Well ID ________
Logged by ________

Client ________ Project ________ Job Number ________
Date ________ Time Start ________ Time End ________
Development Method ________ Purging Equipment ________ WQ Meter (Model) ________
Measured Depth (pre-development) ________ Measured Depth (post-development) ________ Water Level Equipment ________

Casing Diameter Inches	Gallons Per Foot Gallons
1	0.041
2	0.163
4	0.653
6	1.469

Depth to Product: ________ ft
Depth to Water: ________ ft
Total Depth: ________ ft

Casing Diameter: ________ in
Water Column: ________ ft
Casing Volume: ________ gal
Casing Volume: ________ L

1 ga = 3.785 L

Minimum Gallons to Purge (10 WCV's) ________ gal

All Measurements taken from: ☐ Top of Casing ☐ Protective Casing ☐ Ground Level

Time	Amount Purged (gal)	Field Parameters Measured GPM	Water Level	Conductivity mS/cm	pH	Temp. °C	Turbidity NTU	D.O. mg/L	SAL. %	Comments

MONITORING WELL DEVELOPMENT LOG

Trihydro CORPORATION

Page ________ of ________
Well ID ________________
Logged by ________________

Time	Amount Purged (gal)	Field Parameters Measured								Comments
		GPM	Water Level	Conductivity mS/cm	pH	Temp. ℃	Turbidity NTU	D.O. mg/L	SAL. %	

Photograph Log

Trihydro CORPORATION

Project: ______________________

Location: ______________________

Number	Date	Direction	Description

Trihydro CORPORATION

RECORD OF DRILLHOLE ______________ Sheet _1_ of ____

PROJECT: ____________
PROJECT NO: ____________
LOCATION: ____________

BORING METHOD: ____________
DRILLING DATE: ____________
DRILL RIG: ____________

DATUM: ____________
COORDINATES N: ____________
AZIMUTH: ____________

COLLAR ELEV: ________
E: ________________
INCLINATION: ________

J=Joint
F=Fault
S=Shear
B=Bedding
F=Folston

PL=Planar
C=Curved
U=Undulating
ST=Stepped
I=Irregular

P=Polished
K=Sk
SM=Smooth
R=Rough
VR=Very Rough

Fe=F
CL=Clay
CH=Chl
H=Heated
GRV=Gravel Fed

DEPTH SCALE (FEET)	ROCK TYPE / DESCRIPTION	ELEV DEPTH (FT)	CORE RECOVERY	RQD (80 60 40 20)	Fractures Per Foot (2 4 6 8 10)	DISCONTINUITY DATA: DIP Core Axis (0 30 60 90)	DISCONTINUITY DATA: TYPE AND SURFACE DESCRIPTION	WEATHERING INDEX (FR SW MW HW CW)	STRENGTH INDEX (R6 R5 R4 R3 R2 R1)	NOTES WATER LEVELS INSTRUMENTATION
2*										
2										
4										
6										
8										
10										
12										
14										
16										

Staff Gauge Surface Water Level Measurements

Month/Year:________________________
Field Personnel:______________________
Equipment:__________________________

WELL ID	DATE	TIME	SWL	COMMENT

WATER QUALITY METER DAILY CALIBRATION FORM

DATE: ____________________ MAKE: ____________________

PROJECT NAME: ____________________ MODEL: ____________________

PROJECT NUMBER: ____________________ SERIAL NUMBER: ____________________

EVENT: ____________________ CALIBRATION SOLUTION SERIAL NUMBER: ____________________

CALIBRATOR: ____________________ CALIBRATION SOLUTION EXPERATION DATE: ____________________

	pH	pH	CONDUCTIVITY (mS/cm):	TURBIDITY (NTU's):	DISSOLVED OXYGEN (mg/L):	TEMPERATURE (°C):	AUTO CALIBRATED:
STANDARD CONCENTRATION (C_{std}):	4.00	10.00	4.49	0	NA	NA	NA
CALIBRATION READING (C_{act}):							YES ☐ NO ☐
PERCENT RECOVERY (%R):					NA	NA	NA
ACCEPTANCE CRITERIA FOR %R:	90-110%	90-110%	90-110%	+/- 1.0	NA	NA	NA

$\%R = (C_{act} / C_{std}) \times 100$

COMMENTS: ____________________

Well Inspection/Inventory Form

Job Name: ______________________

Job No.: ______________________

Client: ______________________

Site Location: ______________________

Date: ______________________

Well I.D.: ______________________

Completion Depth: ______________________

Measured Depth: ______________________

Inspector: ______________________

☐ **Above Ground**

Protective Casing? ☐ Yes ☐ No

Material: ______________________

Condition ☐ Good ☐ Broken ☐ Cracked

Lid Condition ☐ Good ☐ Broken ☐ Cracked

Hinge Condition: ☐ Good ☐ Broken ☐ Cracked

☐ **Flush Mounted**

Well Cover Present: ☐ Yes ☐ No

Condition: ☐ Good ☐ Broken ☐ Cracked

Condition of Sump: ☐ Clean ☐ Dirty ☐ Standing Water

Concrete Pad:

Visible? ☐ Yes ☐ No

Dimensions:____________ Thickness:__________

Sloped away from casing: ☐ Yes ☐ No

Check and of the following features that apply:

☐ Many Cracks

☐ Few Cracks

☐ Gap Around Casing

☐ No Pad Present

☐ Ponded Water

Intercasing (PVC):

Inner Diameter (Inches):____________

Condition: ☐ Good ☐ Broken ☐ Cracked

Cap Present: ☐ Yes ☐ No

Well Lock Present: ☐ Yes ☐ No

Lock Functioning: ☐ Yes ☐ No

Bumper Posts: ☐ Yes ☐ No

Well I.D. Visible: ☐ Yes ☐ No

Comments:

____

____

____

APPENDIX C

USER MANUALS

Multi Water Quality Checker
U-50 Series

Instruction Manual

CODE:GZ0000144342C

Preface

This manual describes the operation of the Multi Water Quality Checker, U-50 Series.
Be sure to read this manual before using the product to ensure proper and safe operation of the instrument. Also safely store the manual so it is readily available whenever necessary.

Product specifications and appearance, as well as the contents of this manual are subject to change without notice.

■ Warranty and Responsibility

HORIBA warrants that the Product shall be free from defects in material and workmanship and agrees to repair or replace free of charge, at HORIBA's option, any malfunctioned or damaged Product attributable to HORIBA's responsibility for a period of one (1) year from the delivery unless otherwise agreed with a written agreement. In any one of the following cases, none of the warranties set forth herein shall be extended;

- Any malfunction or damage attributable to improper operation
- Any malfunction attributable to repair or modification by any person not authorized by HORIBA
- Any malfunction or damage attributable to the use in an environment not specified in this manual
- Any malfunction or damage attributable to violation of the instructions in this manual or operations in the manner not specified in this manual
- Any malfunction or damage attributable to any cause or causes beyond the reasonable control of HORIBA such as natural disasters
- Any deterioration in appearance attributable to corrosion, rust, and so on
- Replacement of consumables

HORIBA SHALL NOT BE LIABLE FOR ANY DAMAGES RESULTING FROM ANY MALFUNCTIONS OF THE PRODUCT, ANY ERASURE OF DATA, OR ANY OTHER USES OF THE PRODUCT.

■ Trademarks

Generally, company names and brand names are either registered trademarks or trademarks of the respective companies.

Conformable Directive

This equipment conforms to the following directives and standards:

Directives:	the EMC Directive 2004/108/EC
Standards:	[the EMC Directive] EN61326-1:2006 Class B, Portable test and measurement equipment

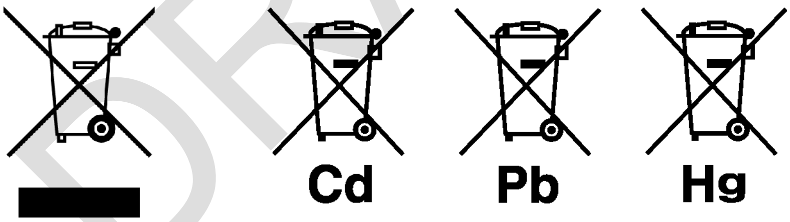
Information on Disposal of Electrical and Electronic Equipment and Disposal of Batteries and Accumulators

The crossed out wheeled bin symbol with underbar shown on the product or accompanying documents indicates the product requires appropriate treatment, collection and recycle for waste electrical and electronic equipment (WEEE) under the Directive 2002/96/EC, and/or waste batteries and accumulators under the Directive 2006/66/EC in the European Union.

The symbol might be put with one of the chemical symbols below. In this case, it satisfies the requirements of the Directive 2006/66/EC for the object chemical.

This product should not be disposed of as unsorted household waste.
Your correct disposal of WEEE, waste batteries and accumulators will contribute to reducing wasteful consumption of natural resources, and protecting human health and the environment from potential negative effects caused by hazardous substance in products.

Contact your supplier for information on applicable disposal methods.



FCC Rules

Any changes or modifications not expressly approved by the party responsible for compliance shall void the user's authority to operate the equipment.

WARNING

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications.
Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

For your safety

Warning messages are described in the following manner. Read the messages and follow the instructions carefully.

● Meaning of warning messages

⚠ DANGER	This indicates an imminently hazardous situation which, if not avoided, will result in death or serious injury. This signal word is to be limited to the most extreme situations.
⚠ WARNING	This indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury.
⚠ CAUTION	This indicates a potentially hazardous situation which, if not avoided, may result in minor or moderate injury. It may also be used to alert against unsafe practices. Without safety alert indication of hazardous situation which, if not avoided, could result in property damage.

● Symbols

(!)	Description of what should be done, or what should be followed
⊘	Description of what should never be done, or what is prohibited

■ Safety Precautions

This section provides precautions to enable you to use the product safely and correctly and to prevent injury and damage. The terms of DANGER, WARNING, and CAUTION indicate the degree of imminency and hazardous situation. Read the precautions carefully as it contains important safety messages.

⚠ WARNING
Do not disassemble or modify the meter. May cause overheating or fire, resulting in accidents.

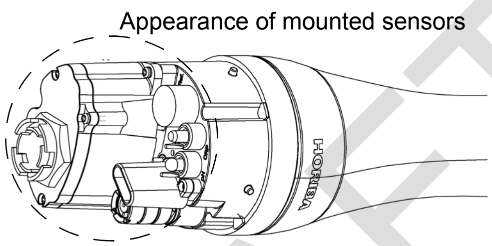
⚠ CAUTION
The pH and ORP sensors are made of glass. Handle them carefully to avoid breakage.
Do not ingest the DO, pH or ORP standard solutions. If it comes into contact with the eyes, rinse thoroughly with water. If swallowed, consult a physician.
Keep away from water when using USB communication. Improper use may result in fire or damage.

Points of concern

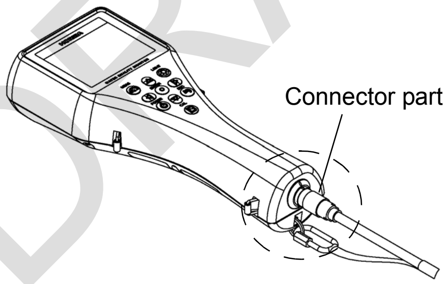
Use of the equipment in a manner not specified by the manufacturer may impair the protection provided by the equipment. It may also reduce equipment performance.

Sensor probe

- Do not immerse the sensor probe in seawater or other samples with high salinity. Doing so may erode metallic parts. After use, promptly wash the sensor probe thoroughly in water.
- Do not immerse the sensor probe in alcohol, organic solvent, strong acid, strong alkaline, and other similar solutions.
- Do not subject to strong shocks.
- Do not perform measurement in environments of magnetic fields. Measurement errors may result.
- The sensor probe is no longer waterproof when the sensors are not mounted.

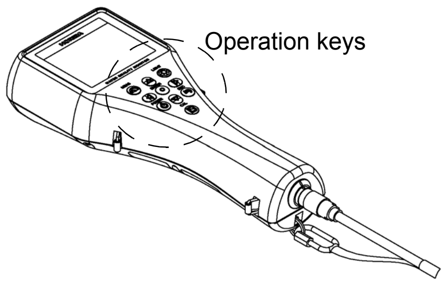


- Does not support measurement of samples containing fluorine.
- To disconnect the sensor cable or interface cable, pull them out with holding the connector part. Do not pull the cable part; it may cause breakage.



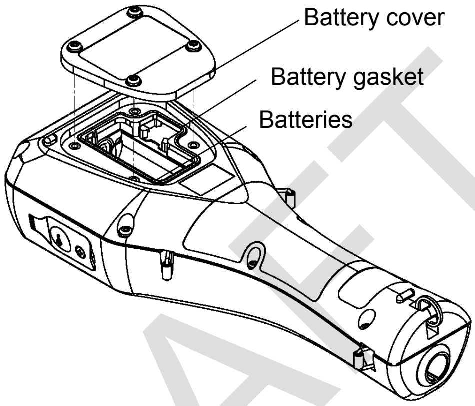
Control unit

- Do not subject to strong shocks.
- The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.



- The control unit is no longer waterproof when the USB cable is connected.
- When operating the control unit only, protect the connector with the connector cap provided.

- Remove the batteries when not using the control unit for an extended period of time. Battery fluid leakage may cause equipment failure.
- Do not wipe the control unit with organic solvents or powder polish. The surface may deteriorate or its printing may disappear. If the display becomes dirty, wipe the dirt off with a soft cloth soaked in neutral detergent.
- Do not turn the power OFF or disconnect the cable during calibration or setting. Memory data may be erased.
- To perform measurement, connect the sensor probe cable before turning the power ON.
- Do not remove the battery gasket or twist it.
- When opening the battery case, make sure that no foreign matter is attached to the battery gasket.
- Do not use any unspecified batteries; it may cause breakage.



Measurement

- Do not pull the cable when lowering the sensor probe into the sample during measurement. Lower the sensor probe into the sample on a chain or string.
- Before lowering the sensor probe into the sample, do not connect the hook on the unit to a human body.
- The correct values are not displayed if the sensor is not mounted when the measurement display is activated.
- Perform DO measurement with no air bubbles in the internal solution.
- Do not reuse a membrane cap of DO sensor.
- Use the spanner for DO sensor provided to attach or remove the DO sensor.
- Avoid both U-53 and U-53G turbidity measurement in air, since the rubber wiper will quickly become damaged.
- Avoid turbidity measurement in direct sunlight, since the readout may be affected.

Calibration

During atmosphere calibration for the DO electrode with DO salinity compensation set to automatic, values are compensated based on electrical conductivity, but calibration is performed normally.

Location of use and storage

- Storage temperature: –10°C to 60°C
- Relative humidity: Under 80% and free from condensation

Store the meter in locations void of dust, strong vibrations, direct sunlight, corrosive gases, near air conditioners or windy areas.

Disposal of the product

When disposing of the product, follow the related laws and/or regulations of your country for disposal of the product.

Description in this manual

Note

This interprets the necessary points for correct operation and notifies the important points for handling the unit.

Reference

This indicates where to refer for information.

Tip

This indicates reference information.

Contents

1 About this Unit

The U-50 Series Multi Water Quality Checker features an integrated control unit and sensors. It is capable of making a maximum of eleven simultaneous measurements for various parameters, and is perfect for use in the field. The U-50 Series is designed with on-site ease-of-use in mind, provides a wide variety of functions, and can be used for water quality measurements and inspections of river water, groundwater, and waste water.

2 Device Information

2.1 Measurement parameters

Parameters	Model				
	U-51	U-52	U-52G	U-53	U-53G
pH (pH)	✓	✓	✓	✓	✓
pH (mV)	✓	✓	✓	✓	✓
Oxidation reduction potential (ORP)	✓	✓	✓	✓	✓
Dissolved oxygen (DO)	✓	✓	✓	✓	✓
Electrical conductivity (COND)	✓	✓	✓	✓	✓
Salinity (SAL) [expressed as electrical conductivity]	✓	✓	✓	✓	✓
Total dissolved solids (TDS) [expressed as electrical conductivity]	✓	✓	✓	✓	✓
Seawater specific gravity (SG) [expressed as electrical conductivity]	✓	✓	✓	✓	✓
Water temperature (TEMP)	✓	✓	✓	✓	✓
Turbidity (TURB) [LED transmission/front 30° scattering method]	–	✓	✓	–	–
Turbidity (TURB) [tungsten lamp 90° transmission/scattering method] with wiper	–	–	–	✓	✓
Water depth (DEP)	–	–	✓	✓	✓
GPS	–	–	✓	–	✓

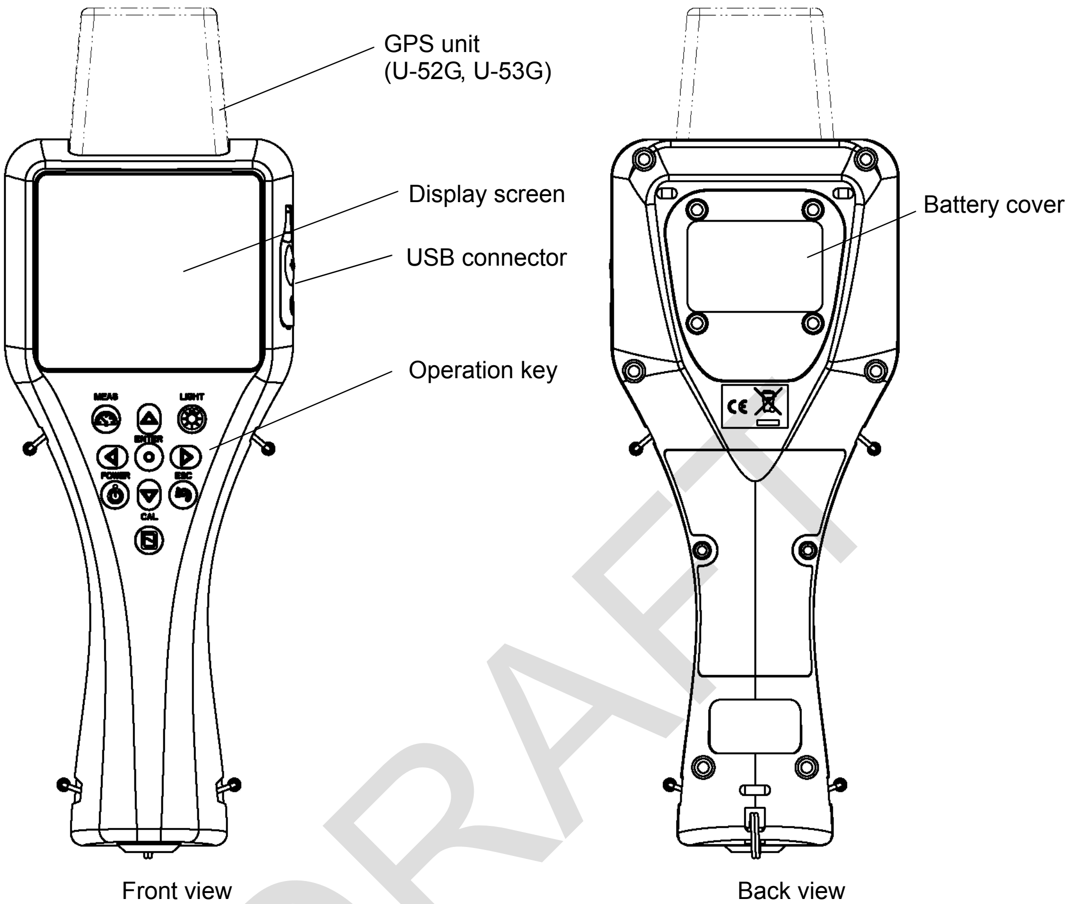
"✓" indicates a measurable parameter.

2.2 Packing list

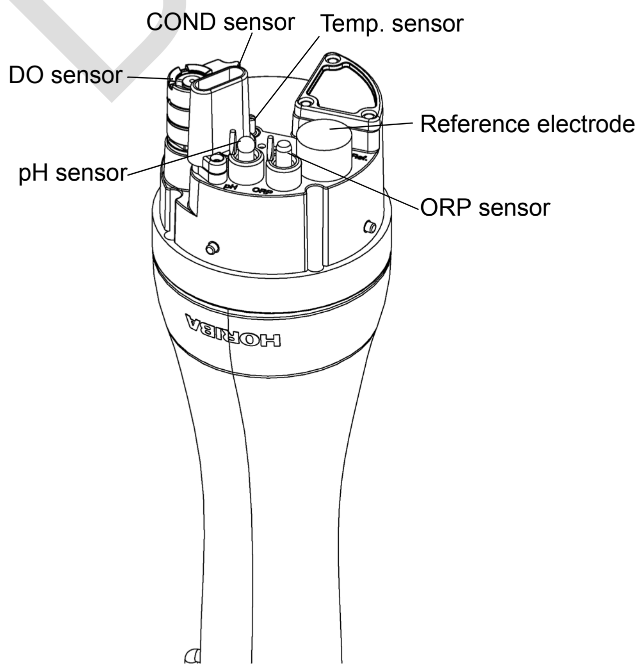
Parts Name	Quantity	Note
Control unit	1	
Sensor probe	1	
pH sensor (#7112)	1	
ORP sensor (#7313)	1	
Reference electrode (#7210)	1	
DO sensor (#7543)	1	
Turbidity sensor (#7800)	1	With U-52/U-52G only. Attached to the sensor probe.
Turbidity sensor (#7801)	1	With U-53/U-53G only. Attached to the sensor probe.
pH 4 standard solution (#100-4)	1	500 mL
pH reference internal solution (#330)	1	250 mL
DO sensor internal solution set (#306)	1	Internal solution (50 mL), Sandpaper (#8000, #600), Syringe
DO Membrane spare parts set	1	
Spanner for DO sensor	1	
Cleaning brush	1	
calibration cup	1	transparent calibration cup, black calibration cup
Back pack	1	
Strap	1	
Alkaline batteries	4	LR14
Silicon grease	1	
Instruction manual	1	

2.3 Parts name and functions

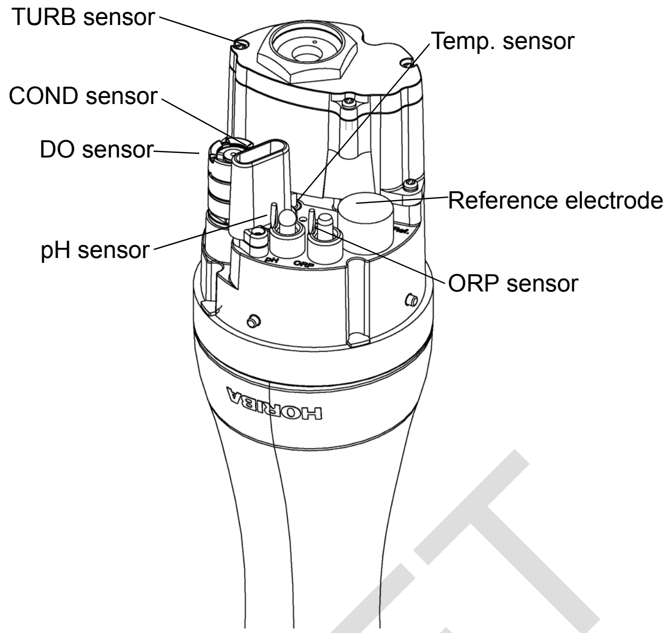
- **Display**



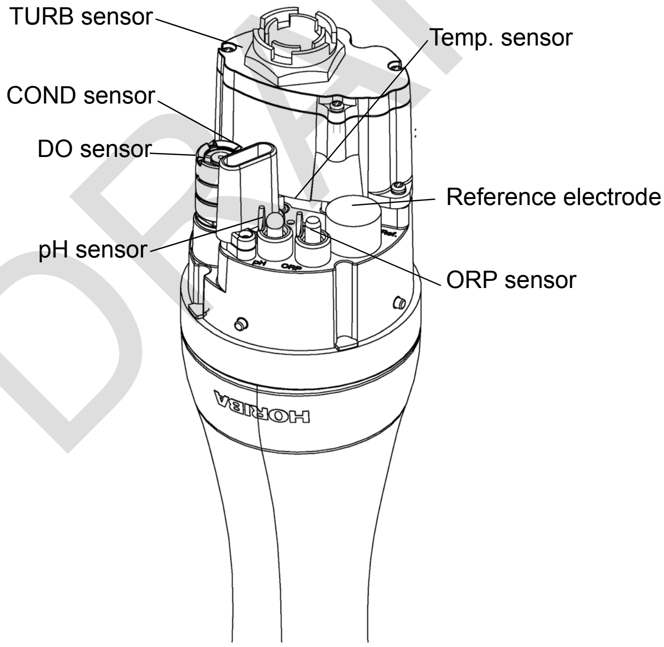
- **Sensor probe (U-51)**



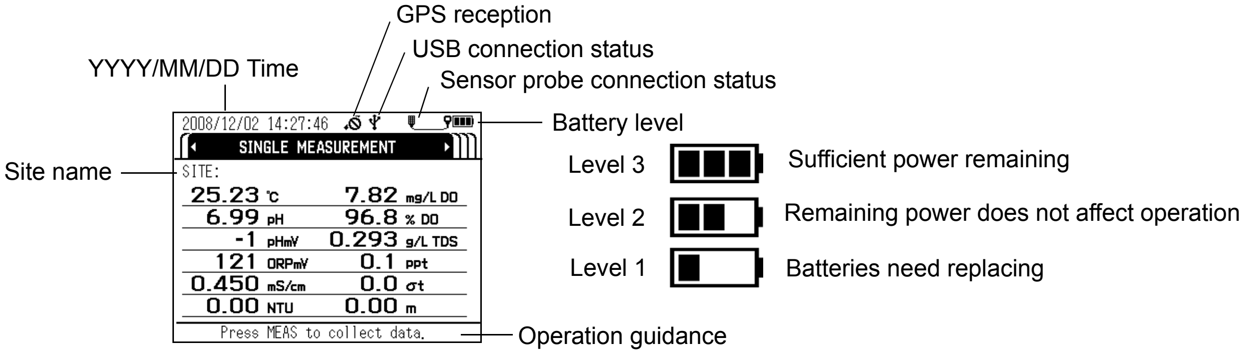
Sensor probe (U-52)



Sensor probe (U-53)



Display screen



Operation key

	Key name	description
	POWER key	Turns the system's power ON/OFF. The initial screen appears immediately after turning the power ON. Press and hold down the POWER key for about 3 seconds to turn the power ON and OFF.
	MEAS key	When pressed in the measurement screen, used to set the measurement values of all the measurement parameters. Measurement values flash until the data stabilizes. When pressed in the setting, calibration or data operation screen, returns to the measurement screen.
	ENTER key	Used to execute functions, set entered values or store data in memory.
	CAL key	Switches to the calibration screen.
	ESC key	Returns to the immediately preceding operation.
	LIGHT key	Turns the backlight ON/OFF. ● Using the backlight shortens battery life. ● The backlight does not light for about 3 seconds after power ON. ● When the sensor probe is connected while the display's backlight is lit, the backlight goes out for about 3 seconds.
	Left key	Moves the cursor to the left.
	Right key	Moves the cursor to the right.
	Up key	Moves the cursor up.
	Down key	Moves the cursor down.

2.4 Setting menu items

- Measurement
  - Single measurement
  - Interval measurement
  - “ 3.2.1 Setting measurement methods ” (page 18)
- Site
  - Select site
  - Create new site
  - Delete site
  - “ 3.2.2 Setting sites ” (page 20)
- Unit for report
  - TEMP (temperature)
  - TURB (turbidity)
  - DO (dissolved oxygen)
  - COND (electrical conductivity)
  - SG (seawater specific gravity)
  - Depth (water depth)
  - SALT (salinity)
  - “ 3.2.3 Unit for report ” (page 23)
- Sensor selection
  - TEMP (temperature)
  - pH
  - pH mV
  - ORP
  - COND (electrical conductivity)
  - TURB (turbidity)
  - DO (dissolved oxygen)
  - TDS (total dissolved solids)
  - SALT (salinity)
  - SG (seawater specific gravity)
  - DEPTH (water depth)
  - “ 3.2.4 Sensor selection ” (page 25)
- Compensation
  - DO salinity compensation
  - DO atmospheric pressure compensation
  - Electrical conductivity temperature coefficient
  - TDS
  - “ 3.2.5 Compensation ” (page 26)
- System
  - Language
  - Version
  - Date/time
  - Auto power OFF
  - Display contrast
  - Initialize
  - GPS locate*
  - GPS locating accuracy*
  - “ 3.2.6 System settings ” (page 32)

*Only on models with a GPS unit.

2.5 Calibration menu items

- Auto calibration
  - pH
  - COND (electrical conductivity)
  - TURB (turbidity)
  - DO (dissolved oxygen)
  - DEPTH (water depth)
  - “ 3.3.1 Auto calibration ” (page 39)
- Manual calibration
  - TEMP (temperature)
  - pH
  - ORP
  - COND (electrical conductivity)
  - TURB (turbidity)
  - DO (dissolved oxygen)
  - DEPTH (water depth)
  - “ 3.3.2 Manual calibration ” (page 42)

2.6 Data operation menu items

- Data operation
  - View data
  - Delete data
  - Check data memory
  - Calibration record
  - GPS information*
  - “ 3.5 Data operations ” (page 64)

*Only on models with a GPS unit.

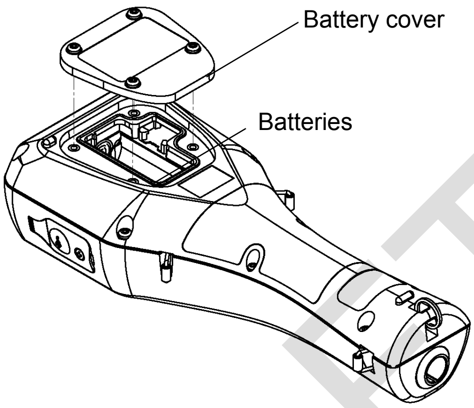
3 Basic Operation

3.1 System setup

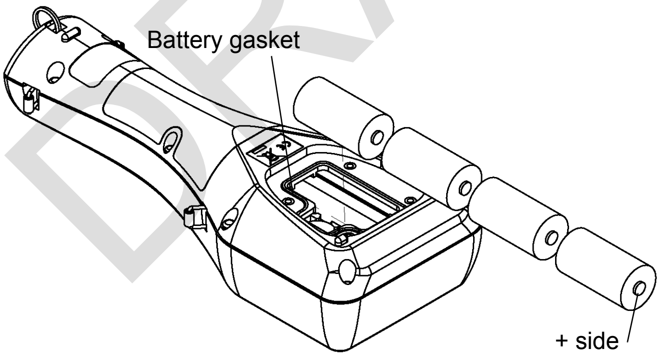
3.1.1 Inserting and replacing the batteries

The control unit is shipped without batteries. Follow the steps below to insert the batteries when using the system for the first time or replacing old batteries.

1. **Loosen the 4 screws on the battery cover by using No. 2 Phillips head screwdriver and remove the cover.**



2. **If replacing the batteries, discard the old batteries.**
3. **Insert new batteries in the control unit.**
   Check that the battery gasket is not dirty or twisted.



4. **Replace the battery cover and fasten it with the 4 screws.**
   Tighten the screws to less than 0.5 N·m.

Note

- **Data and settings will not be lost when the batteries are replaced.**
- **If dirty or twisted, the battery gasket will fail to keep the batteries dry. Check its condition before closing the cover.**
- **To ensure long service life, replacing the battery gasket periodically (once a year) is recommended.**

Precautions when using dry cell batteries

- **Batteries to use: LR14 alkaline dry cell batteries (C-size dry cell batteries) or rechargeable nickel-metal hydride dry cell batteries (C-size)**
  Do not use manganese batteries.
- **Dry cell batteries used incorrectly may leak or burst. Always observe the following**
  - Orient the batteries correctly (positive and negative ends in correct positions).
  - Do not combine new and used batteries, or batteries of different types.
  - Remove the batteries when not using the system for a prolonged period.
  - If batteries leak, have the system inspected at your nearest Horiba service station.

● Battery life

- The battery life for continuous operation when using C-size alkaline dry cell batteries is about 70 hours.
- Using the backlight consumes a proportionate amount of battery power, shortening battery life.
- Searching position information using the GPS unit consumes a proportionate amount of battery power, shortening battery life.
- Nickel-metal hydride secondary batteries can be used, but the battery life is not guaranteed since it will vary according to usage (number of times data is saved, number of charges and amount of each charge). In general, secondary batteries have one-half to one-third the life of C-size alkaline batteries.
- The 70-hour battery life figure applies to a control unit operating temperature of 20°C or more. The battery characteristics shorten the battery life at operating temperatures lower than 20°C, so check the remaining battery level, and replace the batteries before it reaches Level 1.
- The batteries packed with the system at the time of shipment are for checking operation. Their life is not guaranteed.
- The 70-hour battery life figure is the amount of operating time the batteries can provide until the system stops operating. The system may fail during operation if the remaining battery level is low, so it is a good idea to check the remaining battery level and replace the batteries with new ones well before the batteries run out completely.

U-51/52

Battery life: 70 hours (backlight off)

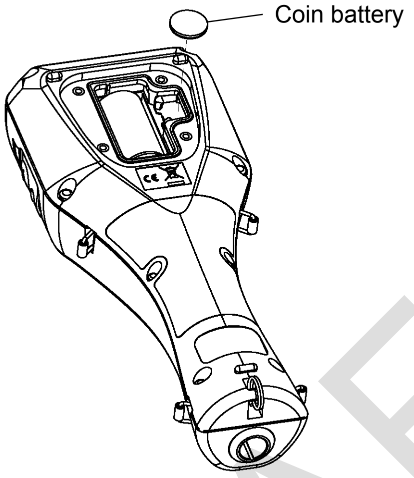
U-53

Battery life: 500 measurements (backlight off)

- Since U-53 is designed for turbidity measurement with wiper, its battery life is estimated in terms of the number of turbidity measurement sequences performed.
- Battery power is also consumed by measurement operations other than turbidity measurement.
- The battery life when turbidity measurement is not performed is about 70 hours.

3.1.2 Replacing the coin battery

- Coin battery to use: CR-2032
- The coin battery is only for the clock. It will provide problem-free operation for three years, but when using the clock continuously, it should be replaced every two years as a precaution.
- When replacing the coin battery for the clock, leave the control unit ON. If the coin battery is replaced when the control unit is turned OFF, the clock will be reset to the default settings.



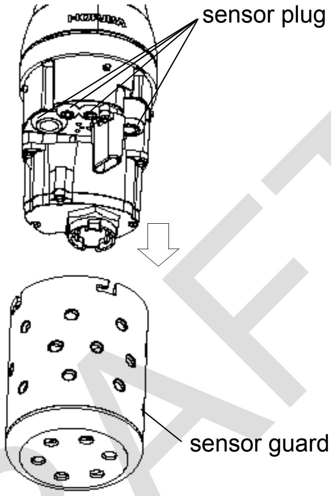
3.1.3 Attaching sensors

Note

- **When attaching or replacing a sensor, wipe any moisture off the sensor probe and sensor.**
- **Be sure to keep water out of sensor connectors. If moisture comes in contact with a sensor connector, blow-dry it with dry air.**
- **The sensor probe is not waterproof when the sensor is not mounted.**
- **Take care not to tighten the sensor too much.**

Attaching the pH sensor

1. **Remove the sensor guard.**

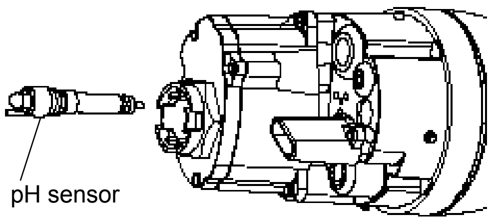


2. **Remove the sensor plug.**
3. **Coat the pH sensor O-ring with a thin layer of silicon grease (part No. 3014017718).**

Note

Be sure no grease from the O-ring gets on the sensor connector. If the sensor connector gets grease on it, wipe it off with a soft cloth soaked in alcohol.

4. **Make sure there is no moisture on the sensor probe's sensor connector (marked "pH").**
5. **Fasten the pH sensor securely by hand.**



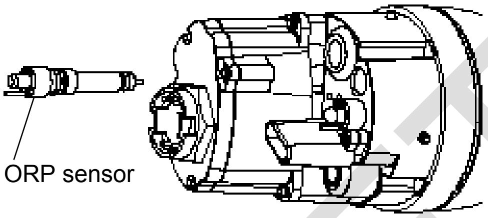
6. **Clean the sensor with an alcohol-soaked cloth.**

- **Attaching the ORP sensor**
  1. **Remove the sensor guard.**
  2. **Remove the sensor plug.**
  3. **Coat the ORP sensor O-ring with a thin layer of grease (part No. 3014017718).**

Note

Be sure no grease from the O-ring gets on the sensor connector. If the sensor connector gets grease on it, wipe it off with a soft cloth soaked in alcohol.

  4. **Make sure there is no moisture on the sensor probe's sensor connector (marked "ORP").**
  5. **Fasten the ORP sensor securely by hand.**



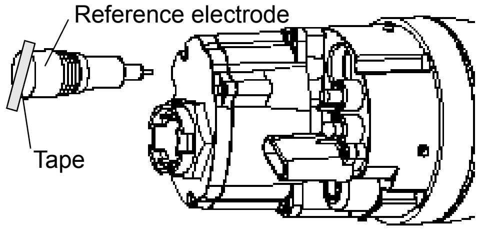
  6. **Clean the sensor with an alcohol-soaked cloth.**

- **Attaching the reference electrode**
  1. **Remove the sensor guard.**
  2. **Remove the sensor plug.**
  3. **Coat the reference electrode O-ring with a thin layer of grease (part No. 3014017718).**

Note

Be sure no grease from the O-ring gets on the sensor connector. If the sensor connector gets grease on it, wipe it off with a soft cloth soaked in alcohol.

  4. **Make sure there is no moisture on the sensor probe's sensor connector (marked "REF").**
  5. **Fasten the reference electrode securely by hand.**
  6. **Remove the tape from the liquid junction part of the reference electrode.**



● Attaching the dissolved oxygen (DO) sensor

1. **Remove the membrane cap mounted on the DO sensor beforehand, and replace it with the new membrane cap provided. Replace the internal solution with fresh solution. The main component of the internal solution is potassium chloride (KCl), so the old solution can be disposed of down a sink or other drain.**

Reference

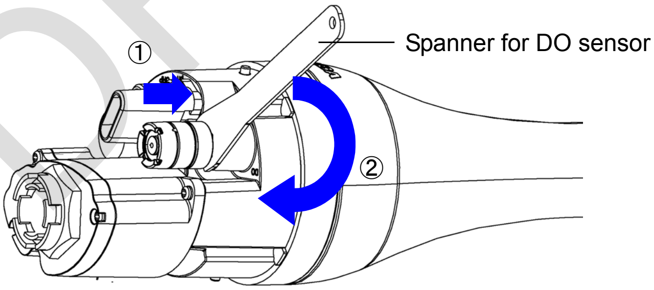
“ 4.5 Replacing the membrane cap ” (page 87)

2. **Screw in the DO sensor to attach it, allowing the internal solution to overflow slightly.**
3. **Use a soft cloth to wipe off the internal solution that overflowed onto the DO sensor.**
4. **Remove the sensor guard.**
5. **Remove the sensor plug.**
6. **Coat the DO sensor O-ring with a thin layer of grease (part No. 3014017718).**

Note

Be sure no grease from the O-ring gets on the sensor connector. If the sensor connector gets grease on it, wipe it off with a soft cloth soaked in alcohol.

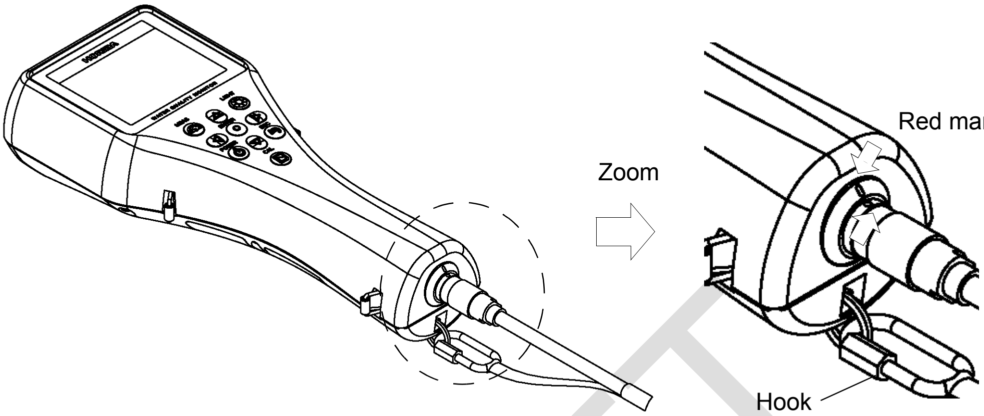
7. **Make sure there is no moisture on the sensor probe’s sensor connector (marked "DO").**
8. **Fasten the DO sensor securely using the spanner for DO sensor.**
   - Hold the DO sensor with the provided spanner for DO sensor and push the sensor down. (Step 1 in figure below)
   - Screw the DO sensor in place. (Step 2 in figure below)



3.1.4 Connecting the control unit and sensor probe

Note

Connect the control unit with its power OFF.

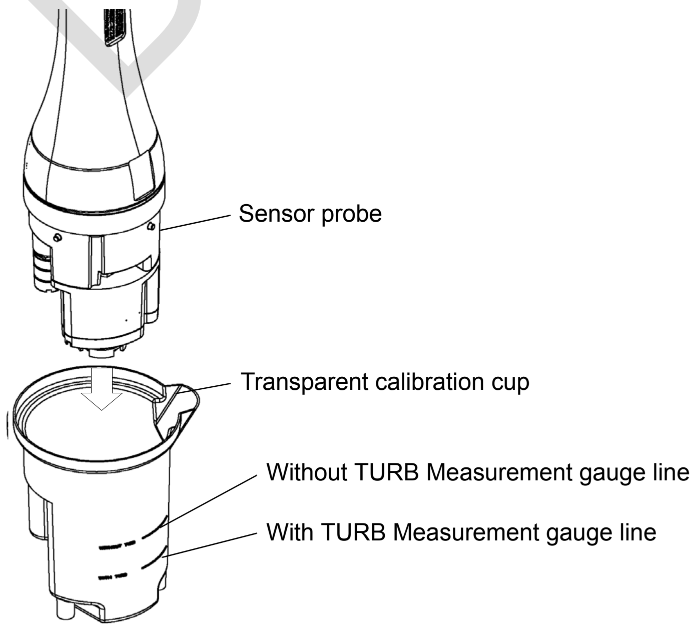


1. **Align the red mark on the connector, and press the connector in until you hear it click.**
2. **Connect the cable's hook to the display.**

3.1.5 Conditioning

Carry out the steps below when using the unit for the first time or when the system has not been used for 3 months or longer.

1. **Fill the transparent calibration cup to the line with pH 4 standard solution.**
   The transparent calibration cup has With TURB Measurement and Without TURB Measurement gauge lines.
2. **Insert the sensor probe in the transparent calibration cup.**



Note

Check that all sensors are attached.

3. **Press and hold down the control unit's POWER key for about 3 seconds to turn the power ON. Leave the unit for at least 20 minutes to condition the sensors.**

Note

The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

Tip

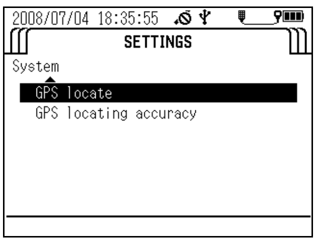
- **The procedure for immersing the sensor probe in the pH standard solution is the same as that described in " 3.3.1 Auto calibration " (page 39).**
  Auto calibration can be performed using the same pH 4 standard solution that was used in the conditioning procedure.
- **Immersing the sensor in the standard solution is generally required for sensor conditioning, but a voltage supply is required for DO sensor conditioning. Turning ON the power of the control unit is necessary during sensor conditioning.**

3.1.6 GPS (U-52G, U-53G)

The GPS position measurement precision is proportional to the GPS position measurement time. When the position measurement precision increases, the position measurement time also increases. See " ● GPS locating accuracy" (page 17) for how to set the position measurement precision. See " ● GPS locate" (page 15) below for how to check acquired GPS data.

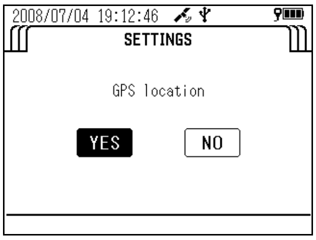
● GPS locate

1. **Press the right (▷) key to switch the display to the "SETTINGS" screen.**
2. **Press the down (▽) key to move the cursor to "System", then press the ENTER key.**
3. **Press the down (▽) key to move the cursor to "GPS locate", then press the ENTER key.**



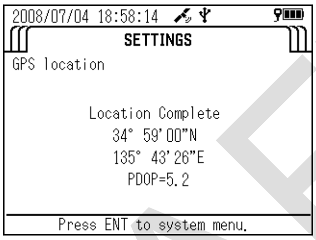
4. **The message "Press ENT key to start position measurement." appears. Press the ENTER key.**

5. **The message "Execute GPS position measurement?" appears. Move the cursor to "YES", then press the ENTER key.**

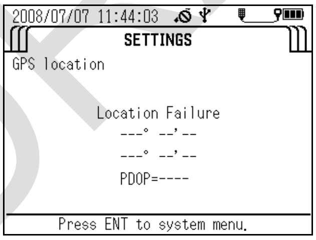


6. **The message "Warming up. Please wait." appears. Wait until the system has finished warming up (about 10 seconds).**

- Position measurement starts automatically when warmup has finished. Position measurement is performed up to 10 times.
- The GPS location complete screen appears after successful position measurement.

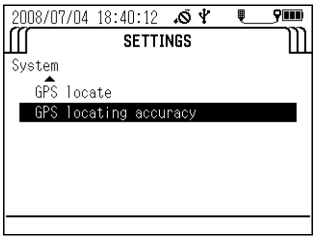


- The GPS location failure screen appears after position measurement has failed. Redo the measurement in a location free from obstacles, or wait for the meteorological conditions to improve before redoing the measurement.

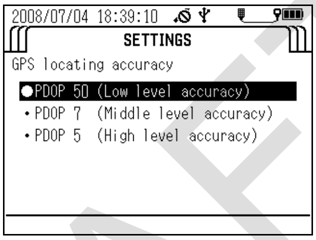


● GPS locating accuracy

1. **Press the right (▷) key to switch the display to the "SETTINGS" screen.**
2. **Press the down (▽) key to move the cursor to "System", then press the ENTER key.**
3. **Press the down (▽) key to move the cursor to "GPS locating accuracy", then press the ENTER key.**



4. **The screen below appears. Move the cursor to the locating accuracy, then press the ENTER key. The black circle (●) indicates the currently set precision.**



3.2 Settings

3.2.1 Setting measurement methods

This section describes how to set the measurement method.

● Measurement methods

● U-51/U-52

Single measurement	Pressing the MEAS key acquires the 5-second average for the selected measurement parameter.
Interval measurement	Pressing the MEAS key acquires and saves the 5-second average for the selected measurement parameter in the set interval. The measurement interval can be set to any value between 10 seconds and 24 hours.

● U-53

The U-53 turbidity sensor uses a tungsten lamp. The lamp lights for about 10 seconds, and the average measurement value acquired during this interval is displayed.

Single measurement	Pressing the MEAS key acquires the 5-second average for the selected measurement parameter after wiper operation. The 10-second average is acquired when measuring turbidity.
Interval measurement	Pressing the MEAS key acquires and saves the 5-second average for the selected measurement parameter in the set interval. The 10-second average is acquired when measuring turbidity. The measurement interval can be set to any value between 10 seconds (final check of this value required; 30 seconds may be better for U-52) and 24 hour.

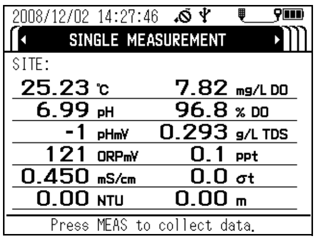
Reference

“ 3.4 Measurement ” (page 61)

● Operation method

1. **Press and hold down the control unit’s POWER key for about 3 seconds to turn the power ON.**

   The "MEASUREMENT" screen appears after about 10 seconds.

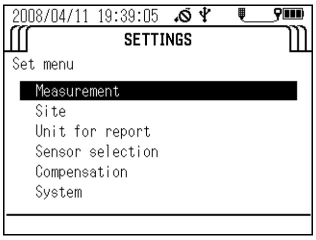


Note

The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

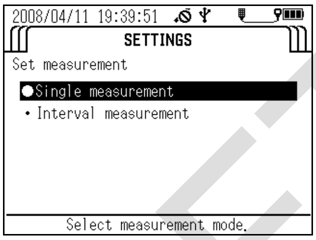
2. **Press the right (▷) key to switch the display to the "SETTINGS" screen.**

3. **Press the down (▽) key to move the cursor to "Measurement", then press the ENTER key.**



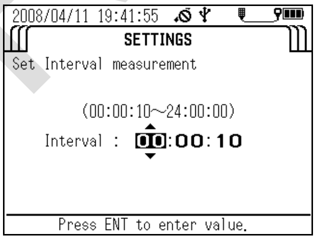
4. **Press the down (▽) key to move the cursor to the desired measurement mode. Press the ENTER key to save the setting.**

   The black circle (●) indicates the currently selected measurement mode.



5. **If you selected "Interval measurement", the display switches to the screen used to set the measurement interval. Press the up (△) and down (▽) keys to set the measurement interval.**

   The measurement interval can be set to any value between 10 seconds and 24 hours in the case of the U-51 and U-52, or between 30 seconds and 24 hours in the case of the U-53.



3.2.2 Setting sites

The site function allows position data to be connected to corresponding measurement data. Sites have the following specifications and features:

Site names: Text data consisting of up to 20 one-byte alphanumeric characters, spaces, etc.
Site names can be used for control unit searches and as labels for computer processing.
Site names allow measurement data to be saved with a name corresponding to the actual location where it was measured.

You can use site information as a search key when viewing data uploaded by a PC or data saved in the control unit (see “ 3.5 Data operations ” (page 64)).

● Selecting sites

You can select previously created sites. The black circle (●) indicates the name of the currently selected site. No sites are created at new purchasing or after initialization. Select a site after first creating one from the "Create new site" menu.

● Creating new sites

You can create and save new sites. Up to 20 site names can be registered.

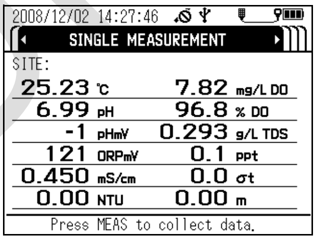
● Deleting sites

You can select a previously created site and delete it.

● Operation methods

● Selecting a site

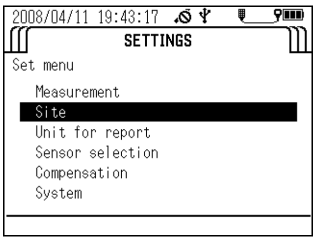
1. **Press and hold down the control unit’s POWER key for about 3 seconds to turn the power ON.**
   The "MEASUREMENT" screen appears after about 10 seconds.



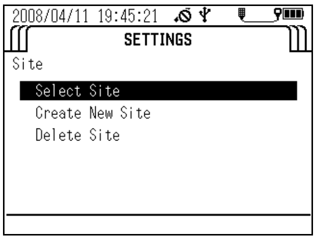
Note

The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

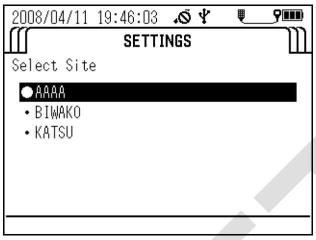
2. **Press the right (▷) key to switch the display to the "SETTINGS" screen.**
3. **Press the down (▽) key to move the cursor to "Site", then press the ENTER key.**



4. **Press the down (▽) key to move the cursor to "Select Site", then press the ENTER key to display the names of the currently saved sites.**

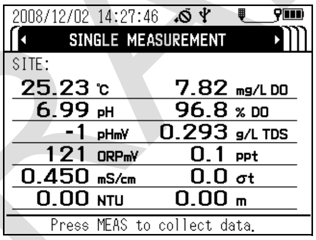


The black circle (●) indicates the currently selected site.



● Creating a new site

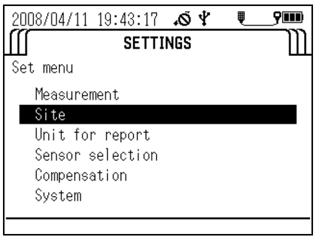
1. **Press and hold down the control unit's POWER key for about 3 seconds to turn the power ON.**
   The "MEASUREMENT" screen appears after about 10 seconds.



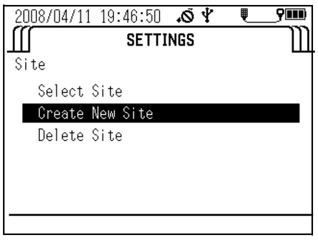
Note

The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

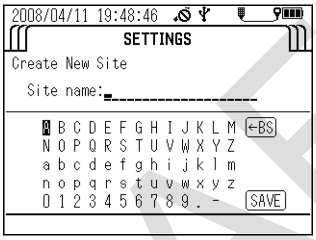
2. **Press the right (▷) key to switch the display to the "SETTINGS" screen.**
3. **Press the down (▽) key to move the cursor to "Site", then press the ENTER key.**



4. **Press the down (▽) key to move the cursor to "Create New Site", then press the ENTER key.**
   Enter the desired site name (up to 20 alphanumeric non-Asian width characters).

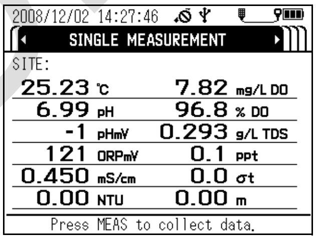


5. **Press the up (△), down (▽), right (▷), and left (◁) keys to move the cursor to each letter or number to use in the name, then press the ENTER key to confirm the entered characters. To delete incorrectly entered characters, move the cursor to "BS" and press the ENTER key to start deleting from the last character. When you have finished entering the name, save it by moving the cursor to "SAVE" and pressing the ENTER key.**



● **Deleting a site**

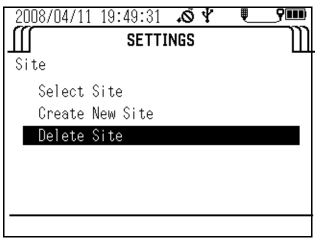
1. **Press and hold down the control unit's POWER key for about 3 seconds to turn the power ON.**
   The "MEASUREMENT" screen appears after about 10 seconds.



Note

The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

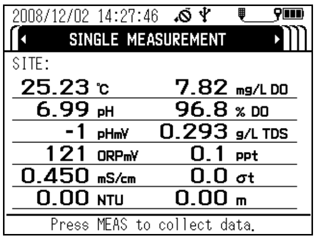
2. **Press the right (▷) key to switch the display to the "SETTINGS" screen.**



3. **Press the down (▽) key to move the cursor to "Site", then press the ENTER key.**

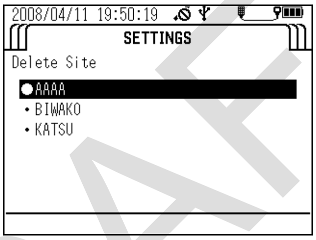
4. **Press the down (▽) key to move the cursor to "Delete Site", then press the ENTER key.**

   A list of the currently saved sites appears. The black circle (●) indicates the currently selected site.



5. **Press the down (▽) key to move the cursor to the site to delete, then press the ENTER key to delete it.**

   The currently selected site can be deleted after a different site has been selected from the site selection menu or after all unselected sites have been deleted. The same site name cannot be registered more than once.



3.2.3 Unit for report

Note

Units can only be selected when the sensor probe is connected.

Follow the steps below to set the measurement units of measurement parameters. No units are displayed if a measurement parameter has not been selected in the measurement parameter selection screen (see “ 3.2.4 Sensor selection ” (page 25)).

1. **Press and hold down the control unit’s POWER key for about 3 seconds to turn the power ON.**

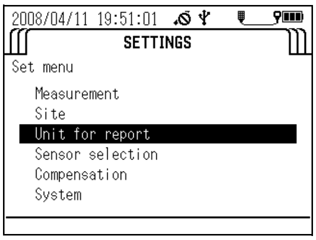
   The "MEASUREMENT" screen appears after about 10 seconds.

Note

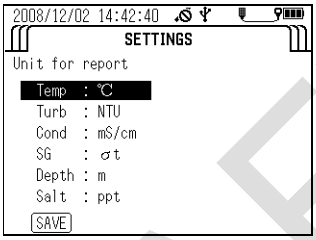
The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

2. **Press the right (▷) key to switch the display to the "SETTINGS" screen.**

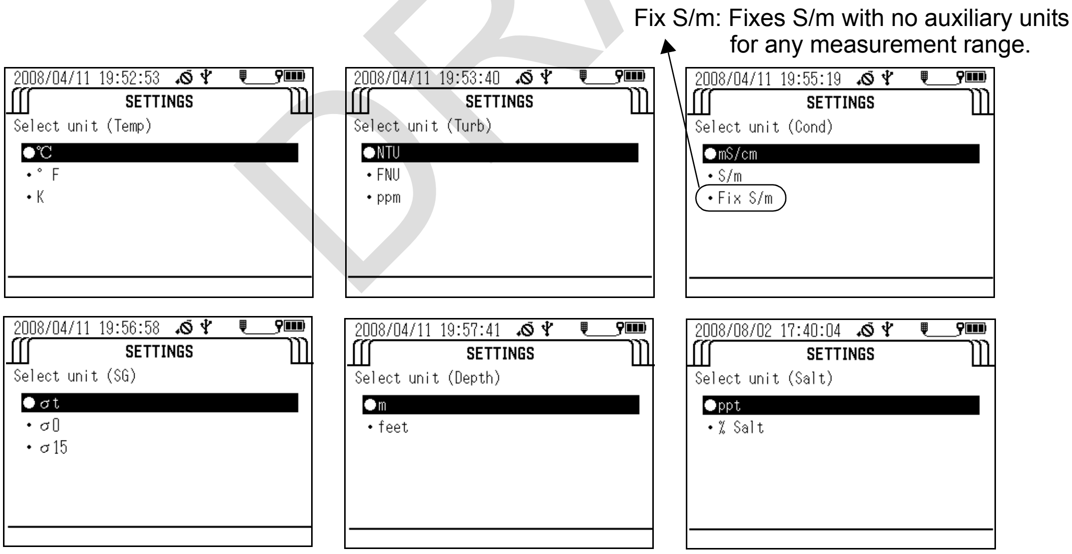
3. **Press the down (▽) key to move the cursor to "Unit for report", then press the ENTER key.**
   A list of the currently selected measurement parameters and their units appears. Note that measurement parameters not selected (in the measurement parameter selection screen) are not displayed.



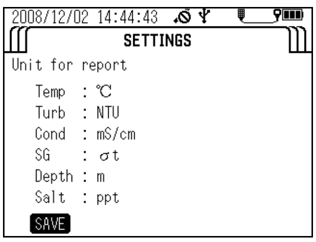
4. **Press the up (△) and down (▽) keys to move the cursor to the item to change, then press the ENTER key.**



5. **A list of the units that can be selected appears. The black circle (●) indicates the currently selected unit. Press the up (△) and down (▽) keys to move the cursor to the desired unit, then press the ENTER key.**



6. **To save the changes, press the up (△) and down (▽) keys to move the cursor to SAVE, then press the ENTER key. If you do not want to save the changes, press the ESC key.**



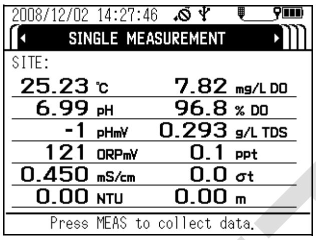
3.2.4 Sensor selection

Note

Measurement parameters can only be selected when the sensor probe is connected.

You can set between 1 and 11 measurement parameters to display in the control unit screen. Follow the steps below to select the desired measurement parameters.

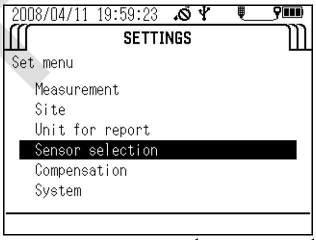
1. **Press and hold down the control unit's POWER key for about 3 seconds to turn the power ON.**
   The "MEASUREMENT" screen appears after about 10 seconds.



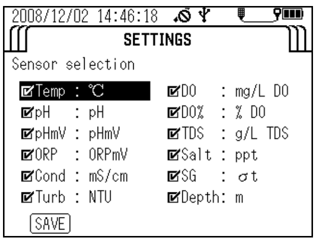
Note

The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

2. **Press the right (▷) key to switch the display to the "SETTINGS" screen.**
3. **Press the down (▽) key to move the cursor to "Sensor selection", then press the ENTER key.**
   A list of the measurement parameters that can be set and the currently set units are displayed.



4. **Move the cursor to each measurement parameter to change, then press the ENTER key.**
   A check in the check box of a measurement parameter indicates it will be displayed.
5. **To save the changes, press the up (△), down (▽), left (◁) and right (▷) keys to move the cursor to SAVE, then press the ENTER key. If you don't want to save the changes, press the ESC key.**



Note

Available measurement parameters differ according to product specifications.

3.2.5 Compensation

Note

Compensation settings can only be made when the sensor probe is connected.

U-50 series have following functions of compensation.

- Salinity compensation and atmospheric pressure compensation for dissolved oxygen (DO)
- Temperature compensation for conductivity (COND)
- Setting total dissolved solid (TDS) coefficient for TDS

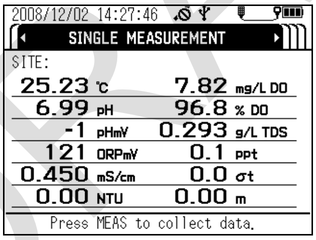
● Salinity compensation (DO)

The dissolved oxygen (DO) value is presented higher than actual value if salinity compensation is not added, because the increase of salinity gives higher DO value. To obtain correct value salinity compensation is needed. The following modes are available for calculation of salinity compensation.

AUTO: Salinity compensation is performed automatically with salinity converted from conductivity.

Value input: Press the up (△) and down (▽) keys to enter a setting value when the salinity is known.

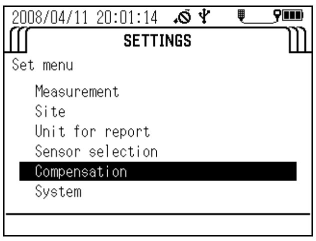
1. **Press and hold down the control unit's POWER key for about 3 seconds to turn the power ON.**
   The "MEASUREMENT" screen appears after about 10 seconds.



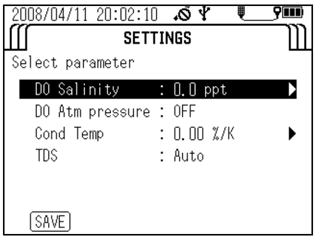
Note

The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

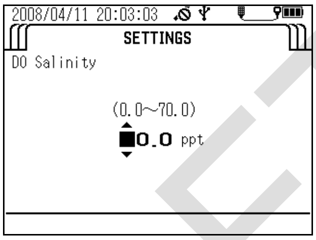
2. **Press the right (▷) key to switch the display to the "SETTINGS" screen.**
3. **Press the down (▽) key to move the cursor to "Compensation", then press the ENTER key.**



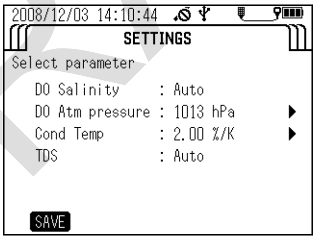
4. Press the down (▽) key to move the cursor to "DO Salinity", then press the ENTER key to toggle the setting between "Auto" and "Input mode".
Default: Auto



5. If you selected "Input mode", press the right (▷) key to display the compensation value input screen. Press the up (△) and down (▽) keys to enter the desired value, then press the ENTER key to set it.



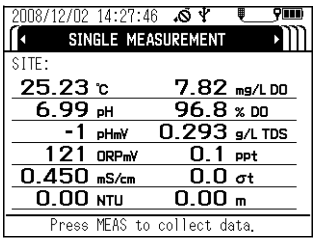
6. To save the change, press the up (△) and down (▽) keys to move the cursor to SAVE, then press the ENTER key. If you don't want to save the change, press the ESC key.



● **Atmospheric pressure compensation (DO)**

Differences in the atmospheric pressure of the measurement location influence the Dissolved Oxygen (DO) measurement. By setting (input) the actual atmospheric pressure of the measurement location into the control unit, it is possible to standardize the measured Dissolved Oxygen (DO) value to a value at the standard atmospheric pressure (1013 hPa).

1. Press and hold down the control unit's POWER key for about 3 seconds to turn the power ON.
The "MEASUREMENT" screen appears after about 10 seconds.

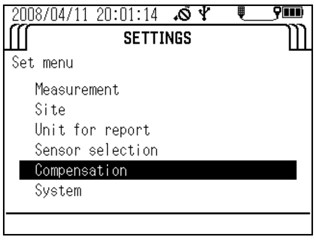


Note

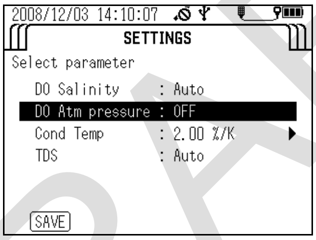
The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

2. **Press the right (▷) key to switch the display to the "SETTINGS" screen.**

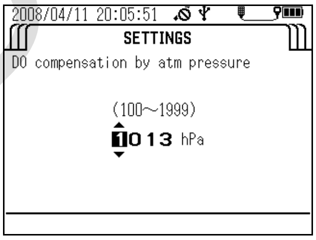
3. **Press the down (▽) key to move the cursor to "Compensation", then press the ENTER key.**



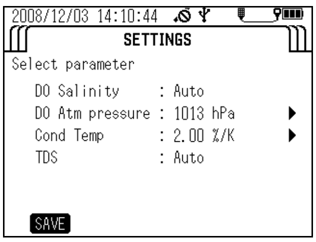
4. **Press the down (▽) key to move the cursor to "Cond Temp", then press the ENTER key to toggle the setting between "OFF" and "Input mode".**
Default: OFF



5. **If you selected "Input mode", press the right (▷) key to display the compensation value input screen. Press the up (△) and down (▽) keys to enter the desired value, then press the ENTER key to set it.**



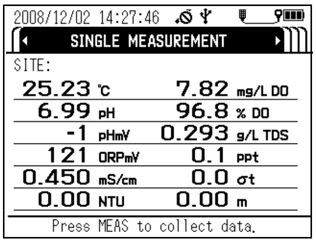
6. **To save the change, press the up (△) and down (▽) keys to move the cursor to SAVE, then press the ENTER key. If you don’t want to save the change, press the ESC key.**



- **Temperature compensation for conductivity (COND)**

Sample conductivity (COND) varies with temperature, and this control unit uses a temperature compensation coefficient to automatically standardize the conductivity (COND) at 25°C. The initial setting coefficient is 2%/K, which is the generally used.

1. **Press and hold down the control unit's POWER key for about 3 seconds to turn the power ON.**
The "MEASUREMENT" screen appears after about 10 seconds.

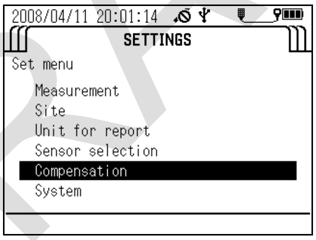


Note

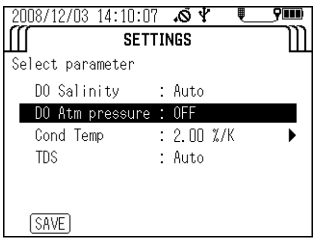
The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

2. **Press the right (▷) key to switch the display to the "SETTINGS" screen.**

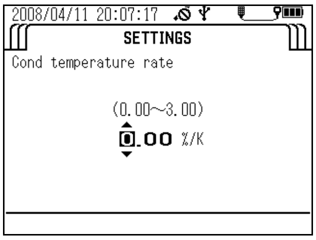
3. **Press the down (▽) key to move the cursor to "Compensation", then press the ENTER key.**



4. **Press the down (▽) key to move the cursor to "Cond Temp", then press the ENTER key to toggle the setting between "OFF" and "Input mode".**
Default: 2.00%/K

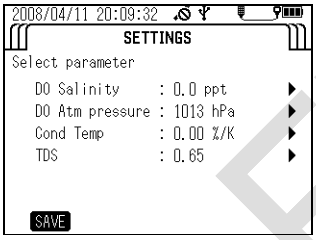


5. **If you selected "Input mode", press the right (▷) key to display the compensation value input screen. Press the up (△) and down (▽) keys to enter the desired value, then press the ENTER key to set it.**



6. **To save the change, press the up (△) and down (▽) keys to move the cursor to SAVE, then press the ENTER key.**

If you don't want to save the change, press the ESC key.

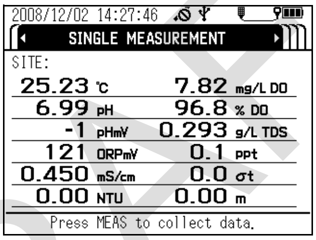


● **Setting a total dissolved solid (TDS) coefficient**

The total dissolved solid amount (TDS) is a converted value obtained by multiplying the conductivity (COND) by a known coefficient. The coefficient initially set for the control unit is based on a conversion for KCl and $CaCO_3$ solutions and it depends on the conductivity (COND) value as shown below.

Conductivity (COND) (S/m)	Conversion coefficient
< 0.05	0.65
0.05 to 0.5	0.64
0.5 to 1	0.63
1 to 3	0.62
3 to 5	0.61
> 5	0.60

1. **Press and hold down the control unit's POWER key for about 3 seconds to turn the power ON.**
The "MEASUREMENT" screen appears after about 10 seconds.

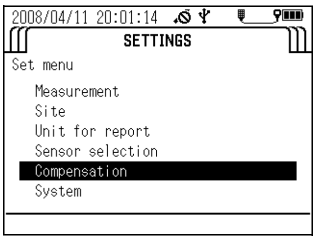


Note

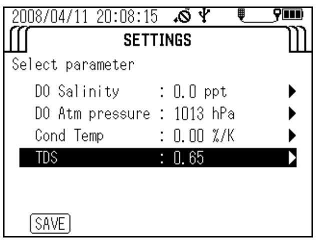
The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

2. **Press the right (▷) key to switch the display to the "SETTINGS" screen.**

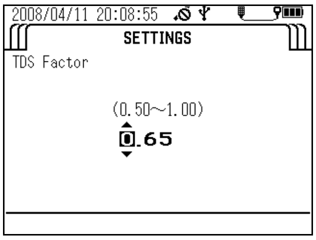
3. **Press the down (▽) key to move the cursor to "Compensation", then press the ENTER key.**



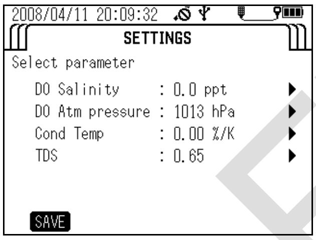
4. **Press the down (▽) key to move the cursor to "TDS", then press the ENTER key to toggle the setting between "AUTO" and "Input mode".**
Default: Auto



5. If you selected "Input mode", press the right (▷) key to display the compensation value input screen. Press the up (△) and down (▽) keys to enter the desired value, then press the ENTER key to set it.



6. To save the change, press the up (△) and down (▽) keys to move the cursor to SAVE, then press the ENTER key. If you don't want to save the change, press the ESC key.



3.2.6 System settings

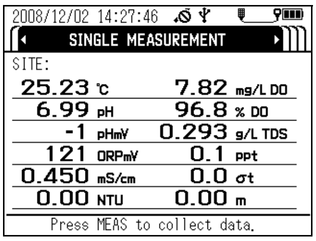
The system settings let you change the display language, check the system software version, set the date/time, set the auto power OFF time, set the display contrast, and initialize the settings.

● **Display language**

Follow the steps below to select either English or Japanese as the display language.

1. Press and hold down the control unit's POWER key for about 3 seconds to turn the power ON.

The "MEASUREMENT" screen appears after about 10 seconds.

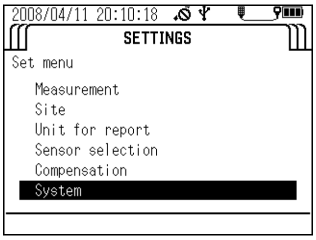


Note

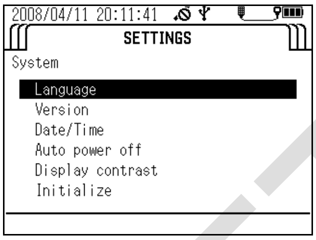
The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

2. Press the right (▷) key to switch the display to the "SETTINGS" screen.

3. **Press the down (▽) key to move the cursor to "System", then press the ENTER key.**

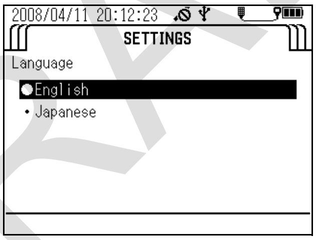


4. **Press the down (▽) key to move the cursor to "Language", then press the ENTER key.**



5. **A list of the supported display languages appears. Press the up (△) and down (▽) keys to move the cursor to the desired language, then press the ENTER key.**

   The black circle (●) indicates the currently selected display language.



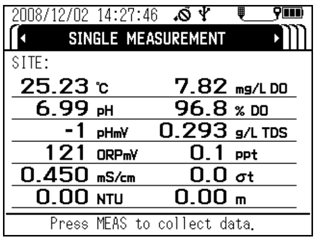
● Version

Follow the steps below to display the program No. and version of the control unit and sensor probe software.

The program No. and version of the sensor probe software will not be displayed if the sensor probe is not connected.

1. **Press and hold down the control unit's POWER key for about 3 seconds to turn the power ON.**

   The "MEASUREMENT" screen appears after about 10 seconds.

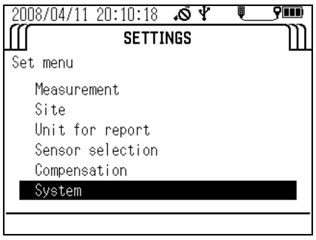


Note

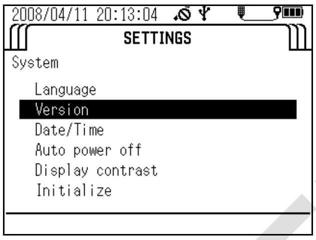
The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

2. **Press the right (▷) key to switch the display to the "SETTINGS" screen.**

3. Press the down (▽) key to move the cursor to "System", then press the ENTER key.



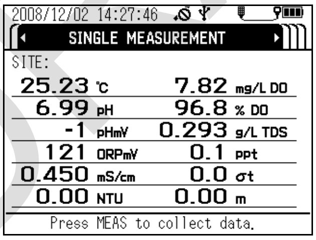
4. Press the down (▽) key to move the cursor to "Version", then press the ENTER key.
The program No. of the control unit and sensor probe software appears.



● Setting the date/time

Follow the steps below to set the date and time.

1. Press and hold down the control unit's POWER key for about 3 seconds to turn the power ON.
The "MEASUREMENT" screen appears after about 10 seconds.

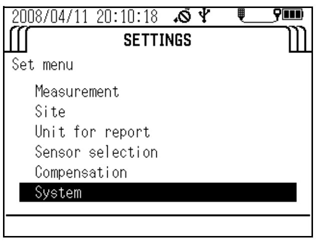


Note

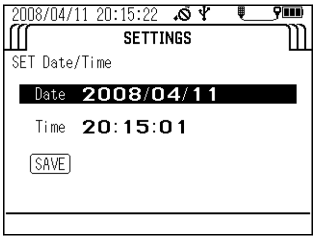
The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

2. Press the right (▷) key to switch the display to the "SETTINGS" screen.

3. Press the down (▽) key to move the cursor to "System", then press the ENTER key.

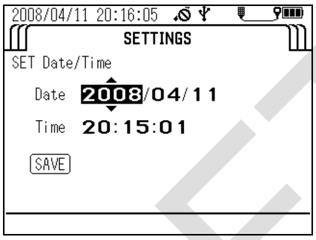


4. **Press the down (▽) key to move the cursor to "Date/time", then press the ENTER key.**

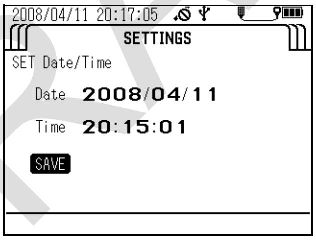


5. **Move the cursor to the date, then press the ENTER key.**

6. **Press the right (▷) key to move the cursor to the year, month, day, hour, minute and second, and press the up (△) and down (▽) keys to enter each value.**



7. **When finished entering settings, press the ENTER key to move the cursor to SAVE, then press the ENTER key again to save the settings.**

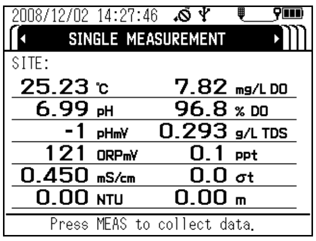


● **Setting the auto power OFF time**

Follow the steps below to set the time for the auto power OFF function (which turns the power OFF automatically when no operation is performed for the preset amount of time).

1. **Press and hold down the control unit's POWER key for about 3 seconds to turn the power ON.**

The "MEASUREMENT" screen appears after about 10 seconds.

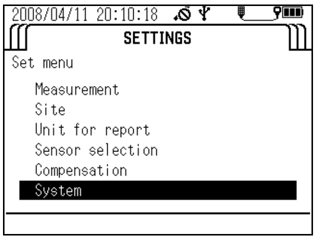


Note

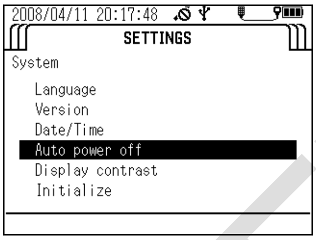
The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

2. **Press the right (▷) key to switch the display to the "SETTINGS" screen.**

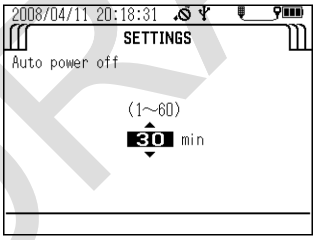
3. **Press the down (▽) key to move the cursor to "System", then press the ENTER key.**



4. **Press the down (▽) key to move the cursor to "Auto power off", then press the ENTER key.**



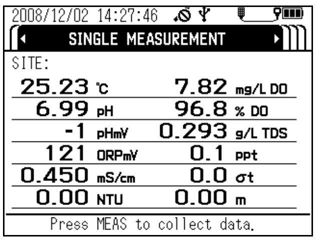
5. **Press the up (△) and down (▽) keys to select the desired time setting, then press the ENTER key.**
You can select OFF, or settings of 1, 2, 5, 10, 20, 30 or 60 minutes.
Default: 30 minutes



● Display contrast

Follow the steps below to adjust the display's contrast.

1. **Press and hold down the control unit's POWER key for about 3 seconds to turn the power ON.**
The "MEASUREMENT" screen appears after about 10 seconds.

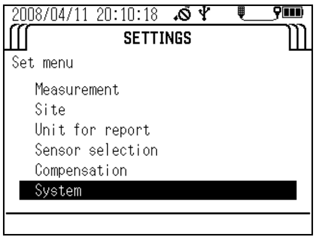


Note

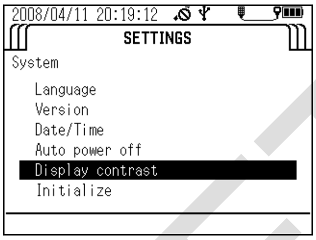
The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

2. **Press the right (▷) key to switch the display to the "SETTINGS" screen.**

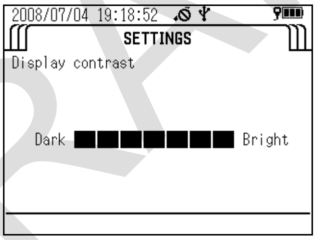
3. **Press the down (▽) key to move the cursor to "System", then press the ENTER key.**



4. **Press the down (▽) key to move the cursor to "Display contrast", then press the ENTER key.**



5. **Press the left (◁) and right (▷) keys to adjust the contrast.**
Adjustment can be made in 26 steps.

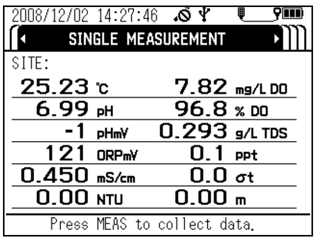


6. **Press the ENTER key.**

● **Initialization**

Follow the steps below to restore all the settings except date/time to their factory defaults. Factory default calibration data for the electrical conductivity and turbidity sensors will also be deleted at the same time.

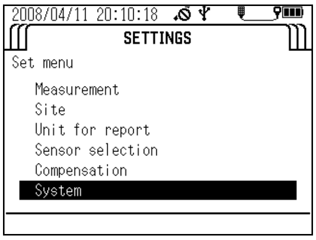
1. **Press and hold down the control unit's POWER key for about 3 seconds to turn the power ON.**
The "MEASUREMENT" screen appears after about 10 seconds.



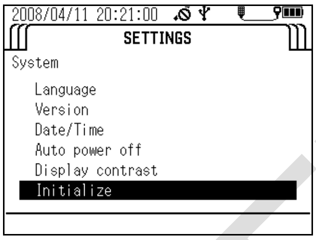
Note

The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

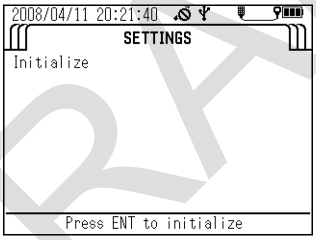
2. **Press the right (▷) key to switch the display to the "SETTINGS" screen.**
3. **Press the down (▽) key to move the cursor to "System", then press the ENTER key.**



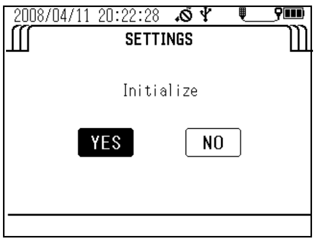
4. **Press the down (▽) key to move the cursor to "Initialize", then press the ENTER key.**



5. **Press the ENTER key again.**



6. **A confirmation message appears asking whether to execute initialization. Press the left (◁) key to move the cursor to YES, then press the ENTER key.**
   The message "Initialize Complete" appears to indicate the process has finished.



3.3 Calibration

To obtain correct measurement values, the sensors need to be calibrated using standard solution before measurement. You can select simultaneous auto calibration of the pH, COND and TURB sensors in pH4 standard solution and DO and DEP sensors simultaneously in air, or manual calibration of individual measurement parameters. You can check the result of the previous calibration using the procedure on “ 3.5.4 Checking the calibration record ” (page 70).

Note

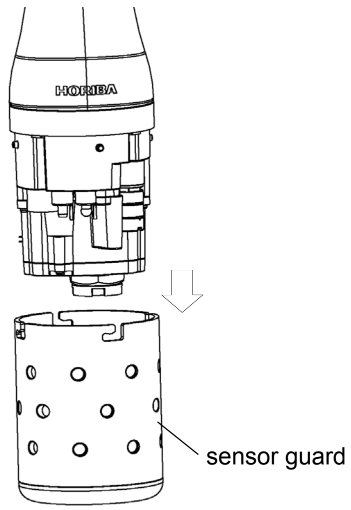
- **Wait at least 20 minutes after turning the system power ON before calibrating the DO sensor.**
- **Make the DO and COND compensation settings before calibration since these settings are applied during calibration.**
- **You can select only the desired parameters for calibration and calibrate just those parameters (see “ 3.2.4 Sensor selection ” (page 25)).**
- **Use about 200 mL of standard solution in the calibration cup.**
- **Calibration data is stored in the sensor probe.**

3.3.1 Auto calibration

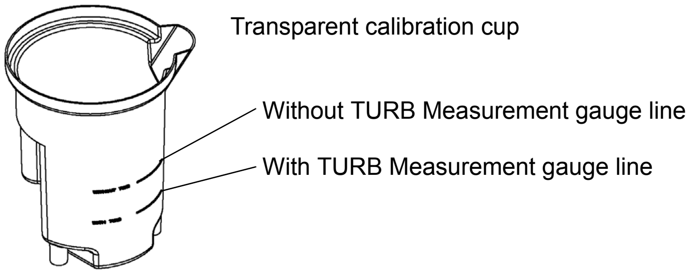
Tip

- **The following parameters are calibrated (at 25°C):**
  pH: Set to 4.01 (zero-point calibration); the span is adjusted to the factory default value.
  COND: 0.449 S/m (4.49 mS/cm, span calibration); the zero point is adjusted to the factory default value.
  TURB: 0 NTU (zero-point calibration); the span is adjusted to the factory default value.
  DO: 8.92 mg/L (span calibration); the zero point is adjusted to the factory default value.
  DEP: 0 m (zero-point calibration); the zero point is adjusted to the factory default value.
- **If the air temperature changes, the readout value may not be stable. Ensure that the ambient air temperature is the same temperature as the calibration solution, because the internal probe temperature sensor and external temperature sensor (in the calibration solution) are used for the auto calibration. Allow the probe and standard solution to equilibrate for 1 hour if a thermometer is not available to verify that these temperatures are the same.**
- **Do not hold the probe while performing the auto calibration. Body temperature may elevate the internal temperature sensor measurement creating DO calibration error.**

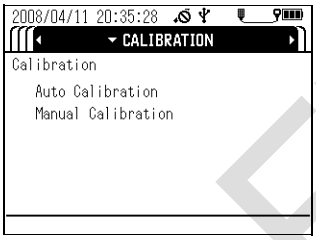
1. **Remove the sensor guard and wash the sensor probe 2 or 3 times with deionized water.**



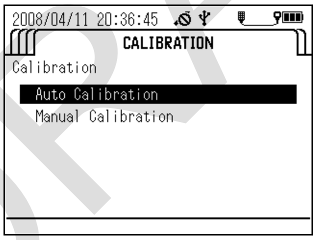
2. **Remove the transparent calibration cup.**
3. **Fill the transparent calibration cup to the line with pH 4 standard solution.**
   The transparent calibration cup has With TURB Measurement and Without TURB Measurement gauge lines.



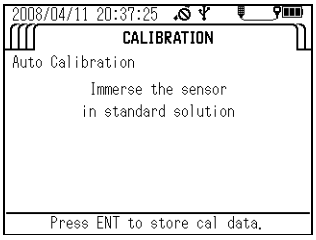
4. **Press the control unit's CAL key to set the calibration mode.**

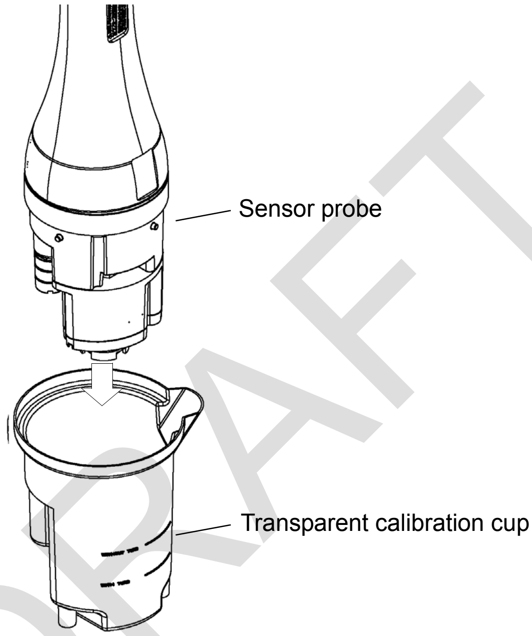


5. **Press the down (▽) key to move the cursor to "Auto Calibration", then press the ENTER key.**

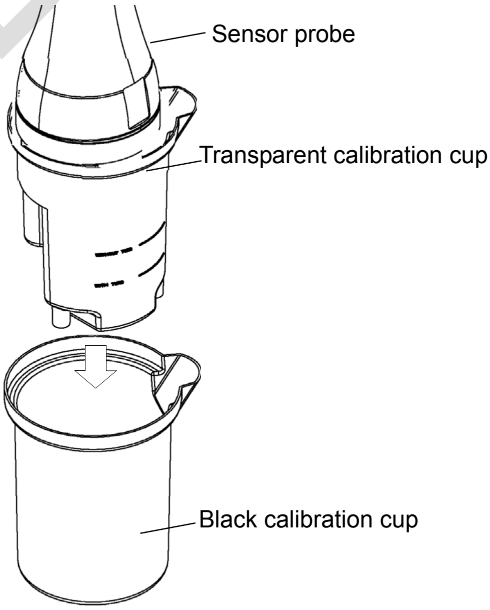


6. **Immerse the sensor probe in the transparent calibration cup.**
Check that the pH sensor, ORP sensor, reference electrode, COND sensor, TURB sensor and temperature sensor are submerged in the pH 4 standard solution and check that there are no air bubbles on the sensor.





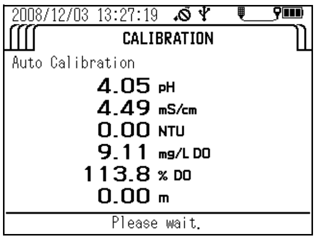
7. **With the sensor probe still in the transparent calibration cup, place the transparent calibration cup into the black calibration cup.**



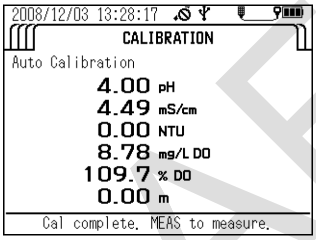
8. **When all the sensor values have stabilized, press the ENTER key to start calibration.**

Note

Do not remove the sensor probe from the calibration solution. U-53 turbidity data will display “----” until the calibration is completed.



Calibration is finished when the message "Cal complete. MEAS to measure." appears. Press the MEAS key to set the measurement screen, then start measurement.



If a calibration error occurs, start calibration after first resolving the issue according to the instructions in “ 4.6 Troubleshooting ” (page 89).

3.3.2 Manual calibration

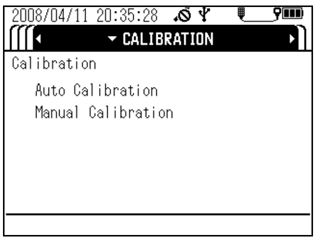
The procedures below describe how to calibrate each sensor individually.

Note

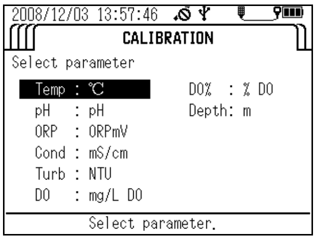
The displayed units are the units set by selecting "Unit for report" in the "SETTINGS" screen.

- **Temperature (TEMP) calibration**

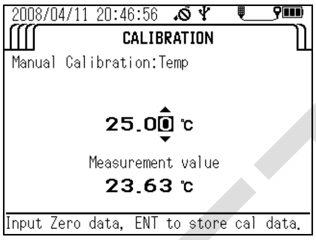
1. **Fill a bucket or similar container with water of a known temperature, and insert the sensor probe in it.**
   Wait 5 minutes before starting calibration to allow the sensor probe temperature to stabilize.
2. **Press the control unit’s CAL key to set the calibration mode.**
3. **Press the down (▽) key to move the cursor to “Manual Calibration”, then press the ENTER key.**



4. **In the parameter selection screen, move the cursor to “Temp”, then press the ENTER key.**



5. **Press the up (△) and down (▽) keys to set the calibration value - the temperature of the water containing the submerged sensor probe.**



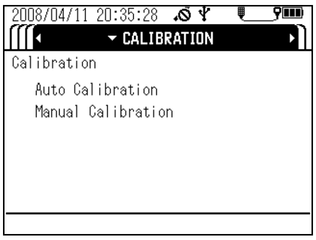
6. **Check that “Measurement value” has stabilized, then press the ENTER key to start calibration.**
   Calibration is finished when the message “Cal complete. CNT to measure.” appears.

● pH calibration

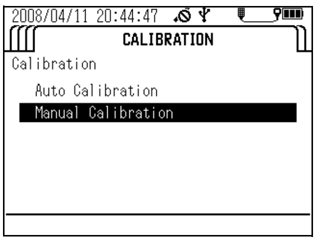
Note

You can select one calibration point (zero-point calibration) or two calibration points (zero-point calibration and span calibration). Carry out two calibration procedures to ensure good measurement precision throughout all measurement ranges.

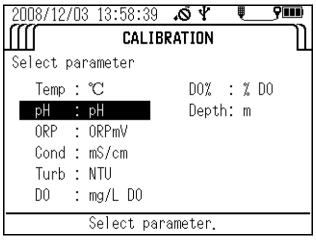
1. **Calibrate the zero point. Wash the transparent calibration cup 2 or 3 times with deionized water, then fill it to the reference line with pH 7 standard solution.**
2. **Wash the sensor probe 2 or 3 times in deionized water to remove any dirt, then submerge the sensor probe in the transparent calibration cup.**
3. **Press the control unit’s CAL key to set the calibration mode.**



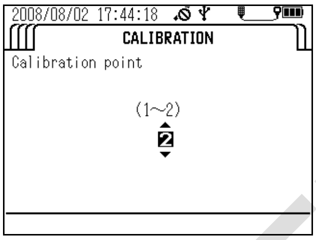
4. **Press the down (▽) key to move the cursor to "Manual Calibration", then press the ENTER key.**



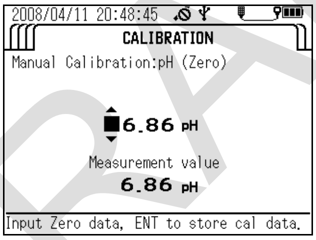
5. In the parameter selection screen, move the cursor to "pH", then press the ENTER key.



6. Set the number of calibration points, then press the ENTER key.



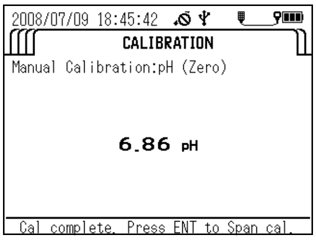
7. Press the up (△) and down (▽) keys to set the pH value of the pH 7 standard solution containing the submerged sensor probe at the measurement temperature



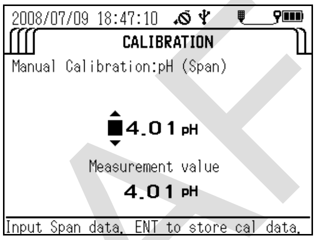
Temp. (°C)	pH 4 standard solution Phthalate	pH 7 standard solution Neutral phosphate	pH 9 standard solution Borate
0	4.01	6.98	9.46
5	4.01	6.95	9.39
10	4.00	6.92	9.33
15	4.00	6.90	9.27
20	4.00	6.88	9.22
25	4.01	6.86	9.18
30	4.01	6.85	9.14
35	4.02	6.84	9.10
40	4.03	6.84	9.07
45	4.04	6.84	9.04

8. Check that "Measurement value" has stabilized, then press the ENTER key to start calibration.

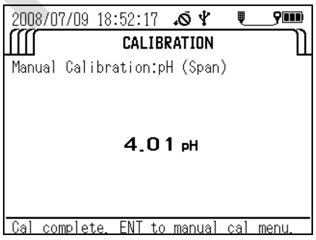
9. **Press the ENTER key to start the span calibration procedure when the message "Cal complete. Press ENT to Span cal." appears.**



10. **Wash the transparent calibration cup 2 or 3 times with deionized water, then fill it to the reference line with pH 4 or pH 9 standard solution.**
11. **Wash the sensor probe 2 or 3 times in deionized water to remove any dirt, then submerge the sensor probe in the transparent calibration cup.**
12. **Press the up (△) and down (▽) keys to set the pH value of the pH 4 or pH 9 standard solution containing the submerged sensor probe at the measurement temperature.**



13. **Check that "Measurement value" has stabilized, then press the ENTER key to start calibration.**
14. **Calibration is finished when the message "Cal complete. ENT to manual cal menu." appears. Press the ENTER key to return to the calibration parameter**

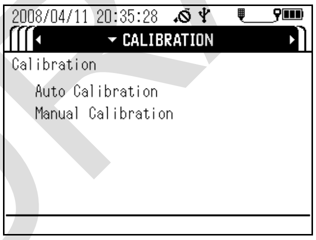


ORP calibration

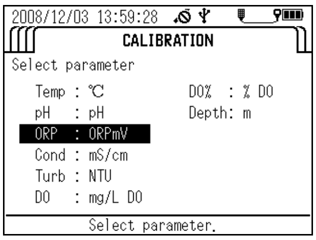
Note

- **If the prepared ORP standard solution is left in open air for one hour or more, the solution may be transformed. For this reason ORP standard solution cannot be stored.**
  Calibrate within one hour of preparing the solution.
- **When measuring sample with low concentrations of oxidants and reductants after conducting an operational check using a standard substance, the measured values may not stabilize or the results of measurement might not be repeatable. If this is the case, start the measurement after immersing the sensors in the sample water sufficiently.**
- **Note that when measuring the ORP of solution with extremely low concentrations of oxidants and reductants, such as tap water, well water, or water treated with purifying equipment, there may be less responsiveness, repeatability, and stability, in general.**
- **When alkaline ion water is left for 5 minutes, its ORP undergoes changes significantly. Always measure alkaline ion water promptly.**

1. **Fill a clean beaker with one bag of ORP standard powder No. 160-22 or No. 160-51. Add 250 mL of deionized water and agitate the solution thoroughly (there will be some excess quinhydrone (a black powder) that floats on the surface when agitating the solution). Fill the transparent calibration cup to the reference line with this standard solution.**
2. **Wash the sensor probe 2 or 3 times in deionized water to remove any dirt, then submerge the sensor probe in the transparent calibration cup.**
3. **Press the control unit's CAL key to set the calibration mode.**
4. **Press the down (▽) key to move the cursor to "Manual Calibration", then press the ENTER key.**



5. **In the parameter selection screen, move the cursor to ORP, then press the ENTER key.**



6. **Press the up (△) and down (▽) keys to set the mV value of the ORP standard solution containing the submerged sensor probe at the measurement temperature.**

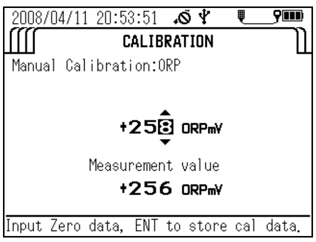


Table 1 Indicated value of ORP standard solution at various temperatures (mV)

Temperature	160-22	16051
5	+274	+112
10	+271	+107
15	+267	+101
20	+263	+95
25	+258	+89
30	+254	+83
35	+249	+76
40	+244	+69

7. **Check that "Measurement value" has stabilized, then press the ENTER key to start calibration.**
8. **Calibration is finished when the message "Cal complete. ENT to manual cal menu." appears. Press the ENTER key to return to the calibration parameter selection screen.**

● Conductivity (COND) calibration

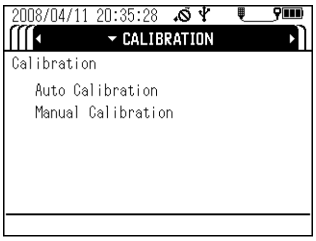
Note

- **To support a wide range of sample concentrations, electrical conductivity is divided into three measurement ranges: 0.0 mS/m to 99.9 mS/m, 0.090 S/m to 0.999 S/m, and 0.9 S/m to 9.99 S/m.**
- **When manually calibrating conductivity, you can select two calibration points (one zero-point calibration point and a span calibration point for one of the three measurement ranges) or four calibration points (one zero-point calibration point and span calibration points for all three measurement ranges). Carry out the four calibration points to ensure good measurement precision throughout all measurement ranges.**
- **Make the compensation setting before calibration since this setting is applied during calibration. (Refer to “ 6.5.3 Temperature coefficient ” (page 104)).**

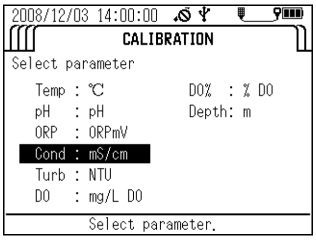
1. **Prepare the standard solution. Dry Potassium chloride (KCl) powder (high-grade commercially available) at 105°C for two hours, and leave it to cool in a desiccator.**
2. **Consult the following table and weigh potassium chloride (KCl), then prepare three standard potassium chloride (KCl) solutions following the procedure below.**

Potassium chloride (KCl) standard solution	Conductivity (COND) value	Potassium chloride (KCl) mass (g) at solution temperature of 25 °C	Calibration range
0.005 mol/L	71.8 mS/m (0.718 mS/cm)	0.373	0.0 mS/m to 99.9 mS/m (0.00 mS/cm to 0.999 mS/cm)
0.050 mol/L	0.667 S/m (6.67 mS/cm)	3.73	0.090 S/m to 0.999 S/m (1.00 mS/cm to 9.99 mS/cm)
0.500 mol/L	5.87 S/m (58.7 mS/cm)	37.2	0.9 S/m to 9.99 S/m (10.0 mS/cm to 99.9 mS/cm)

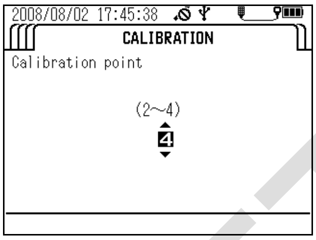
3. **Dissolve the weighed Potassium Chloride (KCl) in deionized water.**
4. **Put the dissolved Potassium Chloride (KCl) into a 1 L measuring flask, and fill to the 1 L mark with deionized water.**
5. **Calibrate the zero point. Wash the sensor probe 2 or 3 times in deionized water to remove any dirt, then remove all moisture from the sensor probe (it will be calibrated in air).**
6. **Press the control unit’s CAL key to set the calibration mode.**
7. **Press the down (▽) key to move the cursor to "Manual Calibration", then press the ENTER key.**



8. In the parameter selection screen, move the cursor to “Cond”, then press the ENTER key.



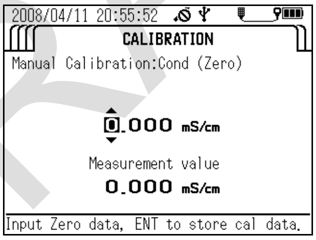
9. Set the number of calibration points, then press the ENTER key.



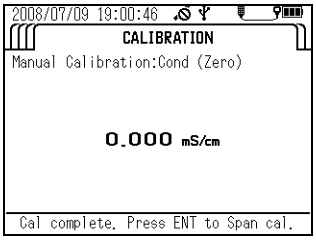
The instructions below assume that four calibration points have been set.

10. Press the up (△) and down (▽) keys to set the "Cond" value to 0.0 mS/m (0.000 mS/cm).

11. Check that "Measurement value" has stabilized, then press the ENTER key to start calibration.



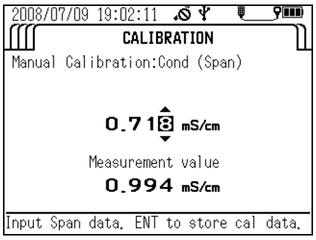
12. When the message "Cal complete. Press ENT to Span cal." appears, press the ENTER key to start the first span calibration procedure.



13. Wash the transparent calibration cup 2 or 3 times with deionized water, then fill it to the reference line with 71.8 mS/m (0.718 mS/cm) standard solution.

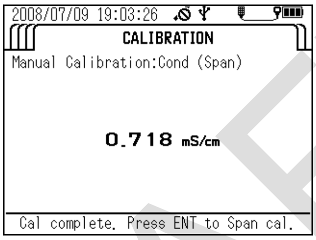
14. Wash the sensor probe 2 or 3 times in deionized water to remove any dirt, then submerge the sensor probe in the transparent calibration cup.

15. **Press the up (△) and down (▽) keys to set the "Cond" value to 71.8 mS/m (0.718 mS/cm).**
Calibration range = 0 mS/m to 99.9 mS/m (0 mS/cm to 0.999 mS/cm)



16. **Check that "Measurement value" has stabilized, then press the ENTER key to start calibration.**

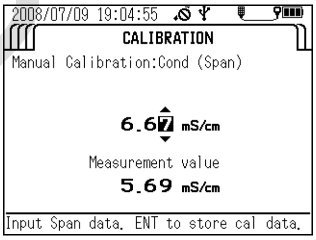
17. **When the message "Cal complete. Press ENT to Span cal." appears, press the ENTER key to start the next span calibration procedure.**



18. **Wash the transparent calibration cup 2 or 3 times with deionized water, then fill it to the reference line with 0.667 S/m (6.67 mS/cm) standard solution.**

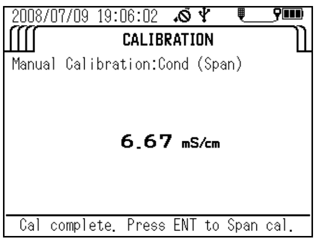
19. **Wash the sensor probe 2 or 3 times in deionized water to remove any dirt, then submerge the sensor probe in the transparent calibration cup.**

20. **Press the up (△) and down (▽) keys to set the "Cond" value to 0.667 S/m (6.67 mS/cm).**
Calibration range = 0.100 S/m to 0.999 S/m (1.00 mS/cm to 9.99 mS/cm)



21. **Check that "Measurement value" has stabilized, then press the ENTER key to start calibration.**

22. **When the message "Cal complete. Press ENT to Span cal." appears, press the ENTER key to start the next span calibration procedure.**

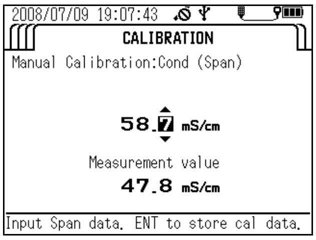


23. **Wash the transparent calibration cup 2 or 3 times with deionized water, then fill it to the reference line with 5.87 S/m (58.7 mS/cm) standard solution.**

24. **Wash the sensor probe 2 or 3 times in deionized water to remove any dirt, then submerge the sensor probe in the transparent calibration cup.**

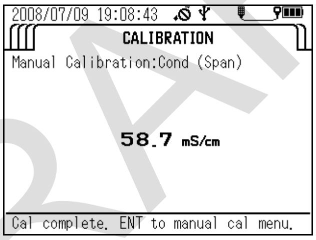
25. **Press the up (△) and down (▽) keys to set the "Cond" value to 5.87 S/m (58.7 mS/cm).**

Calibration range = 1.00 S/m to 10.00 S/m(10.0 mS/cm to 100.0 mS/cm)



26. **Check that "Measurement value" has stabilized, then press the ENTER key to start calibration.**

27. **Calibration is finished when the message "Cal complete. ENT to manual cal menu." appears. Press the ENTER key to return to the calibration parameter selection screen.**



● Turbidity (TURB) calibration

Note

- **To support a wide range of sample concentrations, turbidity is divided into three measurement ranges: 0.0 to 9.9 NTU, 10 to 100 NTU, and over 100 NTU.**
- **When manually calibrating turbidity, you can select two calibration procedures (one zero-point calibration procedure and a span calibration procedure for one of the three measurement ranges), three calibration procedures (one zero-point calibration procedure and a span calibration procedure for two of the three measurement ranges) or four calibration procedures (one zero-point calibration procedure and span calibration procedures for all three measurement ranges). Carry out the four calibration procedures to ensure good measurement precision throughout all measurement ranges.**
- **Always use the calibration cup provided. Using other containers can create effects from ambient light that cause incorrect calibration.**

● Preparing the standard solutions

1. **Weigh out 5.0 g of hydrazine sulfate (commercial special grade or above), and dissolve it in 400 mL of deionized water. Dissolve 50 g of hexamethylene tetramine (commercial special grade or above) in 400 mL of deionized water in anther flask.**
2. **Mix the two solutions and add deionized water until the total solution volume is 1000 mL, and mix well. Store this solution at a temperature of 25°C ±3°C for 48 hours.**
   The turbidity value (TURB) of this solution is equivalent to 4000 NTU.
3. **Dilute 4000 NTU-solution 5 times (use a pipette to measure 50 mL of the 4000 NTU solution and pour it into a 250 mL measuring flask, and fill up to 250 mL meniscus)**
   The turbidity value (TURB) of this solution is equivalent to 800 NTU.
4. **Dilute 800 NTU solution 10 times (use a pipette to measure 25 mL of the 800 NTU solution and pour it into a 250 mL measuring flask, and fill up to 250 mL meniscus)**
   The turbidity value (TURB) of this solution is equivalent to 80 NTU.
5. **Dilute 80 NTU solution 10 times (use a pipette to measure 25 mL of the 80 NTU solution and pour it into a 250 mL measuring flask, and fill up to 250 mL meniscus)**
   The turbidity value (TURB) of this solution is equivalent to 8 NTU.

Note

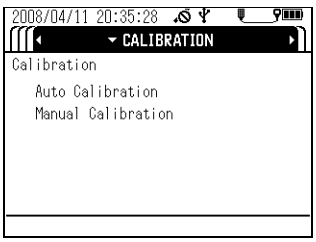
Instead of the standard solutions above, you can use other standard solutions of known concentration measured with other standard instruments.

● U-52, U-53 turbidity calibration

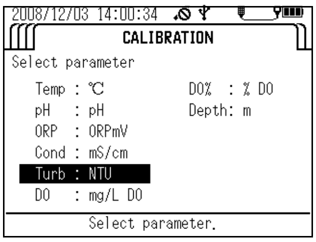
Set the number of calibration points.

You can set between 2 and 4 points.

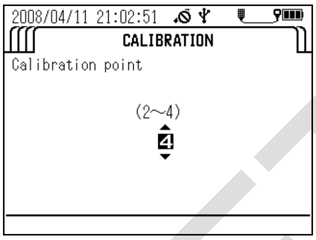
1. **Press the control unit's CAL key to set the calibration mode.**
2. **Press the down (▽) key to move the cursor to "Manual Calibration", then press the ENTER key.**



3. **In the parameter selection screen, move the cursor to "Turb", then press the ENTER key.**



4. **Press the up (△) and down (▽) keys to set the number of calibration points, then press the ENTER key.**

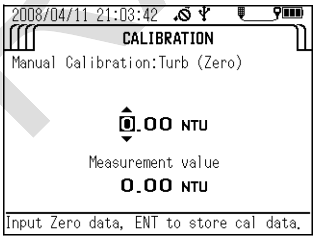


The instructions below assume that four calibration points have been set.

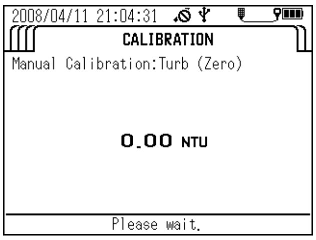
5. **Calibrate the zero point. Wash the transparent calibration cup 2 or 3 times with deionized water, then fill it to the reference line with deionized water.**

6. **Wash the sensor probe 2 or 3 times in deionized water to remove any dirt, then submerge the sensor probe in the transparent calibration cup.**

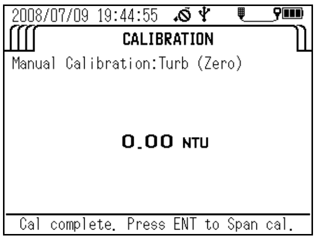
7. **Press the up (△) and down (▽) keys to set the "Turb" value to 0.0 NTU.**



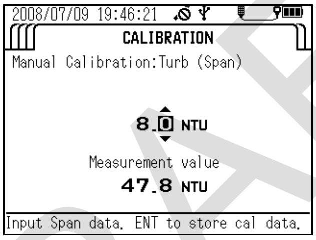
8. **Check that "Measurement value" has stabilized, then press the ENTER key to start calibration.**



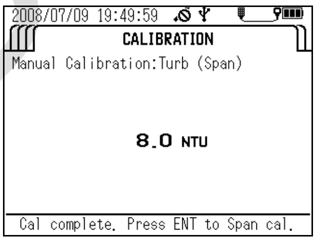
9. **When the message "Cal complete. Press ENT to Span cal." appears, press the ENTER key to start the first span calibration procedure.**



10. **Wash the transparent calibration cup 2 or 3 times with deionized water, then fill it to the reference line with 8 NTU standard solution, or a standard solution of known concentration between 0.1 and 10 NTU.**
11. **Wash the sensor probe 2 or 3 times in deionized water to remove any dirt, then submerge the sensor probe in the transparent calibration cup.**
12. **Press the up (△) and down (▽) keys to set the "TURB" value to 8 NTU, or to the known concentration of the standard solution between 0.1 and 10 NTU. (Input range = 0 NTU to 9.9 NTU (U-51) or 0 NTU to 9.99 NTU (U-52))**

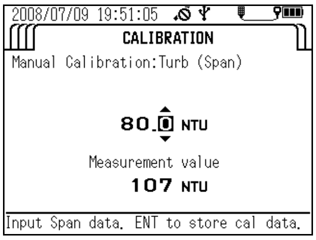


13. **Check that "Current measurement value" has stabilized, then press the ENTER key to start calibration.**
14. **When the message "Cal complete. Press ENT to Span cal." appears, press the ENTER key to start the next span calibration procedure.**



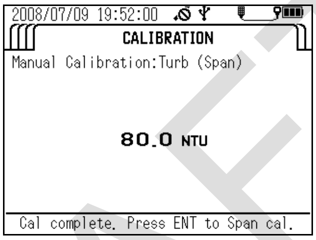
15. **Wash the transparent calibration cup 2 or 3 times with deionized water, then fill it to the reference line with 80 NTU standard solution, or a standard solution of known concentration between 10 and 100 NTU.**
16. **Wash the sensor probe 2 or 3 times in deionized water to remove any dirt, then submerge the sensor probe in the transparent calibration cup.**

17. **Press the up (△) and down (▽) keys to set the "Turb" value to 80 NTU, or to the known concentration of the standard solution between 10 and 100 NTU. (Input range = 10.0 NTU to 99.9 NTU)**



18. **Check that "Measurement value" has stabilized, then press the ENTER key to start calibration.**

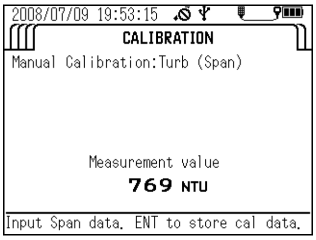
19. **When the message "Cal complete. Press ENT to Span cal." appears, press the ENTER key to start the next span calibration procedure.**



20. **Wash the transparent calibration cup 2 or 3 times with deionized water, then fill it to the reference line with 800 NTU standard solution, or a standard solution of known concentration 100 NTU above.**

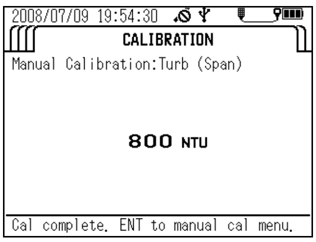
21. **Wash the sensor probe 2 or 3 times in deionized water to remove any dirt, then submerge the sensor probe in the transparent calibration cup.**

22. **Press the up (△) and down (▽) keys to set the "TURB" value to 800 NTU, or to the known concentration of the standard solution 100 NTU above.**
(Input range = 100 NTU to 800 NTU (U-51), 100 NTU to 1000 NTU (U-52))



23. **Check that "Measurement value" has stabilized, then press the ENTER key to start calibration.**

24. **Calibration is finished when the message "Cal complete. ENT to manual cal menu." appears. Press the ENTER key to return to the calibration parameter selection screen.**



● Dissolved oxygen (DO) calibration

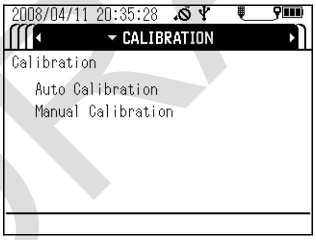
Note

- **You can select one calibration procedure (span calibration) or two calibration procedures (zero-point calibration and span calibration). Carry out the two calibration procedures to ensure good measurement precision throughout all measurement ranges.**
- **It is necessary to prepare new solution before calibration of the Dissolved Oxygen (DO) sensor.**
- **The calibration cup (included) cannot be used to manually calibrate the DO sensor. Use a suitable bottle in which the DO sensor and the temperature sensor can be immersed.**
- **Wait at least 20 minutes after turning the system power ON before calibrating the DO sensor.**
- **Make the compensation setting before calibration since the setting is applied during calibration.**
- **The DO sensor is affected by flow. When performing span calibration with saturated dissolved oxygen water, move the cable slowly up and down (move the sensor probe at a rate of roughly 20 to 30 cm a second) or agitate the saturated dissolved oxygen water.**

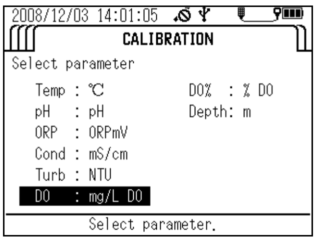
1. **Prepare the standard solution.**
   - Add about 50 g of sodium sulfite to 1000 mL of water (either deionized water or tap water) and stir the mixture to dissolve the sodium sulfite in it.
   - Pour 1 to 2 liters of water into a suitable flask (either deionized water or tap water). Using a air pump, feed air into the water and aerate the solution until oxygen is saturated.

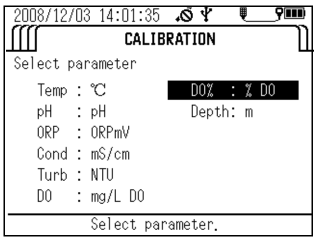
2. **First, calibrate the zero point. Press the control unit's CAL key to set the calibration mode.**

3. **Press the down (▽) key to move the cursor to "Manual Calibration", then press the ENTER key.**

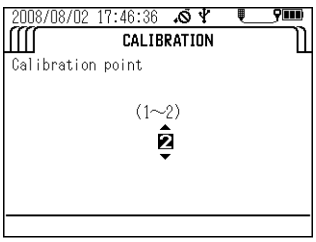


4. **In the parameter selection screen, move the cursor to DO or DO%, then press the ENTER key.**



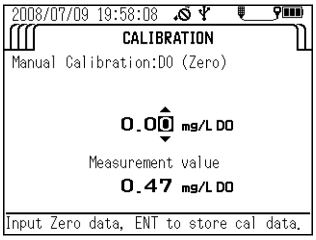


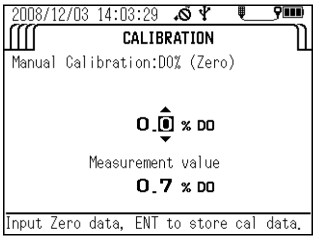
5. **Set the number of calibration procedures, then press the ENTER key.**



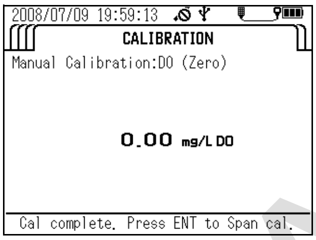
The instructions below assume that two calibration points have been set.

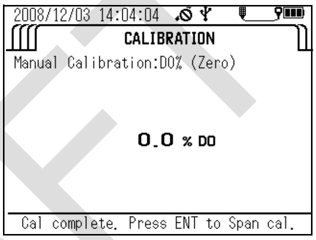
6. Wash the sensor probe 2 or 3 times in deionized water to remove any dirt, then submerge the sensor probe in the bottle.
7. Press the up (△) and down (▽) keys to set the DO value to 0.00 mg/L or 0.0%.



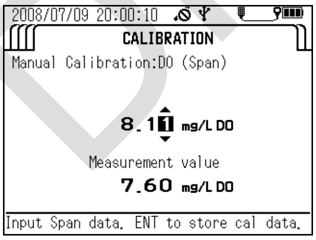


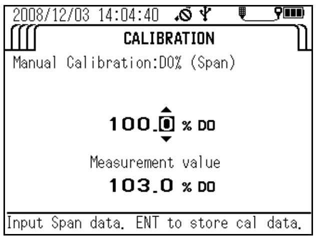
8. Check that "Measurement value" has stabilized, then press the ENTER key to start calibration.
9. When the message "Cal complete. Press ENT to Span cal." appears, press the ENTER key to start the span calibration procedure.



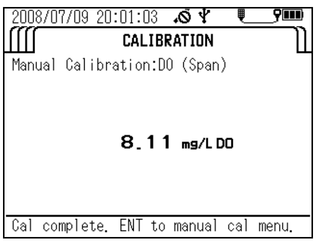


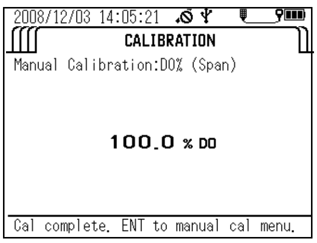
10. Wash the sensor probe 2 or 3 times with deionized water to remove any dirt, then submerge the sensor probe in the container filled with the span solution.
11. Press the up (△) and down (▽) keys to set the DO value to the saturated dissolved oxygen value (mg/L) of the water at that temperature or the dissolved oxygen saturation ratio.





12. Check that "Measurement value" has stabilized, then press the ENTER key to start calibration.
13. Calibration is finished when the message "Cal complete. ENT to manual cal menu." appears. Press the ENTER key to return to the calibration parameter selection screen.





Amounts of saturated dissolved oxygen in water at various temperatures (salinity=0.0%)

JIS K0101

Temp. (°C)	DO (mg/L)	Temp. (°C)	DO (mg/L)	Temp. (°C)	DO (mg/L)	Temp. (°C)	DO (mg/L)
0	14.16						
1	13.77	11	10.67	21	8.68	31	7.42
2	13.40	12	10.43	22	8.53	32	7.32
3	13.04	13	10.20	23	8.39	33	7.22
4	12.70	14	9.97	24	8.25	34	7.13
5	12.37	15	9.76	25	8.11	35	7.04
6	12.06	16	9.56	26	7.99	36	6.94
7	11.75	17	9.37	27	7.87	37	6.86
8	11.47	18	9.18	28	7.75	38	6.76
9	11.19	19	9.01	29	7.64	39	6.68
10	10.92	20	8.84	30	7.53	40	6.59

ISO5814

Temp. (°C)	DO (mg/L)	Temp. (°C)	DO (mg/L)	Temp. (°C)	DO (mg/L)
0	14.62				
1	14.22	11	11.03	21	8.91
2	13.83	12	10.78	22	8.74
3	13.46	13	10.54	23	8.58
4	13.11	14	10.31	24	8.42
5	12.77	15	10.08	25	8.26
6	12.45	16	9.87	26	8.11
7	12.14	17	9.66	27	7.97
8	11.84	18	9.47	28	7.83
9	11.56	19	9.28	29	7.69
10	11.29	20	9.09	30	7.56

● Span setting values for calibration in air

The software should display these values when auto calibration is performed.
Use this table to input values for manual span calibrations in air.

Tip

The DO measurement value of "air-saturated water" and air are different.
Due to the pressure difference against the membrane in air versus the membrane in water, the measurement value in air is about 10% higher than the value of air-saturated water on average.

Amounts of saturated dissolved oxygen in air at various temperatures

Following tables are applicable only to the air calibration of the U-50 DO sensor. Do not use them for other purpose.

Air calibration value in adopting evaluation based on JIS K0101

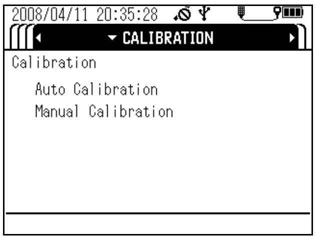
Temp (°C)	DO (mg/L)	Temp (°C)	DO (mg/L)	Temp (°C)	DO (mg/L)	Temp (°C)	DO (mg/L)
0	15.58						
1	15.15	11	11.74	21	9.55	31	8.16
2	14.74	12	11.47	22	9.38	32	8.05
3	14.34	13	11.22	23	9.23	33	7.94
4	13.97	14	10.97	24	9.08	34	7.84
5	13.61	15	10.74	25	8.92	35	7.74
6	13.27	16	10.52	26	8.79	36	7.63
7	12.93	17	10.31	27	8.66	37	7.55
8	12.62	18	10.10	28	8.53	38	7.44
9	12.31	19	9.91	29	8.40	39	7.35
10	12.01	20	9.72	30	8.28	40	7.25

Air calibration value in adopting evaluation based on ISO5814

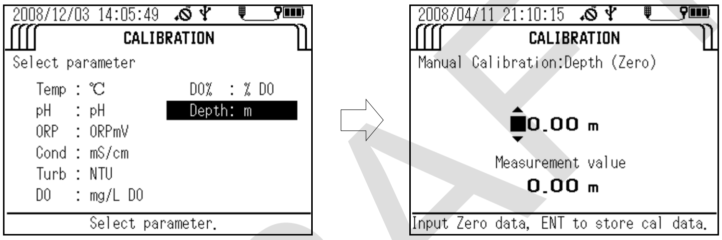
Temp. (°C)	DO (mg/L)	Temp. (°C)	DO (mg/L)	Temp. (°C)	DO (mg/L)
0	16.08				
1	15.64	11	12.13	21	9.80
2	15.21	12	11.86	22	9.61
3	14.81	13	11.59	23	9.44
4	14.42	14	11.34	24	9.26
5	14.05	15	11.09	25	9.09
6	13.70	16	10.86	26	8.92
7	13.35	17	10.63	27	8.77
8	13.02	18	10.42	28	8.61
9	12.72	19	10.21	29	8.46
10	12.42	20	10.00	30	8.32

● Water depth (DEPTH) calibration

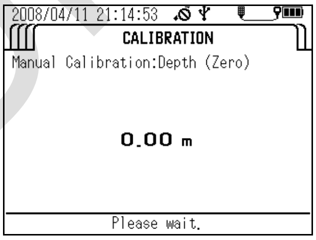
1. **Calibrate the zero point. Wash the sensor probe 2 or 3 times in deionized water to remove any dirt, then remove all moisture from the sensor probe (it will be calibrated in air).**
2. **Press the control unit's CAL key to set the calibration mode.**
3. **Press the down (▽) key to move the cursor to "Manual Calibration", then press the ENTER key.**



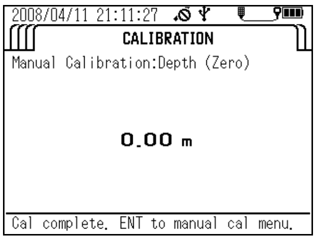
4. **In the parameter selection screen, move the cursor to "Depth", then press the ENTER key.**



5. **Press the up (△) and down (▽) keys to set the "Depth" value to 0.00 m.**
6. **Check that "Measurement value" has stabilized, then press the ENTER key to start calibration.**



7. **Calibration is finished when the message "Cal complete. ENT to manual cal menu." appears. Press the ENTER key to return to the calibration parameter selection screen.**



3.4 Measurement

You can perform measurement by either of the methods below.

- Storing data in memory manually with reference to the measurement value (single measurement)
- Having data stored in memory automatically and continuously
  U-51/U-52: Interval measurement (minimum memory interval of 10 seconds)
  U-53: Interval measurement (minimum memory interval of 30 seconds)

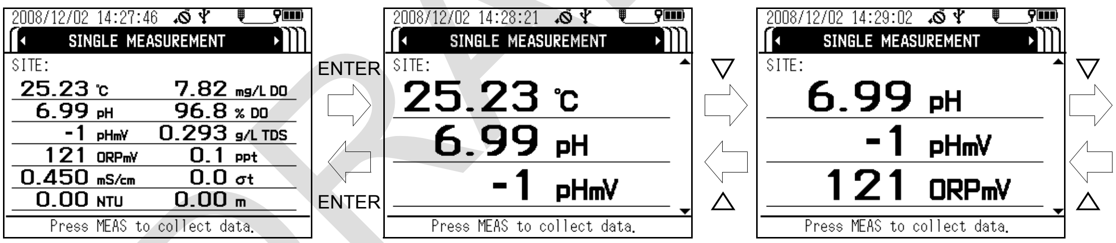
Select the measurement method that meets your requirements.

Note

- **Lower sensor probe slowly when submerging them in samples.**
- **Sensors may break if sensor probe are dropped from a height of 1 meter or more.**
- **Do not submerge sensor probe in water depths of over 30 meters. Sensor probe are only resistant to water pressure of up to 30 meters.**
- **After turning the power ON, check that the DO readout value has stabilized before starting measurement (takes around 20 minutes).**

Tip

- **When on the measurement screen, pressing the ENTER key enlarges the display and shows three measured values at a time.**
- **Pressing the up (△) and down (▽) keys scrolls through the measured values one item at a time.**
- **Pressing the ENTER key again reverts to the normal measurement screen display.**



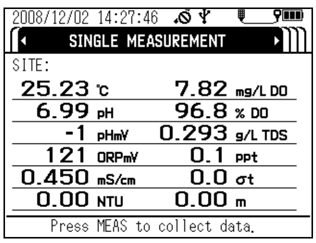
Measurement screen Normal   Enlarged

3.4.1 Storing data in memory manually

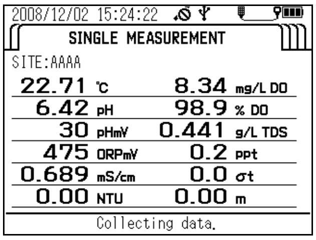
Follow the steps below to manually store data in memory while referring to the measurement value to check the readout value is stable.

● **U-51/U-52**

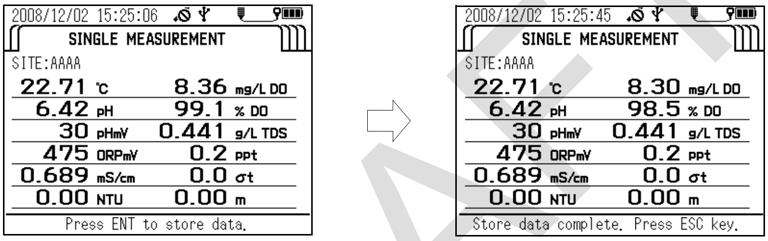
1. **Check that each sensor and sensor guard is mounted.**
2. **Check that "SINGLE MEASUREMENT" has been selected in the measurement screen.**



3. **Submerge the sensor probe in the sample, gently shaking them in the sample to remove any air bubbles from the sensors.**
   If the sample is non-flowing, move the cable slowly up and down (move the sensor probe at a rate of roughly 20 to 30 cm a second) to ensure that fresh sample is continuously supplied to the DO sensor.
4. **When the measurement values are stable, press the MEAS key to acquire the 5-second average.**



5. **Press the ENTER key to save the held measurement values, or press the ESC key to cancel the operation.**

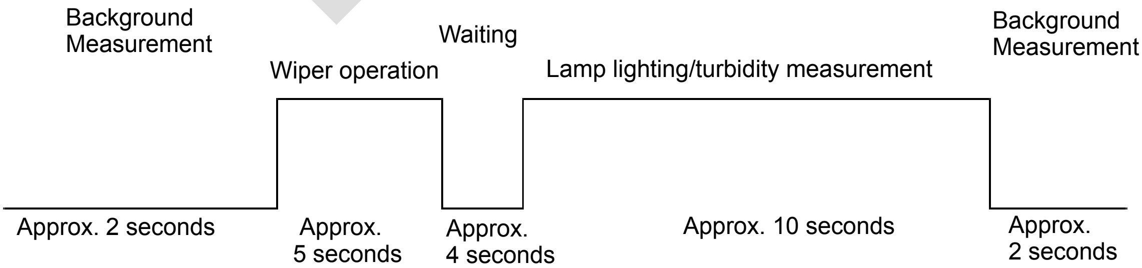


● **U-53**

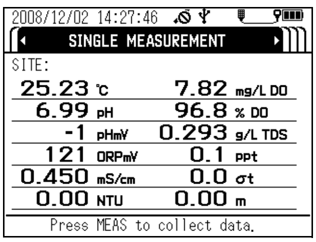
Note

Do not perform turbidity measurement in air as it may damage the wiper.

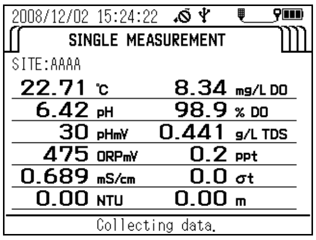
U-53 turbidity measurement follows the sequence below. The measurement values are held after each sequence.



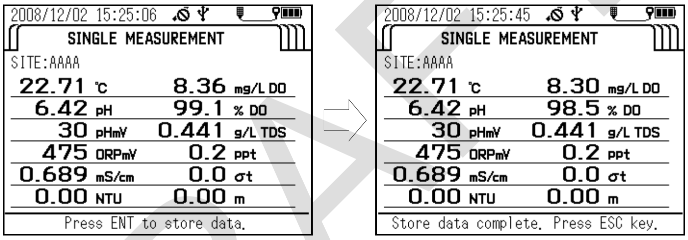
1. **Check that each sensor and sensor guard is mounted.**
2. **Check that "SINGLE MEASUREMENT" has been selected in the measurement screen.**



3. **Submerge the sensor probe in the sample, gently shaking them in the sample to remove any air bubbles from the sensors.**
   If the sample is non-flowing, move the cable slowly up and down (move the sensor probe at a rate of roughly 20 to 30 cm a second) to ensure that fresh sample is continuously supplied to the DO sensor.
4. **When the non-turbidity meter measurement values are stable, press the MEAS key to start the sequence above.**



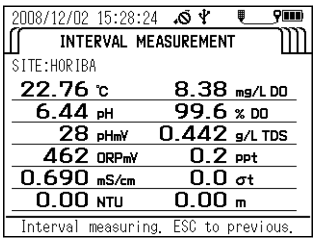
5. **When the sequence has finished, hold the measurement values. Press the ENTER key to store the held measurement values, or press the ESC key to cancel the operation.**



3.4.2 Automatic, continuous measurement

● Interval measurement

1. **Select the "Interval measurement" measurement setting (see " 3.2.1 Setting measurement methods " (page 18)).**
2. **Press the up (△) and down (▽) keys to set the interval value to the desired value (U-51/U-52: minimum interval: 10 seconds, U-53: minimum interval: 30 seconds), then press the ENTER key.**
   The measurement screen appears automatically, and the system becomes ready for measurement.
3. **Check that each sensor and sensor guard is mounted.**
4. **Submerge the sensor probe in the sample, gently shaking them in the sample to remove any air bubbles from the sensors.**
   If the sample is non-flowing, move the cable slowly up and down (move the sensor probe at a rate of roughly 20 to 30 cm a second) to ensure that fresh sample is continuously supplied to the DO sensor.
5. **Press the ENTER key to start measurement.**



3.5 Data operations

Use the procedures below to retrieve data stored in memory, delete all the data, check the remaining data memory capacity, and check the calibration record.

3.5.1 Displaying data

For maximum efficiency, there are 3 methods of displaying data.

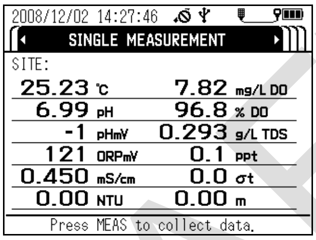
- Displaying the data for a specified site
- Displaying the data for a specified date/time
- Displaying all the data

Use the method that best suits your requirements.

● Displaying the data for a specified site

1. Press and hold down the control unit's POWER key for about 3 seconds to turn the power ON.

The "MEASUREMENT" screen appears after about 10 seconds.

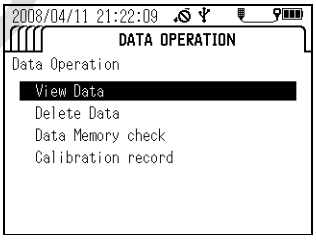


Note

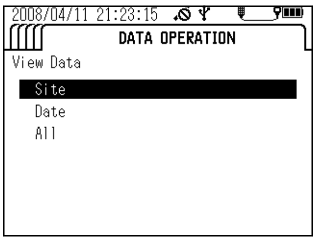
The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

2. Press the right (▷) key 3 times to display the "DATA OPERATION" screen.

3. Press the down (▽) key to move the cursor to "View Data", then press the ENTER key.

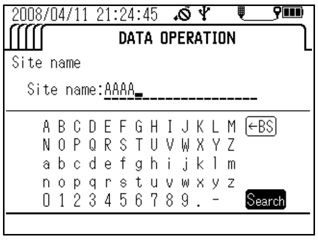


4. Move the cursor to "Site", then press the ENTER key.



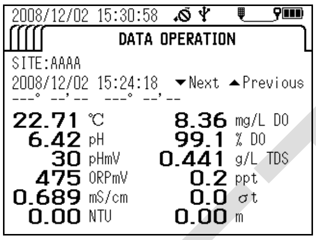
5. Press the up (△), down (▽), left (◁) and right (▷) keys to enter the site to retrieve.

6. **Move the cursor to "Search", then press the ENTER key.**



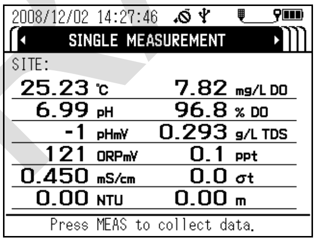
All site names that begin with the entered text are displayed.
The most recently measured data for the entered site is displayed.

7. **Press the up (△) and down (▽) keys to display earlier data.**



● Displaying the data for a specified date/time

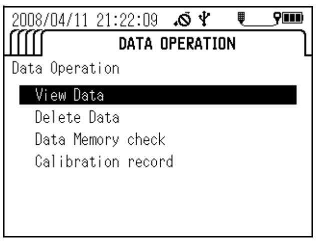
1. **Press and hold down the control unit's POWER key for about 3 seconds to turn the power ON.**
   The "MEASUREMENT" screen appears after about 10 seconds.



Note

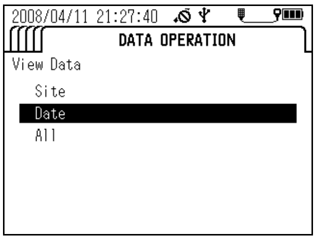
The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

2. **Press the right (▷) key 3 times to display the "DATA OPERATION" screen.**
3. **Press the down (▽) key to move the cursor to "View Data", then press the ENTER key.**



4. **Move the cursor to "Date", then press the ENTER key.**

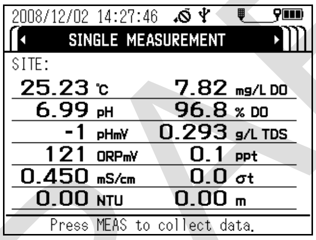
5. **With the cursor on the Date, press the ENTER key.**



6. **Press the up (△), down (▽), left (◁) and right (▷) keys to enter the desired date/ time, then press the ENTER key to apply the setting.**
7. **The cursor moves to "Search". Press the ENTER key to start the search.**
8. **Press the up (△) and down (▽) keys to display earlier data.**

● Displaying all the data

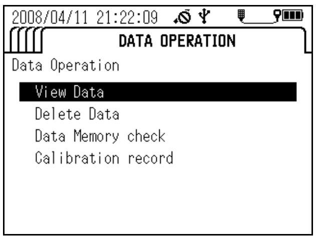
1. **Press and hold down the control unit's POWER key for about 3 seconds to turn the power ON.**
   The "MEASUREMENT" screen appears after about 10 seconds.



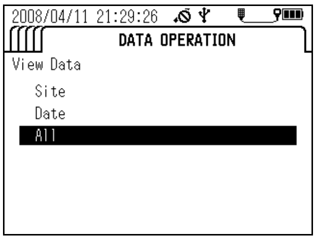
Note

The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

2. **Press the right (▷) key 3 times to display the "DATA OPERATION" screen.**
3. **Press the down (▽) key to move the cursor to "View Data", then press the ENTER key.**



4. Move the cursor to "All", then press the ENTER key.
The most recently measured data is displayed.

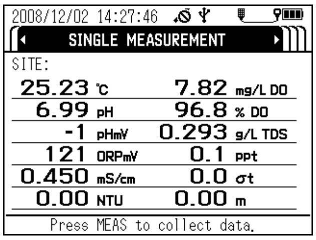


5. Press the up (△) and down (▽) keys to display earlier data.

3.5.2 Deleting data

Follow the steps below to delete all the data stored in memory.

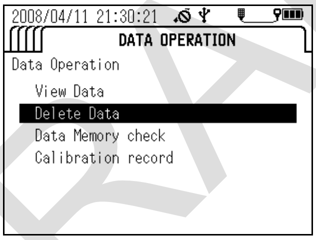
1. **Press and hold down the control unit's POWER key for about 3 seconds to turn the power ON.**
   The "MEASUREMENT" screen appears after about 10 seconds.



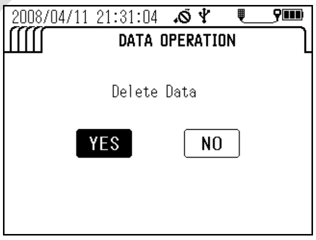
Note

The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

2. **Press the right (▷) key 3 times to display the "DATA OPERATION" screen.**
3. **Press the down (▽) key to move the cursor to "Delete Data", then press the ENTER key.**



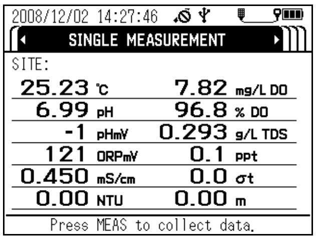
4. **Press the left (◁) key to move the cursor to YES, then press the ENTER key.**
   All the data has been deleted when the indicator appears along with the message "No data exists".



3.5.3 Checking the data memory

You can check the used data capacity and the remaining data capacity.

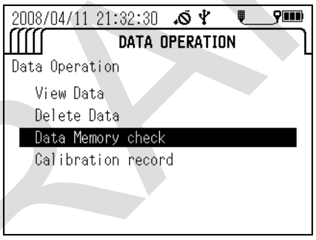
1. **Press and hold down the control unit's POWER key for about 3 seconds to turn the power ON.**
   The "MEASUREMENT" screen appears after about 10 seconds.



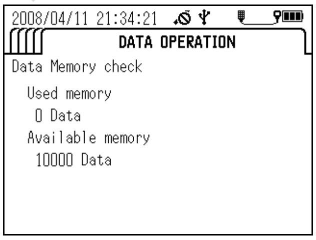
Note

The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

2. **Press the right (▷) key 3 times to display the "DATA OPERATION" screen.**
3. **Press the down (▽) key to move the cursor to "Data Memory Check", then press the ENTER key.**



The amount of memory in use and amount of available memory are displayed.

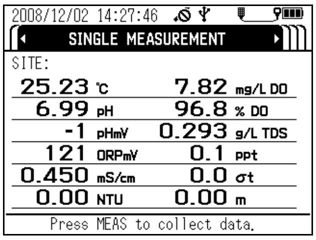


3.5.4 Checking the calibration record

Follow the steps below to check the latest calibration history.

1. **Press and hold down the control unit's POWER key for about 3 seconds to turn the power ON.**

   The "MEASUREMENT" screen appears after about 10 seconds.



Note

The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

2. **Press the right (▷) key 3 times to display the "DATA OPERATION" screen.**
3. **Press the down (▽) key to move the cursor to "Calibration record", then press the ENTER key.**

   The latest calibration record is displayed.

3.5.5 GPS data operations

The menu for GPS data operations appears on the display to which the GPS unit is mounted.

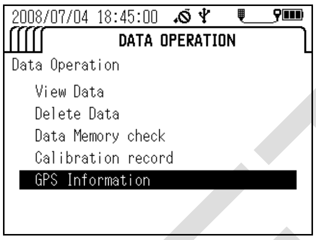
● GPS information

Follow the steps below to display acquired GPS information.

Note

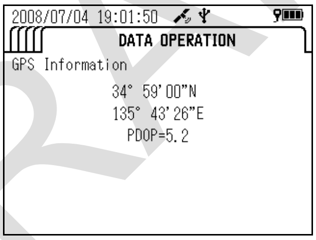
Turning the power OFF erases the GPS information.

1. **Press the right (▷) key to switch the display to the "DATA OPERATION" screen.**
2. **the down (▽) key to move the cursor to "GPS Information", then press the ENTER key.**

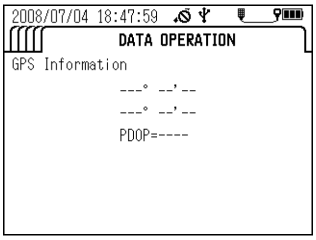


The last GPS information acquired is displayed.

● When received data exists

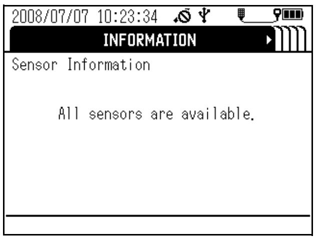


● When no received data exists

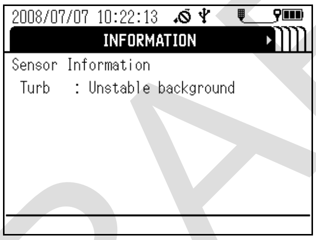


3.6 Sensor information

1. **Press and hold down the control unit's POWER key for about 3 seconds to turn the power ON.**
   The "MEASUREMENT" screen appears after about 10 seconds.
2. **Press the left (◁) key once to display the "INFORMATION" screen.**
   The "Sensor Information" screen displays the sensor probe's status.
   ● When the sensor probe is normal, the display below appears.



● When there is a sensor probe problem, individual measurement parameters generate messages such as the one shown below. Follow the troubleshooting information to remove the problem before continuing to operate the system.

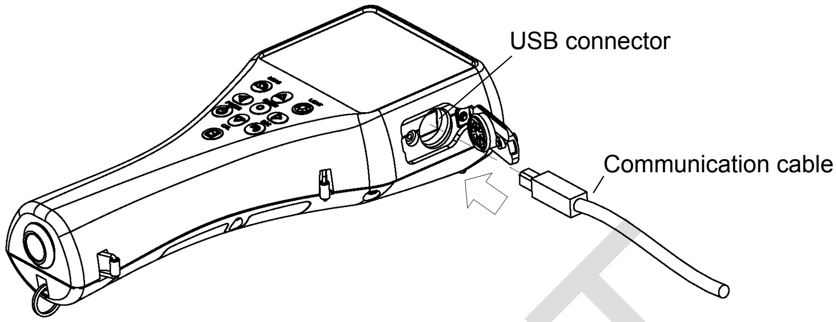


3.7 USB communication

The separately-sold, dedicated PC connection cable comes with data collection software. This software allows data to be downloaded from the control unit in CSV format.

This section contains instructions for communication commands used for USB communication.

● Connecting the cable



Dedicated cable

Part name: Communication cable (with data collection software)

Part no.: 3200174823

● Cautions when using USB communication

Take care to observe the following when using USB communication.

- Use the dedicated cable (with data collection software) or a commercially-available USB cable (A-B type) to connect to a PC.
- Be sure to match the transmission format on the control unit and the computer.
  The control unit uses the following transmission format:

Baud rate:	19200 bps
Number of stop bits:	1 bit
Data bit length:	8 bits
Parity:	None
Flow control:	None

Tip

If the transmission formats do not match, a communication error occurs and USB communication will not function normally. After changing the transmission format, restart the control unit and the computer.

- If received data is not sent back or an error occurs after a data request has been sent, adjust the program configuration so that it allows a little waiting time before a data request is sent again. This will enable more stable communication.
- The unit does not use DCD, CTS, or DSR signals. Take care of this when creating programs.

3.7.1 Communication settings

Baud rate:	19200 bps
Number of stop bits:	1 bit
Data bit length:	8 bits
Parity:	None
Flow control:	None

3.7.2 Commands

● Instant data requests

● Request command format

#	RD	@	XX	[CR]	[LF]
1	2	3	4		

1	Header	1 character
2	Command	2 characters
3	Delimiter character	1 character
4	Frame check sequence (FCS)	2 characters

The two ASCII-code characters created by converting the 8 bits of data created by successively combining the value of each character from # through @ in an exclusive OR (XOR) operation with the value of the next character.

Example: #RD@

(1)	0	XOR	35	(ASCII code of # symbol)	⇒	35
(2)	35	XOR	82	(ASCII code of R)	⇒	113
(3)	113	XOR	68	(ASCII code of D)	⇒	53
(4)	53	XOR	64	(ASCII code of @ symbol)	⇒	117 (decimal)
						↓
						75 (hex)
						↓
						Sets "75".

Example: 35 XOR 82 operation

35 in binary	⇒	0	0	1	0	0	0	1	1	
82 in binary	⇒	0	1	0	1	0	0	1	0	
XOR result		0	1	1	1	0	0	0	1	⇒ 113 (decimal)

Note: Set "XX" if you do not want to test for communication frame errors with FCS.

● Response format

```
#  RD  AAAAAAAAAAAAAAAAAAAA  X  X  XXXX  XX  X  X  XXXXX  X
1  2   3                     4  5  6     7   8  9  10     11

XX  X   X   XXXXX  X   XX  X   X   XXXXX  X   XX  X   X   XXXXX  X
12  13  14  15     16  17  18  19  20     21  22  23  24  25     26
XX  X   X   XXXXX  X   XX  X   X   XXXXX  X   XX  X   X   XXXXX  X
27  28  29  30     31  32  33  34  35     36  37  38  39  40     41

XX  X   X   XXXXX  X   XX  X   X   XXXXX  X   XX  X   X   XXXXX  X
42  43  44  45     46  47  48  49  50     51  52  53  54  55     56
```

XX	X	X	XXXXX	X	XX	X	X	XXXXX	X	XX	X	X	XXXXX	X
57	58	59	60	61	62	63	64	65	66	67	68	69	70	71

XX	XX	XX	XX	XX	XX	XX	XX	XX	X	X	XXX	XX	XX	X	X	@	XX	[CR]	[LF]
72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89		

1	Header		1 character
2	Command		2 characters
3	Site name	Upper- and lowercase letters, numbers, periods (.) hyphens (-) and spaces ( )	20 characters
4	Probe status	(3) Status code	1 character
5	Probe error	(4) Status error code	1 character
6	Unused		4 characters
7	Parameter 1 code	(1) Parameter code	2 characters
8	Parameter 1 status	(5) Parameter status code	1 character
9	Parameter 1 error	(6) Parameter error code	1 character
10	Parameter 1 data	5 characters including decimal point, right-justified with blanks filled	5 characters
11	Parameter 1 unit	(2) Unit code	1 character
12	Parameter 2 code	(1) Parameter code	2 characters
13	Parameter 2 status	(5) Parameter status code	1 character
14	Parameter 2 error	(6) Parameter error code	1 character
15	Parameter 2 data	5 characters including decimal point, right-justified with blanks filled	5 characters
16	Parameter 2 unit	(2) Unit code	1 character
17	Parameter 3 code	(1) Parameter code	2 characters
18	Parameter 3 status	(5) Parameter status code	1 character
19	Parameter 3 error	(6) Parameter error code	1 character
20	Parameter 3 data	5 characters including decimal point, right-justified with blanks filled	5 characters
21	Parameter 3 unit	(2) Unit code	1 character
22	Parameter 4 code	(1) Parameter code	2 characters
23	Parameter 4 status	(5) Parameter status code	1 character
24	Parameter 4 error	(6) Parameter error code	1 character
25	Parameter 4 data	5 characters including decimal point, right-justified with blanks filled	5 characters
26	Parameter 4 unit	(2) Unit code	1 character
27	Parameter 5 code	(1) Parameter code	2 characters
28	Parameter 5 status	(5) Parameter status code	1 character
29	Parameter 5 error	(6) Parameter error code	1 character
30	Parameter 5 data	5 characters including decimal point, right-justified with blanks filled	5 characters
31	Parameter 5 unit	(2) Unit code	1 character
32	Parameter 6 code	(1) Parameter code	2 characters
33	Parameter 6 status	(5) Parameter status code	1 character
34	Parameter 6 error	(6) Parameter error code	1 character

35	Parameter 6 data	5 characters including decimal point, right-justified with blanks filled	5 characters
36	Parameter 6 unit	(2) Unit code	1 character
37	Parameter 7 code	(1) Parameter code	2 characters
38	Parameter 7 status	(5) Parameter status code	1 character
39	Parameter 7 error	(6) Parameter error code	1 character
40	Parameter 7 data	5 characters including decimal point, right-justified with blanks filled	5 characters
41	Parameter 7 unit	(2) Unit code	1 character
42	Parameter 8 code	(1) Parameter code	2 characters
43	Parameter 8 status	(5) Parameter status code	1 character
44	Parameter 8 error	(6) Parameter error code	1 character
45	Parameter 8 data	5 characters including decimal point, right-justified with blanks filled	5 characters
46	Parameter 8 unit	(2) Unit code	1 character
47	Parameter 9 code	(1) Parameter code	2 characters
48	Parameter 9 status	(5) Parameter status code	1 character
49	Parameter 9 error	(6) Parameter error code	1 character
50	Parameter 9 data	5 characters including decimal point, right-justified with blanks filled	5 characters
51	Parameter 9 unit	(2) Unit code	1 character
52	Parameter 10 code	(1) Parameter code	2 characters
53	Parameter 10 status	(5) Parameter status code	1 character
54	Parameter 10 error	(6) Parameter error code	1 character
55	Parameter 10 data	5 characters including decimal point, right-justified with blanks filled	5 characters
56	Parameter 10 unit	(2) Unit code	1 character
57	Parameter 11 code	(1) Parameter code	2 characters
58	Parameter 11 status	(5) Parameter status code	1 character
59	Parameter 11 error	(6) Parameter error code	1 character
60	Parameter 11 data	5 characters including decimal point, right-justified with blanks filled	5 characters
61	Parameter 11 unit	(2) Unit code	1 character
62	Parameter 12 code	(1) Parameter code	2 characters
63	Parameter 12 status	(5) Parameter status code	1 character
64	Parameter 12 error	(6) Parameter error code	1 character
65	Parameter 12 data	5 characters including decimal point, right-justified with blanks filled	5 characters
66	Parameter 12 unit	(2) Unit code (6) Parameter error code	1 character
67	Parameter 13 code	(1) Parameter code	2 characters
68	Parameter 13 status	(5) Parameter status code	1 character
69	Parameter 13 error	(6) Parameter error code	1 character
70	Parameter 13 data	5 characters including decimal point, right-justified with blanks filled	5 characters
71	Parameter 13 unit	(2) Unit code	1 character
72	Year	00 to 99	2 characters

73	Month	01 to 12	2 characters
74	Day	01 to 31	2 characters
75	Hour	00 to 23	2 characters
76	Minute	00 to 59	2 characters
77	Second	00 to 59	2 characters
78	Longitude (degrees)	00 to 90 or "--" (no GPS data)	2 characters
79	Longitude (minutes)	00 to 59 or "--" (no GPS data)	2 characters
80	Longitude (seconds)	00 to 59 or "--" (no GPS data)	2 characters
81	Unused	1 character	1 character
82	North latitude/South latitude	N: North; S: South	1 character
83	Latitude (degrees)	000 to 180 or "---" (no GPS data)	3 characters
84	Latitude (minutes)	00 to 59 or "--" (no GPS data)	2 characters
85	Latitude (seconds)	00 to 59 or "--" (no GPS data)	2 characters
86	Unused		1 character
87	East longitude/West longitude	E: East; W: West	1 character
88	Delimiter character		1 character
89	Frame check sequence (FCS)		2 characters

● Memory data requests

● Request command format

#	RM	X	X	AAAAAAAAAAAAAAAAAAAA	XX	XX	XX	@	XX	[CR]	[LF]
1	2	3	4	5	6	7	8	9	10		

1	Header		1 character
2	Command		2 characters
3	Data specification[*1]	0: Start search; 1: Next data item; 2: Previous data item; 3: Request same data again	1 character
4	Search method specification	0: All data; 1: Site search; 2: Date search	1 character
5	Search site[*2]	Upper- and lowercase letters, numbers, periods (.) hyphens (-) and spaces ( )	20 characters
6	Search year[*3]	00 to 99	2 characters
7	Search month[*3]	01 to 12	2 characters
8	Search day[*3]	01 to 31	2 characters
9	Delimiter character		1 character
10	Frame check sequence (FCS)		2 characters

*1: When sending the RM command, first send 0 [Start search], then 1 [Next data item], 2 [Previous data item] or 3 [Request same data again].

*2: [Search site] is only needed when [Site search] is specified as the search method. If another search method is specified, fill this field with spaces.

*3: [Search year], [Search month] and [Search day] are only needed when [Date search] is specified as the search method. If another search method is specified, fill this field with spaces.

● Response format

(when data exists)

```
#    RM  AAAAAAAAAAAAAAAAAAAA   XX  X   X   XXXXX   X
1    2   3                      4   5   6   7       8

XX  X   X   XXXXX  X   XX  X   X   XXXXX  X   XX  X   X   XXXXX  X
9   10  11  12     13  14  15  16  17     18  19  20  21  22     23

XX  X   X   XXXXX  X   XX  X   X   XXXXX  X   XX  X   X   XXXXX  X
24  25  26  27     28  29  30  31  32     33  34  35  36  37     38

XX  X   X   XXXXX  X   XX  X   X   XXXXX  X   XX  X   X   XXXXX  X
39  40  41  42     43  44  45  46  47     48  49  50  51  52     53

XX  X   X   XXXXX  X   XX  X   X   XXXXX  X   XX  X   X   XXXXX  X
54  55  56  57     58  59  60  61  62     63  64  65  66  67     68

XX  XX  XX  XX  XX  XX  XX  XX  XX  X   X   XXX  XX  XX  X   X   @   XX  [CR] [LF]
69  70  71  72  73  74  75  76  77  78  79  80   81  82  83  84  85  86
```

1	Header		1 character
2	Command		2 characters
3	Site name	Upper- and lowercase letters, numbers, periods (.) hyphens (-) and spaces ( )	20 characters
4	Parameter 1 code	(1) Parameter code	2 characters
5	Parameter 1 selection	0: No selection; 1: Selection made	1 character
6	Parameter 1 error	(6) Parameter error code	1 character
7	Parameter 1 data	5 characters including decimal point, right-justified with blanks filled	5 characters
8	Parameter 1 unit	(2) Unit code	1 character
9	Parameter 2 code	(1) Parameter code	2 characters
10	Parameter 2 selection	0: No selection; 1: Selection made	1 character
11	Parameter 2 error	(6) Parameter error code	1 character
12	Parameter 2 data	5 characters including decimal point, right-justified with blanks filled	5 characters
13	Parameter 2 unit	(2) Unit code	1 character
14	Parameter 3 code	(1) Parameter code	2 characters
15	Parameter 3 selection	0: No selection; 1: Selection made	1 character
16	Parameter 3 error	(6) Parameter error code	1 character
17	Parameter 3 data	5 characters including decimal point, right-justified with blanks filled	5 characters
18	Parameter 3 unit	(2) Unit code	1 character
19	Parameter 4 code	(1) Parameter code	2 characters
20	Parameter 4 selection	0: No selection; 1: Selection made	1 character

21	Parameter 4 error	(6) Parameter error code	1 character
22	Parameter 4 data	5 characters including decimal point, right-justified with blanks filled	5 characters
23	Parameter 4 unit	(2) Unit code	1 character
24	Parameter 5 code	(1) Parameter code	2 characters
25	Parameter 5 selection	0: No selection; 1: Selection made	1 character
26	Parameter 5 error	(6) Parameter error code	1 character
27	Parameter 5 data	5 characters including decimal point, right-justified with blanks filled	5 characters
28	Parameter 5 unit	(2) Unit code	1 character
29	Parameter 6 code	(1) Parameter code	2 characters
30	Parameter 6 selection	0: No selection; 1: Selection made	1 character
31	Parameter 6 error	(6) Parameter error code	1 character
32	Parameter 6 data	5 characters including decimal point, right-justified with blanks filled	5 characters
33	Parameter 6 unit	(2) Unit code	1 character
34	Parameter 7 code	(1) Parameter code	2 characters
35	Parameter 7 selection	0: No selection; 1: Selection made	1 character
36	Parameter 7 error	(6) Parameter error code	1 character
37	Parameter 7 data	5 characters including decimal point, right-justified with blanks filled	5 characters
38	Parameter 7 unit	(2) Unit code	1 character
39	Parameter 8 code	(1) Parameter code	2 characters
40	Parameter 8 selection	0: No selection; 1: Selection made	1 character
41	Parameter 8 error	(6) Parameter error code	1 character
42	Parameter 8 data	5 characters including decimal point, right-justified with blanks filled	5 characters
43	Parameter 8 unit	(2) Unit code	1 character
44	Parameter 9 code	(1) Parameter code	2 characters
45	Parameter 9 selection	0: No selection; 1: Selection made	1 character
46	Parameter 9 error	(6) Parameter error code	1 character
47	Parameter 9 data	5 characters including decimal point, right-justified with blanks filled	5 characters
48	Parameter 9 unit	(2) Unit code	1 character
49	Parameter 10 code	(1) Parameter code	2 characters
50	Parameter 10 selection	0: No selection; 1: Selection made	1 character
51	Parameter 10 error	(6) Parameter error code	1 character
52	Parameter 10 data	5 characters including decimal point, right-justified with blanks filled	5 characters
53	Parameter 10 unit	(2) Unit code	1 character
54	Parameter 11 code	(1) Parameter code	2 characters
55	Parameter 11 selection	0: No selection; 1: Selection made	1 character
56	Parameter 11 error	(6) Parameter error code	1 character
57	Parameter 11 data	5 characters including decimal point, right-justified with blanks filled	5 characters
58	Parameter 11 unit	(2) Unit code	1 character
59	Parameter 12 code	(1) Parameter code	2 characters

60	Parameter 12 selection	0: No selection; 1: Selection made	1 character
61	Parameter 12 error	(6) Parameter error code	1 character
62	Parameter 12 data	5 characters including decimal point, right-justified with blanks filled	5 characters
63	Parameter 12 unit	(2) Unit code	1 character
64	Parameter 13 code	(1) Parameter code	2 characters
65	Parameter 13 selection	0: No selection; 1: Selection made	1 character
66	Parameter 13 error	(6) Parameter error code	1 character
67	Parameter 13 data	5 characters including decimal point, right-justified with blanks filled	5 characters
68	Parameter 13 unit	(2) Unit code	1 character
69	Year	00 to 99	2 characters
70	Month	01 to 12	2 characters
71	Day	01 to 31	2 characters
72	Hour	00 to 23	2 characters
73	Minute	00 to 59	2 characters
74	Second	00 to 5	2 characters
75	Longitude (degrees)	00 to 90 or "--" (no GPS data)	2 characters
76	Longitude (minutes)	00 to 59 or "--" (no GPS data)	2 characters
77	Longitude (seconds)	00 to 59 or "--" (no GPS data)	2 characters
78	Unused		1 character
79	North latitude/South latitude	N: North; S: South	1 character
80	Latitude (degrees)	000 to 180 or "---" (no GPS data)	3 characters
81	Latitude (minutes)	00 to 59 or "--" (no GPS data)	2 characters
82	Latitude (seconds)	00 to 59 or "--" (no GPS data)	2 characters
83	Unused		1 character
84	East longitude/West longitude	E: East; W: West	1 character
85	Delimiter character		1 character
86	Frame check sequence (FCS)		2 characters

When no data exists, or memory is at capacity)

#	RM	@	XX	[CR]	[LF]
1	2	3	4		

1	Header	1 character
2	Command	2 characters
3	Delimiter character\	1 character
4	Frame check sequence (FCS)	2 characters

● Memory data count request

● Request command format

#	RN	@	XX	[CR]	[LF]
1	2	3	4		

1	Header	1 character
2	Command	2 characters
3	Delimiter character\	1 character
4	Frame check sequence (FCS)	2 characters

● Response format

#	RN	XXXXX	@	XX	[CR]	[LF]
1	2	3	4	5		

1	Header		1 character
2	Command		2 characters
3	Total data count	0 to 10000	5 characters
4	Delimiter character\		1 character
5	Frame check sequence (FCS)		2 characters

● Command parse failure response

#	??	X	XX	X	@	XX	[CR]	[LF]
1	2	3	4	5	6	7		

1	Header	1 character
2	Command	2 characters
3	Command parse failure reason[*4]	1 character
4	Received command[*5]	2 characters
5	(3) Status code for probe status[*5]	1 character
6	Delimiter character	1 character
7	Frame check sequence (FCS)	2 characters

*4: List of command parse failure reasons

1: Frame length error
2: FCS mismatch
3: Undefined command
4: Data error
5: Data out of range
6: No "@" delimiter character
7: No "#" header character
8: No [Carriage return] + [Line feed] footer
9: Cannot accept command in this timing.

*5: Only set for command parse failure reason 9, [Cannot accept command in this timing]. Otherwise this field is filled with spaces.

4 Maintenance

Tip

HORIBA recommends regular manufacturer maintenance checks in order to ensure a long product life.

4.1 Routine care

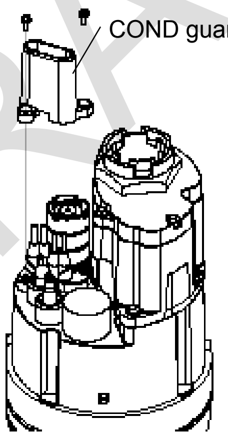
After measurement

1. **Press and hold down the control unit's POWER key for about 3 seconds to turn the power OFF.**

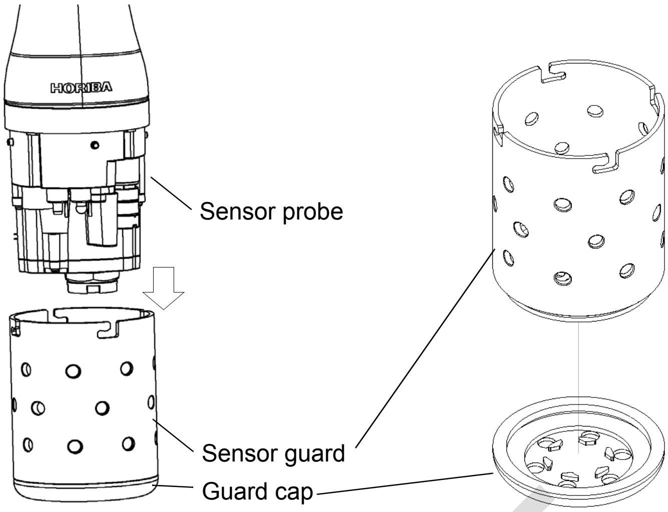
Note

The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

2. **Remove the sensor guard, and clean the sensor with tap water.**
3. **Clean the turbidity sensor with the cleaning brush provided.**
4. **Remove the two screws securing the COND guard, and the COND guard itself, and use a test tube brush to gently remove any dirt from the electrical conductivity electrode.**



5. **Wipe off any dirt with a soft cloth. If parts are very dirty, clean them with neutral detergent, then rinse them. If parts are contaminated by oil, wipe it off with a soft cloth soaked in alcohol.**
6. **Put the COND guard back in place.**
7. **Remove the sensor guard's guard cap, wash off any dirt with tap water, then put the guard cap back in place.**



4.2 Every 2 months maintenance

● Dissolved oxygen (DO) sensor

Note

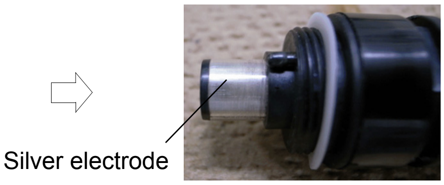
- **The DO sensor's internal solution is potassium chloride (KCl). Although KCl is harmless, protective equipment such as gloves and goggles should be worn when working with it.**
- **Internal solution can be disposed of down a sink.**

- Replace the membrane cap.
- Polish the gold and silver electrodes when replacing the membrane cap.
  The gold electrode does not need to be polished if it is not dirty.

● **Silver electrode**

Polish a silver electrode part with sandpaper (#500) and then wash metal electrode parts with water.

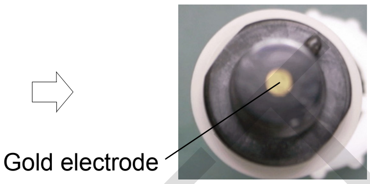
⇨



● **Gold electrode**

Polish a gold electrode part with sandpaper (#8000) and then wash metal electrode parts with water.

⇨



Replace a membrane cap after clean metal electrodes parts.

Refer to “ 4.5 Replacing the membrane cap ” (page 87).

● **Reference electrode**

Note

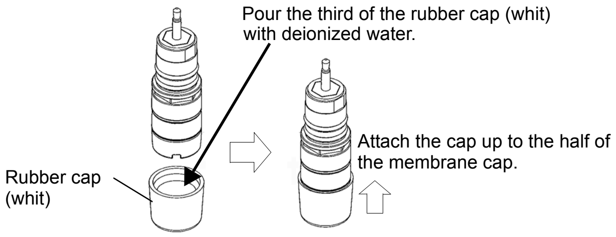
- **The pH reference internal solution is potassium chloride (KCl). Although KCl is harmless, protective equipment such as gloves and goggles should be worn when working with it.**
- **Internal solution can be disposed of down a sink.**

1. **Remove the rubber liquid junction plug from the reference electrode and dispose of the internal solution.**
2. **To prevent air entering, fill the reference electrode to the brim with its internal solution (No. 330).**
3. **Put the rubber liquid junction plug back in place.**
   If the rubber liquid junction plug is dirty, replace the liquid junctions (set of two; No. 9037005100). The reference electrode's internal solution will spill when replacing the liquid junctions. Rinse parts with tap water and dry them with a soft cloth.

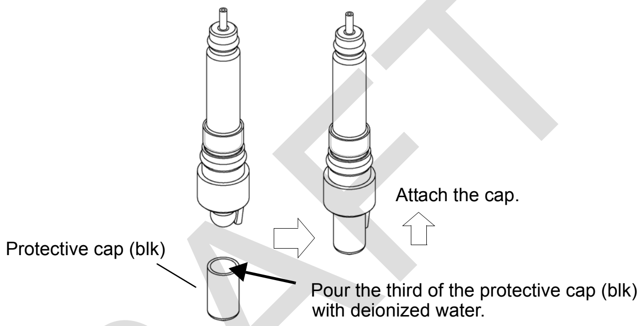
4.3 Storage

● Short-term (under 2 months) storage

- Before storing the DO sensor, pour the third of the rubber cap (whit) provided with deionized water and cover the DO sensor with them.



- Before storing the pH sensor, pour the third of the protective cap (blk) provided with deionized water and cover the pH sensor with them.



Note

Before measuerment, remove the rubber cap (whit) and the protective cap (blk).

● Long-term (2 months or more) storage

- Remove a membrane cap from DO sensor, and wash the gold electrode and silver electrode parts with water. Wipe off the moisture before storing DO sensor in the pack.
- Prevent internal solution seeping out of the reference chip by taping over the point of seepage with electrical tape.
- Before storing the system, remove the control unit's batteries to prevent battery leakage.

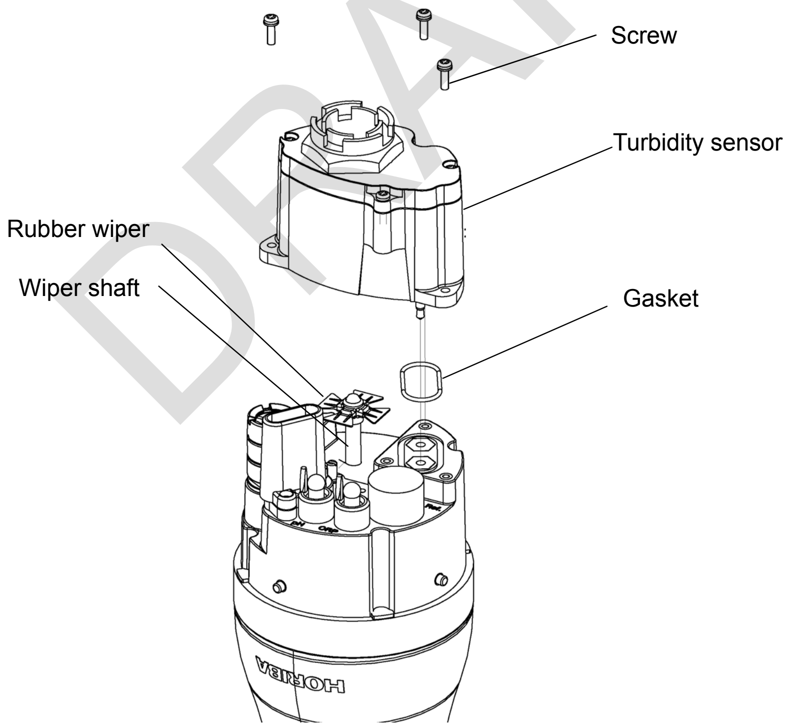
4.4 Replacing the turbidity sensor

1. **Press and hold down the control unit's POWER key for about 3 seconds to turn the power OFF.**

Note

The operation keys are designed to operate using the pad of a finger, sharp objects can tear the control unit cover damaging the operation keys.

2. **Remove the sensor guard, and clean the sensor probe with tap water.**
3. **Use dry air to blow away and dry off any moisture.**
4. **Remove the three screws holding the turbidity sensor by using No. 2 Phillips head screwdriver.**
5. **Pull out the turbidity sensor horizontally.**
6. **Remove the rubber wiper and gasket, and use a soft cloth to wipe off any dirt from the wiper shaft and turbidity sensor attachment. If parts are very dirty, use a soft cloth soaked in neutral detergent or alcohol.**
7. **Replace the rubber wiper and gasket with new ones. Coat the gasket with a thin layer of grease (No. 3014017718).**
8. **Attach the new turbidity sensor and fasten it in place with the three screws.**
9. **Perform four-point calibration before using the sensor.**



4.5 Replacing the membrane cap

● Replacement procedure

1. Prepare the DO sensor.

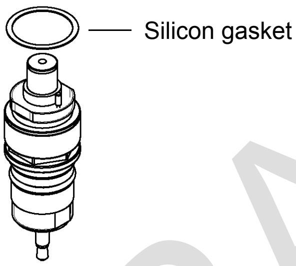
- Take a DO sensor out of pack (newly purchasing).
- Remove a DO sensor from the sensor probe (after use).


Newly purchasing

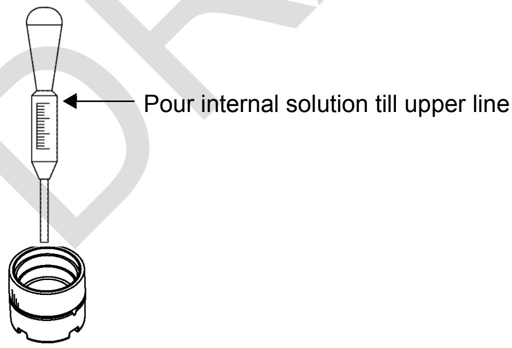

Undo a DO sensor from the sensor probe

- Twist a membrane cap from DO sensor.
- Wash the gold electrode and silver electrode parts with water.

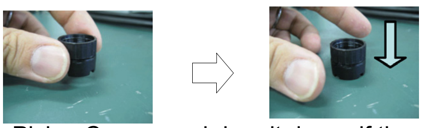
2. Replace the silicone gasket with a new one.



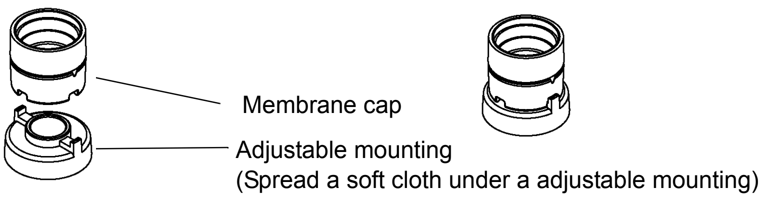
3. Pour internal solution into a membrane cap with a dropper.



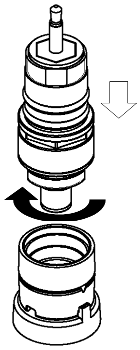
- Check air bubbles in a membrane cap.


Pick a Cap up and drop it down, if there is air bubbles in internal solution of it.

4. Set up a membrane cap on a adjustable mounting.

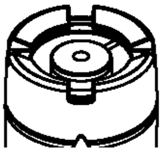


5. Attach a membrane cap to DO sensor

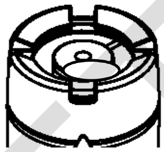


6. Check for membrane surface

Check air bubbles in a membrane cap.



Good: Limited air bubbles



NG: Air bubbles of more than 5 mm in diameter

- NG → Replace a membrane cap again.
- Check that span calibration can be performed.

If the membrane cap is not attached correctly, sensitivity may be lost or response speed may decrease.

4.6 Troubleshooting

Note

If the sensor probe is removed while the control unit is indicating an error, errors cannot be canceled by using the ESC key. Either reconnect the sensor probe or restart the control unit.

4.6.1 Error displays

Error	Cause	Solution
Probe ADC error	Internal IC failure	Contact your nearest sales outlet to have the sensor probe repaired.
Probe EEPROM error/Factory	Internal IC failure	Turn the power OFF, then restart the system. If the error persists, initialize the system from the "System" menu. If the error still persists, contact your nearest sales outlet to have the sensor probe repaired.
Probe EEPROM error/User	Internal IC failure	Turn the power OFF, then restart the system. If the error persists, initialize the system from the "System" menu. If the error still persists, contact your nearest sales outlet to have the sensor probe repaired.
Turbidity sensor light source error	Turbidity sensor light source failure	Turn the power OFF, wipe off any water droplets on the probe, then remove the turbidity sensor. Check there are no water droplets around the turbidity sensor connector, then mount the sensor again. If the error persists, replace the turbidity sensor.
Turbidity sensor wiper motor error	The turbidity sensor wiper is not operating.	Press the ESC key. Check there are no obstacles near the wiper, then perform the measurement again. If the error persists, the motor will need to be replaced. Contact your nearest sales outlet to have the sensor probe repaired.
Probe capacitor error	Low battery voltage or internal IC failure	Turn the power OFF. Replace the display's batteries. If the error persists, contact your nearest sales outlet to have the sensor probe repaired.
Probe EEPROM error	Internal IC failure	Press the ESC key, then redo the operation. If the error persists, turn the power OFF, then restart the system (the current data will not be saved). If the error still persists, contact your nearest sales outlet to have the display repaired.
Probe board error	Probe board failure	Turn the power OFF. Contact your nearest sales outlet to have the sensor probe repaired.

Error	Cause	Solution
Zero-point calibration error	pH sensor 1. The pH standard solution is contaminated. 2. The pH-responsive membrane is dirty. 3. The concentration of the reference electrode's internal solution has changed. 4. The pH-responsive membrane is torn.	pH sensor 1. Replace the standard solution with new solution. 2. Clean the pH-responsive membrane. 3. Refil the reference electrode's internal solution. 4. Replace the sensor.
	COND sensor 1. There is moisture on the sensor. 2. The sensor is dirty. 3. The COND sensor is broken.	COND sensor 1. Blow-dry the moisture off the sensor. 2. Clean the sensor. 3. Contact your nearest sales outlet.
	TURB sensor 1. There are air bubbles on the cell. 2. The cell window is dirty. 3. The sensor is being affected by ambient light. 4. The solution is dirty. 5. The TURB sensor has failed.	TURB sensor 1. Shake the sensor probe vigorously. 2. Clean the cell window. 3. Calibrate using the calibration cup provided. 4. Replace the solution with new solution. 5. Replace the TURB sensor.
	DO sensor 1. There are air bubbles in the internal solution. 2. The DO sensor has failed.	DO sensor 1. Replace the diaphragm with a new one, and fill the DO sensor with new internal solution. 2. Replace the DO sensor.
	Water depth sensor 1. The water depth sensor is dirty. 2. The water depth sensor has failed.	Water depth sensor 1. Clean the water depth sensor. 2. Contact your nearest sales outlet.

Error	Cause	Solution
Span calibration error	pH sensor 1. The pH standard solution is contaminated. 2. The pH-responsive membrane is dirty. 3. The concentration of the reference electrode's internal solution has changed. 4. The pH-responsive membrane is torn.	pH sensor 1. Replace the standard solution with new solution. 2. Clean the pH-responsive membrane. 3. Refil the reference electrode's internal solution. 4. Replace the sensor.
	ORP sensor 1. The ORP standard solution is contaminated. 2. The ORP electrode is dirty. 3. The concentration of the reference electrode's internal solution has changed. 4. The ORP electrode has failed.	ORP sensor 1. Replace the standard solution with new solution. 2. Clean the ORP electrode. 3. Refil the reference electrode's internal solution. 4. Replace the ORP electrode.
	COND sensor 1. The calibration solution is not correct. 2. The sensor is dirty. 3. The COND sensor has failed.	COND sensor 1. Use the correct calibration solution for calibration. 2. Clean the sensor. 3. Contact your nearest sales outlet.
	TURB sensor 1. There are air bubbles on the cell. 2. The cell window is dirty. 3. The sensor is being affected by ambient light. 4. The solution is dirty. 5. The TURB sensor has failed.	TURB sensor 1. Shake the sensor probe vigorously. 2. Clean the cell window. 3. Calibrate using the calibration cup provided. 4. Replace the solution with new solution. 5. Replace the TURB sensor.
	DO sensor 1. The diaphragm is torn. 2. There are air bubbles in the internal solution. 3. The DO sensor has failed.	DO sensor 1. Replace the diaphragm with a new one, and fill the DO sensor with new internal solution. 2. Replace the diaphragm with a new one, and fill the DO sensor with new internal solution. 3. Replace the DO sensor.
	Temperature sensor The temperature sensor has failed.	Temperature sensor Contact your nearest sales outlet.
Calibration stability error	The calibration value of an individual parameter is not stable. 1. The sensor is dirty. 2. The sensor has not adjusted to the standard solution. 3. The temperature was unstable during calibration.	1. Clean the sensor. 2. Fill the transparent calibration cup with pH 4 standard solution, and wait for at least 20 minutes of conditioning before starting calibration. 3. Start calibration after the temperature has stabilized.
Turbidity calibration error	Error in turbidity measurement sequence	Turbidity calibration failed. Redo calibration after removing the displayed error.
Wet check	The cable connector is submerged.	Turn the power OFF and disconnect the cable connector. Wipe or blow-dry off all the water droplets on the probe. If the error persists, contact your nearest sales outlet to have the display and sensor probe repaired.
Power voltage error	The display's power board has failed.	This error could also be caused by poor cable contact. Turn the power OFF and disconnect the cable connector. Reconnect the connector and turn the power ON. If the error persists, contact your nearest sales outlet to have the display and sensor probe repaired.
Turbidity lamp power voltage error	The remaining battery level is low.	Turn the power OFF and replace the display's batteries with new ones.

Error	Cause	Solution
Display RTC error	The time display is incorrect.	Replace the coin battery.
Display FROM error	Internal IC failure	Contact your nearest sales outlet to have the control unit repaired.
Display EEPROM error	Internal IC failure	Contact your nearest sales outlet to have the control unit repaired.
Display save error	Insufficient memory space	Move data from the display, use the data operations screen to delete data, then redo the measurement.
Measurement sequence error	● When the measurement item is turbidity 1. The battery power is low. 2. The wiper is not operating normally. 3. The light source lamp is not lit. ● If items other than turbidity are also displayed 4. Board failure	1. Replace the batteries with new ones. 2. Check there are no obstacles near the wiper, then redo the measurement. If the error persists, the motor will need to be replaced. Contact your nearest sales outlet to have the sensor probe repaired. 3. Wipe off any water droplets on the probe, then remove the turbidity sensor. Check there are no water droplets around the turbidity sensor connector, then mount the sensor again. If the error persists, replace the turbidity sensor. 4. Contact your nearest sales outlet to have the sensor probe repaired.
Out of measurement range	The attempted measurement is outside the measurement range supported for that item.	The system must be used within its supported measurement ranges.
Last zero-point calibration invalid	pH sensor 1. The pH standard solution is contaminated. 2. The pH-responsive membrane is dirty. 3. The concentration of the reference electrode's internal solution has changed. 4. The pH-responsive membrane is torn.	pH sensor 1. Replace the standard solution with new solution. 2. Clean the pH-responsive membrane. 3. Refil the reference electrode's internal solution. 4. Replace the sensor.
	COND sensor 1. There is moisture on the sensor. 2. The sensor is dirty. 3. The COND sensor has failed.	COND sensor 1. Blow-dry the moisture off the sensor. 2. Clean the sensor. 3. Contact your nearest sales outlet.
	TURB sensor 1. There are air bubbles on the cell. 2. The cell window is dirty. 3. The sensor is being affected by ambient light. 4. The solution is dirty. 5. The TURB sensor has failed.	TURB sensor 1. Shake the sensor probe vigorously. 2. Clean the cell window. 3. Calibrate using the calibration cup provided. 4. Replace the solution with new solution. 5. Replace the TURB sensor.
	DO sensor 1. There are air bubbles in the internal solution. 2. The DO sensor has failed.	DO sensor 1. Replace the diaphragm with a new one, and fill the DO sensor with new internal solution. 2. Replace the DO sensor.
	Water depth sensor 1. The water depth sensor is dirty. 2. The water depth sensor has failed.	Water depth sensor 1. Clean the water depth sensor. 2. Contact your nearest sales outlet.
Out of measurement range	[See above.]	[See above.]
Last zero-point calibration invalid		

Error	Cause	Solution
Last span calibration invalid	pH sensor 1. The pH standard solution is contaminated. 2. The pH-responsive membrane is dirty. 3. The concentration of the reference electrode's internal solution has changed. 4. The pH-responsive membrane is torn.	pH sensor 1. Replace the standard solution with new solution. 2. Clean the pH-responsive membrane. 3. Refil the reference electrode's internal solution. 4. Replace the sensor.
	ORP sensor 1. The ORP standard solution is contaminated. 2. The ORP electrode is dirty. 3. The concentration of the reference electrode's internal solution has changed. 4. The ORP sensor glass is broken.	ORP sensor 1. Replace the standard solution with new solution. 2. Clean the ORP electrode. 3. Refil the reference electrode's internal solution. 4. Replace the sensor.
	COND sensor 1. The calibration solution is not correct. 2. The sensor is dirty. 3. The COND sensor has failed.	COND sensor 1. Use the correct calibration solution for calibration. 2. Clean the sensor. 3. Contact your nearest sales outlet.
	TURB sensor 1. There are air bubbles on the cell. 2. The cell window is dirty. 3. The sensor is being affected by ambient light. 4. The solution is dirty. 5. The TURB sensor has failed.	TURB sensor 1. Shake the sensor probe vigorously. 2. Clean the cell window. 3. Calibrate using the calibration cup provided. 4. Replace the solution with new solution. 5. Replace the TURB sensor.
	DO sensor 1. The diaphragm is torn. 2. There are air bubbles in the internal solution. 3. The DO sensor has failed.	DO sensor 1. Replace the diaphragm with a new one, and fill the DO sensor with new internal solution. 2. Replace the diaphragm with a new one, and fill the DO sensor with new internal solution. 3. Replace the DO sensor.
	Temperature sensor ● The temperature sensor has failed.	Temperature sensor ● Contact your nearest sales outlet.
Out of measurement range	[See above.]	[See above.]
Last zero-point calibration invalid		
Last span calibration invalid	The calibration value of an individual parameter is not stable. 1. The sensor is dirty. 2. The sensor has not adjusted to the standard solution. 3. The temperature was unstable during calibration.	1. Clean the sensors. 2. Fill the transparent calibration cup with pH 4 standard solution, and wait for at least 20 minutes of conditioning before starting calibration. 3. Start calibration after the temperature has stabilized.
Out of measurement range	[See above.]	[See above.]
Last zero-point calibration invalid		
Calibration value is factory default value.	Internal IC failure	Turn the power OFF, then restart the system. If the error persists, initialize the system from the "System" menu. If the error still persists, contact your nearest sales outlet to have the sensor probe repaired.

Error	Cause	Solution
Sample is unstable.	1. The concentration of the sample is unstable. 2. External light disturbance has affected the sensor. 3. Water has entered the turbidity sensor's connector.	1. Use a stirrer to agitate the sample during measurement. 2. Perform measurement away from direct sunlight. 3. Turn the power OFF, wipe off any water droplets on the probe, then remove the turbidity sensor. Check there are no water droplets around the turbidity sensor connector, then mount the sensor again. If the error persists, replace the turbidity sensor.

4.6.2 Error displays in sensor information

Error display	Cause	Solution
Measurement sequence error	Measurement sequence error	Turn the power OFF, then restart the system. If the error persists, have the probe repaired.
Out of measurement range	The measurement value is outside the measurement range.	Samples for measurement must be within the measurement range.
Last calibration invalid	The last calibration failed.	Redo calibration.
Calibration invalid	The calibration value is the factory default value.	Redo calibration.
Background unstable	The U-53 turbidity sensor is exposed to direct light.	Mount the guard cap and sensor guard and perform measurement away from direct sunlight.
	The turbidity value changed rapidly during measurement.	Measure a sample that has stable turbidity.

5 Specifications

Specification		Basic value	Model				
			U-51	U-52	U-52G	U-53	U-53G
Sensor probe	Measurement temperature range	−10°C to 55°C	✓	✓	✓	✓	✓
	Maximum sensor outer diameter	Approx. 96 mm	✓	✓	✓	✓	✓
	Sensor length	Approx. 340 mm	✓	✓	✓	✓	✓
	Cable length	2 m (standard) 10 m/30 m (options)	✓	✓	✓	✓	✓
	Mass	Approx. 1800 g	✓	✓	✓	✓	✓
	Auto calibration function	Uses pH 4 standard solution.	✓	✓	✓	✓	✓
	Measurement depth	30 m max.	✓	✓	✓	✓	✓
	Wet-part materials*3	PPS, glass, SUS316L, SUS304, FKM, PEEK, Q, titanium, FEP membrane, POM	✓	✓	✓	✓	✓
	Waterproofing standard	IP-68	✓	✓	✓	✓	✓
Control unit	Outer dimensions (W × D × H)	115 × 66 × 283 mm	✓	✓	—	✓	—
		115 × 66 × 335 mm	—	—	✓	—	✓
	Mass	Approx. 800 g	✓	✓	✓	✓	✓
	LCD	320 × 240 mm graphic LCD (monochrome) with backlight	✓	✓	✓	✓	✓
	Memory data items	10000	✓	✓	✓	✓	✓
	Communication interface	USB peripheral	✓	✓	✓	✓	✓
	Batteries	C-size dry cells (×4)	✓	✓	✓	✓	✓
	Waterproofing standard	IP-67	✓	✓	✓	✓	✓
	GPS unit	● Reception method (12 channel parallel) ● Measurement precision [With PDOP (high precision): 30 m or less (2 drms)]	—	—	✓	—	✓
	Estimated battery life*1	—	70 hours (no backlight)			500 measurements (no backlight)	
	Storage temperature range	−10°C to 60°C	✓	✓	✓	✓	✓
	Ambient temperature range	−5°C to 45°C	✓	✓	✓	✓	✓

Specification		Basic value	Model				
			U-51	U-52	U-52G	U-53	U-53G
pH measurement Two calibration	Measurement method	Glass electrode method	✓	✓	✓	✓	✓
	Range	pH 0 to 14					
	Resolution	0.01 pH					
	Precision*2	±0.1 pH					
Dissolved oxygen measurement ● Salinity conversion (0 to 70 PPT, automatic) ● Automatic temperature compensation	Measurement method	Polarographic method	✓	✓	✓	✓	✓
	Film thickness	25 µm					
	Range	0 mg/L to 50.0 mg/L					
	Resolution	0.01 mg/L					
	Precision*2	0 mg/L to 20 mg/L: ±0.2 mg/L 20 mg/L to 50 mg/L: ±0.5 mg/L					
Electrical conductivity measurement ● Auto range ● Automatic temperature conversion (25°C)	Measurement method	Four-AC-electrode method	✓	✓	✓	✓	✓
	Range	0 S/m to 10 S/m (0 mS/cm to 100 mS/cm)					
	Resolution	0.000 mS/cm to 0.999 mS/cm: 0.001 1.00 mS/cm to 9.99 mS/cm: 0.01 10.0 mS/cm to 99.9 mS/cm: 0.1 0.0 mS/m to 99.9 mS/m: 0.1 0.100 S/m to 0.999 S/m: 0.001 1.00 S/m to 9.99 S/m: 0.01					
	Precision*2	1% of full-scale (midpoint of two calibration points)					
Salinity measurement	Measurement method	Electrical conductivity conversion	✓	✓	✓	✓	✓
	Range	0 PPT to 70 PPT (parts per thousand)					
	Resolution	0.1 PPT					
	Precision	±3 PPT					
TDS (total dissolved solid) measurement ● Conversion coefficient setting	Measurement method	Electrical conductivity conversion	✓	✓	✓	✓	✓
	Range	0 g/L to 100 g/L					
	Resolution	0.1% of full-scale					
	Repeatability	±2 g/L					
	Precision	±5 g/L					
Seawater specific gravity measurement ● σt, σ0, σ15 display	Measurement method	Electrical conductivity conversion	✓	✓	✓	✓	✓
	Range	0 σt to 50 σt					
	Resolution	0.1 σt					
	Precision	±5 σt					

Specification		Basic value	Model: U-51	U-52	U-52G	U-53	U-53G
Temperature measurement	Measurement method	Platinum temperature sensor	✓	✓	✓	✓	✓
	Range	−10°C to 55°C					
	Resolution	0.01°C					
	Sensor	Platinum temperature sensor, JIS Class B (0.3 + 0.005 |t|)					
Turbidity measurement	Measurement method		—	LED forward 30° transmission/ scattering method		Tungsten lamp 90° transmission scattering method	
	Range			0 NTU to 800 NTU		0 NTU to 1000 NTU	
	Resolution			0.1 NTU		0.01 NTU	
	Precision*2			±5%of readout or ±1 NTU, whichever is larger		● ±0.5NTU (for 0 NTU to 10 NTU measurement range) ● 3% of readout or 1 NTU, whichever is larger (for 10 NTU to 1000 NTU measurement range)	
	Turbidity sensor wiper			—		✓	
Water depth measurement	Measurement method	Pressure method	—	—	✓	✓	✓
	Range	0 m to 30 m					
	Resolution	0.05 m					
	Precision*2	±0.3 m					
ORP (oxidation reduction potential) measurement	Measurement method	Platinum electrode method	✓	✓	✓	✓	✓
	Range	−2000 ～ +2000 mV					
	Resolution	1 mV					
	Precision*2	±15 mV					

*1: Battery life is estimated under following conditions.
- Continuous operation
- Using batteries: C-size alkaline dry cells
- Ambient temperature of the control unit: 20°C or more
- Backlight off

*2: The precision is defined by measuring the standard solution in the following cases.
- Turbidity and conductivity: after four point calibration
- pH and DO: after two point calibration
- Water depth and ORP: after one point calibration

*3: Metallic parts are made of stainless steel. Immersing in seawater may erode metallic parts.

6 Reference

6.1 Consumable parts

● Sensor

Name	Model	No.	Description
pH sensor	#7112	3014057312	Standard type pH sensor
pH sensor ToupH	#7113	3200170923	Tough glass type pH sensor
ORP sensor	#7313	3200170920	
DO sensor	#7543	3200170924	
Reference electrode	#7210	3200043582	
R bush unit	—	3200043587	Reference electrode liquid junction
TURB cell U-52	#7800	3200172803	For U-52/U-52G
TURB cell U-53	#7801	3200172800	For U-53/U-53G
Membrane cap	—	3200170194	For DO sensor

● Standard solution and inner solution

Name	Model	No.	Description
pH 4 (For automatic calibration) 500 mL	#100-4	3200043638	Standard solution for auto calibration. Also used for manual pH span calibration.
pH 4 (For automatic calibration) 4 L	#140-4	3200174430	
pH 7 500 mL	#100-7	3200043637	Standard solution for pH zero-point calibration.
pH 9 500 mL	#100-9	3200043636	Standard solution for pH manual span calibration.
Powder for ORP standard solution 10 packs	#160-51	3200043618	For ORP calibration.
Powder for ORP standard solution 10 packs	#160-22	3200043617	
Inner solution for DO sensor, 50 mL	#306	3200170938	Internal solution for DO sensor.
Internal solution for pH, 250 mL	#330	3200043641	Supplementary internal solution for pH reference electrode.

● Others

Name	Model	No.	Description
Silicone grease	—	3014017718	Silicone grease for coating sensor O-ring.
Sponge brush unit	—	3200169531	Brush for cleaning sensor probe.
O-ring set for reference electrode	—	3200169376	O-rings for reference electrode.
O-ring set for DO sensor	—	3200169426	O-rings for DO sensor.
Rubber cap set for sensor guard	—	3200169428	Rubber caps used between sensor guard and sensor probe.
O-ring set for pH and ORP sensor	—	3200169520	O-rings for pH and ORP sensors.
Wiper unit	—	3200169789	Rubber wiper for U-53/U-53G turbidity sensors.
Protective cap (blk) for pH sensor	—	3200175019	Cap attached to tip of pH sensor for sensor probe storage.
Rubber cap (whit) for DO sensor	—	3200175020	Cap attached to tip of DO sensor for sensor probe storage.

6.2 Options sold separately

Name	Model	No.	Description
Bag	U-5030	3200174772	Storage bag for sensor probes and flow cell. Can be carried in one hand.
Flow cell assy	—	3200156570	Used when collecting measurement samples by pump.
Probe guard	—	3200167002	Used for taking measurements in locations where there is a current or where there is a thick layer of sludge.
Communication cable	—	3200174823	A PC connection cable. Comes with data collection software.

6.3 pH measurement

6.3.1 Principle of pH measurement

U-50 series use the glass electrode method for pH measurements. The glass electrode method measures a potential difference between the glass film for pH and the reference electrode. For more information, refer to “JIS Z 8802 pH measurement method”.

6.3.2 Temperature compensation

The electromotive force generated by the glass electrode changes depending on the temperature of the solution.

Temperature compensation is used to compensate for the change in electromotive force caused by temperature.

This function does not compensate the change in pH caused by the temperature of the solution. When pH is to be measured, the temperature of the solution must be recorded along with that pH value, even if a pH meter has automatic temperature compensation function. If the solution temperature is not recorded, the results of the pH measurement may be meaningless.

6.3.3 Standard solutions

When measuring pH, the pH meter must be calibrated using standard solution. There are five kinds of standard solutions specified in “JIS Z 8802 pH measurement”. For normal measurement, two of standard solutions with pH of 4, 7, and 9 are sufficient to accurately calibrate the meter.

For standard solutions, refer to “JIS Z 8802 pH measurement”.

pH 4 standard solution: (Phthalate) — 0.05 mol/L potassium hydrogen phthalate aqueous solution

pH 7 standard solutio: (Neutral phosphate) — 0.025 mol/L potassium dihydrogenphosphate, 0.025 mol/L disodium hydrogenphosphate aqueous solution

pH 9 standard solution: (Borate) — 0.01 mol/L sodium tetraborate aqueous solution

Table 2 pH values of pH standard solutions at various temperatures settings

Temp. (℃)	pH 4 standard solution Phthalate	pH 7 standard solution Neutral phosphate	pH 9 standard solution Borate
0	4.01	6.98	9.46
5	4.01	6.95	9.39
10	4.00	6.92	9.33
15	4.00	6.90	9.27
20	4.00	6.88	9.22
25	4.01	6.86	9.18
30	4.01	6.85	9.14
35	4.02	6.84	9.10
40	4.03	6.84	9.07
45	4.04	6.84	9.04

6.4 DO measurement

6.4.1 Principle of DO measurement

Dissolved oxygen (DO) refers to the amount of oxygen that is contained in water.

The concentration of dissolved oxygen is generally given as mg/L or as a percentage value (the dissolved oxygen saturation ratio).

Dissolved oxygen is essential for maintaining the self-purifying ability of rivers and seas and also for fish to live. The concentration of dissolved oxygen acts as an indicator of water quality. It is often measured when processing waste water and managing water quality. Fig. 1 provides an overview of the principles behind dissolved oxygen sensor measurement.

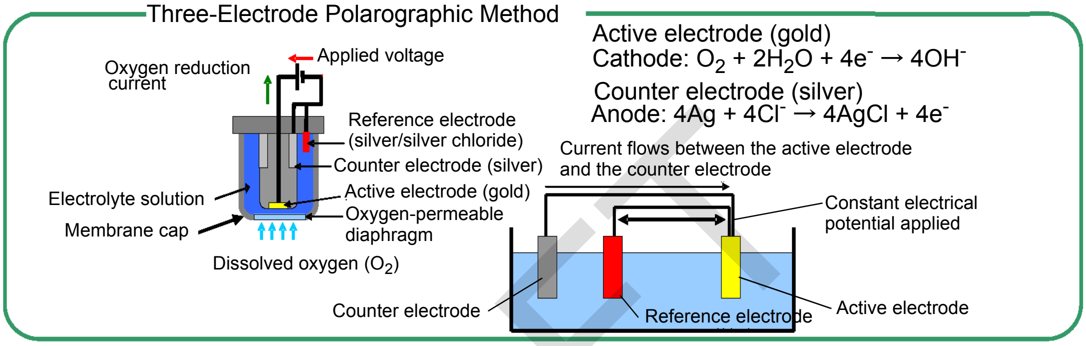


Fig. 1 Overview of principles behind dissolved oxygen sensor

The polarographic oxygen sensor is an enclosed sensor wherein voltage is applied to a cathode made of a precious metal (such as gold or platinum) and an anode also made of a precious metal (such as silver) via an external circuit, and a cap with an oxygen permeable diaphragm (membrane) is filled with electrolyte solution. As indicated in Fig. 1, the concentration of dissolved oxygen can be measured by measuring the current proportional to the amount of reduced oxygen when oxygen that has dispersed through the oxygen permeable diaphragm produces a reductive reaction on the surface of the active electrode (gold). The method of measuring dissolved oxygen based on the above principle is called the Membrane Electrode Method. Compared to the Chemical Analysis Method, which requires complicated pre-processing to alleviate the effect of reduced materials and oxidizing materials, this method allows dissolved oxygen to be measured very easily. It is also easy to remove undesired buildup from the silver electrode by polishing and cleaning if an insulator forms on it due to oxidation, making the method reusable.

6.4.2 Salinity calibration

When the solution and air come into contact and form an equilibrium (i.e. saturation), the relationship between the concentration of dissolved oxygen in the solution, C, [mol/L], and the partial pressure of oxygen in the air, Ps, [MPa/(mg/L)], can be represented by the following formula:

$C = Ps/H$

Where H [MPa/(mg/L)] is the Henry constant, a value that changes according to the composition of the solution. As H typically becomes larger as the salinity of the water increases, C becomes smaller.

The DO sensor detects the partial pressure of oxygen (Ps) in the above formula. Accordingly, if the DO sensor is immersed in deionized water saturated with air, or in an aqueous solution containing salt, the output current does not change, resulting in an erroneous measurement. For example, when salt is added to a sample, the amount of oxygen that can be dissolved in the solution decreases, but because the partial pressure of oxygen does not change, the value displayed by the control unit stays the same regardless of salt content. This concept is indicated in graph form below. (Fig. 2)

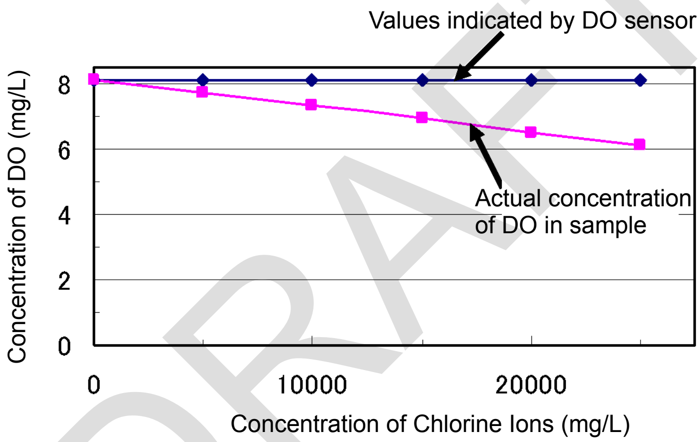


Fig. 2 Relationship between chlorine ion concentration and dissolved oxygen concentration

In samples with a high salt concentration, the solubility of oxygen is lower, but as the partial pressure of oxygen does not change, the value actually indicated on the control unit is higher than the actual value. In order to obtain a measurement of the concentration of dissolved oxygen in an aqueous solution that contains salt, it is therefore necessary to first perform salinity compensation. Conventionally, dissolved oxygen sensors have performed salinity compensation by inputting the salinity of the sample. This is fine as long as the salinity is already known. However, in most cases salinity is unknown, so even if dissolved oxygen sensors contained a salinity compensation function, it was of no practical use.

The U-50 Series can calculate and measure salinity in samples from electrical conductivity values, and can thus be used to automatically compensate for salinity.

6.5 Conductivity (COND) measurement

6.5.1 Four-AC-electrode method

Conductivity is an index of the flow of electrical current in a substance.

Salts dissolved in water are separated into cations and anions. Such solution is called electrolytic solution.

Electrolytic solution has the property of allowing the flow of current according to Ohm's law. This property is referred

to as ionic conductivity, since current flow is caused by ion movement in electrolytic solution.

Metals, on the other hand, allow the flow of current by means of electrons. This property is called electronic conductivity,

which is distinguished from ionic conductivity.

A cube with 1 m on each side, as shown in Fig. 3, is used to demonstrate an electrolytic solution. Two electrode plates are placed on opposite sides, and the cube is filled with solution. If the resistance between these two electrode plates is represented by r(Ω), the conductivity of the solution L($S \cdot m^{-1}$) is represented as L=1/r. S stands for Siemens, a unit of measurement of conductance.

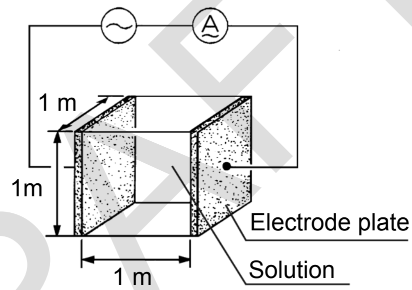


Fig. 3 Definition of conductivity

The most general method for measuring conductivity is based on the above principle, and is called the 2-electrode method.

In the 2-electrode method the influence of polarization cannot be ignored for solutions with high conductivity and conductivity cannot be measure accurately. In addition, contamination on the surface of the electrode increases apparent resistance, resulting in inaccurate measurement of conductivity.

The U-50 series has adopted the 4-electrode method to overcome these disadvantages of the the 2-electrode method.

As shown in Fig. 4, the U-50 series uses two voltage-detecting electrodes and two voltage-applying electrodes, for a total of four electrodes. The voltage-detecting electrodes are for detecting AC voltage, and the voltage-applying electrodes are for applying AC voltage.

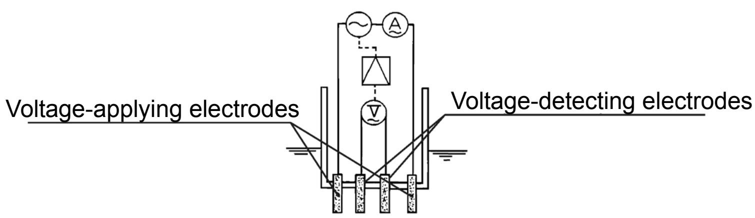


Fig. 4 Principle of the 4-electrode method

Let us assume that the current, I(A), flows in a sample of conductivity L – under automatic control of the voltage-applying electrodes – so that the voltage at the voltage-detecting-electrodes, E(V), remains constant at all times.

Then, the resistance of the sample, R(Ω), across the voltage-detecting electrodes is represented as R=E/I. The resistance, R, of the sample is inversely proportional to its conductivity, L. Accordingly, a measurement of current, Is,

of a standard solution of known conductivity, Ls, enables calculation of conductivity of a sample according to the formula L = Ls (I/Is) from the ratio L : Ls = I : Is.

Even in the 4-electrode method, polarization occurs, since AC current flows in the voltage-applying electrodes. The voltage-detecting electrodes are, however, free from the effects of polarization, since they are separated from the voltage-applying electrodes, and furthermore, current flow is negligible. Therefore, the 4-electrode method is an excellent method to enable measurement of conductivity covering a very high range.

6.5.2 SI units

New measurement units, called SI units, have been in use from 1996. Accordingly, the U-50 series also uses SI units. The following conversion table is provided for people who use the conventional kind of conductivity meter.

Note that along with the change in unit systems, the measurement values and cell counts have also changed.

	Former units	→	SI unit
Measurement value	0.1 mS/cm 1 mS/cm 100 mS/cm	→ → →	0.01 S/m 0.1 S/m 10 S/m

6.5.3 Temperature coefficient

In general, the conductivity of a solution varies largely with its temperature.

The conductivity of a solution depends on the ionic conductivity, described earlier. As the temperature rises, conductivity becomes higher since the movement of the ions becomes more active.

The temperature coefficient shows the change in % of conductivity per °C, with a certain temperature taken as the reference temperature. This is expressed in units of %/°C. The temperature coefficient assumes the premise that the conductivity of a sample changes linearly according to temperature.

Strictly speaking, with actual samples, however, conductivity changes along a curve. Furthermore, the cuve varies with the type of sample. In the ranges of smaller temperature changes, however, samples are said to have the temperature coefficient of 2%/°C (at reference temperature 25°C); this holds for most samples, except in certain special cases.

(The temperature coefficients for various types of solutions are listed on the next page.)

The U-50 series uses an automatic temperature conversion function to calculate conductivity at 25°C at a temperature

coefficient of 2 %/°C based on the measured value of the temperature. Results are displayed on the readout.

The U-50 series's temperature conversion function is based on the following formula.

$L_{25} = L_t / \{ 1 + K (t - 25) \}$

L_{25} : Conductivity of solution converted to 25°C

t : Temperature of solution at time of measurement (°C)

L_t : Conductivity of solution at t (°C)

K : Temperature coefficient (%/°C)

Conductivity and temperature coefficient for various solutions

Conductivity and related temperature coefficients of representative substances (at 25°C) are shown in the table below.

Substance	Temp. (ºC)	Conc. (wt%)	Cond. (S/m)	Temp.coef. (%/°C)	Substance	Temp. (ºC)	Conc. (wt%)	Cond. (S/m)	Temp.coef. (%/°C)
NaOH	15	5	19.69	2.01	NaCl	18	5	6.72	2.17
		10	31.24	2.17			10	12.11	2.14
		15	34.63	2.49			15	16.42	2.12
		20	32.70	2.99			20	19.57	2.16
		30	20.22	4.50			25	21.35	2.27
		40	11.64	6.48	Na_2SO_4	18	5	4.09	2.36
KOH	15	25.2	54.03	2.09			10	6.87	2.49
		29.4	54.34	2.21			15	8.86	2.56
		33.6	52.21	2.36	Na_2CO_3	18	5	4.56	2.52
		42	42.12	2.83			10	7.05	2.71
NH_3	15	0.1	0.0251	2.46			15	8.36	2.94
		1.6	0.0867	2.38	KCl	18	5	6.90	2.01
		4.01	0.1095	2.50			10	13.59	1.88
		8.03	0.1038	2.62			15	20.20	1.79
		16.15	0.0632	3.01			20	26.77	1.68
HF	18	1.5	1.98	7.20			21	28.10	1.66
		4.8	5.93	6.66	KBr	15	5	4.65	2.06
		24.5	28.32	5.83			10	9.28	1.94
HCl	18	5	39.48	1.58			20	19.07	1.77
		10	63.02	1.56	KCN	15	3.25	5.07	2.07
		20	76.15	1.54			6.5	10.26	1.93
		30	66.20	1.52			—	—	—
H_2S0_4	18	5	20.85	1.21	NH_4Cl	18	5	9.18	1.98
		10	39.15	1.28			10	17.76	1.86
		20	65.27	1.45			15	25.86	1.71
		40	68.00	1.78			20	33.65	1.61
		50	54.05	1.93			25	40.25	1.54
		60	37.26	2.13	NH_4NO_3	15	5	5.90	2.03
		80	11.05	3.49			10	11.17	1.94
		100.14	1.87	0.30			30	28.41	1.68
		—	—	—			50	36.22	1.56
HNO_3	18	6.2	31.23	1.47	$CuSO_4$	18	2.5	10.90	2.13
		12.4	54.18	1.42			5	18.90	2.16
		31	78.19	1.39			10	32.00	2.18
		49.6	63.41	1.57			15	42.10	2.31
		62	49.64	1.57	CH_3COOH	18	10	15.26	1.69
H_3PO_4	15	10	5.66	1.04			15	16.19	1.74
		20	11.29	1.14			20	16.05	1.79
		40	20.70	1.50			30	14.01	1.86
		45	20.87	1.61			40	10.81	1.96
		50	20.73	1.74			60	4.56	2.06

6.6 Salinity (SAL) conversion

The U-50 series is designed to calculate salinity as well as the other parameters.

Note that the “salinity” here is the salinity of sea water. There is a constant relation between conductivity and salinity at certain temperatures.

Therefore, if data on the conductivity and temperature are available, the corresponding salinity can be known. In other words, the salinity measurement of the U-50 series is based on the principle of calculating the salt content, making use of the measured values of conductivity and temperature.

Note therefore, that measured results of all substances whose conductivity is detected are displayed as salinity. For example, the measured result is displayed as NaCl concentration, even if in fact the sample component is, hydrochloric acid (HCl).

6.7 TDS conversion

TDS is short for Total Dissolved Solids and means the total dissolved solid amount.

The conductivity of a solution is affected by the amount of salinity, minerals, and dissolved gases. That is, conductivity is an index that shows the total amount of all substances in the solution. Of these substances, TDS indicates only the amount of dissolved solids.

TDS can be used for a comparison of the state of substances composed of a single component such as NaCl. However, the use of TDS for the comparison of solutions of different types causes serious errors.

Conductivity and TDS are expressed by the following formulas.

Conductivity in SI units (S/m) .... TDS(g/L) = L (S/m) × K × 10

TDS(g/L) = L (mS/m) × K ÷ 100

Conductivity in the old units (mS/cm) .... TDS(g/L) = L (mS/cm)× K

K = TDS coefficient

Initial settings use the values listed in the table (Page 80) that generally uses TDS coefficients.

For accurate TDS comparisons, find the TDS coefficient from measured conductivity values. Then set the value thus obtained and make measurements.

6.8 σt conversion

- **Specific gravity of seawater**

The density and specific gravity of seawater are equal numerically and generally are not distinguished strictly. Since seawater density ρ is between 1.000 and 1.031, 1 is subtracted from ρ and σ is obtained by multiplying the value by 1000.

The resultant value is used as the specific gravity of seawater.

$\sigma = (\rho - 1) \times 1000$

The density of seawater ρ is expressed by function of temperature, hydraulic pressure, and salinity. The density of seawater under the atmospheric pressure is expressed as σ_t. The density of seawater under the atmospheric pressure is determined by temperature and salinity.

The U-50 Series models make salinity measurement through temperature measurements and conductivity conversion and find σ_t through calculations.

In Japan σ_{15} at 15°C is called a standard specific gravity and widely used while in foreign countries σ_0 at 0°C is employed. σ_{15} and σ_0 are determined by the function of salinity.

In ocean surveys, in particular, these values σ_t, σ_{15}, and σ_0 are more widely used than conductivity and salinity and, in the U-50 Series models, newly added as measurement components.

6.9 Turbidity (TURB) measurement

6.9.1 Principle of turbidity measurement

U-52 and U-53 sensors measure turbidity using the Transmitting and Scattering Method shown in Fig. 5. U-52 sensors use a pulse light LED (infra-red emitting diode) as a light source, and detect scattered light from a 30° angle off center. U-53 sensors use a tungsten lamp as a light source and detect scattered light from a 90° angle. Both models display turbidity as a ratio of scattered light to transmitted light to reduce the affect of the color of the sample. The U-53 method conforms to EPA Method 180.1, and employs wipers to reduce the affect of air bubbles.

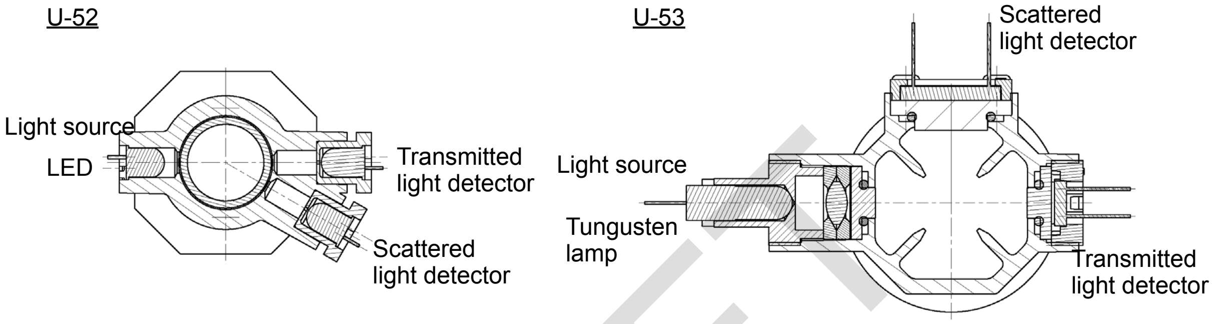


Fig. 5 Turbidity cell

6.9.2 Standard solution

U-50 series can perform calibration using formazin (NTU) or kaolin standard solutions as a turbidity standard solution. However, units for the solution used for calibration should be displayed in measurements. Do not use more than 400 mg/L of kaolin standard solution because it increases precipitation speed, resulting in measurement error.

6.10 Depth (DEPTH) measurement

6.10.1 Principle of depth measurement

For the W-22XD and W-23XD models, depth measurement can be made through use of a pressure gauge. The principle of the depth measurement uses the relation between depth and pressure.

Although the measurement with the depth sensor is affected by atmospheric pressure, the depth sensor, however, makes zero-point adjustments through the automatic calibration before measurements.

6.10.2 Influence of temperature and calibration

The depth sensor depends greatly on temperature. For a wide difference between the temperature at which the sensor has been automatically calibrated and the temperature of the measurement sample, the sensor can make depth measurements with a higher accuracy by the following method:

1. **Immerse the depth sensor of the sensor probe in the sample.**
2. **Keep the sensor immersed in the sample for about 30 minutes until the temperatures of the sensor and the sample are the same.**
3. **Then make the zero calibration of the sensor manually.**

6.11 Oxidation reduction potential (ORP) measurement

6.11.1 Principle of ORP measurement

ORP is an abbreviation for oxidation-reduction potential. ORP is the energy level (potential) determined according to the state of equilibrium between the oxidants (M^{Z+}) and reductants $M^{(Z-N)+}$ that coexist within a solution.

$$M^{Z+} + ne^{-} \Leftrightarrow M^{(Z-N)+} \quad \cdots (1)$$

If only the solution, forming the ORP measuring system shown in Fig. 6. The difference of potential between two electrodes is generally expressed by the following equation.

$$E = E_0 - \frac{RT}{nF} \ln \frac{a_M{}^{(z-n)+}}{a_M{}^{z+}} \quad \cdots (2)$$

E: Electric potential E_0 : Constant R: Gas constant T : Absolute temperature
n: Electron count F : Faraday constant a : Activity

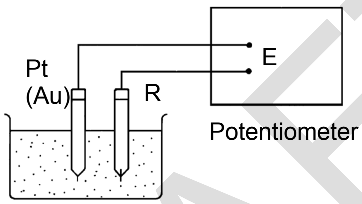


Fig. 6 Measuring mV

For example, for a solution in which trivalent iron ions coexist with bivalent iron ions, equations 1 and 2 would be as follows.

$$Fe^{3+} + e^{-} \Leftrightarrow Fe^{2+} \quad \cdots (1)$$

$$E = E_0 - \frac{RT}{F} \ln \frac{a_{Fe}{}^{2+}}{a_{Fe}{}^{3+}} \quad \cdots (2)$$

When only one type of state of equilibrium uniquely by equation (Fe^{3+}) and the reductant (Fe^{2+}) (using the equation $a_{Fe}{}^{2+}/ a_{Fe}{}^{3+}$). Actually, however many kinds of states of equilibrium exist simultaneously between various kinds of ions, in most solutions. This means that under actual circumstances, ORP cannot be expressed using the simple equation shown above and that the physical and chemical significance with respect to the solution is not very clear.

In this respect, the value of ORP must be understood to be only one indicator of the property of a solution. The measurement of ORP is widely used, however, as an important index in the analysis of solutions (potentiometric titration) and in the waste water treatment.

6.11.2 Standard electrode (reference electrode) types and ORP

The ORP is obtained comparing with corresponding reference electrode employed.

If different kinds of reference electrodes are used for measurement, the ORP value of the same solution may appear to be different. HORIBA's reference electrode uses Ag/AgCl with 3.33 mol/L KCl as inner solution. According to general technical literature, normal hydrogen electrodes (N.H.E.) are often used as the standard electrode.

The relationship between N.H.E. and the ORP that is measured using an Ag/AgCl with 3.33 mol/L KCl electrode is expressed by the following equation.

$E_{N.H.E.} = E + 206 - 0.7(t - 25)$ mV t = 0 - 60°C

$E_{N.H.E.}$: Measured ORP value using N.H.E. as the reference electrode

E: Measured ORP value using Ag/AgCl with 3.33 mol/L KCl as the reference electrode

Potential sign

Standard ORP is expressed in the following way, in literature related to electrochemistry and analytical chemistry.

A $Li^{+} + e^{-} \rightarrow Li$
$E_0 = -3.024$ V VS N.H.E.

However, in some literature, the "+" and "-" signs are reversed.

B $Li \rightarrow Li^{+} + e^{-}$
$E_0 = +3.024$ V VS N.H.E.

In expressions like B, above, the reaction is just reversed and there is no essential difference. But this kind of expression does invite confusion. The majority of the world, today, is consistent in its use of the signs as they are used in A, above.

For this reason, HORIBA, too, uses signs concerning ORP that are consistent with A, above.

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LUDLUM MODEL 19
MICRO R METER

January 2019

Serial Number 207422 and Succeeding Serial Numbers

LUDLUM MODEL 19
MICRO R METER

January 2019

Serial Number 207422 and Succeeding Serial Numbers

LUDLUM MEASUREMENTS, INC
501 OAK STREET, P.O. BOX 810
SWEETWATER, TEXAS 79556
325-235-5494, FAX: 325-235-4672

STATEMENT OF WARRANTY

Ludlum Measurements, Inc. warrants the products covered in this manual to be free of defects due to workmanship, material, and design for a period of twelve months from the date of delivery. The calibration of a product is warranted to be within its specified accuracy limits at the time of shipment. In the event of instrument failure, notify Ludlum Measurements to determine if repair, recalibration, or replacement is required.

This warranty excludes the replacement of photomultiplier tubes, G-M and proportional tubes, and scintillation crystals which are broken due to excessive physical abuse or used for purposes other than intended.

There are no warranties, express or implied, including without limitation any implied warranty of merchantability or fitness, which extend beyond the description of the face there of. If the product does not perform as warranted herein, purchaser's sole remedy shall be repair or replacement, at the option of Ludlum Measurements. In no event will Ludlum Measurements be liable for damages, lost revenue, lost wages, or any other incidental or consequential damages, arising from the purchase, use, or inability to use product.

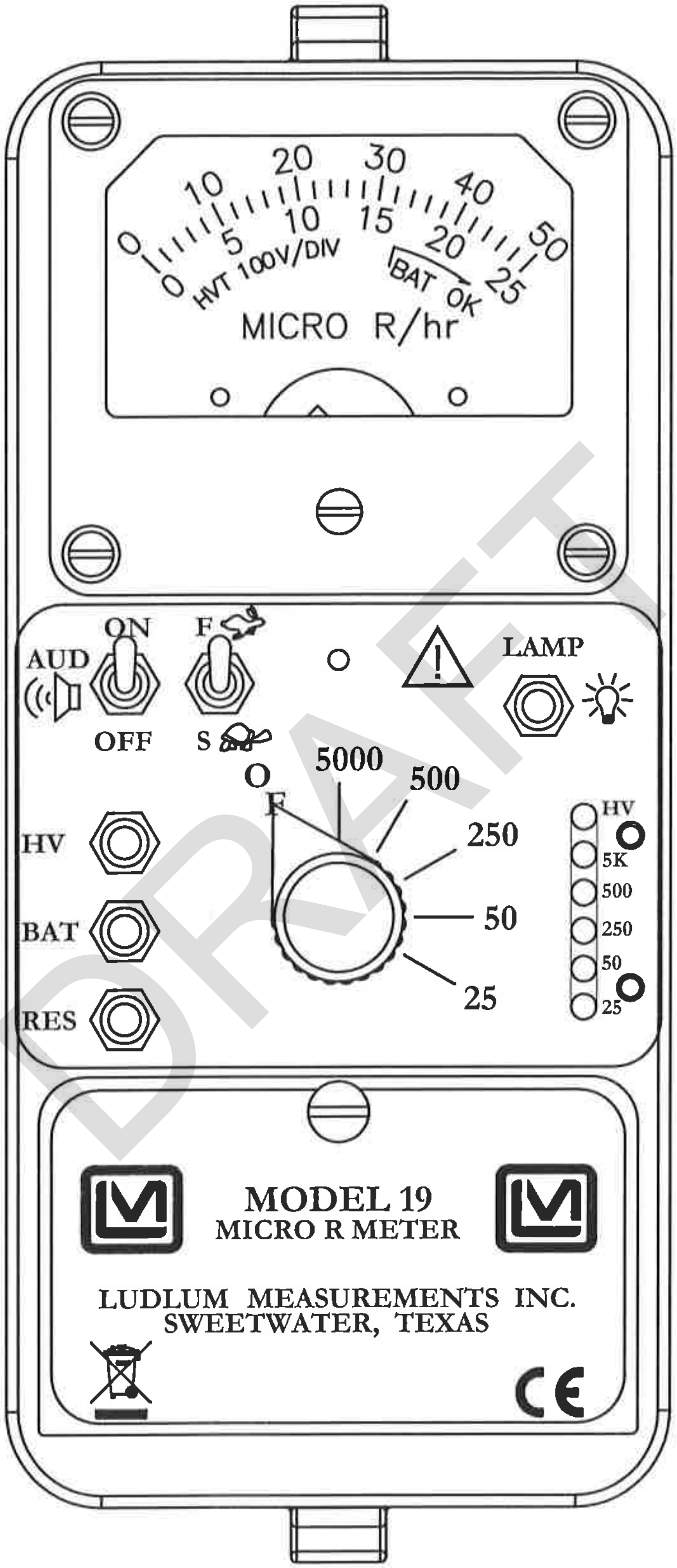
RETURN OF GOODS TO MANUFACTURER

If equipment needs to be returned to Ludlum Measurements, Inc. for repair or calibration, please send to the address below. All shipments should include documentation containing return shipping address, customer name, telephone number, description of service requested, and all other necessary information. Your cooperation will expedite the return of your equipment.

LUDLUM MEASUREMENTS, INC.
ATTN: REPAIR DEPARTMENT
501 OAK STREET
SWEETWATER, TX 79556

800-622-0828 325-235-5494
FAX 325-235-4672

REV #	ALTERATIONS	DATE	BY
1	VALID	3/16/04	DDW
2	UPDATED BATTERY LID	8/14/06	CMC
3	UPDATED METERFACE	2/15/12	CMC



DWN	DATE	CHECKED	APPROVED
CMC	2/15/12		NGW 2-15-12

TITLE: MODEL 19 ASSY

	SERIES	SHEET
LUDLUM MEASUREMENTS, INC. 501 OAK STREET SWEETWATER, TEXAS 79556	367	169

Table of Contents

Section 1

Introduction

The Ludlum Model 19 Micro R Meter utilizes an internally-mounted 2.5 x 2.5 cm (1 × 1 in.) NaI(T1) scintillator for optimum performance in locating and measuring low-level (near background) gamma radiation.

Note:

For customers in need of a Model 19 with μSv units on the meterface instead of μR units, the Model 19 Series 8 (part # 48-2582) has μSv units.

The unit features a push-button, lighted meter and was designed to be moisture and dust resistant. The meter is housed in a rugged aluminum bezel with waterproof seals. All controls, including a calibration potentiometer for each range, are located on the front panel. Front-panel switches are rubber-booted to seal out moisture and dust. A high-voltage (HV) test control is provided to allow rapid plateau testing of the detector.

Five range divisions are provided in the 0-5000 micro R/hr spectrum. The meter face is made up of two scales, 0-50 and 0-25, plus battery test. The 0-50 scale corresponds to the 50, 500 and 5000 positions on the range selector switch. The 0-25 scale corresponds to the 25 and 250 positions on the range selector switch.

The instrument is capable of using either standard "D" cell flashlight batteries or nickel-cadmium rechargeable batteries. However, the Model 19 does not include circuitry for recharging the batteries. The two "D" cell batteries are located in an isolated compartment, easily accessible from the front panel.

The Model 19 NaI scintillator is energy sensitive. An energy response curve is included in section 10 of this manual for further reference.

Section 2

Getting Started

Unpacking and Repacking

Remove the calibration certificate and place it in a secure location. Remove the instrument and accessories (batteries, cable, etc.) and ensure that all of the items listed on the packing list are in the carton. Check individual item serial numbers and ensure calibration certificates match. The Model 19 serial number is located on the front panel below the battery compartment. Most Ludlum Measurements, Inc. detectors have a label on the base or body of the detector for model and serial number identification.

Important!

If multiple shipments are received, ensure that the detectors and instruments are not interchanged. Each instrument is calibrated to specific detectors, and therefore, not interchangeable.

To return an instrument for repair or calibration, provide sufficient packing material to prevent damage during shipment. Also provide appropriate warning labels to ensure careful handling. Include detector(s) and related cable(s) for calibration. Include brief information as to the reason for return, as well as return shipping instructions:

- **Return shipping address**
- **Customer name or contact**
- **Telephone number**
- **Description of service requested and all other necessary information**

Battery Installation

Ensure the Model 19 power switch is in the "OFF" position. Open the battery lid by pushing down and turning the quarter-turn thumbscrew counterclockwise a quarter of a turn. Install two "D" size batteries in the compartment.

Note the (+) and (-) marks inside the battery door. Match the battery polarity to these marks. Close the battery box lid, push down and turn the quarter-turn thumb screw clockwise a quarter of a turn.

Note:

Center post of a flashlight battery is positive. The batteries are placed in the battery compartment in opposite directions.

Operational Check

Turn the range selector switch to the “25” position. Depress the “BAT” pushbutton switch and ensure that the meter needle falls within the “BAT OK” marks. Check for a proper background reading. A typical reading would be: 5-15 uR/hr

Turn the range selector switch to the “5000” position. Expose the instrument to a check source and verify that the instrument indicates within 20% of the check source reading obtained during the last calibration.

Switch the “AUD ON/OFF” switch to the “ON” position and confirm that the external unimorph speaker produces an audible click for each event detected. The “AUD ON/OFF” switch will silence the audible clicks if in the “OFF” position. It is recommended that the “AUD ON/OFF” switch be kept in the “OFF” position when not needed in order to preserve battery life.

Turn the range selector switch to the “250” position and increase the source activity for a meter reading of 10-100 uR/hr. While observing the meter fluctuations, select between the fast and slow response time (F/S) positions to observe variations in the display. The "S" position should respond approximately five times slower than the “F” position.

Note:

The slow response position is normally used when the instrument is displaying low numbers, which require a more stable meter movement. The fast response position is used at high rate levels.

Check the meter reset function by depressing RESET and ensuring the meter needle drops to “0.”

Depress the "LAMP" pushbutton switch. Ensure that the meter face illuminates when the switch is depressed. Proceed to use the instrument.

Maintenance

Instrument maintenance consists of keeping the instrument clean and periodically checking the batteries and the calibration. The Model 19 instrument may be cleaned with a damp cloth (using only water as the wetting agent). Do not immerse instrument in any liquid. Observe the following precautions when cleaning:

1. Turn the instrument off and remove the batteries.

2. Allow the instrument to sit for one minute before accessing internal components.

Recalibration

Recalibration should be accomplished after any maintenance or adjustment of any kind has been performed on the instrument. Battery replacements are not considered maintenance and do not normally require instrument recalibration.

Note:

Ludlum Measurements, Inc. recommends recalibration at intervals no greater than one year. Check the appropriate regulations to determine required recalibration intervals.

Ludlum Measurements offers a full-service repair and calibration department. We not only repair and calibrate our own instruments but most other manufacturers' instruments. Calibration procedures are available upon request for customers who choose to calibrate their own instruments.

Batteries

The batteries should be removed any time the instrument is placed into storage. Battery leakage may cause corrosion on the battery contacts, which must be scraped off and/or washed using a paste solution made from baking soda and water. Use a spanner wrench to unscrew the battery contact insulators, exposing the internal contacts and battery springs. Removal of the handle will facilitate access to these contacts.

Note:

Never store the instrument over 30 days without removing the batteries. Although this instrument will operate at very high ambient temperatures, battery seal failure may occur at temperatures as low as 37 °C (100 °F).

Section 3

Specifications

Linearity: reading within 10% of true value

High Voltage: variable from 400 to 1500 Vdc; electronically regulated to within 1%

Battery Dependence: instrument calibration change less than 3% within the meter battery check limits

Power: two standard alkaline "D" cell batteries, secured in an isolated compartment

Battery Life: expected lifetime of approximately 2000 hours with the "AUD ON/OFF" switch in the OFF position

Audio Output: built-in unimorph speaker and "ON/OFF" switch provided on the front panel

Counting Ranges: two-scale meter face presenting 0-50 μR/hr with full scale range positions of 5000, 500 and 50; and 0-25 μR/hr with full scale range positions of 250 and 25.

Meter: 1 mA, 6.4 cm (2.5 in.) scale, pivot-and-jewel suspension

Detector: photomultiplier coupled to a 2.5 x 2.5 (1 × 1 in.) NaI(Tl) crystal, mounted inside the instrument housing

Construction: cast-and-drawn aluminum with beige powder-coat finish and printed membrane front panel

Size: 15.2 x 8.9 x 21.6 cm (6.0 x 3.5 x 8.5 in.), not including instrument handle

Weight: 2.04 kg (4.5 lb), including batteries

Section 4

Identification of Controls and Functions

Range Selector Switch: a six-position switch marked OFF, 5000, 500, 250, 50, and 25. Moving the range selector switch to one of the range positions (5000, 500, 250, 50, 25) provides the operator with an overall range of 0-5000 μR/hr. Note that the range positions 5000, 500 and 50 are screened in black and correspond to the meter scale screened in black. The range positions 250 and 25 are screened in red and correspond to the meter scale screened in red.

AUD ON-OFF Toggle Switch: In the ON position, the switch operates the unimorph speaker, located on the left side of the instrument. The frequency of the clicks is relative to the rate of the incoming pulses. The higher the rate is, the higher the audio frequency. The audio should be turned OFF when not required in order to reduce battery drain.

F-S Toggle Switch: provides meter response. Selecting the fast, "F," position of the toggle switch provides 90% of full-scale meter deflection in four seconds. In the slow, "S," position, 90% of full-scale meter deflection takes 22 seconds. In "F" position, there is fast response and large meter deviation. The "S" position should be used for slow response and damped, meter deviation.

BAT Pushbutton Switch: when depressed, this switch indicates the battery charge status on the meter. The range selector switch must be out of the OFF position.

RES Pushbutton Switch: When depressed, this switch provides a rapid means to drive the meter to zero.

LAMP Pushbutton Switch: When depressed, this switch lights the meter face.

HV Pushbutton Switch: When depressed, the meter reads the detector high voltage. Each meter division is equivalent to 100 V.

HV Adjustment: provides a means to vary the high voltage from 400 to 1500 V.

Range Calibration Adjustments: recessed potentiometers located under the calibration cover on the right side of the front panel. These adjustment controls allow individual calibration for each range multiplier.

Section 5

Safety Considerations

Environmental Conditions for Normal Use

Indoor or outdoor use

No maximum altitude

Temperature range of -20 to 50 °C (-4 to 122 °F)

Maximum relative humidity of less than 95% (non-condensing)

Pollution Degree 3 (as defined by IEC 664) (Occurs when conductive pollution or dry nonconductive pollution becomes conductive due to condensation. This is typical of industrial or construction sites.)

Warning Markings and Symbols

Caution!

The operator or responsible body is cautioned that the protection provided by the equipment may be impaired if the equipment is used in a manner not specified by Ludlum Measurements, Inc.

The Model 19 Micro R Meter is marked with the following symbols:

CAUTION (per ISO 3864, No. B.3.1) – designates hazardous live voltage and risk of electric shock. During normal use, internal components are hazardous live. This instrument must be isolated or disconnected from the hazardous live voltage before accessing the internal components. This symbol appears on the front panel. **Note the following precautions:**

Warning!

The operator is strongly cautioned to take the following precautions to avoid contact with internal hazardous live parts that are accessible using a tool:

1. Turn the instrument power OFF and remove the batteries.
2. Allow the instrument to sit for one minute before accessing internal components.

The "**crossed-out wheelie bin**" symbol notifies the consumer that the product is not to be mixed with unsorted municipal waste when discarding; each material must be separated. The symbol is placed on the battery compartment lid. See section 8, "Recycling," for further information.

The "CE" mark is used to identify this instrument as being acceptable for use within the European Union.

Cleaning and Maintenance Precautions

The Model 19 may be cleaned externally with a damp cloth, using only water as the wetting agent. Do not immerse the instrument in any liquid. Observe the following precautions when cleaning or performing maintenance on the instrument:

1. Turn the instrument OFF and remove the batteries.

2. Allow the instrument to sit for one minute before cleaning the exterior or accessing any internal components for maintenance.

Section 6

Troubleshooting

Occasionally, you may encounter problems with your LMI instrument or detector that may be repaired or resolved in the field, saving turn-around time and expense in returning the instrument to us for repair. Toward that end, LMI electronics technicians offer the following tips for troubleshooting the most common problems. Where several steps are given, perform them in order until the problem is corrected. Keep in mind that with this instrument, the most common problems encountered are: (1) sticky meters; and (2) battery contacts.

Note that the first troubleshooting tip is for determining whether the problem is with the electronics or with the detector. A Ludlum Model 500 Pulser is invaluable at this point, because of its ability to simultaneously check high voltage, input sensitivity or threshold, and the electronics for proper counting.

We hope these tips will prove to be helpful. As always, please call if you encounter difficulty in resolving a problem or if you have any questions.

Troubleshooting Electronics which Utilize a Scintillation Detector

SYMPTOM	POSSIBLE SOLUTION
No power (or meter does not reach BAT TEST or BAT OK mark)	1. Check batteries and replace if weak. 2. Check polarity (see marks inside batter lid). Are the batteries installed backwards?

SYMPTOM	**POSSIBLE SOLUTION**
No power (or meter does not reach BAT TEST or BAT OK mark) (continued)	3. Check battery contacts. Clean them with rough sandpaper or use an engraver to clean the tips.
	4. Check for loose or broken wires, especially between the main board and the calibration board.
Nonlinear Readings	1. Check the high voltage (HV) by pressing the HV TEST button. If a multimeter is used to check the HV, ensure that one with high impedance is used, as a standard multimeter could be damaged in this process.
	2. Check for "sticky" meter movement. Does the reading change when you tap the meter? Does the meter needle "stick" at any spot?
	3. Check the "meter zero." Turn the power OFF. The meter should come to rest on "0."
Meter goes full-scale or "pegs out"	1. Check the HV and, if possible, the input threshold for proper setting.
	2. Check for loose wires, especially between the main board and the calibration board.

Section 7

Technical Theory of Operation

Detector

The detector consists of a crystal of sodium iodide with Thallium activation (NaI Tl) that gives off light pulses when penetrated by radiation photons.

The light pulses are converted to electrical pulses by the photo cathode of the photomultiplier tube. The photomultiplier includes a nine-stage electron amplifier. This amplifier utilizes an electrostatic field for each stage, adding up to a required 500 to 1500 V supply.

Input

Detector pulses are coupled from the detector through C6 to the amplifier. CR1 protects the amplifier from input shorts. R37 couples the detector to the high-voltage supply.

Amplifier

A self-biased amplifier provides gain in proportion to R15 and C4 divided by R14. Transistor (pin 3 of U4) provides amplification. U6 is configured as a current mirror to provide a load for pin 3 of U4. The output self biases to 2 Vbe (approximately 1.4 volts) at emitter of Q1. This provides just enough bias current through pin 3 of U4 to conduct all of the current from the current mirror.

Positive pulses at R16 are coupled to the discriminator through C5.

Discriminator

Comparator U8 provides discrimination. The discriminator is set by the voltage divider, R21 and R23, coupled to pin 3 of U8. U8 output pulses are coupled to pin 5 of U9A for meter drive and pin 12 of U9B for audio.

Audio

Discriminator pulses are coupled to univibrator pin 12 of U9B. Front-panel audio ON-OFF selector controls the reset at pin 13 of U9B. When ON, pulses from pin 10 of U9B turn on oscillator U12, which drives the can-mounted unimorph. Speaker tone is set by R31, C14; duration by R22, C7.

Scale Ranging

Detector pulses from the discriminator are coupled to univibrator pin 5 of U9A. For each scale, the pulse width of pin 6 of U9A is controlled by the front-panel calibration controls and their related capacitors. This arrangement allows the same current to be delivered to C9 in proportion to the meter reading.

Digital Analog Converter

U5 is configured as a current mirror. For each pulse of current through R24, an equal current is delivered to C9. This charge is drained off by R25. The voltage across C9 is proportional to the incoming count rate.

Meter Drive

The meter is driven by the collector of Q2 coupled as a voltage follower in conjunction with pin 1 of U10.

For the battery test, the voltage follower is bypassed and the meter movement is directly coupled to the battery through R8.

Fast/Slow Time Constant

For slow-time constant, C17 is switched from the output of the meter drive to parallel C9.

Low Voltage Supply

Battery voltage is coupled to U11 and associated components (a switching regulator) to provide 5 V at pin 8 to power all circuits.

High Voltage Test

A constant current is developed by collector of Q3 in proportion to HV signal at pin 1 of U17. U16 provides a current mirror to drive the meter through analog switch logic circuit U15, U14, and U3.

High Voltage Supply

High voltage is developed by switching regulator U13 and T1. Voltage multiplier CR3 thru CR7, and associated components, develop the detector voltage. Voltage feedback is provided by R39 thru U17 to feed back pin 8 of U13 for voltage regulation. Pin 1 of U17 is proportional to the high voltage, and its output is also utilized to measure the high voltage. High voltage is adjusted by varying the feedback current with R42.

Section 8

Recycling

Ludlum Measurements, Inc. supports the recycling of the electronics products it produces for the purpose of protecting the environment and to comply with all regional, national, and international agencies that promote economically and environmentally sustainable recycling systems. To this end, Ludlum Measurements, Inc. strives to supply the consumer of its goods with information regarding reuse and recycling of the many different types of materials used in its products. With many different agencies – public and private – involved in this pursuit, it becomes evident that a myriad of methods can be used in the process of recycling. Therefore, Ludlum Measurements, Inc. does not suggest one particular method over another, but simply desires to inform its consumers of the range of recyclable materials present in its products, so that the user will have flexibility in following all local and federal laws.

The following types of recyclable materials are present in Ludlum Measurements, Inc. electronics products, and should be recycled separately. The list is not all-inclusive, nor does it suggest that all materials are present in each piece of equipment:

Batteries	Glass	Aluminum and Stainless Steel
Circuit Boards	Plastics	Liquid Crystal Display (LCD)

Ludlum Measurements, Inc. products, which have been placed on the market after August 13, 2005, have been labeled with a symbol recognized internationally as the "crossed-out wheelie bin." This notifies the consumer that the product is not to be mixed with unsorted municipal waste when discarding; each material must be separated. The symbol will be placed near the AC receptacle, except for portable equipment where it will be placed on the battery lid.

The symbol appears as such: 

Section 9

Parts List

Model 19 Micro R Meter

Reference	Description	Part Number
UNIT	Completely Assembled Model 19 Micro R Meter	48-1615

Main Board, Drawing 367 × 166

Reference	Description	Part Number
BOARD	Completely Assembled Circuit Board	5367-166

CAPACITORS

Reference	Description	Part Number
C1	47pF, 100V	04-5660
C2	0.0022µF, 50V	04-5676
C3	0.001µF, 100V	04-5659
C4	10pF, 100V	04-5673
C5	0.01µF, 50V	04-5664
C6	100pF, 3KV	04-5735
C7	0.022µF, 50V	04-5667
C8	1µF, 16V	04-5701
C9	10µF, 25V	04-5655
C10	100pF, 100V	04-5661
C11	68µF, 10V	04-5654
C12	10µF, 25V	04-5728
C14	470pF, 100V	04-5668
C17	47µF, 10V	04-5666
C18-C27	0.01µF, 500V	04-5696
C28	0.001µF, 2KV	04-5703
C29	68µF, 10V	04-5654
C30-C31	1µF, 16V	04-5701
C32	270pF, 100V	04-5679
C33	0.01µF, 50V	04-5664

	Reference	Description	Part Number
TRANSISTORS	Q1	MMBT3904LT1	05-5841
	Q2	MMBT4403LT1	05-5842
	Q3	MMBT3904LT1	05-5841
VOLTAGE REGULATOR	VR1	LT1460KCS3-2.5TR	05-5867
INTEGRATED CIRCUITS	U1-U3	MAX4542ESA	06-6453
	U4-U5	CMXT3904	05-5888
	U6	CMXT3906	05-5890
	U7	MAX4541ESA	06-6452
	U8	MAX985EUK-T	06-6459
	U9	CD74HC4538M	06-6297
	U10	LMC7111BIM5X	06-6410
	U11	LT1304CS8-5	06-6434
	U12	MIC1557BM5	06-6457
	U13	LT1304CS8	06-6394
	U14-U15	MAX4542ESA	06-6453
	U16	CMXT3906	05-5890
	U17-C18	LMC7111BIM5X	06-6410
DIODES	CR1	CMPD2005S	07-6468
	CR2	CMSH1-40M	07-6411
	CR3-CR7	CMPD2005S	07-6468
	CR9	CMSH1-40M	07-6411
SWITCHES	SW1	RANGE SELECTOR	08-6761
	SW2	HV TEST	7464-186
	SW3	F-S TOGGLE	08-6781
	SW4	AUD ON-OFF TOGGLE	08-6781
	SW5	RES PUSHBUTTON	7464-186
	SW6	LAMP PUSHBUTTON	7464-186
	SW7	BAT PUSHBUTTON	7464-186
POTENTIOMETERS / TRIMMERS	R33	1M, 64W105 NAME	09-6814
	R34	1M, 64W105 X10	09-6814
	R35	1M, 64W105 X1	09-6814
	R36	1M, 64W105 X0.1	09-6814
	R41	100K, 64W104 X100	09-6813

	Reference	Description	Part Number
	R42	100K, 64W104 HV ADJ	09-6813
	R52	10K, 3266X1-103 NAME	09-6822
RESISTORS			
	R1-R5	200K, 1/8W, 1%	12-7992
	R6	8.25K, 1/8W, 1%	12-7838
	R7	10K, 1/8W, 1%	12-7839
	R8	2.37K, 1/8W, 1%	12-7861
	R9-R11	10K, 1/8W, 1%	12-7839
	R12	200 Ohm, 1/8W, 1%	12-7846
	R13	10K, 1/8W, 1%	12-7839
	R14	4.75K, 1/8W, 1%	12-7858
	R15	200K, 1/8W, 1%	12-7992
	R16	10K, 1/8W, 1%	12-7839
	R17	1K, 1/8W, 1%	12-7832
	R18	4.75K, 1/8W, 1%	12-7858
	R19	2K, 1/8W, 1%	12-7926
	R20-R21	100K, 1/4W, 1%	12-7834
	R22	1M, 1/8W, 1%	12-7844
	R23	2.49K, 1/8W, 1%	12-7999
	R24	14.7K, 1/8W, 1%	12-7068
	R25	200K, 1/4W, 1%	12-7992
	R26	100K, 1/4W, 1%	12-7834
	R27	68.1K, 1/8W, 1%	12-7881
	R28	100K, 1/8W, 1%	12-7834
	R29	1K, 1/8W, 1%	12-7832
	R30	100K, 1/8W, 1%	12-7834
	R31	475K, 1/8W, 1%	12-7859
	R32	100K, 1/8W, 1%	12-7834
	R37	100K, 1/8W, 1%	12-7834
	R38	4.75M, 1/8W, 1%	12-7995
	R39	500M, 3KV, 2%	12-7031
	R40	1M, 1/4W, 1%	12-7844
	R43	22.1K, 100mW, 1%	12-7094
	R44	1K, 1/4W, 1%	12-7832
	R45	8.25K, 1/8W, 1%	12-7838
	R46-R48	200K, 1/4W, 1%	12-7992
	R49	825K, 1/8W, 1%	12-7005
	R50	953K, 1/8W, 1%	12-7950
	R53	1K, 1/4W, 1%	12-7832

	Reference	Description	Part Number
CONNECTORS			
	P1	CONN-640456-4 MTA100x4 NAME	13-8088
	P2	CONN-640456-3 MTA100x3 NAME	13-8081
	P3	CONN-640456-2 MTA100x2 NAME	13-8073
	P4	CONTACT #1434 NAME	18-9124
INDUCTOR			
	L1	22µH, CD43-220	21-9808
TRANSFORMER			
	T1	31032R	21-9925
AUDIO			
	DS1	Model 19 LAMP BOARD 5367-113	5367-113
	DS2	UNIMORPH TEC-3526-PU	21-9251
CONNECTOR			
	P1	MTA100x4 MAIN BOARD 5367-166	13-8170
	P2	MTA 100x3 MAIN BOARD 5367-166	13-8135
	P3	MTA 100x2 MAIN BOARD 5367-166	13-8178
BATTERY	B1-B2	DURACELL "D"	21-9313
MISCELLANEOUS			
	*	MODEL 19 INTERNAL DETECTOR	47-3426
	*	TUBE/XTAL ASSY	2004-061
	M1	MODEL 19 METER ASSY 987010-001 1mA	4367-024
	*	MODEL 19 METERFACE	9202-1070
	*	METER BEZEL W/ GLASS W/ SCREWS	4363-352-00
	*	METER MOVEMENT (1mA)	15-8030
	*	Model 19 BATTERY BOX LID W/CNTCT	2363-191
	*	DEEP PORTABLE CAN ASSY	4363-615

Reference	Description	Part Number
*	MODEL 19 CASTING	7367-171
*	MODEL 19 MAIN HARNESS	8367-170
*	PORTABLE KNOB	08-6613
*	SWITCH SEAL (P/B)	08-6611
*	UNIMORPH W/WIRES, O'RING	40-0034
*	CAL COVER W/SCREWS	4363-200
*	HANDLE- PORTABLE (GRIP)	7363-139

Section

10

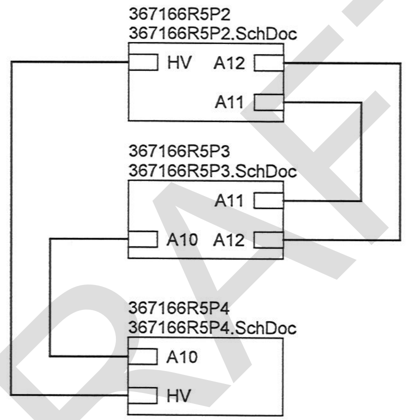
Drawings

Model Board Circuit, Drawing 367 × 166 (4 sheets)

Model Board Component Layouts, Drawings 367 × 167A (2 sheets)

Wiring Diagram, Drawing 367 × 174

Energy Response for Ludlum Model 19



LUDLUM MEASUREMENTS, INC.
PO Box 810
501 Oak Street
Sweetwater, Texas 79556
U.S.A. 1-800-622-0828

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Design: DL	5/22/2017	**Model:** 19		
		Board#: 5367-166		
Approve:		**Sheet:** 1 of 4	**Series** 367	**Sheet** 166
Print Date: 8/17/2017	9:11:44 AM	**Rev:** 5		
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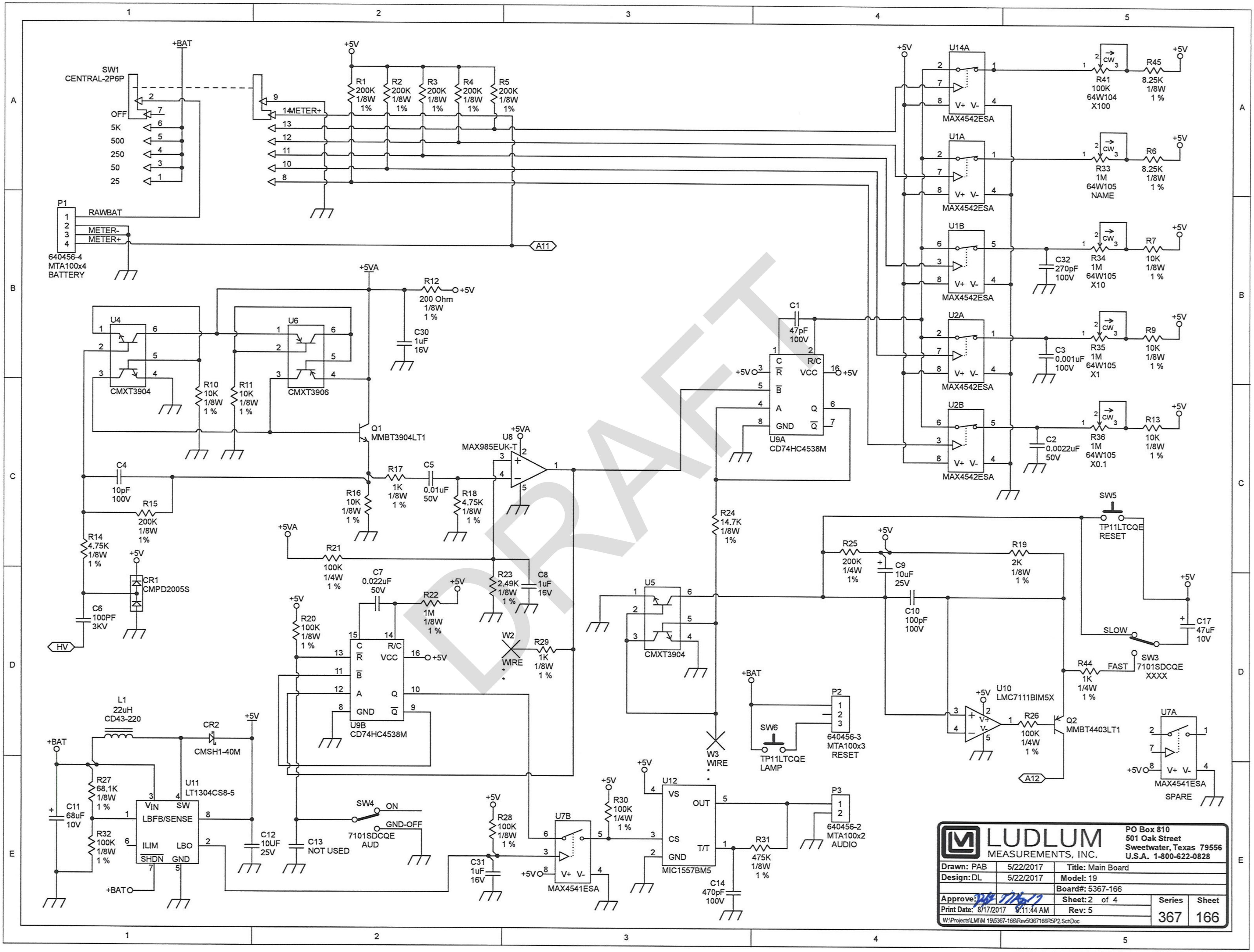
DRAFT
SW1 CENTRAL-2P6P
OFF 5K 500 250 50 25
METER+
P1 RAWBAT METER- METER+
640456-4 MTA100x4 BATTERY
A11
R1 200K 1/8W 1%
R2 200K 1/8W 1%
R3 200K 1/8W 1%
R4 200K 1/8W 1%
R5 200K 1/8W 1%
U14A MAX4542ESA
U1A MAX4542ESA
U1B MAX4542ESA
U2A MAX4542ESA
U2B MAX4542ESA
R41 100K 64W104 X100
R45 8.25K 1/8W 1 %
R33 1M 64W105 NAME
R6 8.25K 1/8W 1 %
R34 1M 64W105 X10
R7 10K 1/8W 1 %
C32 270pF 100V
R35 1M 64W105 X1
R9 10K 1/8W 1 %
C3 0.001uF 100V
R36 1M 64W105 X0.1
R13 10K 1/8W 1 %
C2 0.0022uF 50V
+5VA
R12 200 Ohm 1/8W 1 %
C30 1uF 16V
U4 CMXT3904
U6 CMXT3906
R10 10K 1/8W 1 %
R11 10K 1/8W 1 %
Q1 MMBT3904LT1
U8 MAX985EUK-T
C4 10pF 100V
R15 200K 1/8W 1%
R14 4.75K 1/8W 1 %
CR1 CMPD2005S
C6 100PF 3KV
HV
R16 10K 1/8W 1 %
R17 1K 1/8W 1 %
C5 0.01uF 50V
R18 4.75K 1/8W 1 %
C1 47pF 100V
U9A CD74HC4538M
R24 14.7K 1/8W 1%
R21 100K 1/4W 1 %
R23 2.49K 1/8W 1 %
C8 1uF 16V
C7 0.022uF 50V
R22 1M 1/8W 1 %
R20 100K 1/8W 1 %
U9B CD74HC4538M
W2 WIRE
R29 1K 1/8W 1 %
U5 CMXT3904
W3 WIRE
SW5 TP11LTCQE RESET
R25 200K 1/4W 1%
C9 10uF 25V
R19 2K 1/8W 1 %
C10 100pF 100V
C17 47uF 10V
SLOW FAST
SW3 7101SDCQE XXXX
R44 1K 1/4W 1 %
U10 LMC7111BIM5X
R26 100K 1/4W 1 %
Q2 MMBT4403LT1
A12
U7A MAX4541ESA SPARE
P2 640456-3 MTA100x3 RESET
SW6 TP11LTCQE LAMP
L1 22uH CD43-220
CR2 CMSH1-40M
C11 68uF 10V
R27 68.1K 1/8W 1 %
R32 100K 1/8W 1 %
U11 LT1304CS8-5
C12 10UF 25V
C13 NOT USED
SW4 7101SDCQE AUD ON GND-OFF
R28 100K 1/8W 1 %
C31 1uF 16V
U7B MAX4541ESA
R30 100K 1/4W 1 %
U12 MIC1557BM5
R31 475K 1/8W 1 %
C14 470pF 100V
P3 640456-2 MTA100x2 AUDIO
LUDLUM MEASUREMENTS, INC.
PO Box 810
501 Oak Street
Sweetwater, Texas 79556
U.S.A. 1-800-622-0828
Drawn: PAB 5/22/2017
Design: DL 5/22/2017
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Model: 19
Board#: 5367-166
Sheet: 2 of 4
Rev: 5
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Series 367
Sheet 166
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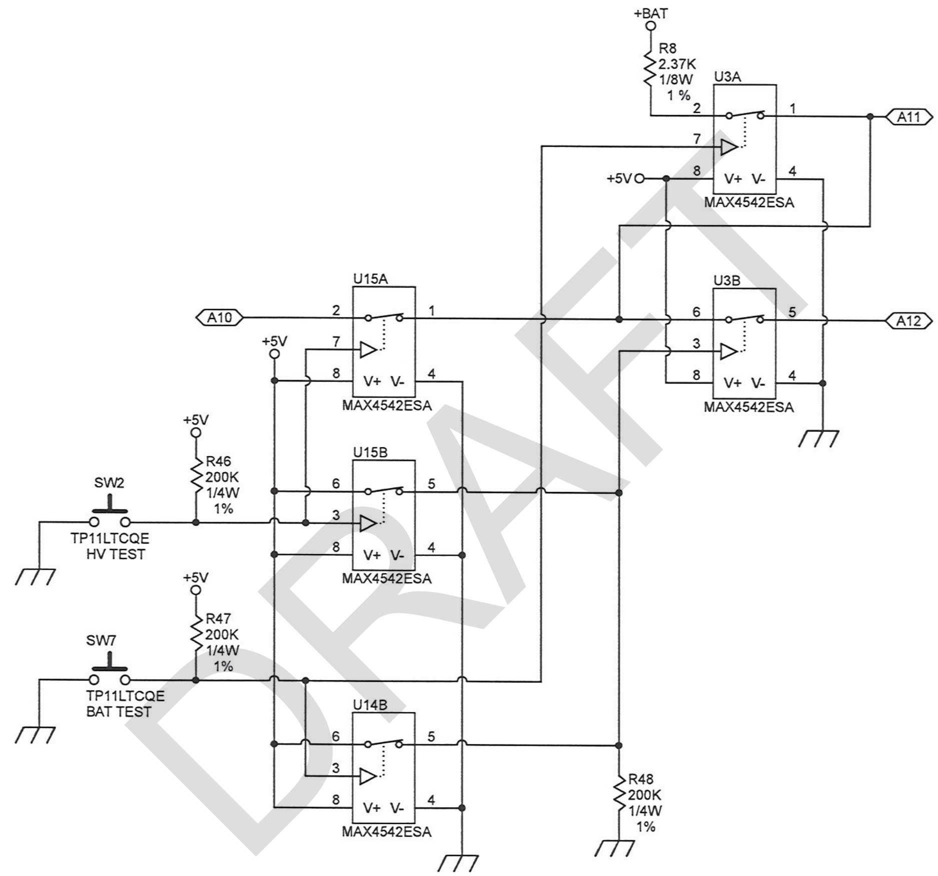

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		Board#: 5367-166		
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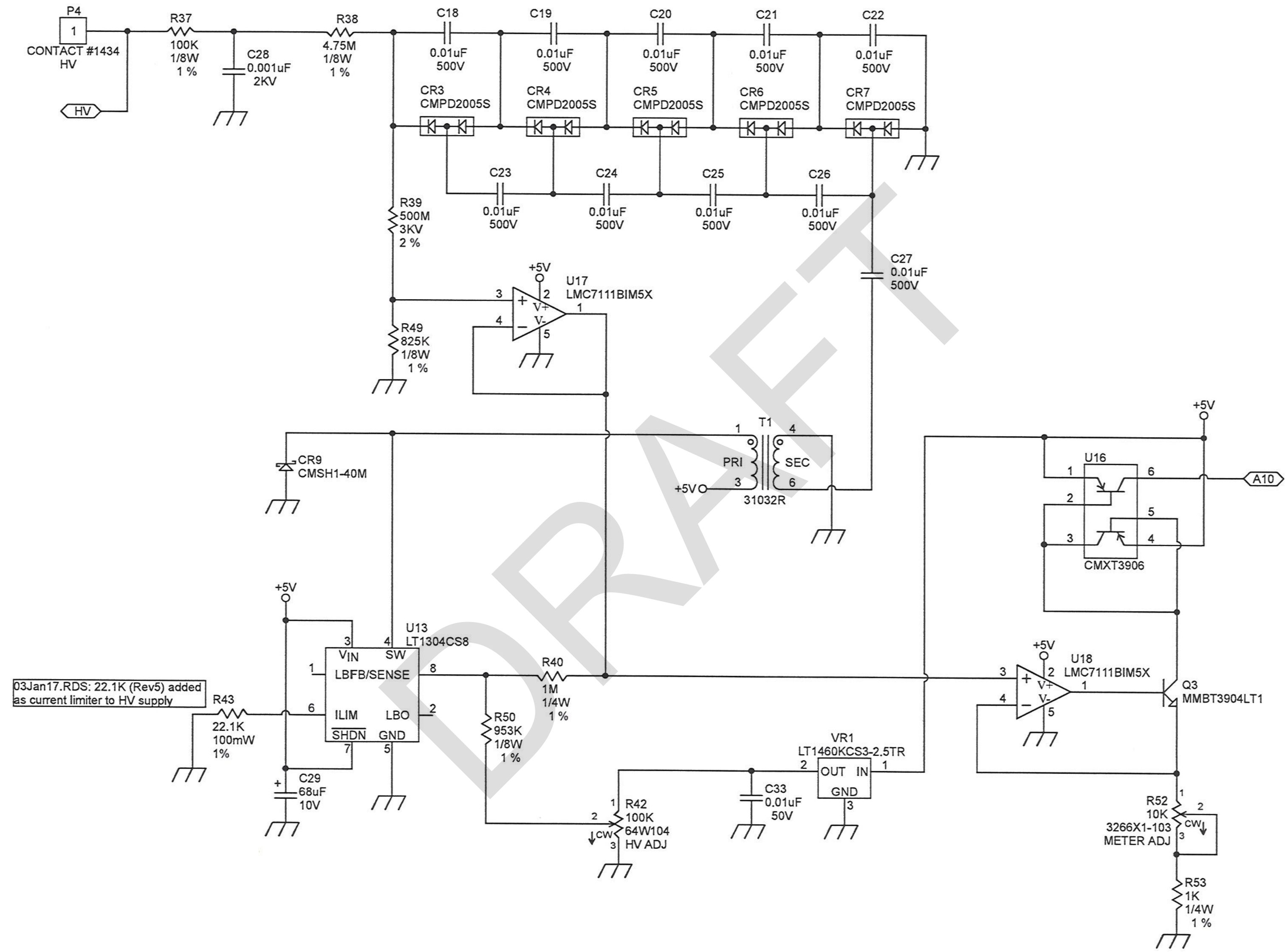

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PO Box 810
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		Board#: 5367-166
Approve:		Sheet: 4 of 4
Print Date: 8/17/2017	9:11:45 AM	Rev: 5

Series 367 Sheet 166

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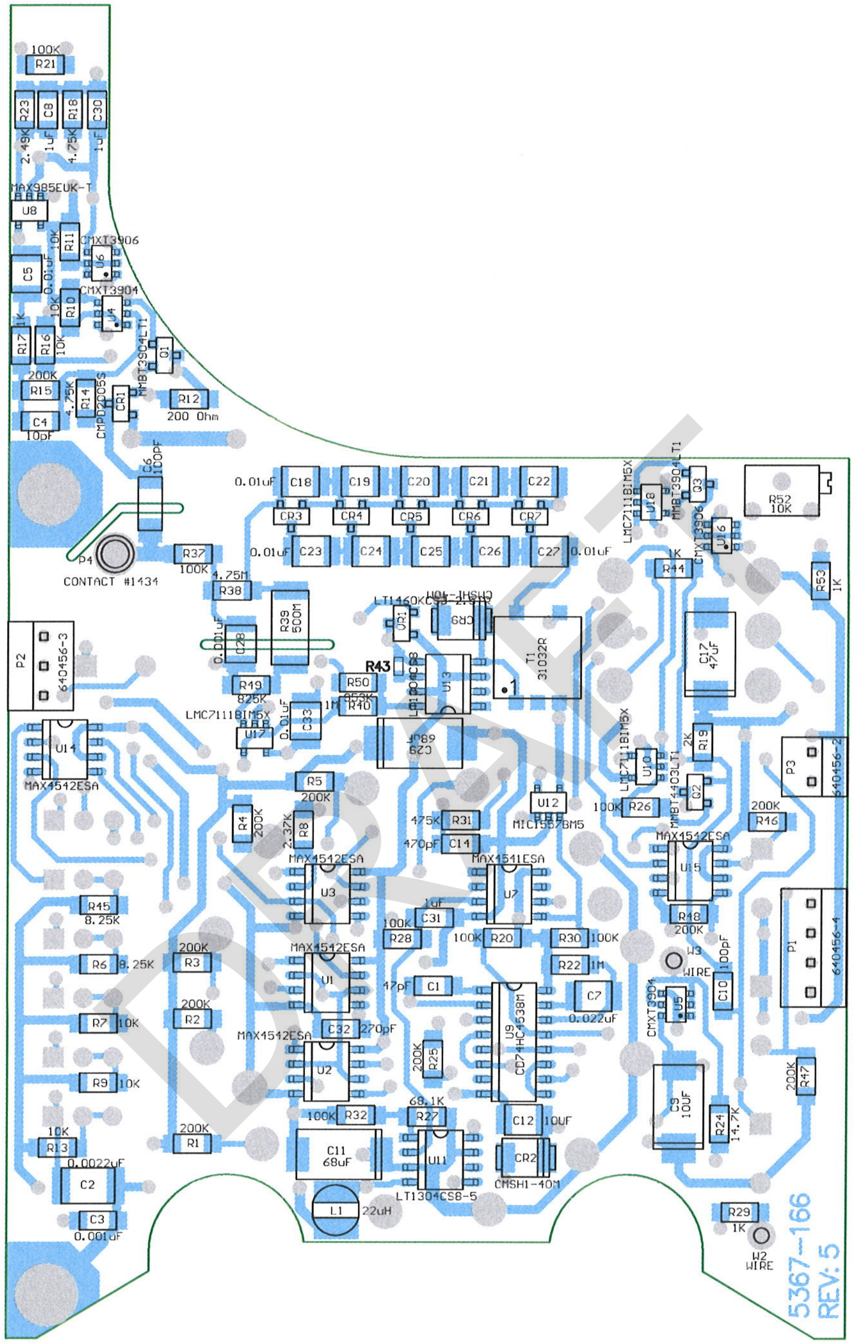

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PO Box 810
501 Oak Street
Sweetwater, TX 79556
U.S.A. 1-800-622-0828

Title: Main Board				
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Design: DL	5/22/2017	**Board#:** 5367-166		
Approve:		**Rev:** 5		
Print Date: 8/17/2017	9:12:03 AM	**SCALE: 1.00** Top Overlay	**Series** 367	**Sheet** 167 A

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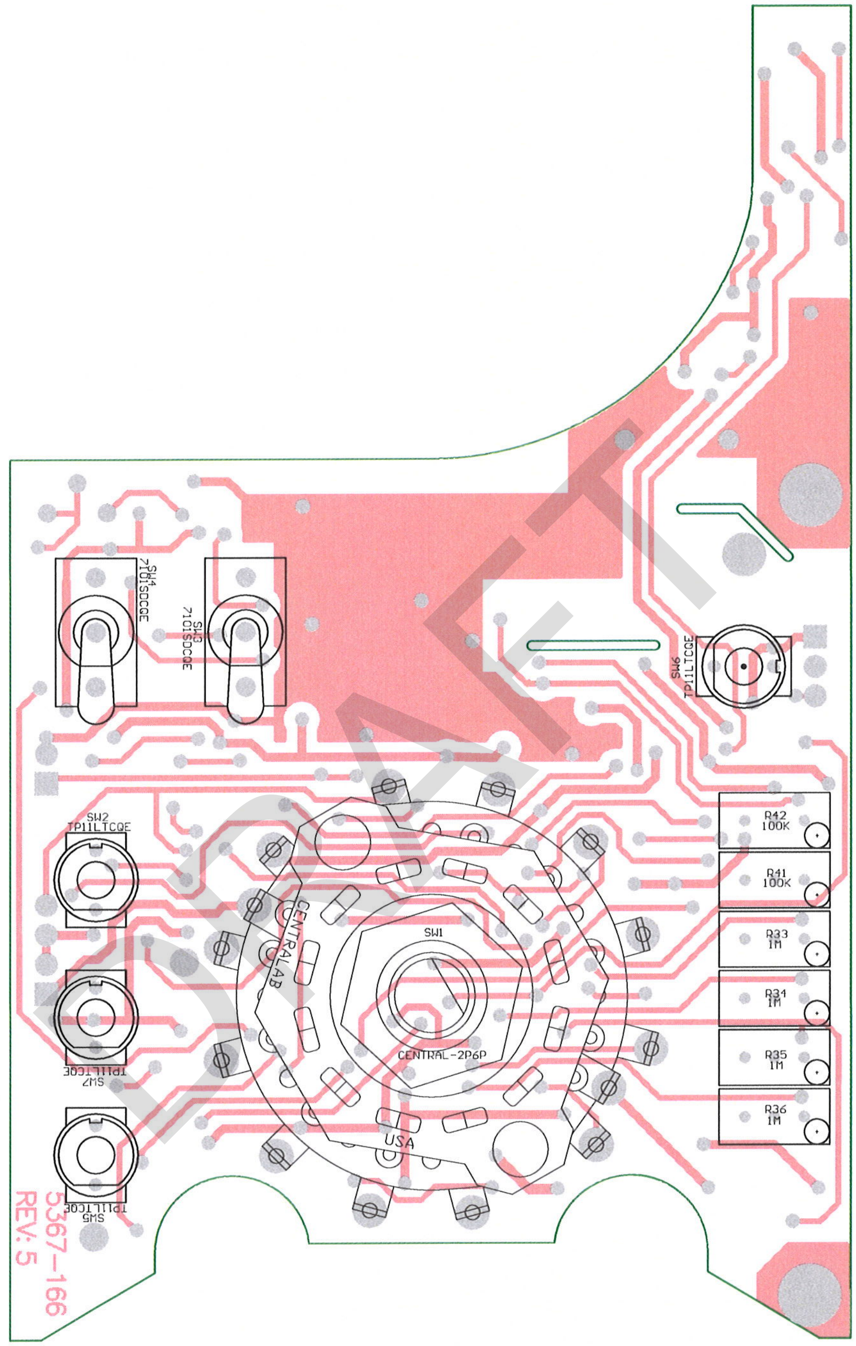

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PO Box 810
501 Oak Street
Sweetwater, TX 79556
U.S.A. 1-800-622-0828

Title: Main Board				
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Design: DL	5/22/2017	**Board#:** 5367-166		
Approve: RSS	17 Aug 17	**Rev:** 5		
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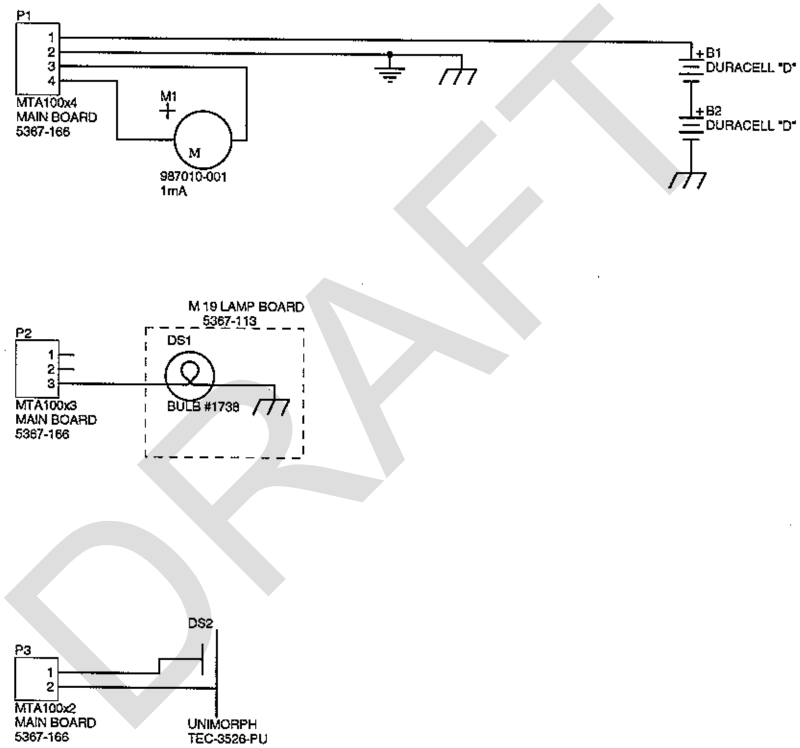

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Sweetwater, Texas 79556
U.S.A. 1-800-622-0828

Drawn: MEB	02-APR-04	Title: WIRING DIAGRAM	
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		Board#: 367-174	
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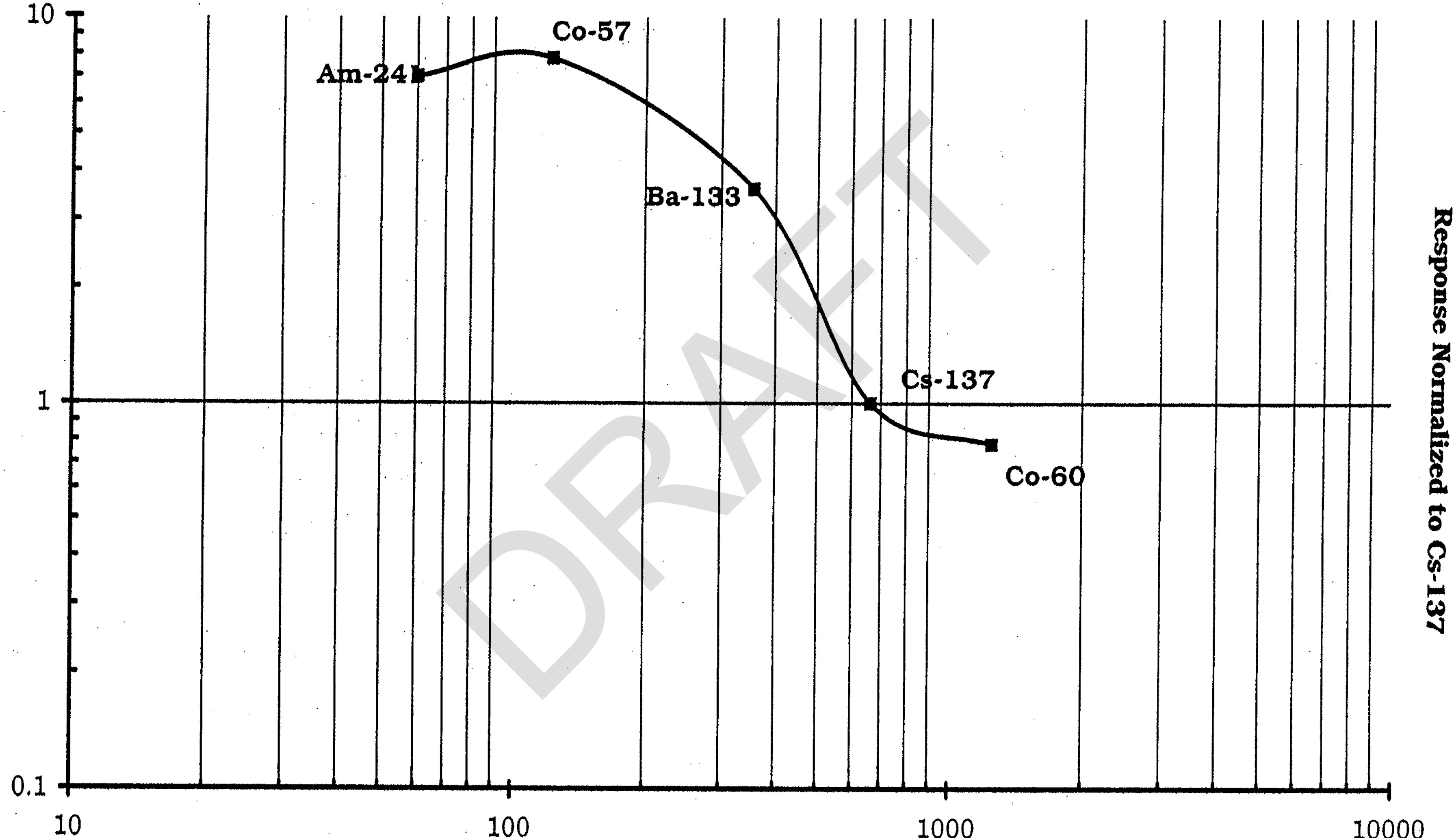
10:25:34	7-Apr-2004	Rev:	Sheet 174
367x174			

Energy Response for Ludlum Model 19



Gamma Energy (keV)

LUDLUM MODEL 43-93 AND MODEL 43-93-2 ALPHA/BETA SCINTILLATORS

March 2018

LUDLUM MODEL 43-93 AND MODEL 43-93-2 ALPHA/BETA SCINTILLATORS

March 2018

LUDLUM MEASUREMENTS, INC
501 OAK STREET, P.O. BOX 810
SWEETWATER, TEXAS 79556
325-235-5494, FAX: 325-235-4672

STATEMENT OF WARRANTY

Ludlum Measurements, Inc. warrants the products covered in this manual to be free of defects due to workmanship, material, and design for a period of twelve months from the date of delivery. The calibration of a product is warranted to be within its specified accuracy limits at the time of shipment. In the event of instrument failure, notify Ludlum Measurements to determine if repair, recalibration, or replacement is required.

This warranty excludes the replacement of photomultiplier tubes, G-M and proportional tubes, and scintillation crystals which are broken due to excessive physical abuse or used for purposes other than intended.

There are no warranties, express or implied, including without limitation any implied warranty of merchantability or fitness, which extend beyond the description of the face there of. If the product does not perform as warranted herein, purchaser's sole remedy shall be repair or replacement, at the option of Ludlum Measurements. In no event will Ludlum Measurements be liable for damages, lost revenue, lost wages, or any other incidental or consequential damages, arising from the purchase, use, or inability to use product.

RETURN OF GOODS TO MANUFACTURER

If equipment needs to be returned to Ludlum Measurements, Inc. for repair or calibration, please send to the address below. All shipments should include documentation containing return shipping address, customer name, telephone number, description of service requested, and all other necessary information. Your cooperation will expedite the return of your equipment.

LUDLUM MEASUREMENTS, INC.
ATTN: REPAIR DEPARTMENT
501 OAK STREET
SWEETWATER, TX 79556

800-622-0828 325-235-5494
FAX 325-235-4672

Table of Contents

Section 1

Introduction

The Model 43-93 and 43-93-2 detectors are designed for alpha-beta surveying when coupled with compatible instruments. Functionally, these two detectors are very similar but differ in the type of protective window screen and the size of the active and open window areas.

Discriminating between alpha and beta radiation simultaneously requires the counting instrument to have either separate power supplies or window/threshold controls for each channel. The Ludlum Model 2929 Scaler, Model 2223, Model 2224, or Model 2360 instruments provide the necessary circuitry for simultaneous alpha-beta discrimination.

A Zinc Sulfide [ZnS (Ag)] scintillator is used for detecting alpha particles, and a thin plastic scintillator is employed for detecting beta radiation. The scintillation material is covered by metallized Mylar to reduce light response, limiting excessive background counts. The Model 43-93 window is protected by an 88% open square-hole screen, where the Model 43-93-2 window is protected by a 79% open hexagonal-hole screen.

The photomultiplier tube (PMT) and crystal assembly may easily be removed for repair. Refer to the assembly view drawing in section 5 of this manual for details on construction and parts. The photomultiplier tube typically operates between 500 and 1200 volts with a recommended maximum of 1500 volts.

Section 2

Specifications

Photomultiplier Tube: 2.9 cm (1.1 in.) diameter; magnetically shielded

Scintillator Material: Zinc Sulfide [ZnS (Ag)] deposited on a 0.25 mm (0.010 in.) rectangular plastic scintillator

Window: 1.2 mg/cm^2 metalized polyester

Window Area (Model 43-93):

Active area: approximately 100 cm^2

Open area: approximately 88 cm^2

Window Area (Model 43-93-2):

Active area: approximately 126 cm^2

Open area: approximately 100 cm^2

Efficiency (4π):

Model 43-93: typically 15% for ^{99}Tc, 20% for ^{90}Sr ^{90}Y, and 20% for ^{239}Pu

Model 43-93-2: typically 10% for ^{99}Tc, 17% for ^{90}Sr ^{90}Y, and 15% for ^{239}Pu

Background (in a 10µR/hr field):

Alpha: 3 cpm or less

Beta: 300 cpm or less

Response Uniformity: 10% or less from average reading

Operating Voltage: typically 500-1200 Vdc (1500 Vdc max.)

Dynode String Resistance: 60 megohm

Gamma Sensitivity: 15-20 cpm/µR/hr (^{137}Cs)

Dead Time: typically 5 µsec or less

Connector: Series "C" unless otherwise specified

Temperature Range: -20 to 50 °C (-4 to 122 °F)

Size: 6.4 x 9.5 x 31 cm (2.5 x 3.8 x 12.3 in.) (H x W x L)

Weight: approximately 0.45 kg (1 lb)

Construction: aluminum housing with beige powder-coat finish

Section

3

Safety Considerations

Environmental Conditions for Normal Use

Indoor or outdoor use

No maximum altitude

Temperature range of -20 to 50°C (-4 to 122 °F)

Maximum relative humidity of less than 95% (non-condensing)

Cleaning Instructions and Precautions

The detectors specified in this manual may be cleaned externally with a damp cloth, using only water as the wetting agent. Do not immerse the detector in any liquid. Do not attempt to clean a detector that is attached to an instrument providing high voltage. Disconnect the detector cable before cleaning.

Repair and Calibration

To return an instrument for repair or calibration, provide sufficient packing material to prevent damage during shipment.

Every returned instrument must be accompanied by an Instrument Return Form, which can be downloaded from the Ludlum website at www.ludlums.com. Find the form by clicking the "Support" tab and selecting "Repair and Calibration" from the drop-down menu. Then choose the appropriate Repair and Calibration division where you will find a link to the form.

Section 4

Parts List

For Model 43-93

Assembly View, Drawing 393 × 140

Reference	Description	Part Number
UNIT	Completely Assembled Model 43-93 Alpha /Beta Scintillator	47-2556

Quantity	Description	Part Number
1 ea	Welded Body Assembly	2393-141
1 ea	Mirror	2310698
1 ea	Connector Cap	7393-102
1 ea	Mylar Window Assembly	4393-149
1 ea	Window Frame	7393-148
1 ea	Face Ring	7393-137
1 ea	Square Screen (external snap-on screen)	7393-171
1 ea	Backup w/Plastic Scintillator and ZnS	4393-153
1 ea	Plastic Scintillator- EJ444L-2.94 x5.91x 0.010	01-5692
1 ea	Photomultiplier Tube	01-5842
1 ea	Voltage Divider Board	5435-484
*	Foil-NETIC	01-5019
*	Foil-CO-NETIC	01-5026
9 ea	Sponge	7002-065-04
1 ea	Tube Holder Assembly	2393-117
1 ea	Gasket	7393-139
1 ea	O-Ring	16-8366
1 ea	Series "C" Connector RECPT-UG706/U	4478-011
1 ea	Model 43-93 Vinyl Cover	7393-162

For Model 43-93-2

Assembly View, Drawing 393 × 119

Reference	Description	Part Number
UNIT	Completely Assembled Model 43-93-2 Alpha /Beta Scintillator	47-3227

Quantity	Description	Part Number
1 ea	Welded Body Assembly	2393-105
1 ea	Mirror	2310654
1 ea	Connector Cap	7393-102
1 ea	Mylar Window Assembly	4393-126
1 ea	Window Frame	7393-109
1 ea	Face Ring	7393-112
1 ea	Hex Screen (external snap-on screen)	7393-116
1 ea	Backup w/Plastic Scintillator and ZnS	4393-127
1 ea	Plastic Scintillator-EJ212-3.12 x 6.67 x 0.010	01-5685
1 ea	Photomultiplier Tube	01-5842
1 ea	Voltage Divider Board	5435-484
*	Foil-NETIC	01-5019
*	Foil-CO-NETIC	01-5026
9 ea	Sponge	7002-065-04
1 ea	Tube Holder Assembly	2393-117
1 ea	Gasket	7393-110
1 ea	O-Ring	16-8366
1 ea	Series "C" Connector RECPT-UG706/U	4478-011
1 ea	Model 43-93-2 Vinyl Cover	7393-169

Parts Common to both Model 43-93 and 43-93-2

1 1/8-inch Voltage Divider Board, Drawing 435 × 1325

	Reference	Description	Part Number
	BOARD	Completely Assembled 1 1/8 inch Voltage Divider Board (Models 43-93 & 43-93-2)	5435-484
CAPACITORS	C1- C3	0.01uF, 200V	04-5725
	C4	0.0047uF, 3KV	04-5547
RESISTORS	R1	10M, 1/8W, 1%	12-7996

	Reference	Description	Part Number
	R2	7.5M, 1/8W, 5%	12-7971
	R3-R10	10M, 1/8W, 1%	12-7996
	R11	2.21M, 1/8W, 1%	12-7002
	R12-R13	10M, 1/8W, 1%	12-7996
MISCELLANEOUS	*	SOCKET 1 1/8 inch PCB MOUNT	4435-103
	W1	Wire-#22AWG WHT 9 65/40	21-8543
	W4	Wire-#22AWG BLK 0 65/40	21-8552

Section 5

Drawings and Diagrams

Model 43-93 Assembly View, Drawing 393 × 140

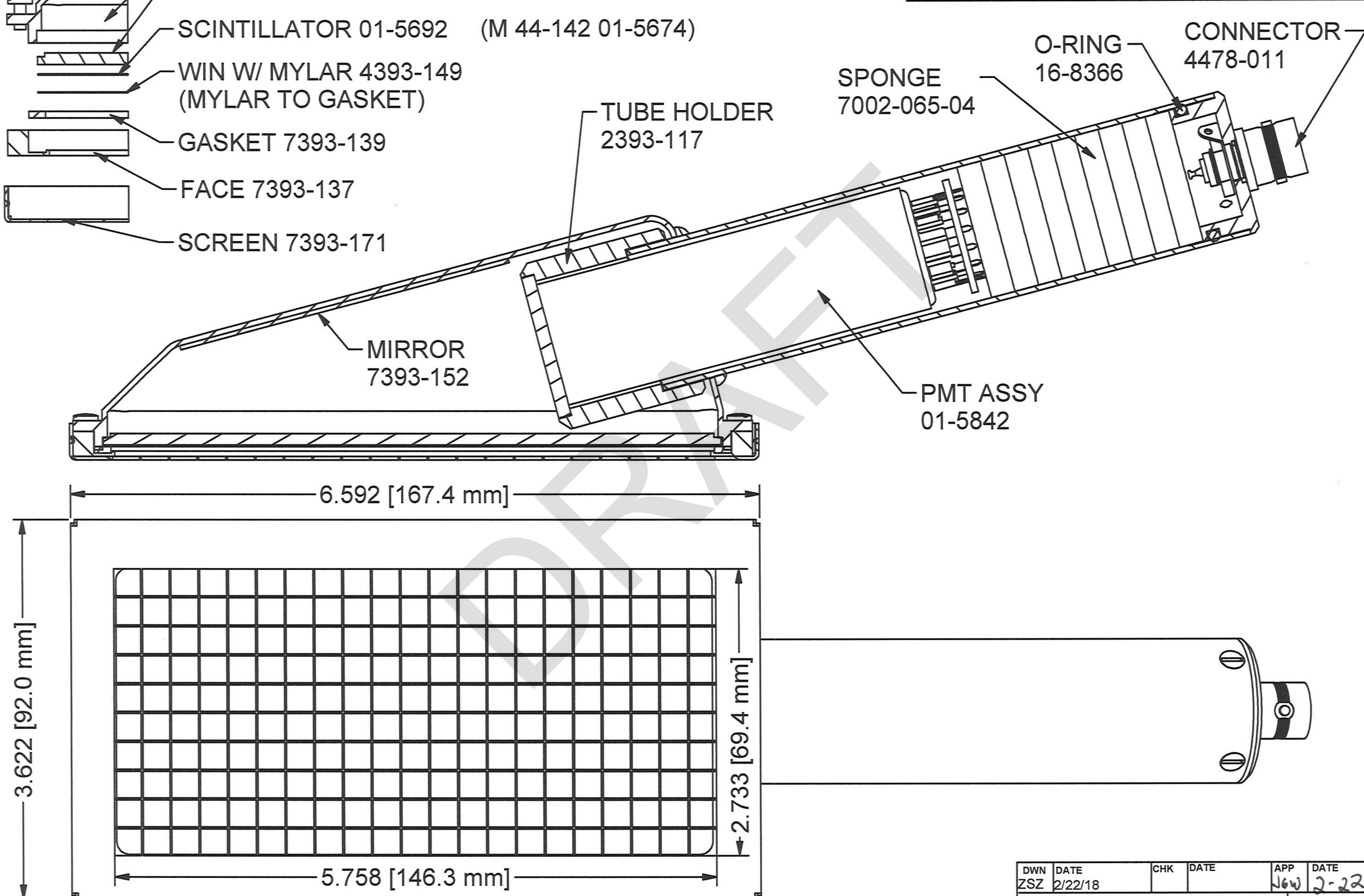
Model 43-93-2 Assembly View, Drawing 393 × 119

Mylar Window Replacement, Drawing 393 x 165A

1 1/8 inch Voltage Divider Circuit Board, Drawing 435 × 1325

1 1/8 inch Voltage Divider Component Layout, Drawing 435 × 1324 (2 sheets)

REVISION HISTORY			
REV	DESCRIPTION	DATE	BY
3	REDESIGNED	11-13-00	JGW
4	UPDATED	2-22-18	ZSZ



DWN	DATE	CHK	DATE	APP	DATE
ZSZ	2/22/18			JGW	2-22-18

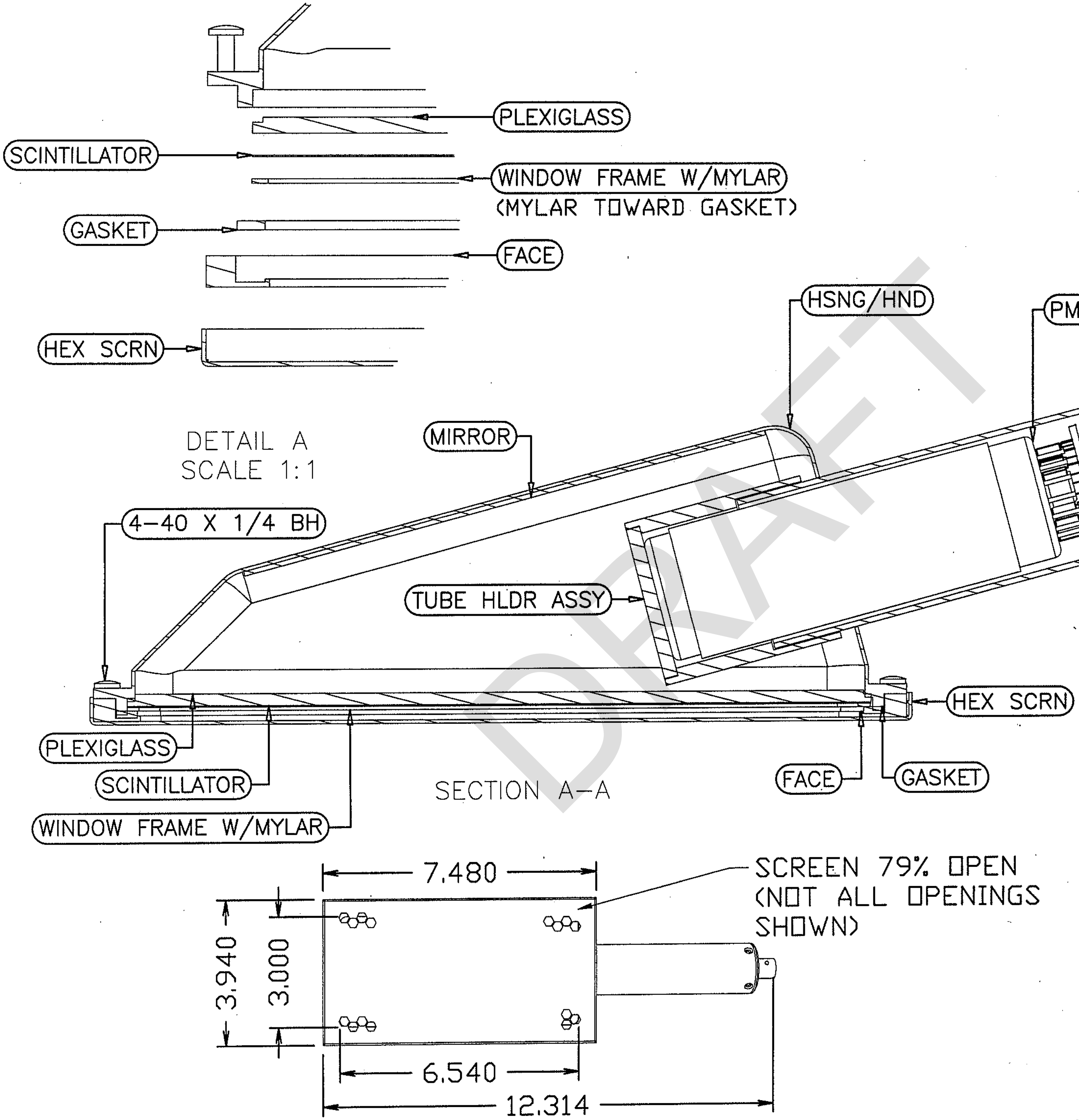
DWG NUM: 4393-140 — SCALE: 3/4

TITLE M43-93, 44-142 W/ SNAP ON SCRN

LUDLUM MEASUREMENTS, INC.
501 OAK STREET
SWEETWATER, TEXAS 79556

SERIES 393 — SHEET 140

REV #	ALTERATIONS	DATE	BY
1	VALID	2/12/02	DSW



DWN	DATE	CHK	DATE	APP	DATE
DSW	2/12/02	JGW	2-12-02		2-12-02

PART NUM: 4393-119 SCALE: FULL ☐ OTHER

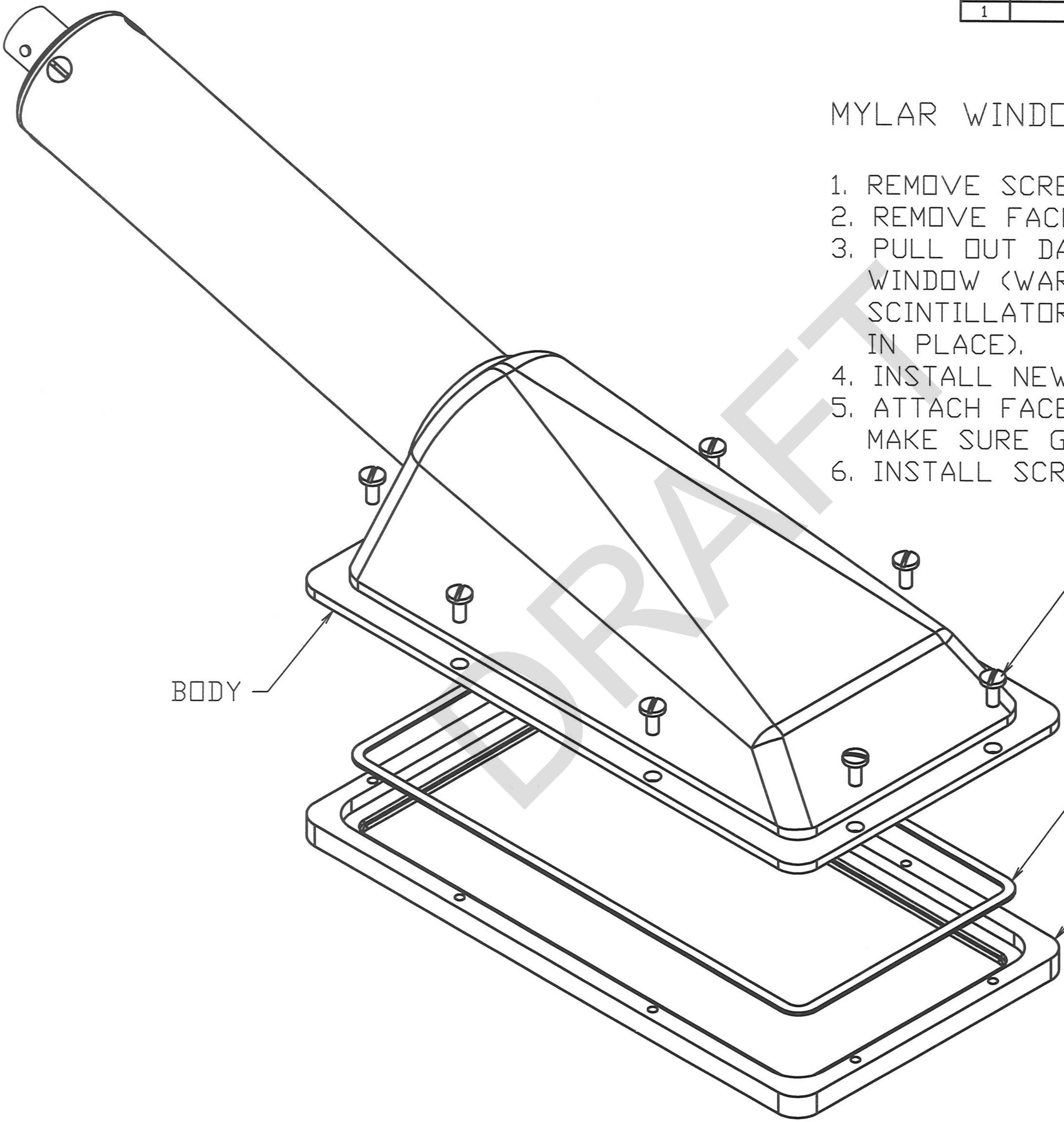
TITLE M 43-93-2 & 44-142-2 ASSEMBLY

LUDLUM MEASUREMENTS, INC. 501 OAK STREET SWEETWATER, TEXAS 79556 | SERIES 393 | SHEET 119

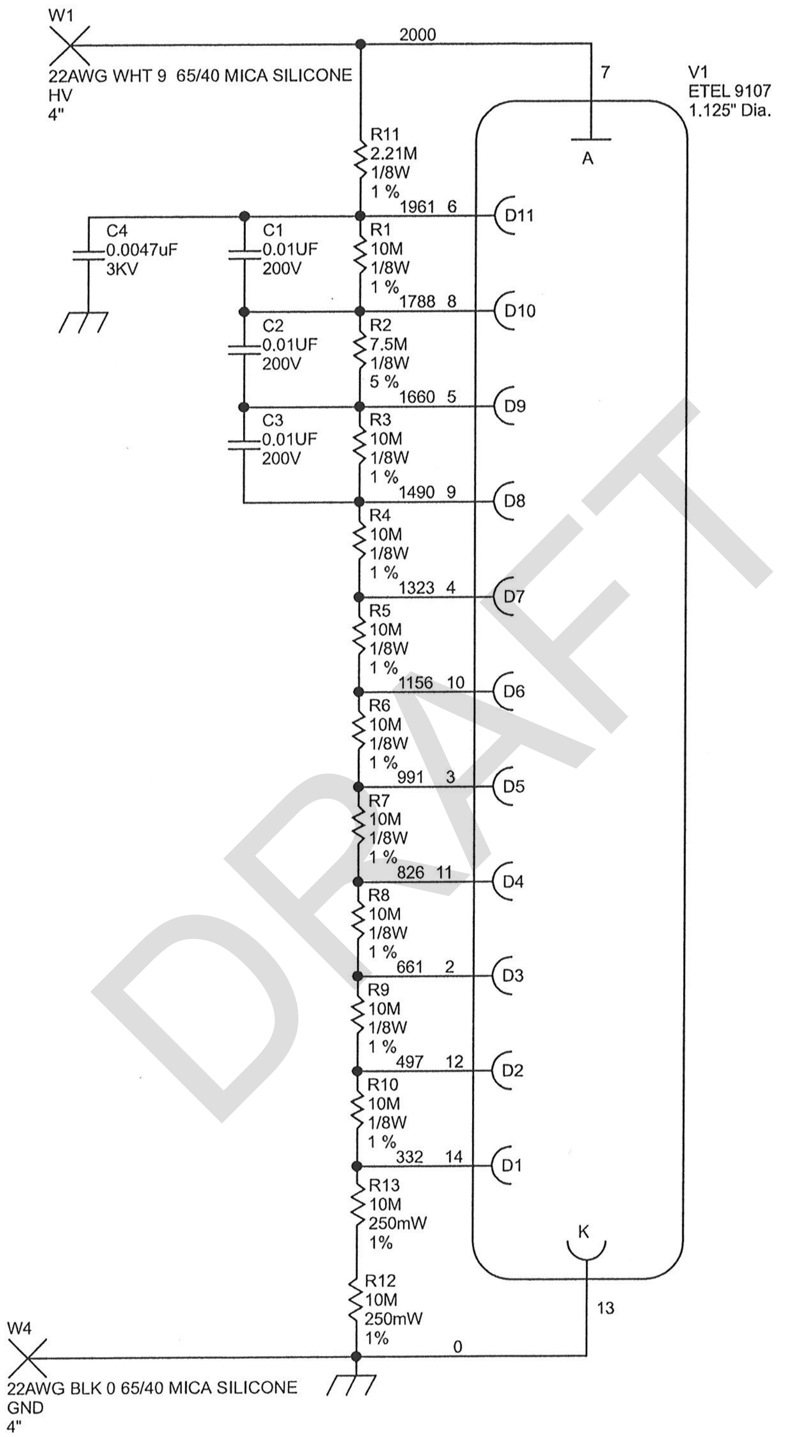
REV #	ALTERATIONS	DATE	BY
1	VALID	1-27-11	CMC

MYLAR WINDOW REPLACEMENT

1. REMOVE SCREWS
2. REMOVE FACE RING
3. PULL OUT DAMAGED MYLAR WINDOW (WARNING!!! MAKE SURE SCINTILLATOR ASSEMBLY STAYS IN PLACE).
4. INSTALL NEW MYLAR WINDOW.
5. ATTACH FACE RING (WARNING!!! MAKE SURE GASKET IS NOT DAMAGED)
6. INSTALL SCREWS



DWN CMC	DATE 1-27-11	CHK / DATE	APP JGW / DATE 1-27-11
DWG NUM: 4393-165		SCALE: FULL ☒ OTHER	
TITLE M 43-92, M 43-93 MYLAR WINDOW			
LUDLUM MEASUREMENTS, INC. 501 OAK STREET SWEETWATER, TEXAS 79556		SERIES 393	SHEET 165A



LUDLUM MEASUREMENTS, INC.

PO Box 810
501 Oak Street
Sweetwater, Texas 79556
U.S.A. 1-800-622-0828

Drawn: PAB	8/19/2015	**Title:** 1 1/8" VOLTAGE DIVIDER		
Design: LL	8/19/2015	**Model:** ETEL 9107		
		Board#: 5435-484		
Approve: RBS 2/25/16		**Sheet:** 1 of 1	**Series**	**Sheet**
Print Date: 2/25/2016	2:39:31 PM	**Rev:** 1	435	1325

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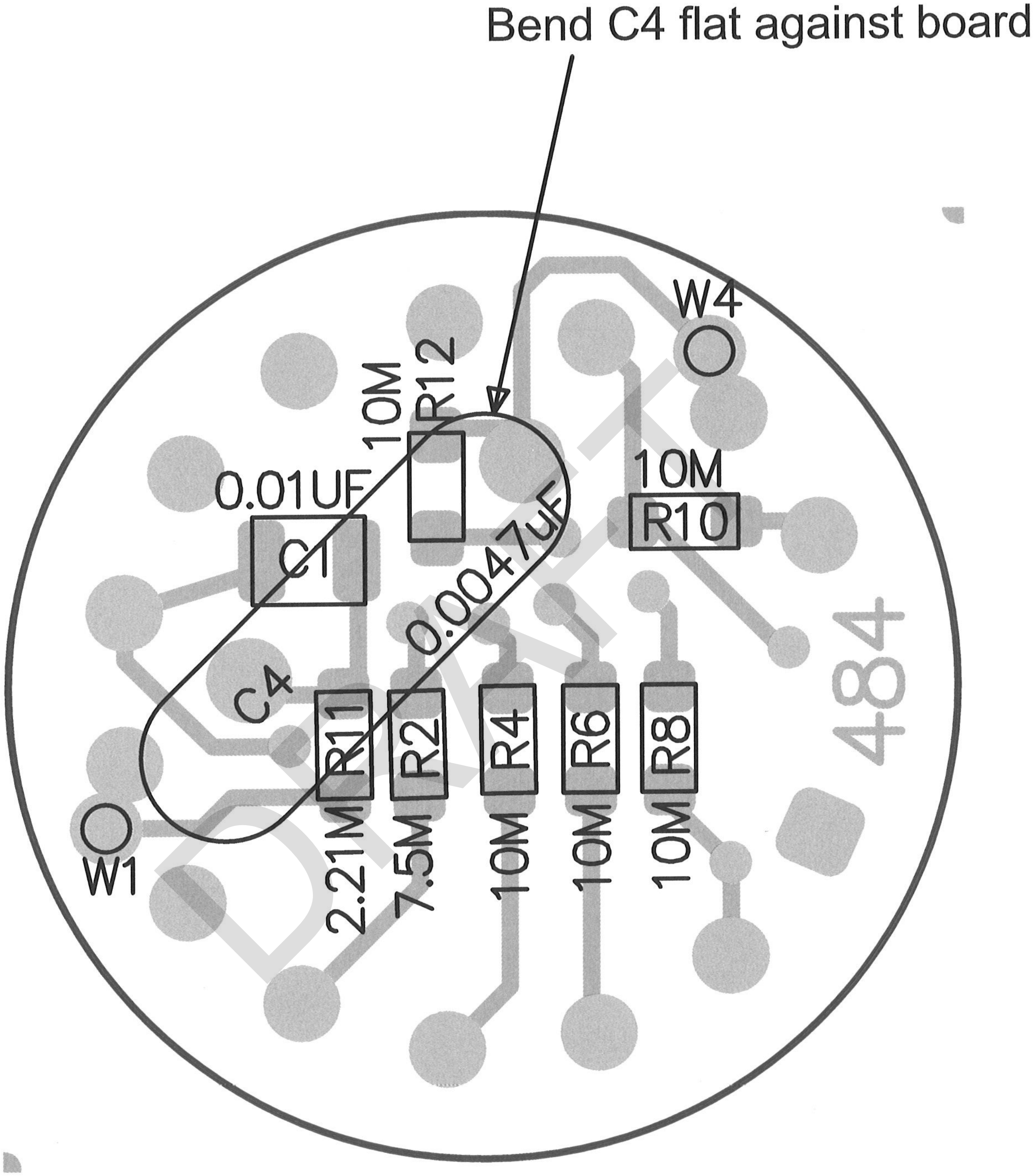

LUDLUM MEASUREMENTS, INC.
PO Box 810
501 Oak Street
Sweetwater, TX 79556
U.S.A. 1-800-622-0828

Title: 1 1/8" VOLTAGE DIVIDER				
Drawn: PAB	8/19/2015	**Model:** ETEL 9107		
Design: LL	8/19/2015	**Board#:** 5435-484		
Approve: RAS	22 JAN 16	**Rev:** 2		
PCBA Drawing		**SCALE: 1.08**	**Series**	**Sheet**
Print Date: 1/22/2016	4:43:42 PM	Top Overlay	435	1324

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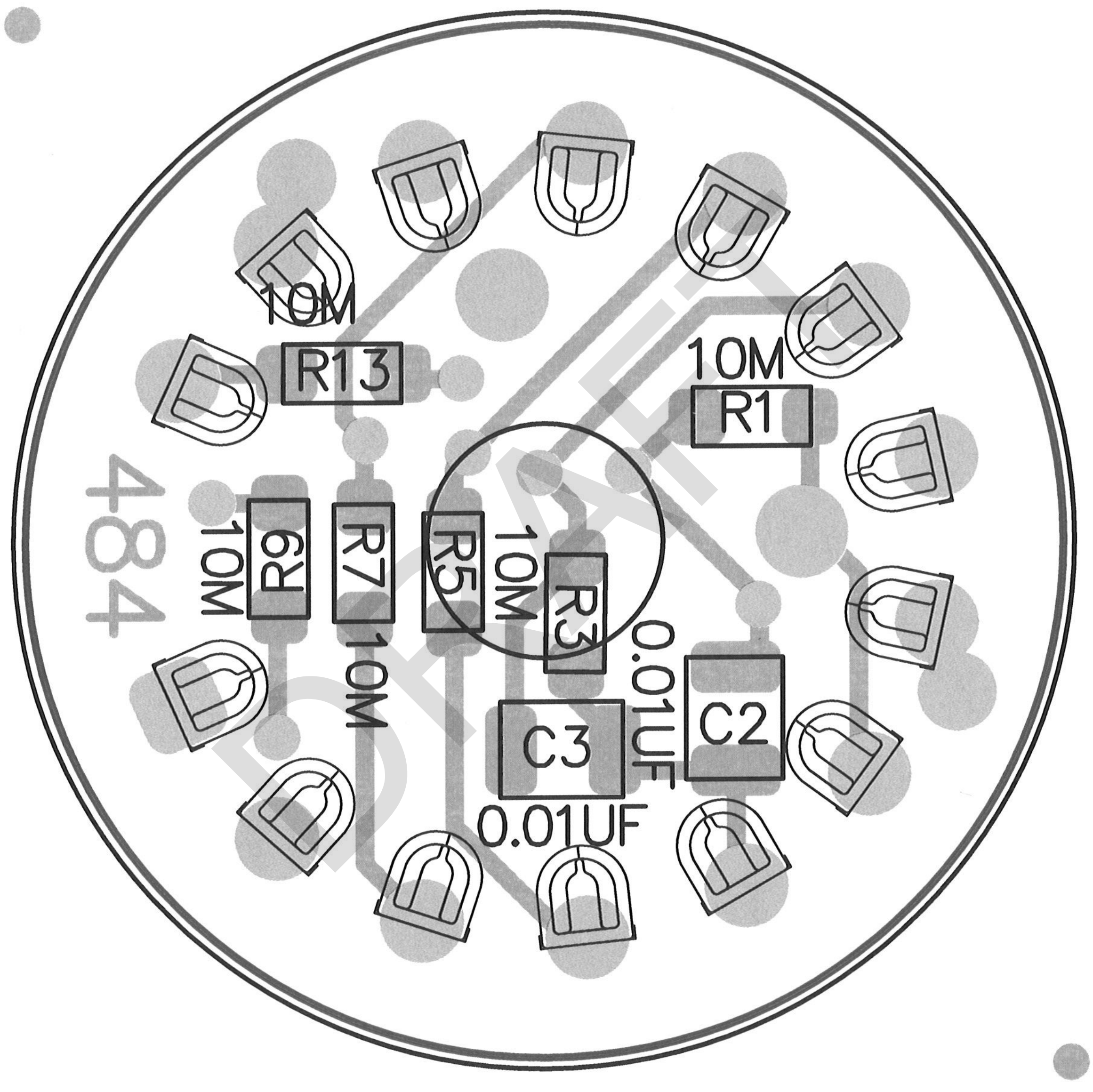

LUDLUM MEASUREMENTS, INC.

PO Box 810
501 Oak Street
Sweetwater, TX 79556
U.S.A. 1-800-622-0828

Title: 1 1/8" VOLTAGE DIVIDER				
Drawn: PAB	8/19/2015	**Model:** ETEL 9107		
Design: LL	8/19/2015	**Board#:** 5435-484		
Approve: [signature]	[handwritten date]	**Rev:** 1		
PCBA Drawing		**SCALE: 1.08**	**Series**	**Sheet**
Print Date: 3/9/2016	3:57:27 PM	Bottom Overlay	435	1324

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LUDLUM MODEL 2360
SCALER/RATEMETER DATA LOGGER

July 2016

Serial Number 133669 and Succeeding

Serial Numbers

LUDLUM MODEL 2360
SCALER/RATEMETER DATA LOGGER

July 2016

Serial Number 133669 and Succeeding Serial Numbers

LUDLUM MEASUREMENTS, INC
501 OAK STREET, P.O. BOX 810
SWEETWATER, TEXAS 79556
325-235-5494, FAX: 325-235-4672

STATEMENT OF WARRANTY

Ludlum Measurements, Inc. warrants the products covered in this manual to be free of defects due to workmanship, material, and design for a period of twelve months from the date of delivery. The calibration of a product is warranted to be within its specified accuracy limits at the time of shipment. In the event of instrument failure, notify Ludlum Measurements to determine if repair, recalibration, or replacement is required.

This warranty excludes the replacement of photomultiplier tubes, G-M and proportional tubes, and scintillation crystals which are broken due to excessive physical abuse or used for purposes other than intended.

There are no warranties, express or implied, including without limitation any implied warranty of merchantability or fitness, which extend beyond the description of the face there of. If the product does not perform as warranted herein, purchaser's sole remedy shall be repair or replacement, at the option of Ludlum Measurements. In no event will Ludlum Measurements be liable for damages, lost revenue, lost wages, or any other incidental or consequential damages, arising from the purchase, use, or inability to use product.

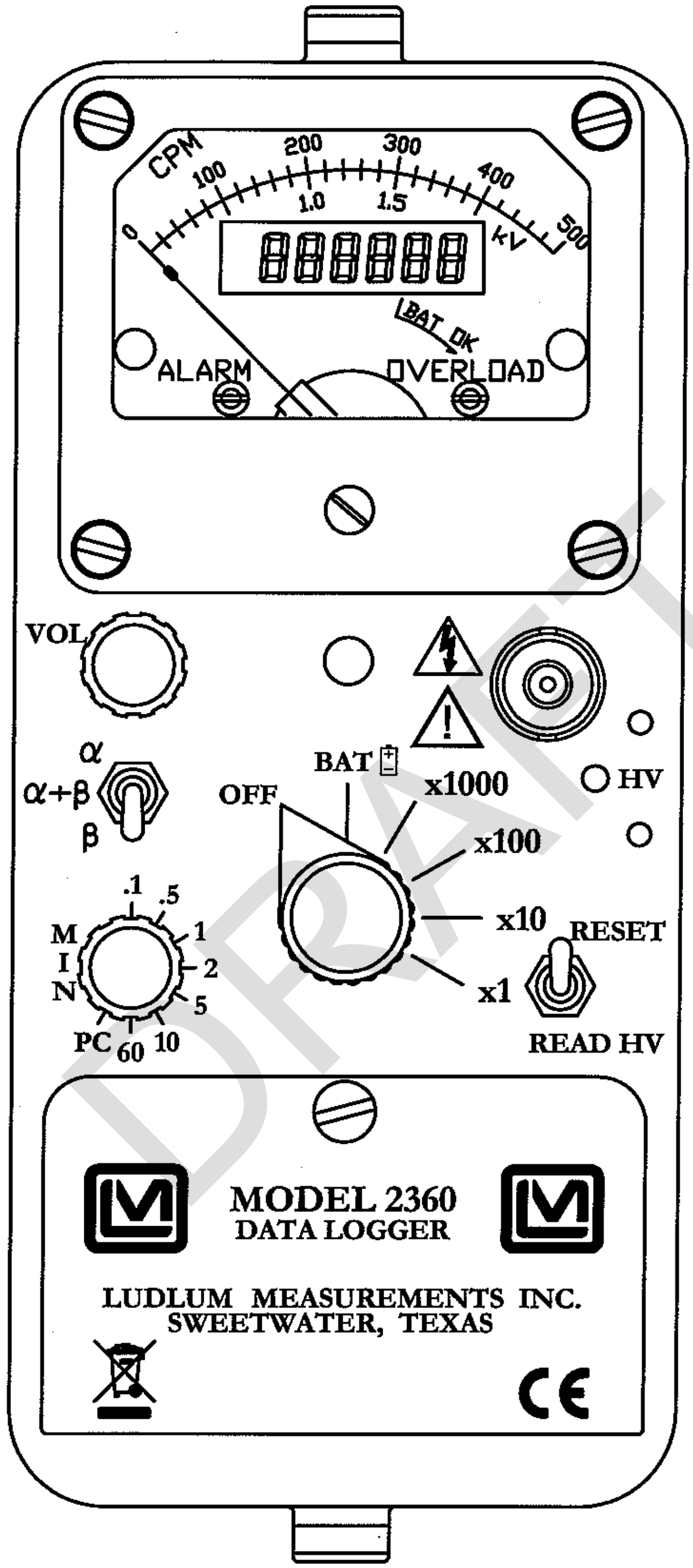
RETURN OF GOODS TO MANUFACTURER

If equipment needs to be returned to Ludlum Measurements, Inc. for repair or calibration, please send to the address below. All shipments should include documentation containing return shipping address, customer name, telephone number, description of service requested, and all other necessary information. Your cooperation will expedite the return of your equipment.

LUDLUM MEASUREMENTS, INC.
ATTN: REPAIR DEPARTMENT
501 OAK STREET
SWEETWATER, TX 79556

800-622-0828 325-235-5494
FAX 325-235-4672

REV #	ALTERATIONS	DATE	BY
1	VALID	8/1/96	RSS
2	UPDATED ARTWORK	5/15/06	CMC



DWN	DATE	CHK	DATE	APP	DATE
CMC	5-15-06				5-15-06

PART NUM: 4390-159 SCALE: FULL [x] OTHER

TITLE M 2360 ALPHA/BETA DATA LOGGER

LUDLUM MEASUREMENTS, INC. 501 OAK STREET SWEETWATER, TEXAS 79556

SERIES	SHEET
390	157

Table of Contents

Section 1

Introduction

The Ludlum Model 2360 Scaler/Ratemeter Data Logger is an easy-to-use survey instrument incorporating the best of the analog and digital worlds. Able to measure both alpha and beta radiation levels simultaneously, the Model 2360 presents the data in scaler (digital display) mode or ratemeter (analog meter) mode. The Model 2360 also logs up to 550 data points, consisting of sample number, date/time stamp, sample measurements (both alpha and beta, cpm if ratemeter measurement, or counts per count time if logging scaler count), scaler count time, "S" or "R," identifying whether scaler count or ratemeter was logged, and location identifier (10 characters).

Each alpha-beta data point is logged by simply pressing the button located in the instrument handle. The appropriate scaler or ratemeter measurement is taken, and both alpha and beta readings are logged into non-volatile memory. An internal dipswitch allows for logging of the scaler reading, ratemeter reading, both scaler and ratemeter readings, and NO logging. The location identifier can be input by a PC or other RS-232 device prior to logging a sample.

There are also 6 lines (15 characters each) of header information that can be stored at the beginning of the non-volatile memory. The header lines can contain such information as the user name, survey name, serial numbers, etc. The "CALIBRATION DUE DATE" can also be stored in non-volatile memory, which will disable the instrument when the internal clock date reaches the stored date.

The Model 2360 has a long arc length (6.0 cm {2.4 in.}) meter face that normally reads from 0 to 500 cpm. The main rotary switch allows for multiplication ranges of ×1, ×10, ×100, and ×1000. The Model 2360 has a three-position toggle switch on the front panel to switch between displaying alpha, beta, or alpha + beta levels.

Alpha and beta pulses have different audio tones, so that the user can discriminate between the two. A two-position momentary action switch allows either a meter reset, or displays the detector HV onto the meter. The following six alarms may be set via the RS-232 port:

Alpha Ratemeter (0-999999 cpm)

Beta Ratemeter (0-999999 cpm)

Alpha + Beta Ratemeter (0-999999 cpm)

Alpha Scaler (0-999999)

Beta Scaler (0-999999)

Alpha + Beta Scaler (0-999999)

These alarm points, when exceeded, light the meter face LED, marked ALARM, and activate the audio speaker. The ratemeter alarms are non-latching (will cease when the radiation level drops below the alarm point). The scaler alarm will continue until the RESET is pressed, or the next scaler count is started.

The digital display is a full 6-digit liquid crystal display (LCD) display, which is direct-driven for good viewing and a wide temperature response from -4 to 60 °C (40 to 140 °F). The digital display displays the scaler count, and prior to each sample logging, displays the current sample number. The display also has an arrow symbol for counting overflow and two colons that indicate that a scaler count is in progress.

The Model 2360 communicates through an RS-232 port located on the instrument can. The computer interface software is supplied on CD and includes the following functions:

downloading of header and logged data into an ASCII file

setting and reading of instrument parameters/header information

setting of the ″CALIBRATION DUE DATE″

setting of the internal real-time clock/calendar

setting of the user-definable scaler time

setting of location code and alarm points

clearing of logged memory

Section

2

Getting Started

Unpacking and Repacking

Remove the calibration certificate and place it in a secure location. Remove the instrument and accessories (batteries, cable, etc.) and ensure that all of the items listed on the packing list are in the carton. Check individual item serial numbers and ensure calibration certificates match. The Model 2360 serial number is located on the front panel below the battery compartment. Most Ludlum Measurements, Inc. detectors have a label on the base or body of the detector for model and serial number identification.

Important!

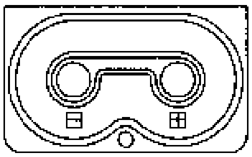
If multiple shipments are received, ensure that the detectors and instruments are not interchanged. Each instrument is calibrated to specific detectors, and is therefore not interchangeable.

To return an instrument for repair or calibration, provide sufficient packing material to prevent damage during shipment. Also provide appropriate warning labels to ensure careful handling

Every returned instrument must be accompanied by an **Instrument Return Form**, which can be downloaded from the Ludlum website at www.ludlums.com. Find the form by clicking the "Support" tab and selecting "Repair and Calibration" from the drop-down menu. Then choose the appropriate Repair and Calibration division where you will find a link to the form.

Battery Installation

Ensure the Model 2360 range selector switch is in the ˝OFF˝ position. Open the battery lid by pushing down and turning the quarter-turn thumbscrew



counterclockwise a quarter of a turn. Install two ˝D˝ size batteries in the compartment.

Note the (+) and (-) marks inside the battery door. Match the battery polarity to these marks. Close the battery box lid, push down, and turn the quarter-turn thumb screw clockwise a quarter of a turn.

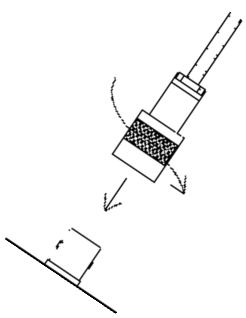
Note:

The center post of a flashlight battery is positive. The batteries are placed in the battery compartment in opposite directions.

Connecting a Detector to the Instrument

Caution!

The detector operating voltage (HV) is supplied to the detector via the detector input connector. A mild electric shock may occur if you make contact with the center pin of the input connector. Switch the Model 2360 to the ˝OFF˝ position before connecting or disconnecting the cable or detector.



Connect one end of a detector cable to the detector by firmly pushing the connectors together while twisting clockwise ¼ turn. Repeat the process in the same manner with the other end of the cable and the instrument.

Internal Switches

Release the can latches and remove the cover from the 2360, taking care not to damage the speaker wires. Using a ball-point pen, set the switches for the desired AUDIO division and TONE described on Page 4-3. Replace the cover and fasten the latches.

Battery Test

The batteries should be checked each time the instrument is turned on. Move the range selector switch to the BAT position. Ensure that the meter needle deflects to the battery check portion on the meter scale. If the meter does not respond, check to see if the batteries have been correctly installed. Replace the batteries if necessary.

Turn the range selector switch from the off position to the ×1000 position and verify that the meter needle is driven full-scale for approximately two seconds and then returns to zero. Also ensure both alarm LEDs on the front panel turn on briefly. The LCD should go through an initialization sequence displaying ˝88:8.8:8.8,˝ then the current sample number, and finally "0."

Operating the Instrument

Connect a detector to the instrument if you have not already done so. Obtain a meter reading from a check source or calibrated source, if available. Verify that the reading falls within the expected range. Remove the source.

If a radiation source is available, increase the meter count to exceed the alarm threshold. Both the appropriate alarm lamp and audio alarm signal should activate.

Depress the RESET toggle switch. The meter needle should drive to zero and the alarm circuit should de-energize, shutting off both visual and audible alarms.

Proceed with use.

Principle of Operation

The Model 2360 is to be used in combination with an alpha/beta scintillation or proportional detector. The pulse height differential between the alpha and beta pulses from the scintillation or proportional detector is discriminated by the Model 2360.

The detected alpha count is displayed by selecting the "α" position on the three-position "α/α+β/β" toggle switch. Likewise, the sum of the alpha and beta counts or the beta counts only are displayed by selecting the appropriate "α + β" or "β" position. Multiply the cpm reading on the analog ratemeter by the range multiplier position. When using the LCD and preset count time interval, the counts are accumulated in each of the three channels during the count cycle. The count cycle is started by depressing the push-button located in the end of the carrying handle. If a scaler or ratemeter alarm is activated, the ALARM LED will light and the audio will sound a steady tone.

The RESET toggle switch position resets the meter pointer to zero and deactivates any current alarm. The detector operating voltage is displayed on the meter dial by selecting the READ HV position. The high-voltage scale ranges from 0 to 2 kV. The OL (overload) lamp, located in the lower, right corner of the meter dial, indicates that the detector is saturated either by a puncture in the detector face or an exposure to a radiation field above the counting capability of the instrument. The analog meter deflects full scale when the OL lamp is illuminated.

Section
3

Specifications

Compatible Detectors: proportional and dual phosphor scintillation detectors; common Models: 43-1-1, 43-2-2, 43-20, 43-68, 43-89 and 43-93

Data Logger: capable of logging up to 550 individual data points into non-volatile memory with the following identifiers for each point:

alpha and beta sample counts
sample number
date/time stamp
scaler count time
10-character location identifier

Range: four linear range multiples of ×1, ×10, ×100, and ×1000; used in combination with the 0-500 CPM meter dial providing an overall range of 0-500 kcpm

Thresholds: internal control allows for adjustment from -2 to -15 mV for beta and -40 to -700 mV for alpha

Window: internal control allows for adjustment from the beta threshold up to the alpha threshold setting (beta only)

Audio: built-in unimorph speaker with volume control (greater than 60 dB at 0.61 m {2 ft}, full volume); headset jack located on the instrument can

Audio Divide: selectable dual or individual click-per-event for alpha and beta counts with divisions of 1, 10, 100, or 1000 events per click (beta only)

Alarm points: six separate alarm points, set through the RS-232 port, activating the alarm audio tone and lighting the ALARM LED. The six alarm points can be set from 0 to 99999. Ratemeter alarms are non-latching, while scaler alarms are not. (A latched alarm requires the RESET button be pressed in order for the alarm to clear) The six alarms are:

Alpha Ratemeter
Beta Ratemeter
Alpha + Beta Ratemeter
Alpha Scaler
Beta Scaler
Alpha + Beta Scaler

High Voltage: recessed front-panel potentiometer; adjustable from 200 to 2000 Vdc

Linearity: within 10% of true value for the analog CPM meter; within 2% for the LCD

Response Time: ×1 = 7 seconds, ×10 = 2 seconds, ×100 = 2 seconds, x1000 = 2 seconds; all response times measured from 10-90% of full scale

Analog Meter: rugged 1 milliamp (mA), with pivot-and-jewel suspension and 6.0 cm (2.4 in.) arc length

Connector: series ˝C˝ standard, others available

Temperature Range: -20 to 50 °C (-4 to 122 °F); may be certified for operation from -40 to 65 °C (-40 to 150 °F)

Maximum Relative Humidity: less than 95% (non-condensing)

Power: two standard ˝D˝ size batteries housed in an externally accessible sealed compartment

Battery Life: typically 250 hours of operation with a fresh set of alkaline ˝D˝ cell batteries

Size: 16.5 x 8.9 x 21.6 cm (6.5 x 3.5 x 8.5 in.) (H x W x L)

Weight: 1.6 kg (3.5 lb), including batteries

Finish: drawn-and-cast aluminum, with beige powder coating

Section 4

Description of Controls and Functions

Operator Controls

OFF/BAT/X1000/X100/X10/X1 Switch (or Range Selector Switch): a six-position rotary switch to select the analog meter range multipliers and check the battery status. When switched to the ˝BAT˝ position, the meter pointer should deflect above the left vertical mark on the ˝BAT OK˝ line. Moving the range selector switch to one of the range multiplier positions (×01, ×10, ×100, ×1000) provides the operator with an overall range of 0-500 kcpm. Multiply the scale reading by the multiplier to determine the actual reading.

During initial instrument turn-on, the meter will be driven full scale for about two seconds and then return to zero. The LCD will show ˝88:8.8:8.8,˝ display the current sample number, and then "0." If the count button is pressed while the display is showing all 8s then the following numbers are shown: firmware number, date, time, PC defined scaler time, alpha ratemeter alarm, alpha + beta rate meter alarm, alpha scaler alarm, alpha + beta scaler alarm, current sample number, and then "0."

Liquid Crystal Display (LCD): six-digit display that shows the scaler count for the selected channel or the sum of both. It also indicates when a count is in progress by displaying two colons; the colons are turned off when the count is complete. Is the counter exceeds 999999, an arrow in the upper-left corner of the display turns on in order to indicate an overflow; the counter then rolls over to zero and continues counting.

VOL: Turning this control clockwise will increase the speaker volume, and counterclockwise will decrease the volume.

Note:

The volume should be turned down, when not required, to reduce battery drain.

α/α+β/β Switch: A three-position toggle switch used to select the sum of alpha and beta count channels (α+B), alpha count only (α), or beta count only (B), for display. This switch affects both the analog meter and digital display. The rate meter channels are active regardless of the switch position and will continue to function when the channel is not selected for display. This ability allows the operator to view each channel separately or together by simply selecting the appropriate switch position.

Headphone Jack: 0.32 cm (0.13 in. or one-eighth inch) phone jack on instrument can for the connection of external headphones. Inserting a phone plug into the jack disconnects the external unimorph speaker from the audio circuitry. Use 0.32 cm (0.13 in. or one-eighth inch) mating plug-LMI part # 21-9653.

RS-232 Port: located on the instrument can and allows for connection of the instrument to a PC for dumping data and setting up parameters

RESET/HV: a dual-position momentary toggle switch which provides readout of the detector high voltage when the HV position is selected. When the RESET position is selected, this switch provides a rapid means of driving the analog ratemeter to zero and resetting the meter after an alarm condition. Use the 0-2 kV meter scale for high-voltage readings.

MIN 0.1, 0.5, 1, 2, 5, 10, 60, PC Count Time Select Switch: an eight-position rotary switch used to select scaler count times in minutes. When set to PC, the scaler will use the user-defined count time. The count cycle is initiated by depressing the push-button switch in the carrying handle.

Log Push-button (located in the carrying handle): When depressed, the current sample number is displayed, the counter is reset to zero, and the timer is started. If selected, the instrument will also log the current reading. The colons on the display turn on and stay on until the count has expired.

Remove the front panel calibration cover to access the following calibration potentiometer:

HV: a multi-turn potentiometer used to adjust the detector high voltage from 200 to 2000 Vdc

Internal Controls

Remove the instrument cover (can) to access the following dipswitches on SW1.

RECYCLE: A one-pole DIP switch (#1) used to select recycle scaler mode. When placed in the ON position, the instrument will start a count cycle. If the instrument is set to log the sample, it will be saved and a new count will start again. The ratio is selected from the following table:

SWITCH 1	RECYCLE MODE
ON	ON
OFF	OFF

TONE: a one-pole DIP switch (#2) used to select tone discrimination between alpha and beta count channels. When in the DUAL mode, alpha and beta pulse tones will be audible in all selector switch positions (i.e. if in the β-only position and beta radiation is detected, the beta tones will be heard in addition to the alpha tones).

When the SNGL tone position is selected, both alpha and beta pulse tones can be heard in the "α+β" selection, but alpha pulses are the only audible tones in the α-channel selection, and beta pulse tones are the only audible tones in the β-channel selection.

SWITCH 2	TONE MODE
ON	DUAL
OFF	SINGLE

AUDIO Divide: A two-pole DIP switch (#3 & #4) used to select audio divisions of 1, 10, 100, and the beta audio subtract mode.

Note:

The AUDIO divide function only affects the lower-frequency beta tones. The higher-frequency alpha click-per-event will be unaffected by the divide-by selection.

The ratio is selected from the following table:

SWITCH 3	4	DIVIDE BY RATIO
ON	ON	1
ON	OFF	10
OFF	ON	100
OFF	OFF	Beta audio Subtract Mode

LOG SAMPLE: A two-pole DIP switch (#5 & #6) used to select logging mode. When both switches are OFF, the instrument will not log samples but will output the ratemeter readings to the RS-232 port every two seconds in ASCII format. When set to log both scaler and ratemeter, two samples are actually saved. The logging mode is selected from the following table.

SWITCH 5	6	LOGGING MODE
ON	ON	Log ratemeter and scaler
ON	OFF	Log ratemeter
OFF	ON	Log scaler
OFF	OFF	No sample saved. Output ratemeter every 2 seconds.

The following controls are utilized during calibration only and should only be altered by a qualified calibration technician.

MTR: a multi-turn potentiometer used to calibrate the meter to the CPM reading

AT: a multi-turn potentiometer used to vary the alpha pulse discriminator from 40 to 700 millivolts (mV)

BW: a multi-turn potentiometer used to vary the upper beta pulse discriminator from BT setting to AT setting

BT: a multi-turn potentiometer used to vary the lower beta pulse discriminator from 2 to 15 mV

OL: a multi-turn potentiometer thatprovides a means to vary the detector current overload set point

LIM: a multi-turn potentiometer used to set the maximum HV limit to 2000 Vdc

HV: a multi-turn potentiometer used to adjust the high-voltage test reading (0 to 2 kV scale) to correspond with the actual high-voltage output. The HV switch must be depressed during adjustment.

LB: a multi-turn potentiometer used to adjust the minimum battery voltage level (2.2 Vdc), corresponding to the low-battery indication on the meter dial. The BAT switch position must be selected during adjustment.

Section

5

Safety Considerations

Environmental Conditions for Normal Use

Indoor or outdoor use

No maximum altitude

Temperature range of -20 to 50 °C (-4 to 122 °F); may be certified for operation from -40 to 65°C (-40 to 150 °F)

Maximum relative humidity of less than 95% (non-condensing)

Pollution Degree 3 (as defined by IEC 664) (Occurs when conductive pollution or dry nonconductive pollution becomes conductive due to condensation. This is typical of industrial or construction sites.)

Cleaning Instructions and Precautions

The Model 2360 Scaler/Ratemeter may be cleaned externally with a damp cloth, using only water as the wetting agent. Do not immerse the instrument in any liquid. Observe the following precautions when cleaning:

1. Turn the instrument range selector switch to the OFF position.

2. Allow the instrument to sit for one minute before cleaning.

Warning Markings and Symbols

Caution!

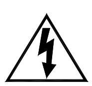
The operator or responsible body is cautioned that the protection provided by the equipment may be impaired if the equipment is used in a manner not specified by Ludlum Measurements, Inc.

> **Caution!**
>
> Verify instrument voltage input rating before connecting to a power converter. If the wrong power converter is used, the instrument and/or power converter could be damaged.

The Model 2360 Scaler/Ratemeter is marked with the following symbols:

CAUTION (per ISO 3864, No. B.3.1) – designates hazardous live voltage and risk of electric shock. During normal use, internal components are hazardous live. This instrument must be isolated or disconnected from the hazardous live voltage before accessing the internal components. This symbol appears on the front panel. **Note the following precautions:**

> **Warning!**
>
> The operator is strongly cautioned to take the following precautions to avoid contact with internal hazardous live parts that are accessible using a tool:
>
> 1. Turn the instrument power OFF and disconnect the power cord.
> 2. Allow the instrument to sit for one minute before accessing internal components.



CAUTION, RISK OF ELECTRIC SHOCK (per ISO 3864, No. B.3.6) – designates a terminal (connector) that allows connection to a voltage exceeding 1 kV. Contact with the subject connector while the instrument is on or shortly after turning off may result in electric shock. This symbol appears on the front panel.

The "**crossed-out wheelie bin**" symbol notifies the consumer that the product is not to be mixed with unsorted municipal waste when discarding; each material must be separated. The symbol is placed on the battery lid. See section 10, "Recycling," for further information.

The "CE" mark is used to identify this instrument as being acceptable for use within the European Union. This is located on the front panel.

Section 6

Calibration and Maintenance

Calibration

Note:

Local procedures may supersede the following.

Establishing an Operating Point

The detector operating parameters are established by adjusting the detector operating voltage (HV), alpha threshold, and beta window to find an optimum efficiency for the alpha/beta scintillator or proportional detector.

The threshold and window parameters can be adjusted to optimize alpha/beta count discrimination, count efficiency, and minimize "cross talk" between channels. Refer to the specific detector operation manual or calibration certificate for the suggested threshold and window settings. Once the thresholds and window settings are established, an operating voltage-versus-count rate plot should be performed for both alpha and beta count channels with alpha and beta particle emission sources.

The following procedure is an example of determining the operating voltage for an alpha/beta scintillation or proportional detector:

- Connect a Ludlum Model 500 Pulser or equivalent to the Model 2360.
- Switch the 2360 to the β position. Adjust the beta threshold (BT) for 3.5 mV and the window (BW) for 30 mV. The pulser counts should be detected on the 2360 ratemeter above 3.5 ± 1 mV and should shut off above 30 mV.
- Switch the channel selector switch to the α position. Adjust the pulser for 120 mV pulse output and vary the AT control until counts are detected on the ratemeter.

- Depress the HV switch and adjust the HV potentiometer for 0.4 to 0.5 kV on the 0-2.0 kV scale. Connect the scintillator and switch to the β only position. Place an alpha source on the detector face.

- Slowly increase the HV potentiometer to observe an increase, then decrease, and increase again in count as the HV is increased. Decrease the HV until the ratemeter is in the "dip" of the observed count rate-versus-HV plot just performed. Depress the HV switch and note the HV setting.

- Plot a HV versus count rate plateau in 25 V increments, 50 V each side of the HV reading found in the above step (i.e., HV setting for count "dip" in the above step = 675 V, start the plot at 625 V and increase in 25 V steps until 725 V is reached). Plot alpha source, beta source, and background counts for both α and β channel positions.

- Find the optimum operating voltage from the plot, which gives the greatest alpha and beta source efficiency while maintaining no greater than the maximum acceptable level of cross talk between channels.

- Select the desired count channel display, and proceed to use instrument.

METER CALIBRATION

A Ludlum Model 500 Pulser or equivalent is required. If the pulser does not have high-voltage readout, use a high-impedance voltmeter with at least 1000 megohm input resistance to measure the detector voltage.

Ensure that the meter movement has proper mechanical zero. The adjustment is on the front of the meter bezel. It must be adjusted to ˝0˝ with the ON/OFF selector switch in the OFF position.

Connect the Model 500 Pulser to the Model 2360 with the appropriate cable. Rotate the Model 2360 range multiplier switch to the ×100 position. Select the α+β channel position.

Adjust the Pulser for 40,000 cpm and adjust the pulse amplitude to at least twice the beta threshold level (i.e.; beta threshold = 3.5 mV, adjust the pulser to 7-10 mV).

Remove the instrument cover and adjust the MTR potentiometer until the meter reads 400 cpm. Adjust the pulser to 10,000 cpm and ensure ratemeter reads 100 ± 10%. Decade the pulser and Model 2360 range multiplier switch to check meter linearity on the ×1000, ×10, and ×1 positions. Linearity should be within 10% of each reading.

Set the LCD count time for one minute. Adjust the pulser count rate to 40 kcpm. Depress the count button, and when the count cycle is complete, confirm that LCD reads within 2% of the incoming count rate.

Adjust the BT, BW, and AT controls for the appropriate set points as described in the following subsection.

Connect a high-impedance, high-voltage meter (may use the Model 500 Pulser if equipped with an HV meter) to the detector input connector and adjust the HV control for a reading of 1000 Vdc on the voltmeter.

Depress the RES/HV switch to the HV position and adjust the HV potentiometer located on the circuit board for a reading of 1.0 kV on the meter dial. Adjust the HV output from 500 to 1500 Vdc and confirm that the 2360 HV meter corresponds to the external voltmeter within 10% of each reading.

Rotate the range multiplier switch to the OFF position. Remove the batteries from the battery compartment and connect a DC power supply to the two screw terminals located at the rear of the battery compartment. The positive power supply lead should connect to the terminal with the red wire, and the negative lead to the terminal with the black wire.

Adjust the power supply for 2.2 Vdc and switch the 2360 to the BAT position. Adjust the LB potentiometer to align the meter needle with the low-battery mark on the meter dial (vertical line to the left of BAT OK).

Replace the instrument can and proceed with use.

DETECTOR OVERLOAD CALIBRATION

> **Note**:
>
> The detector operating voltage (HV) must be determined and set before the OL (overload) adjustment is performed. If the detector operating voltage is re-adjusted, the overload adjustment must be re-adjusted.

Adjust the OL control to the maximum counterclockwise position.

Note:

Detector saturation is when the meter response no longer increases with increasing radiation field intensity.

For alpha/beta scintillators, expose the detector photomultiplier tube (PMT) to a small light leak by loosening the detector window. Some scintillation detectors incorporate a screw in the detector body, which when removed, will simulate a detector face puncture or light leak. The meter should start to decrease toward zero as light saturates the scintillation material.

Expose just enough light to where the meter starts to decrease. Adjust the OL control until the overload LED just begins to flicker on the meter dial. The ratemeter should deflect above full-meter scale at this point.

Re-seal the detector window and expose the detector to a radiation source that will drive the meter near full scale. Confirm that the LED does not turn on and the meter remains on scale.

Maintenance

Instrument maintenance consists of keeping the instrument clean and periodically checking the batteries and the calibration. The Model 2360 instrument may be cleaned with a damp cloth (using only water as the wetting agent). Do not immerse instrument in any liquid. Observe the following precautions when cleaning:

1. Turn the instrument OFF and remove the batteries.
2. Allow the instrument to sit for one minute before accessing internal components.

RECALIBRATION

Recalibration should be accomplished after maintenance or adjustments have been performed on the instrument. Recalibration is not normally required following instrument cleaning, battery replacement, or cable replacement.

Note:

Ludlum Measurements, Inc. recommends recalibration at intervals no greater than one year. Check the appropriate regulations to determine required recalibration intervals.

Ludlum Measurements offers a full-service repair and calibration department. We not only repair and calibrate our own instruments, but most other manufacturers' instruments as well. Calibration procedures are available upon request for customers who choose to calibrate their own instruments.

BATTERIES

The batteries should be removed any time the instrument is placed into storage. Battery leakage may cause corrosion on the battery contacts, which must be scraped off and/or washed using a paste solution made from baking soda and water. Use a spanner wrench to unscrew the battery contact insulators, exposing the internal contacts and battery springs. Removal of the handle will facilitate access to these contacts.

Note:

Never store the instrument over 30 days without removing the batteries. Although this instrument will operate at very high ambient temperatures, battery seal failure may occur at temperatures as low as 37 °C (100 °F).

Section 7

RS-232 Interface

Communicating with the Model 2360

The Model 2360 has an RS-232 serial port that can be connected to a PC or other RS-232 device. The proper communication settings are (2400,8,N,1):

2400 Baud
8 data bits
No parity
1 stop bit

Commands

The following table shows all the commands used to communicate with the Model 2360. All commands must be in uppercase letters. The data can be in either uppercase or lowercase. All set commands should return ″OK″ + a carriage return and line feed.

READ COMMANDS

RA	Read sample number
RC	Read calendar date
RD	Read date
RHx	Read header
RL	Read current location
RP	Read user (PC) time
RR	Read α / β ratemeter
RS	Read samples
R1	Read α ratemeter alarm
R2	Read β ratemeter alarm
R3	Read α+β ratemeter alarm
R4	Read α scaler alarm
R5	Read β scaler alarm
R6	Read α+β scaler alarm

SET COMMANDS

SCmmddyyyy	Set calibration date
SDmmddyyyy	Set current date
SHxyyyyyyyyyyyyyy	Set Header
SLxxxxxxxxxx	Set current location
SMx	Sets ratemeter dumping
SPxxx.x	Set user (PC) time
SR	Send reset samples
SThhmm	Set current time
S1xxxxxx	Set α ratemeter alarm
S2xxxxxx	Set β ratemeter alarm
S3xxxxxx	Set α+β ratemeter alarm
S4xxxxxx	Set α scaler alarm
S5xxxxxx	Set β scaler alarm
S6xxxxxx	Set α+β scaler alarm

COMMAND DESCRIPTIONS

RA
This command reads the current sample number. The output is six characters, including a [CR] and [LF]. The format is:

```
0001[CR][LF]
```

RC
This command reads the calibration date. During power-up, the Model 2360 checks the current date against this date. If the current date is past the calibration date, the message "OUTCAL" is displayed and the Model 2360 is disabled until the calibration date is changed ahead of the current date. The output is 10 characters including a [CR] and [LF]. The format is:

```
MMDDYYYY
12251996[CR][LF]
```

RD
This command reads the current date and time. The output is 21 characters including a [CR] and [LF]. The format is :

```
HH:MM:SS MM/DD/YYYY
16:16:29 11/20/1996[CR][LF]
```

RHx
This command reads the specified header where "x" equals a number 1-6. The output is 17 characters, including a carriage return [CR] & line-feed [LF].

```
[15 characters]
John Smith [5 SPACES][CR][LF]
```

RL
This command reads the current location. The output is 12 characters, including a [CR] and [LF]. The format is:

```
TABLE0001[SPACE][CR][LF]
```

RP
This command reads the user-defined "PC" count time. This is the scaler count time when the Model 2360 count time switch is on the "PC" position. The output is 7 characters, including a [CR] and [LF]. The format is:

```
012.5[CR][LF]
```

RR
This command reads the current alpha and beta ratemeter reading. When dip-switch 5 and 6 are set to **OFF,** the Model 2360 sends this message every 2 seconds. The alpha Ratemeter reading is first, followed by the beta ratemeter reading. The output is 15 characters, including a [CR] and [LF]. The format is:

Alpha Beta
```
000003 002305[CR][LF]
```

RS
This command will return all logged samples from memory. A "$" signifies the end of samples. The maximum number of samples stored is 550. The format is:

```
0001 11/18/96 14:50:05 000020 000450 R 001.0 CHKSRC
0002 11/18/96 14:50:07 000015 000390 S 001.0 TABLE0001
0003 11/18/96 16:49:49 000040 001400 R 000.1 TABLE0002
$
```

R1, R2, R3, R4, R5, R6
These commands read the alarm set points.

R1 = Alpha Ratemeter.
R2 = Beta Ratemeter.
R3 = Alpha + Beta Ratemeter.
R4 = Alpha Scaler.
R5 = Beta Scaler.
R6 = Alpha + Beta Scaler.

The output is eight characters, including a [CR] and [LF]. The format is:

```
000500[CR][LF]
```

SCmmddyyyy
This command sets the calibration due date. The date is entered in Month-Day-Year (MMDDYYYY) format. During power-up, the Model 2360 checks to see if the current date is past the calibration due date. If it is, then the Model 2360 displays "OUTCAL" and is disabled until this command is issued to set the calibration date ahead of the current date. The length of the command is 12 characters, including a [CR] and [LF]. The format is:

```
SC11201997[CR][LF]
```

Sdmmddyyyyz
This command sets the current date. The date is entered in Month-Day-Year format. The PCF8593 clock/calendar chip uses a counter from 0 to 3 to represent the year. The variable "z" must correspond to the following table. The length of the command is 13 characters, including a [CR] and [LF].

Year ending in	Year Code
04	0
05	1
06	2
07	3
08	0
09	1
10	2
11	3

For example, the command to set the date to March 20, 2006 is:

```
SD032020062[CR][LF]
```

SHxyyyyyyyyyyyyyyy

This command sets the specified header. The variable "x" can be any number between 1 and 6. The variable "y" must be 15 characters. If the value is less than 15 characters, it must be padded with spaces. The length of the command is 20 characters, including a [CR] and [LF]. The format is:

```
SH1JOHN SMITH[5 SPACES][CR][LF]
```

SLxxxxxxxxxx

This command sets the current location that will be saved with any subsequent logged samples. The location can be up to 10 characters in length and must be padded with spaces if less than 10 characters. The length of the command is 14 characters, including a [CR] and [LF]. The format is:

```
SLTABLE0007[SPACE][CR][LF]
```

SMx

This command disables or enables the automatic dumping of the ratemeter when the Model 2360 is set not to log samples (dip-switch 5 and 6 both OFF). Specifying SM0 will disable the ratemeter dumping until the unit is turned off or the command SM1 is issued.

SPxxx.x

This command sets the user-defined count time that is selectable by setting the count time switch on the Model 2360 to "PC". The count time can be set from 000.1 minutes (6 seconds) to 546.1 minutes (32766 seconds). The length of the command is nine characters, including a [CR] and [LF]. The format is:

```
SP001.0[CR][LF]
```

SR

This command resets the sample number to one and clears all samples stored in memory. Use this command with caution. The length of the command is four characters, including a [CR] and [LF]. The format is:

WARNING!

This command will erase all logged samples from memory.

```
SR[CR][LF]
```

SThhmm
This command sets the current time in 24-hour format. Twenty-four-hour time is as follows:

```
12:00 AM   0000       12:00 PM   1200
01:00 AM   0100       01:00 PM   1300
02:00 AM   0200       02:00 PM   1400
03:00 AM   0300       03:00 PM   1500
04:00 AM   0400       04:00 PM   1600
05:00 AM   0500       05:00 PM   1700
06:00 AM   0600       06:00 PM   1800
07:00 AM   0700       07:00 PM   1900
08:00 AM   0800       08:00 PM   2000
09:00 AM   0900       09:00 PM   2100
10:00 AM   1000       10:00 PM   2200
11:00 AM   1100       11:00 PM   2300
```

The length of the command is eight, characters including a [CR] and [LF]. For example, the command to set the time to 1:00 pm is:

ST1300[CR][LF]

S1, S2, S3, S4, S5, S6
These commands set the alarms for the alpha, beta, and alpha + beta ratemeter and also the alpha, beta, and alpha + beta scaler. If the alarm is set to 0, then the alarm is disabled. S1 = Alpha Ratemeter.

S2 = Beta Ratemeter.
S3 = Alpha + Beta Ratemeter.
S4 = Alpha Scaler.
S5 = Beta Scaler.
S6 = Alpha + Beta Scaler.

The length of the command is 10 characters, including a [CR] and [LF]. For example, to set the alpha ratemeter alarm to 500 the command is:

```
S1000500[CR][LF]
```

Model 2360 Interface Software

The Model 2360 Interface (LMI Part #:1370-039) is Windows-based and has a user-friendly interface, which allows the user to communicate with the Model 2360. The Model 2360 interface features automatically loading default values, and a Auto Dump Mode Display. When the program is started, the user is prompted to either allow the software to find the Model 2360 or to manually specify a serial port. Once connected, the software will download all data from the Model 2360, which includes headers and logged data. The user is able to change any information and update the Model 2360, print hard copies, or save data to an ASCII file for later import into word processors, spreadsheets, or other applications.

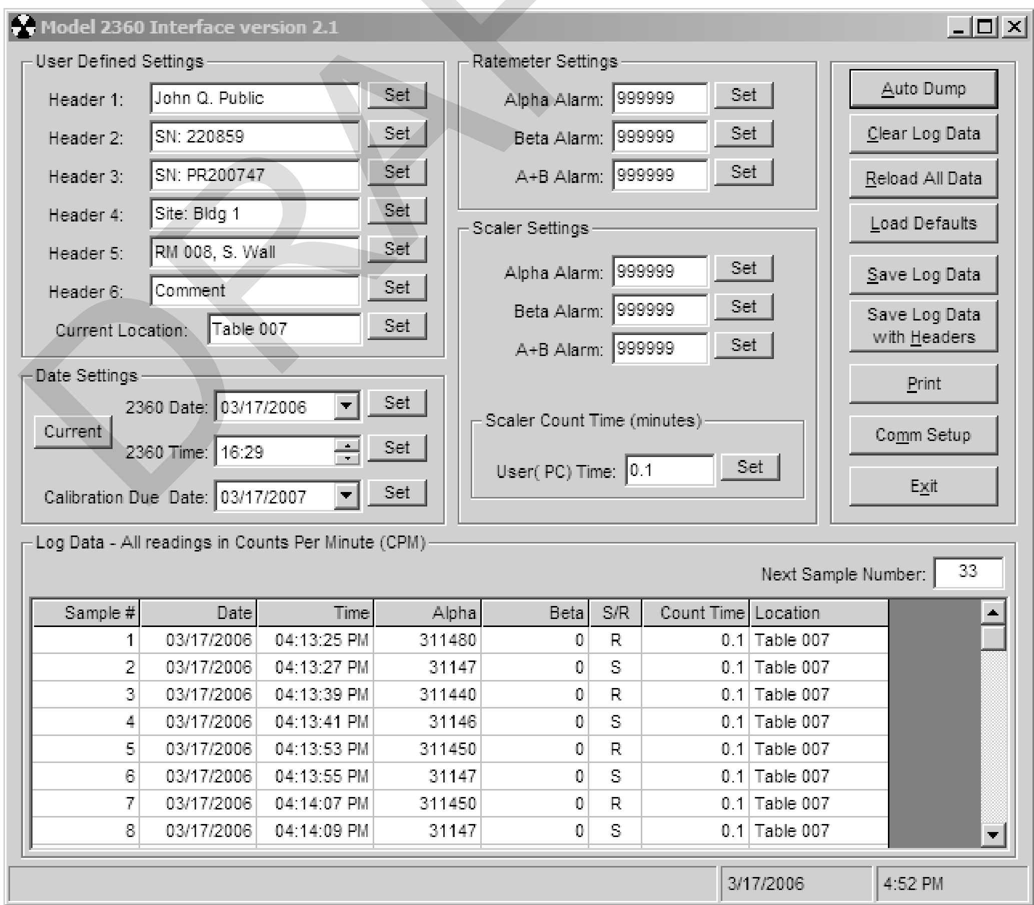
FUNCTIONS

The Model 2360 Interface software has three main functions:

1. Read or update the parameters stored in the Model 2360.

2. Read, save, or delete the logged data stored in the Model 2360.

3. Collect and save real-time data at specified intervals of time.



MAIN SCREEN

[**Set**]—Clicking the **Set** button will save the parameter to the Model 2360. Each parameter has its own **Set** button.

[**Auto Dump**]—Displays the Auto Dump Data screen, which allows for real time logging of data.

[**Clear Log Data**]—Erases the logged sample data in the Model 2360.

Caution:

Data will be lost if this button is pressed and the data has not previously been saved.

[**Reload All Data**]—Downloads all information from the Model 2360.

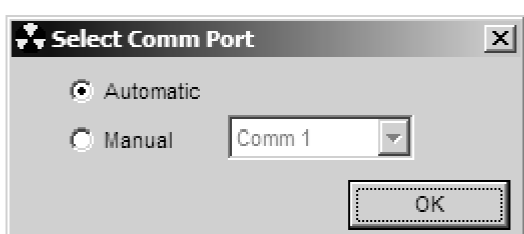
[**Load Defaults**]—Reloads all header data to the original state as shipped from Ludlum Measurements, Inc.

[**Save Log Data**]—Displays the "save file" prompt to allow the user to specify which drive and directory to save the Log File.

[**Save Log Data**]—Displays the "save file" prompt to allow the user to specify which drive and directory to save the Log File. This option also saves the six header fields to the file.

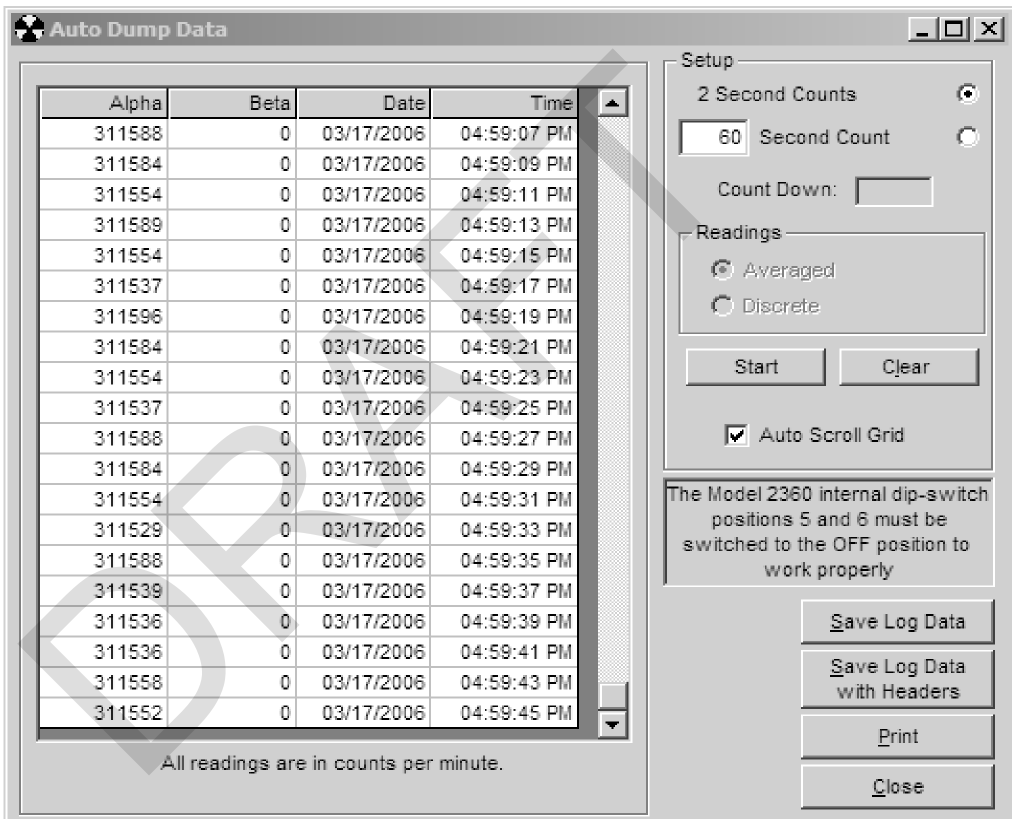
[**Print**]—Prints all parameters as well as logged data to the default printer. If there is no logged data, only the parameters will printed.

[**Comm Setup**]—Displays the Select Comm Port screen. Select "Automatic" to allow the software to scan all available serial ports to find the Model 2360. Select "Manual" and choose a specific serial port.



AUTO DUMP DATA (SETUP)

> **Note:**
>
> For auto dumping to work properly, the Model 2360 internal dip switches 5 and 6 must be set to the OFF position.



[**Two-Second Counts**]—The Model 2360 outputs the ratemeter reading every two seconds. This option will capture each two-second reading.

[**User Defined Count**]—This option will log the data based on a user-defined count time, which is adjustable from 2 to 9998 seconds. The count time specified here must be evenly divided by 2. The count time may be changed while a count is in progress and will take effect when the current count time is finished. When a user-defined count is in progress, the "Count Down" box will display the remaining count time.

[**Readings**]--When counting with a user-defined count time, the saved readings can be averaged or discrete. When the "Averaged" option is selected, the readings accumulated every two seconds during the count time are averaged. When the "Discrete" option is selected, the last two-second reading at the end of the count time is used. This option is only available when the user-defined count time option is selected.

[**Start**] [**Stop**]—Toggle from Start/Stop to start or stop the dumping of counts.

[**Clear**]—Clears data from the display box. This only clears the grid and does not affect the samples stored in the memory of the Model 2360.

[**Auto Scroll Grid**]—When checked, the grid automatically scrolls to keep the newest record visible.

[**Save Log Data**]—Save the data to a user-specified file and location. The data is saved in standard ASCII and is readable in almost any program.

[**Save Log Data with Headers**]—This button performs the same function as above, but also saves the six header fields.

[**Print**]—Sends data, including the displayed readings, to the default printer. If there is no data displayed, only the header information will be printed.

[**Close**]—Returns to the main menu area.

MODEL 2360 INTERFACE SOFTWARE SAMPLE PRINTOUTS (following pages)

Table 1: Logged data downloaded from the Model 2360 and saved to an ASCII file

Table 2: Auto dump data saved to an ASCII file

Table 3: Printout of logged data

Table 1:

Header 1: John Q. Public
Header 2: SN: 220859
Header 3: SN: PR200747
Header 4: Site: Bldg 1
Header 5: RM 008, S. Wall
Header 6: Comment

S=Scaler, R=Ratemeter

Sample #	Date	Time	Alpha	Beta	S/R	Count Time	Location
1	03/17/2006	11:48:37 AM	311092	0	R	0.1	Table 007
2	03/17/2006	11:48:39 AM	31112	0	S	0.1	Table 007
3	03/17/2006	11:48:51 AM	311144	0	R	0.1	Table 007
4	03/17/2006	11:48:53 AM	31113	0	S	0.1	Table 007
5	03/17/2006	11:49:05 AM	311127	0	R	0.1	Table 007
6	03/17/2006	11:49:07 AM	31113	0	S	0.1	Table 007
7	03/17/2006	11:49:19 AM	311143	0	R	0.1	Table 007
8	03/17/2006	11:49:21 AM	31113	0	S	0.1	Table 007
9	03/17/2006	11:49:33 AM	311129	0	R	0.1	Table 007
10	03/17/2006	11:49:35 AM	31113	0	S	0.1	Table 007

Table 2:

Header 1: John Q. Public
Header 2: SN: 220859
Header 3: SN: PR200747
Header 4: Site: Bldg 1
Header 5: RM 008, S. Wall
Header 6: Comment

Alpha	Beta	Date	Time
311348	0	03/17/2006	01:49:44 PM
311344	0	03/17/2006	01:49:46 PM
311299	0	03/17/2006	01:49:48 PM
311348	0	03/17/2006	01:49:50 PM
311314	0	03/17/2006	01:49:52 PM
311312	0	03/17/2006	01:49:54 PM
311297	0	03/17/2006	01:49:56 PM
311296	0	03/17/2006	01:49:58 PM
311348	0	03/17/2006	01:50:00 PM
311314	0	03/17/2006	01:50:02 PM

Table 3:

```
Model 2360 Log Data    Date: 03/17/2006    Time: 01:44:49 PM       Page 1
---------------------------------------------------------------------
Header 1: John Q. Public
Header 2: SN: 220859
Header 3: SN: PR200747
Header 4: Site: Bldg 1
Header 5: RM 008, S. Wall
Header 6: Comment

Calibration Due Date: 03/15/2007
     Model 2360 Date: 03/17/2006
     Model 2360 Time: 01:37:21 PM

Logged Samples:  10

User PC Scaler Count Time:  0.1 minutes

        Alpha Ratemeter Alarm Setpoint:  999999
        Beta Ratemeter Alarm Setpoint:  999999
Alpha + Beta Ratemeter Alarm Setpoint:  999999

        Alpha Scaler Alarm Setpoint:  999999
        Beta Scaler Alarm Setpoint:  999999
Alpha + Beta Scaler Alarm Setpoint:  999999

S=Scaler, R=Ratemeter
```

Sample #	Date	Time	Alpha	Beta	S/R	Count Time	Location
1	03/17/2006	11:48:37 AM	311092	0	R	0.1	Table 007
2	03/17/2006	11:48:39 AM	31112	0	S	0.1	Table 007
3	03/17/2006	11:48:51 AM	311144	0	R	0.1	Table 007
4	03/17/2006	11:48:53 AM	31113	0	S	0.1	Table 007
5	03/17/2006	11:49:05 AM	311127	0	R	0.1	Table 007
6	03/17/2006	11:49:07 AM	31113	0	S	0.1	Table 007
7	03/17/2006	11:49:19 AM	311143	0	R	0.1	Table 007
8	03/17/2006	11:49:21 AM	31113	0	S	0.1	Table 007
9	03/17/2006	11:49:33 AM	311129	0	R	0.1	Table 007
10	03/17/2006	11:49:35 AM	31113	0	S	0.1	Table 007

INSTALLATION OF THE 2360 INTERFACE SOFTWARE

User must comply with the software license agreement located at the end of this section (pages 7-14 thru 7-16). By installing this software you are consenting to be bound by this agreement. If you do not agree to all the terms of this agreement, do not install the product!

Insert the Model 2360 Interface software CD into the computer. The installation routine should start automatically. If it does not, click on the Start button, select "Run" and type in the following: "d:\setup.exe".

Replace the drive letter with the correct drive letter of the CD-ROM drive. Follow the onscreen prompts to install the software. When complete, the software should be installed in C:\Program Files\2360Win. A shortcut is created in the Start Menu under “Ludlum Measurements, Inc.”

REMOVAL OF MODEL 2360 INTERFACE SOFTWARE

To remove the program, start from the Windows Desktop. Click on Start Button, Settings, Control Panel, and then Add/Remove Programs. Find LMI 2360 Interface from the list and highlight, then click on the add/remove button to start uninstall.

Setup will prompt to ensure removal of program LMI 2360 Interface is acceptable.

Setup will also present a prompt asking if you wish to keep, remove, remove none, or remove all. Files can be removed since they are installed in C:\Program Files\Model 2360 and should not cause any problems.

Uninstall screen appears and the program removal will be complete.

CONNECTING TO A COMPUTER

Using the supplied cable, connect the end with the female connector to the Model 2360 and the other end to a free COM port on your computer. The pin-outs of the cables are as follows:

9-pin cable

Model 2360	Computer
2	2
3	3
5	5
7	7
8	8

25-pin cable

Model 2360	Computer
2	3
3	2
5	7
7	4
8	5

LUDLUM MEASUREMENTS, INC.
501 OAK ST., P.O. BOX 810
SWEETWATER, TX 79556
325/235-5494 FAX: 325/235-4672

Software License Agreement

Rev. (number) 1.0
Written by (or Revised by): Rich Grola **Date:** 20 Jan 06
Approved by: Ed Ess **Date:** 20 JAN 06

BY INSTALLING THIS SOFTWARE, YOU ARE CONSENTING TO BE BOUND BY THIS AGREEMENT. IF YOU DO NOT AGREE TO ALL OF THE TERMS OF THIS AGREEMENT, DO NOT INSTALL THE PRODUCT.

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Section

8

Technical Theory of Operation

Refer to Amplifier/Power Supply Board Drawing 390 × 180 for the following:

Detector Input/Amplifier

Negative-going detector pulses are coupled from the detector through C022 to Amplifier U021. R023 and CR021 protect the input of U021 from inadvertent shorts. Self-biased amplifier U021 provides gain in proportion to R021 divided by R022. Transistor pins 4, 5, and 6 of U021, provide amplification. Pins 12 and 15 of U021 are coupled as a constant current source to pin 6 of U021. The output self biases to 2Vbe (approximately 1.4 volts) at pin 7 of U021. This provides just enough bias current through pin 6 of U021 to conduct all of the current for the constant current source. Positive pulses from pin 7 of U021 are coupled to the discriminators through R011 and C011.

Alpha/Beta Discriminator

Positive pulses from amplifier U021 are coupled to comparator U012, pin 6, for alpha discrimination and pins 6 and 2 of U011 for beta discrimination. R201, alpha threshold, provides the reference voltage for alpha comparator U012. R102, beta threshold (defined as the lower threshold limit of the beta counting window), provides the reference voltage for beta threshold comparator pins 1, 2, and 3 of U011. R104, beta window (defined as the upper threshold limit of the beta counting window), provides the reference voltage for the beta window comparator pins 5, 6, and 7 of U011.

Alpha/Beta Discriminator Logic Circuit

Alpha pulses from U012 are coupled to univibrator U111. Pulses at pin 6 of U111 are inverted by Q111 for connection to reset (R) pins 3, 13 of U101. Pin 9 of U111 provides the pulses to be counted by the microprocessor (μP). Pulses from pin 9 of U111 are connected to pin 3 of U111 to provide a time delay for the μP clock cycle to complete before the next alpha pulse can be recognized by the μP.

Beta pulses from pin 1 of U011 are coupled to univibrator U101. Pulses are coupled to the µP from pin 7 of U101 as long as pins 3 and 13 of U011 remain high (+5 V). When an alpha and/or a beta window pulse is present, the reset (pins 3 and 13 of U101) function is enabled, and 7 of U101 remains high. Pin 7 of U101 is connected to pin 13 of U101 to provide a time delay for the µP clock cycle to complete before the next beta pulse can be recognized by the µP.

Low Voltage Supply

Battery voltage is coupled to switching regulator U201 and associated components to provide +5 V to power op-amps and logic circuitry. The charge pump (cp) output C202, CR211, CR212, and C201 form a voltage doubler circuit to provide +9 V for U201 amplifier supply. U001 and related components provide +2.5 V reference for HV SET and alpha/beta discriminator controls. R201 (LO BAT) is adjusted so that the meter pointer is aligned with the left vertical mark on the BAT OK line with 2.2 V battery input.

High Voltage Supply

High voltage is developed by blocking oscillator Q421, T321, C412, and rectified by voltage multiplier CR221-CR224, C221-C223, C211, and C114. High voltage increases as current through Q421 increases, with maximum output voltage with Q421 saturated.

High voltage is coupled back through R123 to op-amp pin 2 of U311. Resistor network R211-214 completes the HV division circuit to ground. R214 provides HV limit at 2.0 kV when the HV SET control on the calibration board is at maximum. The regulated HV output is controlled by HV potentiometer located under the CAL cover on the front panel. This control provides the reference for comparator pin 3, U311. During stable operation, the voltage at pin 2 of U311 will equal the voltage at pin 3 of U311. Pin 1 of U311 will cause conduction of Q312 to increase or decrease until the HV finds a level of stability. R115 (HV TEST) calibrates the analog meter to the HV output when the HV test push-button switch is depressed.

Detector Overload

A voltage drop is developed across R121 and sensed by comparator U012 as detector current increases. When the voltage at pin 3 of U012 goes below pin 2, pin 1 goes low, illuminating the OL LED and driving the meter to full scale. R211, overload, provides adjustment for the overload set point.

Meter Drive

Pulses are coupled from the µP board to the gate of Q302. Q302 inverts the pulses at CR403, and C401 provides integration. Integrated meter drive voltage is coupled from P1-13 via the battery (BAT) and HV test switch to pin 5 of U311. The meter is driven by the emitter of Q111, coupled as a voltage follower in conjunction with pin 6 and 7 of U311. R406, "Meter Cal," is adjusted to calibrate the ratemeter reading corresponding to the incoming count rate. R407 and R408 provide temperature compensation for changes in the meter resistance due to temperature variations.

Refer to Processor Board Drawing 390 × 173 for the following:

Power supply

Battery voltage is coupled to switching regulator U321 and associated components to provide +5 V to power the µP and display drivers U211, 212. R101, C101, Q101, and Q201 form a delay switch, which allows U321 to stabilize before the load current is connected to the +5 V supply.

Microprocessor (µP)

U111, Intel N87C51FC, controls all of the data, control inputs, and display information. The clock frequency is crystal controlled by Y111 and related components at 6.144 MHz. The µP incorporates internal memory (ROM) storing the program information. C211 resets the µP at power-up to initiate the start of the program routine. During the program loop the µP looks at all of the input switches for initiation or status changes and responds accordingly.

The µP uses pulse-width modulation to control the analog ratemeter. The analog output, RATE (P1-3) is divided into 255 increments in a 166 µs period. At full meter deflection the low pulse period – leading edge to leading edge – will be 166 µs, 500 cpm = 163 µs, 400 cpm = 130 µs, 200 cpm = 65 µs, 100 cpm = 33 µs, and 0 = no pulse or +5 V. The pulses are inverted by Q302 on the amp/power supply board and then integrated by R403, C401.

LCD Drive

U101 and U001 make up the liquid crystal display drive circuitry. The display information is sent from the µP to U101 and U001 via DATA 0-1 lines. Each bit is latched into the drivers when the CLOCK line is brought high, then low by the µP. When 32 bits have been clocked to the drivers, the

LOAD line is brought high, and then low. The corresponding digits and segments are illuminated, corresponding to the stored-count information from the μP.

Audio

Alpha and/or beta audio pulse frequency is generated by the μP and coupled to Q211. Q211 then inverts the pulses and drives the low side of the audio transformer T321. Front-panel VOL control provides the bias voltage to the top of T321. Secondary winding of T321 is coupled to unimorph speaker via front-panel audio jack.

Section 9

Troubleshooting

Occasionally, you may encounter problems with your LMI instrument or detector that may be repaired or resolved in the field, saving turn-around time and expense in returning the instrument to us for repair. Toward that end, LMI electronics technicians offer the following tips for troubleshooting the most common problems. Where several steps are given, perform them in order until the problem is corrected. Keep in mind that the most common problems encountered with this particular instrument are: (1) detector cables, (2) sticky meters, (3) battery contacts.

Note that the first troubleshooting tip is for determining whether the problem is with the electronics or with the detector. A Ludlum Model 500 Pulser can be invaluable at this point because of its ability to simultaneously check high voltage, input sensitivity or threshold, and the electronics for proper counting.

We hope these tips will prove to be helpful. As always, please call if you encounter difficulty in resolving a problem or if you have any questions.

Troubleshooting Electronics that Utilize Proportional and Scintillator Type Detectors

SYMPTOM	POSSIBLE SOLUTION
No power (or meter does not reach BAT TEST or BAT OK mark)	1. Check batteries and replace if weak. 2. Check polarity (see marks inside battery lid). Are the batteries installed backwards?

SYMPTOM	**POSSIBLE SOLUTION**
No power (or meter does not reach BAT TEST or BAT OK mark) (continued)	3. Check battery contacts. Clean them with rough sandpaper or use an engraver to clean the tips. 4. Check for loose or broken wires, especially between the main board and the calibration board.
Nonlinear Readings	1. Check the high voltage (HV) by using a Ludlum Model 500 Pulser (or equivalent). If a multimeter is used to check the HV, ensure that one with high impedance is used, as a standard multimeter could be damaged in this process. 2. Check for noise in the detector cable by disconnecting the detector, placing the instrument on the lowest range setting, and wiggling the cable while observing the meter face for significant changes in readings. 3. Check for "sticky" meter movement. Does the reading change when you tap the meter? Does the meter needle "stick" at any spot? 4. Check the "meter zero." Turn the power OFF. The meter should come to rest on "0."
Meter goes full scale or "pegs out"	1. Replace the detector cable to determine whether or not the cable has failed, causing excessive noise. 2. Check the HV and, if possible, the input threshold for proper setting.

SYMPTOM		**POSSIBLE SOLUTION**
Meter goes full scale or "pegs out" (continued)	3.	Open the instrument can and check for loose wires.
	4.	Ensure that the instrument's can is properly attached. When attached properly, the speaker will be located on the left side of the instrument. If the can is on backwards, interference between the speaker and the input preamplifier may cause noise.

Section 10

Recycling

Ludlum Measurements, Inc. supports the recycling of the electronics products it produces for the purpose of protecting the environment and to comply with all regional, national, and international agencies that promote economically and environmentally sustainable recycling systems. To this end, Ludlum Measurements, Inc. strives to supply the consumer of its goods with information regarding reuse and recycling of the many different types of materials used in its products. With many different agencies – public and private – involved in this pursuit, it becomes evident that a myriad of methods can be used in the process of recycling. Therefore, Ludlum Measurements, Inc. does not suggest one particular method over another, but simply desires to inform its consumers of the range of recyclable materials present in its products, so that the user will have flexibility in following all local and federal laws.

The following types of recyclable materials are present in Ludlum Measurements, Inc. electronics products and should be recycled separately. The list is not all-inclusive, nor does it suggest that all materials are present in each piece of equipment:

Batteries	Glass	Aluminum and Stainless Steel
Circuit Boards	Plastics	Liquid Crystal Display (LCD)

Ludlum Measurements, Inc. products, which have been placed on the market after August 13, 2005, have been labeled with a symbol recognized internationally as the "crossed-out wheelie bin." This notifies the consumer that the product is not to be mixed with unsorted municipal waste when discarding; each material must be separated. The symbol will be placed near the AC receptacle, except for portable equipment where it will be placed on the battery lid.

The symbol appears as such:

Section 11

Parts List

	Reference	Description	Part Number
Model 2360 Scaler/Ratemeter	UNIT	Completely Assembled Model 2360 Scaler/Ratemeter	48-2872
Amplifier/Power Supply Board, Drawing 390 × 180	BOARD	Completely Assembled Amplifier/ Power Supply Board	5390-174
CAPACITORS	C001	100PF, 100V	04-5661
	C002	47PF, 100V	04-5660
	C011	0.1µF, 50V	04-5663
	C012	0.001µF, 100V	04-5659
	C013	0.001µF, 100V	04-5659
	C014	0.01µF, 50V	04-5664
	C015	0.1F, 50V	04-5663
	C016	0.001µF, 100V	04-5659
	C017	10µF, 20V	04-5655
	C021	10PF, 100V	04-5673
	C022	100PF, 3KV	04-5532
	C101	47PF, 100V	04-5660
	C102	47PF, 100V	04-5660
	C111	47PF, 100V	04-5660
	C112	47PF, 100V	04-5660
	C113	47PF, 100V	04-5660
	C114	0.0047µF, 3KV	04-5547
	C121	0.0047µF, 3KV	04-5547
	C122	0.0047µF, 3KV	04-5547
	C201	10µF, 20V	04-5655
	C202	10µF, 20V	04-5655
	C203	330PF, 100V	04-5657
	C211	0.0047µF, 3KV	04-5547
	C212	68µF, 6.3V	04-5654
	C213	1µF, 35V	04-5656

	Reference	Description	Part Number
	C214	0.01µF, 50V	04-5664
	C221	0.0047µF, 3KV	04-5547
	C222	0.0047µF, 3KV	04-5547
	C223	0.0047µF, 3KV	04-5547
	C301	68µF, 6.3V	04-5654
	C311	01µF, 50V	04-5664
	C401	1µF, 50V	04-5663
	C411	1µF, 50V	04-5663
	C412	1µF, 35V	04-5656
	C421	68µF, 6.3V	04-5654
TRANSISTORS	Q111	2N7002L	05-5840
	Q301	MMBT4403LT1	05-5842
	Q302	2N7002L	05-5840
	Q311	MMBT3904T	05-5841
	Q312	MMBT3904T	05-5841
	Q421	MJD210	05-5843
INTEGRATED CIRCUITS	U001	LM285M-2.5	06-6291
	U011	TLC372ID	06-6290
	U012	TLC372ID	06-6290
	U021	CA3096M	06-6288
	U101	CD74HC4538M	06-6297
	U111	CD74HC4538M	06-6297
	U201	MAX631AESA	06-6285
	U301	CD74HC4066M	06-6323
	U311	TLC27M7ID	06-6292
DIODES	CR021	MMBD7000LT1	07-6355
	CR111	MMBD914L	07-6353
	CR112	MMBD914L	07-6353
	CR211	BAT54	07-6354
	CR212	BAT54	07-6354
	CR221	GI250-2	07-6266
	CR222	GI250-2	07-6266
	CR223	GI250-2	07-6266
	CR224	GI250-2	07-6266
	CR225	GI250-2	07-6266
	CR411	MMBD914L	07-6353
THERMISTOR	R407	250, 03006-165.9-55-G100	07-6366

	Reference	Description	Part Number
POTENTIOMETERS	R102	10K, BETA THRESH	09-6921
	R103	1M, BETA WIN	09-6906
	R115	1M, (HV) HV READOUT	09-6906
	R406	5K, METER CAL (MTR)	09-6907
	R214	1M, HV LIMIT	09-6906
	R201	1M, ALPHA THRESH	09-6906
	R202	200K, LO BAT (LB)	09-6908
	R211	1M, OVERLOAD	09-6906
RESISTORS	R001	22.1K, 125mW, 1%	12-7843
	R002	249K, 125mW, 1%	12-7862
	R003	22.1K, 125mW, 1%	12-7843
	R004	1.5K, 125mW, 1%	12-7878
	R011	100, 125mW, 1%	12-7840
	R012	22.1K, 125mW, 1%	12-7843
	R013	33.2K, 125mW, 1%	12-7842
	R014	10.0K, 125mW, 1%	12-7839
	R015	22.1K, 125mW, 1%	12-7843
	R016	10.0K, 125mW, 1%	12-7839
	R021	392K, 125mW, 1%	12-7841
	R022	10.0K, 125mW, 1%	12-7839
	R023	10.0K, 125mW, 1%	12-7839
	R024	33.2K, 125mW, 1%	12-7842
	R025	22.1K, 125mW, 1%	12-7843
	R026	1.00M, 250mW, 5%	10-7028
	R101	100K, 125mW, 1%	12-7834
	R104	22.1K, 125mW, 1%	12-7843
	R105	100K, 125mW, 1%	12-7834
	R111	100, 125mW, 1%	12-7840
	R112	1G	12-7686
	R113	100K, 125mW, 1%	12-7834
	R114	100K, 125mW, 1%	12-7834
	R116	249K, 125mW, 1%	12-7862
	R121	4.7M, 250mW, 5%	10-7030
	R122	1.00M, 250mW, 5%	10-7028
	R123	1G	12-7686
	R212	1.00M, 125mW, 1%	12-7844
	R213	1.00M, 125mW, 1%	12-7844
	R215	1.00M, 125mW, 1%	12-7844
	R301	2.21K, 125mW, 1%	12-7835
	R302	22.1K, 125mW, 1%	12-7843

	Reference	Description	Part Number
	R303	22.1K, 125mW, 1%	12-7843
	R311	10.0K, 125mW, 1%	12-7839
	R312	22.1K, 125mW, 1%	12-7843
	R313	2.21K, 125mW, 1%	12-7835
	R314	10.0K, 125mW, 1%	12-7839
	R401	200, 1/8W, 1%	12-7846
	R402	221K, 125mW, 1%	12-7845
	R403	7.5K, 125mW, 1%	12-7847
	R404	2.21K, 125mW, 1%	12-7835
	R405	1.00M, 125mW, 1%	12-7844
	R408	301, 125mW, 1%	12-7863
	R411	200, 125mW, 1%	12-7846
	R412	10.0K, 125mW, 1%	12-7839
CONNECTORS	P1	1-640456-5	13-8355
	P2	640456-3 MTA100	13-8081
INDUCTOR	L301	220µH	21-9678
TRANSFORMER	T321	7000T/100T, 200T	40-0902

Processor Board, Drawing 390 × 173

	Reference	Description	Part Number
	BOARD	Completely Assembled Processor Board	5390-171
CRYSTALS	Y111	MICRO XTAL-6.144 MHZ	01-5262
	Y401	MICRO XTAL-32.768 KHZ	01-5305
CAPACITORS	C111	27PF, 100V	04-5658
	C112	27PF, 100V	04-5658
	C211	4.µ, 20V	04-5653
	C221	47µF, 10V	04-5666
	C311	68µF, 6.3V	04-5654
	C312	68µF, 6.3V	04-5654
	C313	68µF, 6.3V	04-5654
	C314	68µF, 6.3V	04-5654
	C315	68µF, 6.3V	04-5654
	C316	68µF, 6.3V	04-5654
	C401	10PF, 100V	04-5673
	C411	10µF, 20V	04-5655
	C421	4.7µF, 20V	04-5653
	C422	10µF, 20V	04-5655

	Reference	Description	Part Number
	C423	4.7µF, 20V	04-5653
TRANSISTORS	Q101	TRANS-2N7002L	05-5840
	Q102	TRANS-2N7002L	05-5840
	Q211	TRANS-2N7002L	05-5840
INTEGRATED CIRCUITS	U101	IC-24C65ISM	06-6401
	U111	IC-N87C51FC	06-6331
	*	SOCKET-822276-1 44P	06-6293
	U201	IC-24C65ISM	06-6401
	U202	IC-PCF8574TD	06-6402
	U311	IC-LT1304CS8	06-6394
	U401	IC-PCF8593TD	06-6403
	U421	IC-MAX220CSE	06-6329
DIODES	CR211	CXSH-4 EB33	07-6358
	CR212	CXSH-4 EB33	07-6358
	CR401	MMBD914L	07-6353
	CR402	MMBD914L	07-6353
SWITCH	S301	CONFIGURE SWITCH	08-6710
RESISTORS	R101	200, 125mW, 1%	12-7846
	R102	200, 125mW, 1%	12-7846
	R103	22.1K, 125mW, 1%	12-7843
	R104	100K, 125mW, 1%	12-7834
	R170	1.00M, 125mW, 1%	12-7844
	R201	22.1K, 125mW, 1%	12-7843
	R202	100K, 125mW, 1%	12-7834
	R211	100K, 125mW, 1%	12-7834
	R311	150K, 125mW, 1%	12-7833
	R312	22.1K, 125mW, 1%	12-7843
	R313	68.1K, 125mW, 1%	12-7881
	R321	1.00K, 125mW, 1%	12-7832
	R401	1.00K, 125mW, 1%	12-7832
RESISTOR NETWORKS	RN201	NETWORK-220K	12-7923
	RN211	NETWORK-220K	12-7923
CONNECTORS	P3	1-640456-7 MTA100	13-8121
	P4	1-640456-1 MTA100	13-8059
	P12	640456-6 MTA100	13-8095

	Reference	Description	Part Number
	P13	640456-2 MTA100	13-8073
INDUCTOR	L211	22µH	21-9808
BATTERY	B411	DL2450 LITHIUM	22-9786
TRANSFORMER	T321	XFMR- M 177 AUDIO	4275-083
LCD Display Board, Drawing 390 × 372	BOARD	Completely Assembled LCD Display Board	5390-372
CAPACITOR	C201	27PF, 100V	04-5658
INTEGRATED CIRCUITS	U001	AY0438-I/L	06-6358
	U101	AY0438-I/L	06-6358
LEDS	DS001	E118, RED	07-6308
	DS201	E118, RED	07-6308
LCD	DSP101	LCD-GD-7427WP 6 DIGIT	07-6624
RESISTORS	R011	10K, 125mW, 1%	12-7839
	R012	10K, 125mW, 1%	12-7839
	R111	10K, 125mW, 1%	12-7839
	R112	10K, 125mW, 1%	12-7839
Calibration Board, Drawing 390 × 176	BOARD	Completely Assembled Calibration Board	5390-172
POTENTIOMETER	R3	250K, HV SET	09-6819
CONNECTOR	P7	640456-5 MTA100	13-8057
BCD Board, Drawing 261 × 107	BOARD	Completely Assembled BCD Board	5261-154
SWITCH	S111	513384	08-6656
CONNECTOR	P5	640456-5 MTA100	13-8057

Chassis Wiring Diagram, Drawing 390 × 179

	Reference	Description	Part Number
SWITCHES	S1	SWITCH-PA-600-210	08-6501
	S3	SWITCH-MPS-103F	08-6699
	S4	PHONE JACK TINI #42A	21-9333
	S5	SWITCH-7103SYZQE TOGGLE	08-6720
	S6	SWITCH-7205SYZQE TOGGLE	08-6750
POTENTIOMETER	R1	10K, VOLUME	09-6753
CONNECTORS	J1	CONN-1-640442-5 MTA100	13-8383
	J2	CONN-640442-3 MTA100	13-8135
	J3	CONN-1-640442-7 MTA100	13-8505
	J4	CONN-640442-3 MTA100	13-8135
	J5	CONN-640442-6 MTA100	13-8171
	J6	D RECPT-RD9F000V3 9 PIN	13-8003
	J7	JACK-09-9011-1-0419	18-9080
	J8	CONN-640442-6 MTA100	13-8171
	J9	CONN-640442-2 MTA100	13-8178
	J12	CONN-640442-6 MTA100	13-8171
	J13	CONN-640442-2 MTA100	13-8178
	J14	Series “C”-UG706/U	13-7751
BATTERIES	B1-B2	“D” DURACELL BATTERY	21-9313
AUDIO	DS1	S100RL-M, UNIMORPH	21-9676
MISCELLANEOUS	M1	METER ASSEMBLY	4390-160
	*	METER-PORT BZL W/GLS	4363-352
	*	M2360 METERFACE	7390-157
	*	METER-MVT #919492 1 MA	15-8030
	*	O RING-BEZEL	16-8334
	*	SPACER-#2 X .187 NYL	18-9143
	*	BATTERY CONTACT SET	40-1707
	*	MAIN HARNESS	8390-162
	*	LCD HARNESS	8390-163
	*	CAN-RS232 HARNESS	8390-166

Section 12

Drawings and Diagrams

MAIN BOARD, Drawing 390 × 180

MAIN BOARD COMPONENT LAYOUT, Drawing 390 × 181 A

PROCESSOR BOARD, Drawing 390 × 173

PROCESSOR BOARD COMPONENT LAYOUT,
Drawing 390 × 174

LCD DISPLAY BOARD, Drawing 390 × 372

LCD DISPLAY BOARD COMPONENT LAYOUT,
Drawing 390 × 373A (2 sheets)

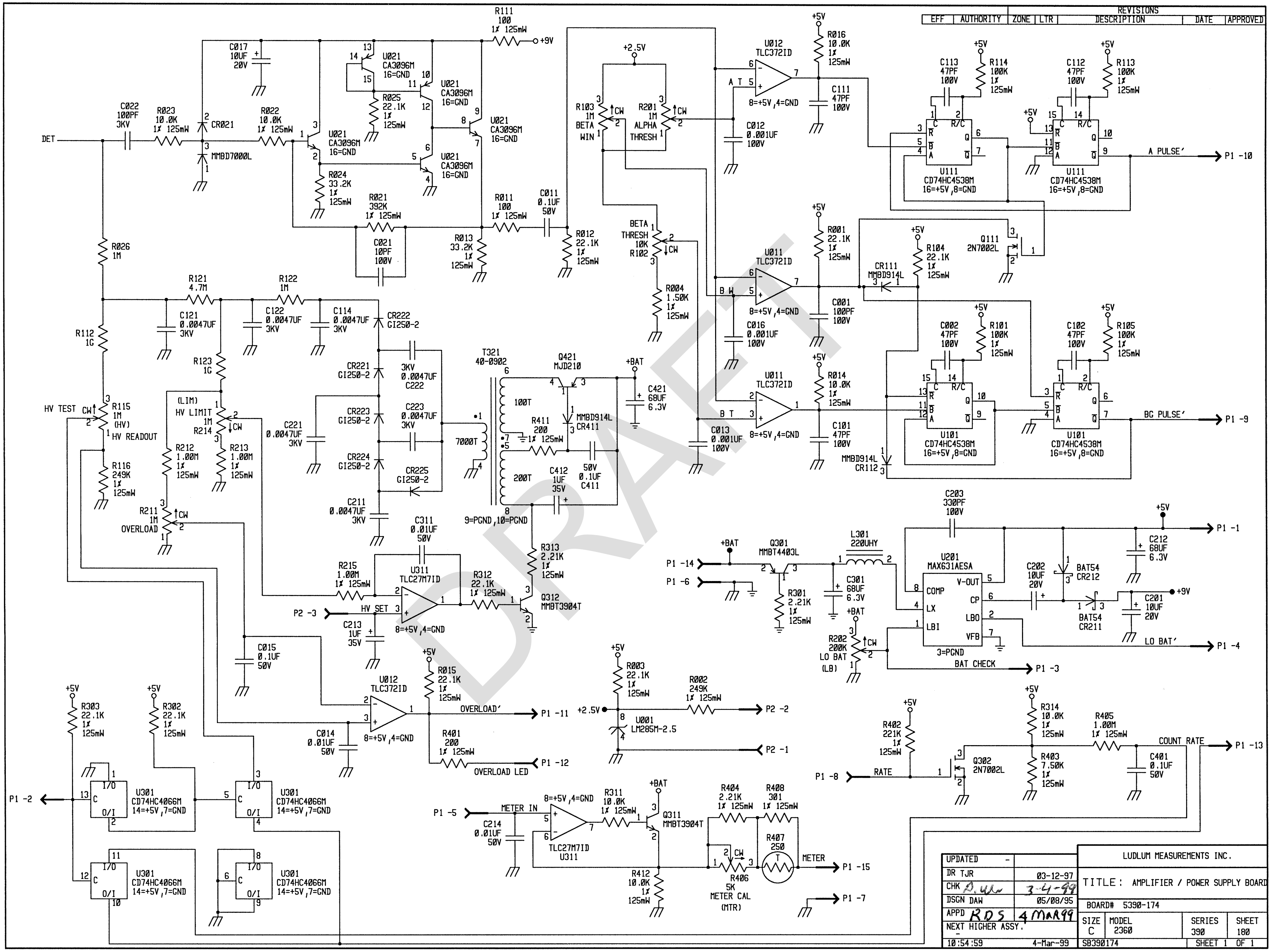
CALIBRATION BOARD, Drawing 390 × 176

CALIBRATION BOARD COMPONENT LAYOUT,
Drawing 390 × 177 (2 sheets)

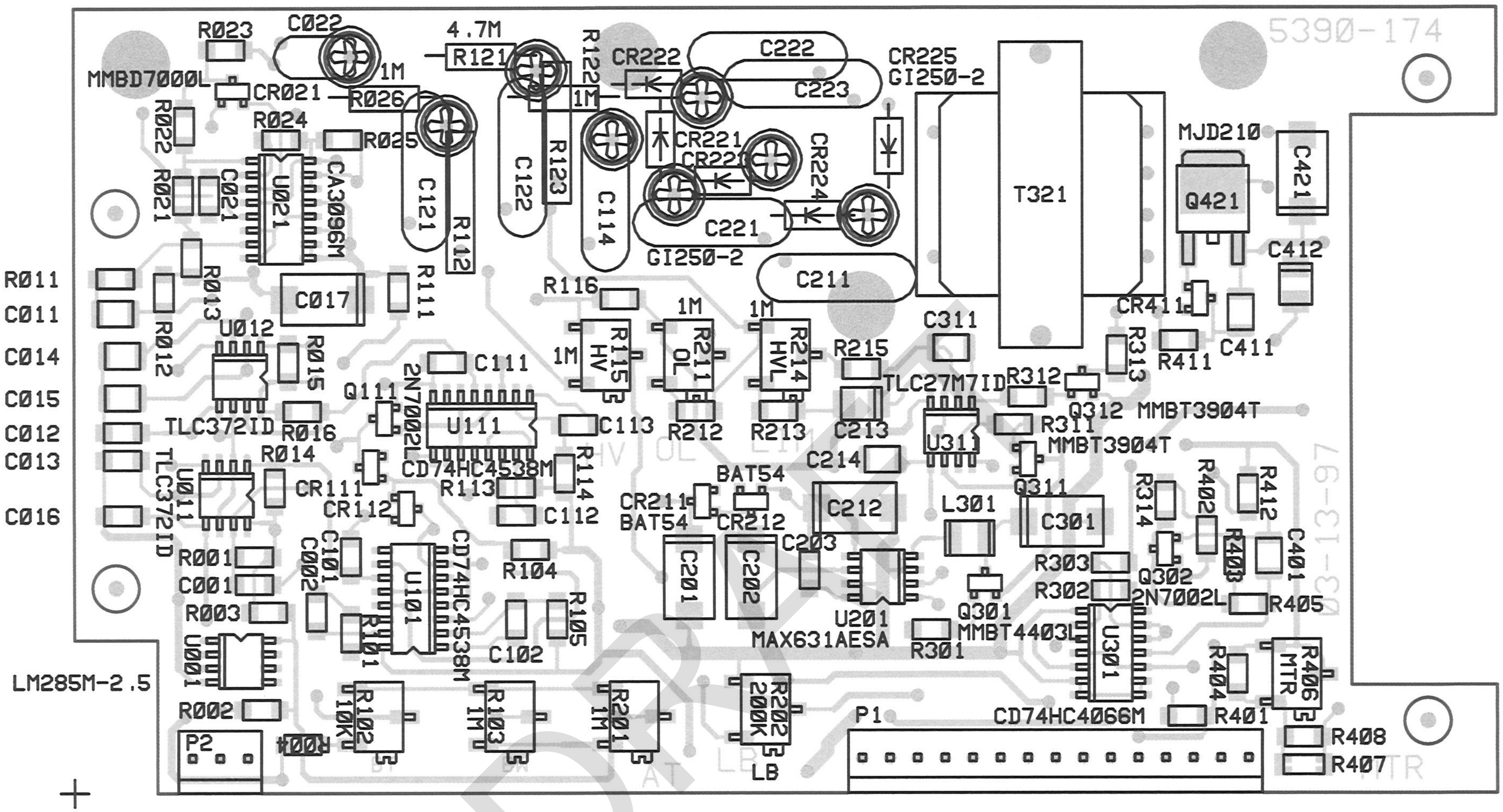
BCD BOARD, Drawing 261 × 107

BCD BOARD COMPONENT LAYOUT, Drawing 261 × 105A
(2 sheets)

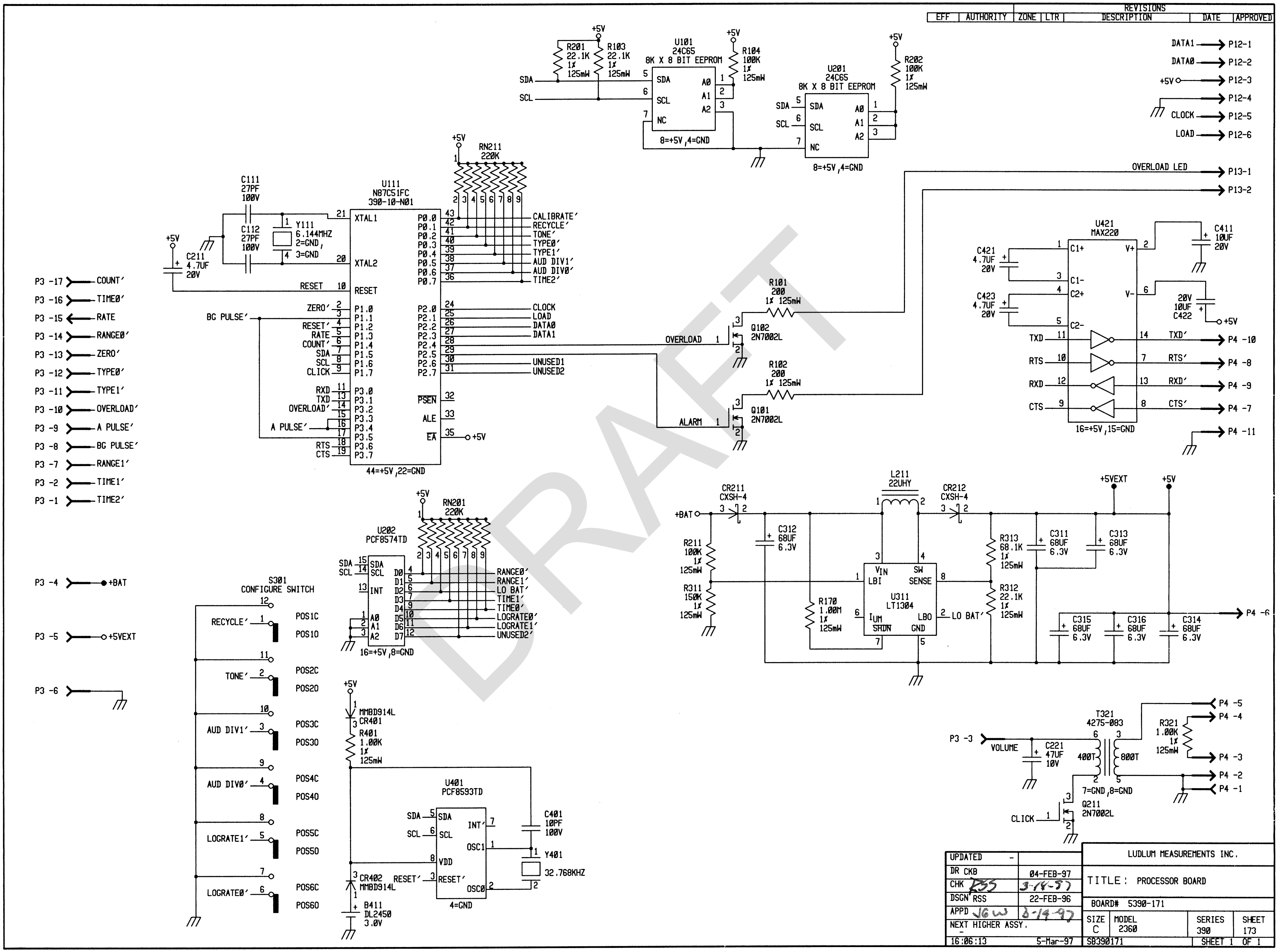
WIRING DIAGRAM, Drawing 390 × 179



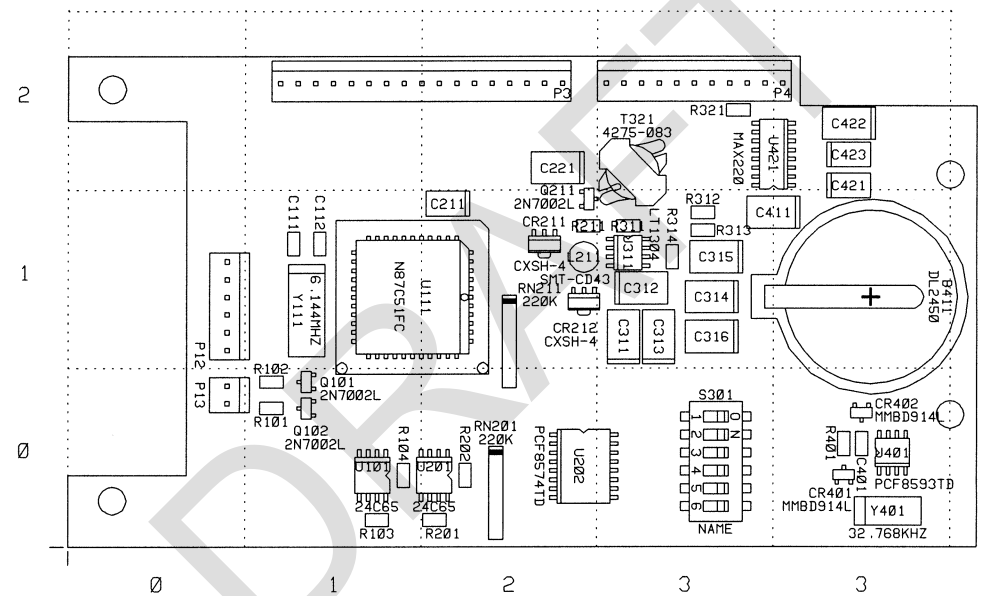
REVISIONS
EFF | AUTHORITY | ZONE | LTR | DESCRIPTION | DATE | APPROVED
DET
HV TEST
HV READOUT
HV LIMIT
OVERLOAD
BETA WIN
ALPHA THRESH
BETA THRESH
A PULSE'
BG PULSE'
OVERLOAD'
OVERLOAD LED
HV SET
METER IN
METER
METER CAL (MTR)
LO BAT'
BAT CHECK
COUNT RATE
RATE
LO BAT (LB)
DRAFT
LUDLUM MEASUREMENTS INC.
TITLE: AMPLIFIER / POWER SUPPLY BOARD
BOARD# 5390-174
UPDATED -
DR TJR 03-12-97
CHK D. W. 3-4-99
DSGN DAW 05/08/95
APPD RDS 4 MAR 99
NEXT HIGHER ASSY.
SIZE C
MODEL 2360
SERIES 390
SHEET 180
10:54:59 4-Mar-99
SB390174
SHEET 1 OF 1



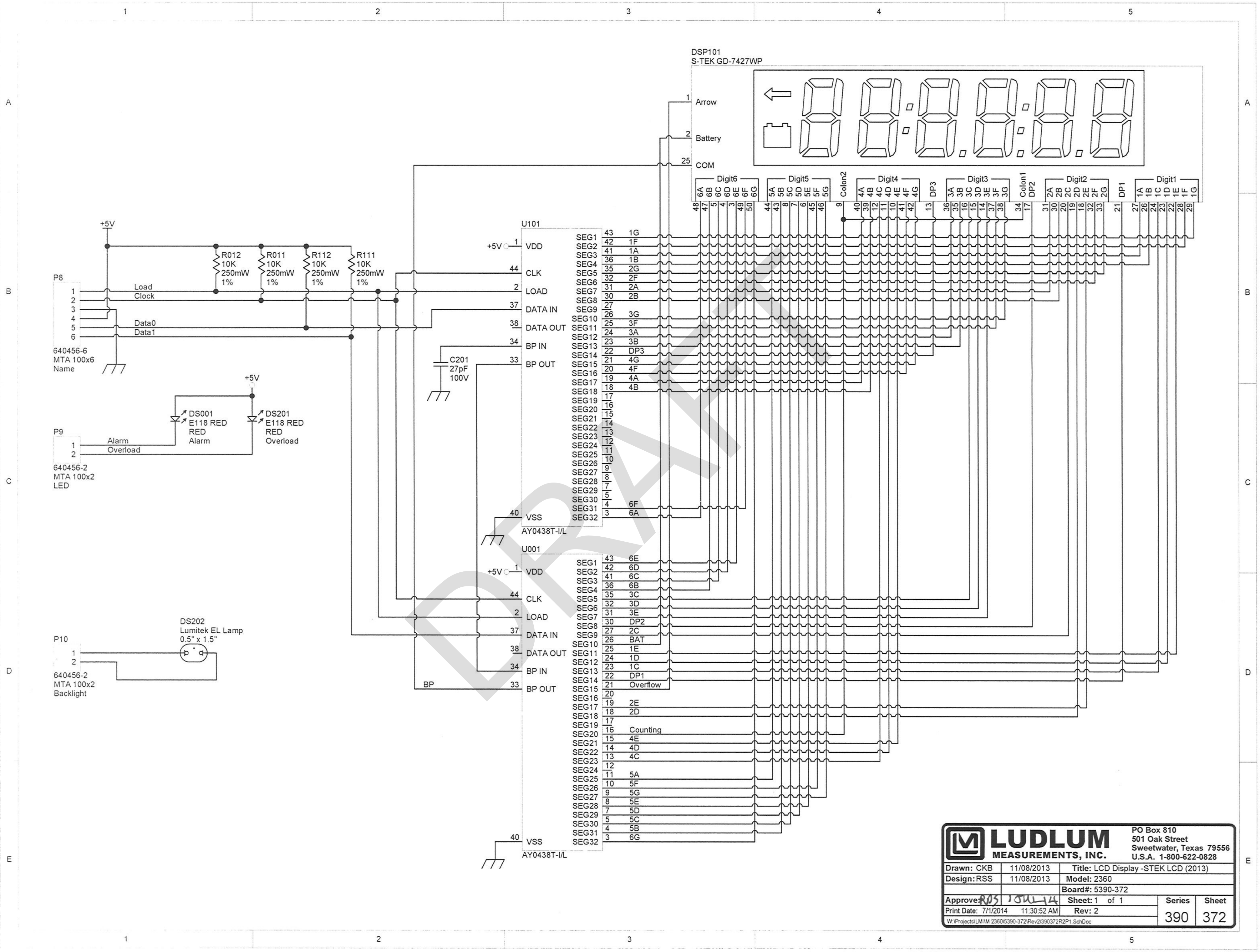
LUDLUM MEASUREMENTS, INC.		PO Box 810 501 Oak Street Sweetwater, TX 79556 U.S.A. 1-800-622-0828	
Title: AMPLIFIER/PS BOARD			
Drawn: TJR	03/12/1997	**Model:** 2360	
Design: DAW	05/08/1995	**Board#:** 5390-174	
Approve: RDS	23 Sep 13	**Rev:** 1	
Print Date: 9/23/2013	10:57:45 AM	**SCALE: 1.00** Top Overlay	**Series** 390 / **Sheet** 181 A
W:\Projects\LMI\M 2360\5390-174\Rev1\390174R1_Assy.PcbDoc			



REVISIONS
EFF | AUTHORITY | ZONE | LTR | DESCRIPTION | DATE | APPROVED
DRAFT
U101 24C65 8K X 8 BIT EEPROM
U201 24C65 8K X 8 BIT EEPROM
8=+5V,4=GND
U111 N87C51FC 390-10-N01
44=+5V,22=GND
Y111 6.144MHZ 2=GND, 3=GND
C111 27PF 100V
C112 27PF 100V
C211 4.7UF 20V
RN211 220K
RN201 220K
U202 PCF8574TD
16=+5V,8=GND
S301 CONFIGURE SWITCH
U401 PCF8593TD
4=GND
Y401 32.768KHZ
C401 10PF 100V
B411 DL2450 3.0V
CR401 MMBD914L
CR402 MMBD914L
R401 1.00K 1% 125mW
Q102 2N7002L
Q101 2N7002L
R101 200 1% 125mW
R102 200 1% 125mW
U421 MAX220
16=+5V,15=GND
C421 4.7UF 20V
C423 4.7UF 20V
C411 10UF 20V
C422 10UF 20V
L211 22UHY
CR211 CXSH-4
CR212 CXSH-4
U311 LT1304
R211 100K 1% 125mW
R311 150K 1% 125mW
R170 1.00M 1% 125mW
R313 68.1K 1% 125mW
R312 22.1K 1% 125mW
C312 68UF 6.3V
C311 68UF 6.3V
C313 68UF 6.3V
C315 68UF 6.3V
C316 68UF 6.3V
C314 68UF 6.3V
T321 4275-083
7=GND,8=GND
C221 47UF 10V
R321 1.00K 1% 125mW
Q211 2N7002L
LUDLUM MEASUREMENTS INC.
TITLE : PROCESSOR BOARD
BOARD# 5390-171
UPDATED -
DR CKB 04-FEB-97
CHK RSS 3-18-97
DSGN RSS 22-FEB-96
APPD JGW 3-19-97
NEXT HIGHER ASSY. -
SIZE C
MODEL 2360
SERIES 390
SHEET 173
16:06:13 5-Mar-97
S0390171
SHEET 1 OF 1



LUDLUM MEASUREMENTS INC. SWEETWATER, TX.				
DR CKB	04-FEB-97	TITLE: PROCESSOR BOARD		
CHK RSS	3-14-97	BOARD# 5390-171	BS390171	
DSGN RSS	22-FEB-96	MODEL 2360	SERIES 390	SHEET 174
APP JGW	3-14-97	COMP ARTWORK ☐	SLDR ARTWORK ☐	
16:50:03	5-Mar-97	COMP OUTLINE ☒	SLDR OUTLINE ☐	
COMP PASTE ☐	COMP MASK ☐	SLDR PASTE ☐	SLDR MASK ☐	


DSP101
S-TEK GD-7427WP
Arrow
Battery
COM
Digit6
Digit5
Colon2
Digit4
DP3
Digit3
Colon1
DP2
Digit2
DP1
Digit1
U101
AY0438T-I/L
U001
AY0438T-I/L
VDD
CLK
LOAD
DATA IN
DATA OUT
BP IN
BP OUT
VSS
+5V
R012 10K 250mW 1%
R011 10K 250mW 1%
R112 10K 250mW 1%
R111 10K 250mW 1%
P8
Load
Clock
Data0
Data1
640456-6
MTA 100x6
Name
C201
27pF
100V
DS001
E118 RED
RED
Alarm
DS201
E118 RED
RED
Overload
P9
Alarm
Overload
640456-2
MTA 100x2
LED
DS202
Lumitek EL Lamp
0.5" x 1.5"
P10
640456-2
MTA 100x2
Backlight
BP
BAT
Overflow
Counting
DRAFT
LUDLUM
MEASUREMENTS, INC.
PO Box 810
501 Oak Street
Sweetwater, Texas 79556
U.S.A. 1-800-622-0828
Drawn: CKB 11/08/2013
Design: RSS 11/08/2013
Title: LCD Display -STEK LCD (2013)
Model: 2360
Board#: 5390-372
Approve: RDS 1JUL14
Sheet: 1 of 1
Print Date: 7/1/2014 11:30:52 AM
Rev: 2
Series 390
Sheet 372
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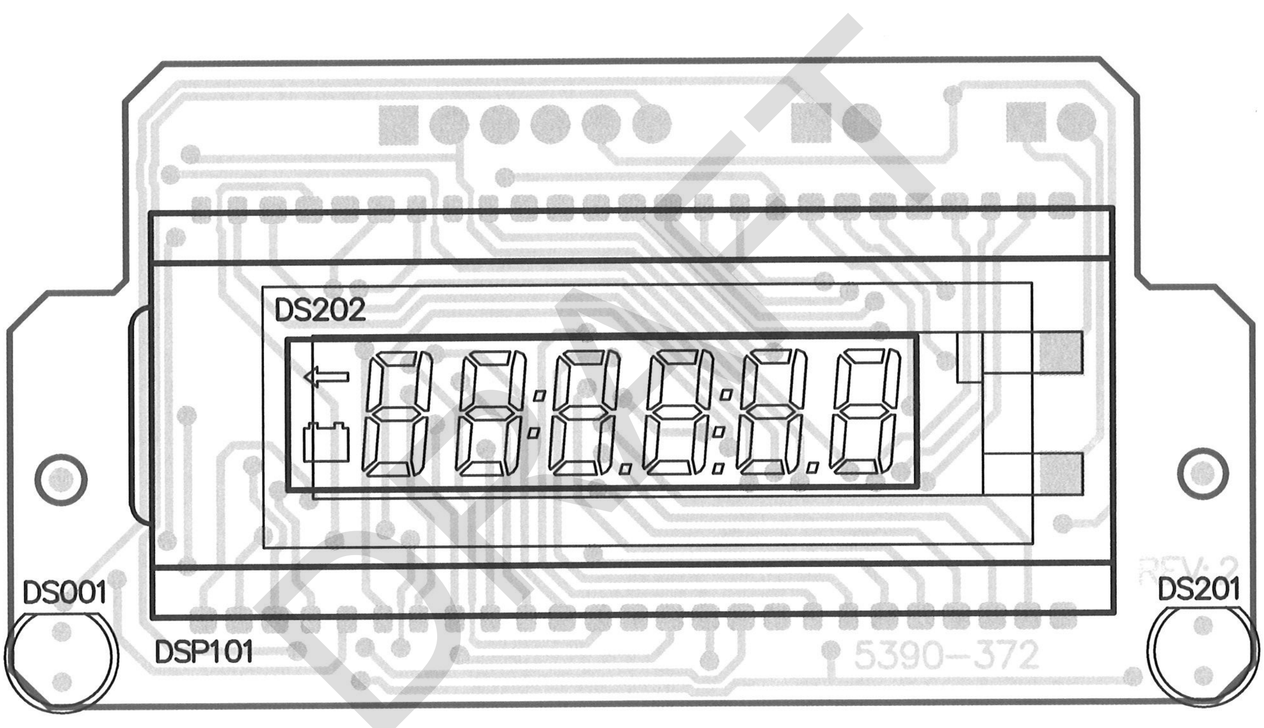

LUDLUM MEASUREMENTS, INC.

PO Box 810
501 Oak Street
Sweetwater, TX 79556
U.S.A. 1-800-622-0828

Title: LCD Display -STEK LCD (2013)

Drawn: CKB	11/08/2013	**Model:** 2360		
Design: RSS	11/08/2013	**Board#:** 5390-372		
Approve: RDS	1 Jul 14	**Rev:** 2		
PCBA Drawing		**SCALE: 1.05**	**Series**	**Sheet**
Print Date: 7/1/2014	11:31:01 AM	Top Overlay	390	373A

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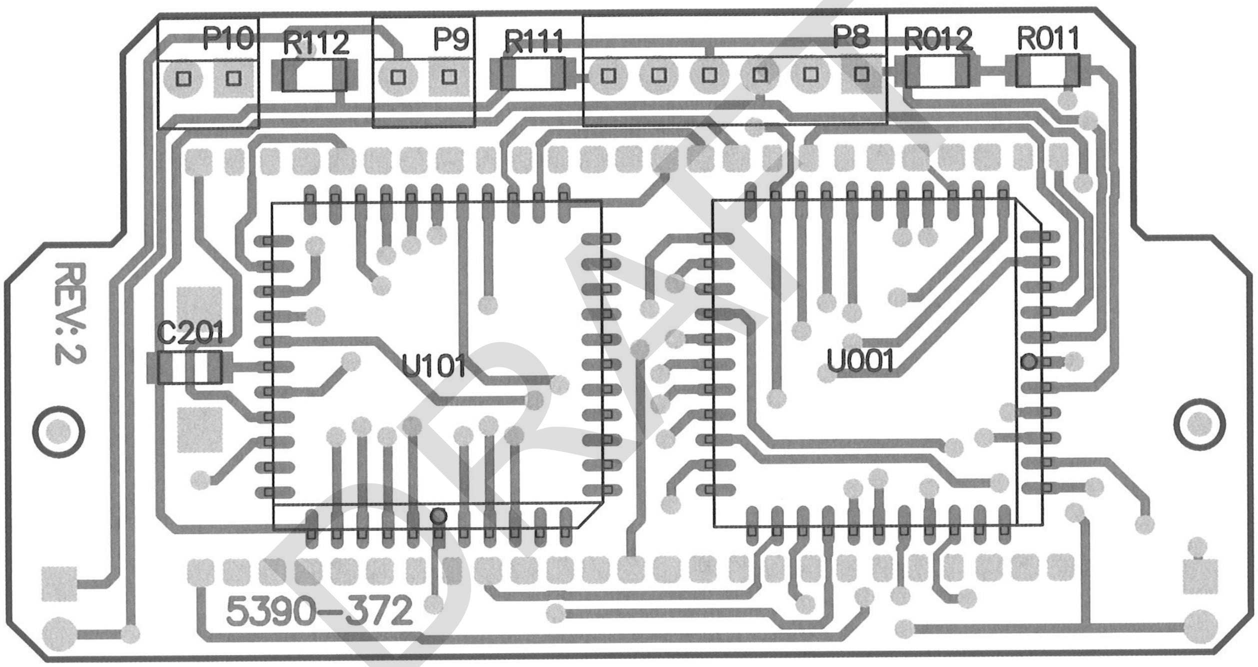
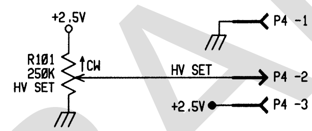


LUDLUM MEASUREMENTS, INC.
PO Box 810
501 Oak Street
Sweetwater, TX 79556
U.S.A. 1-800-622-0828

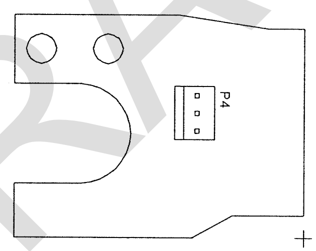
Title: LCD Display -STEK LCD (2013)				
Drawn: CKB	11/08/2013	**Model:** 2360		
Design: RSS	11/08/2013	**Board#:** 5390-372		
Approve: RDS	1JUL14	**Rev:** 2		
PCBA Drawing		**SCALE: 1.05**	**Series**	**Sheet**
Print Date: 7/1/2014	11:31:03 AM	Bottom Overlay	390	373A

W:\Projects\LMI\M 2360\5390-372\Rev2\390372R2_Assy.PcbDoc

EFF	AUTHORITY	ZONE	LTR	REVISIONS DESCRIPTION	DATE	APPROVED

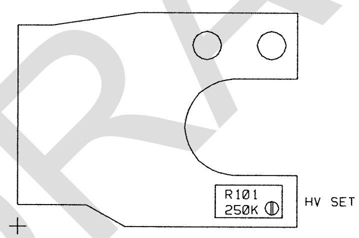


UPDATED -	/ /	LUDLUM MEASUREMENTS INC.
DR CKB	12/14/96	TITLE: CALIBRATION BOARD
CHK RSS	3/14/97	
DSGN RSS	12/14/96	BOARD# 5390-172
APPD JGW	3/14/97	SIZE D · MODEL 2360 · SERIES 390 · SHEET 176
NEXT HIGHER ASSY. -		
13:49:27	16-Dec-96	SB390172 · SHEET 1 OF 1



LUDLUM MEASUREMENTS INC. SWEETWATER, TX.

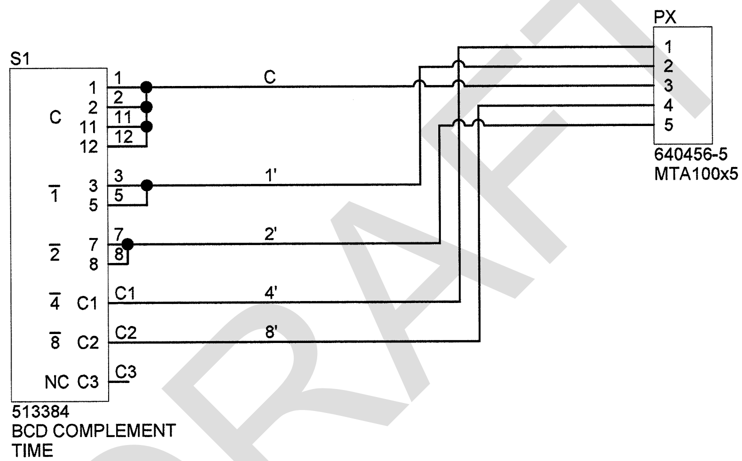
DR CKB	12/14/96	TITLE: CALIBRATION BOARD		
		BOARD# 5390-172		BS390104
DSGN RSS	12/14/96	MODEL 2224-1	SERIES 390	SHEET 177
APP BS	3KT/12	COMP ARTWORK ☐	SLDR ARTWORK ☐	
09:38:12	20-Nov-96	COMP OUTLINE ☐	SLDR OUTLINE ☒	
COMP PASTE ☐	COMP MASK ☐	SLDR PASTE ☐	SLDR MASK ☐	



LUDLUM MEASUREMENTS INC. SWEETWATER, TX.

DR CKB	12/14/96	TITLE: CALIBRATION BOARD	
		BOARD: 5390-172	
DSGN RSS	12/14/96	MODEL: 2360	
APP RS	31 Jul 12	FILENAME: BS390172	
COMPONENT	SOLDER	09:48:56	31-Jul-12
OUTLINE	OUTLINE	REVISION 1.0	SERIES 390 / SHEET 177

POS	FUNCTION
1	0.1 MIN
2	0.5 MIN
3	1 MIN
4	2 MIN
5	5 MIN
6	10 MIN
7	60 MIN
8	PC
10	
11	
12	



LUDLUM MEASUREMENTS, INC.

PO Box 810
501 Oak Street
Sweetwater, Texas 79556
U.S.A. 1-800-622-0828

Drawn: CKB	03/27/01	Title: BCD Board
Design: PW	10/30/96	Model: 2360
		Board#: 5261-154
Approve: RDS 7Sep12		Sheet: 1 of 1
Print Date: 9/7/2012	4:39:16 PM	Rev: 1

Series 261 | Sheet 107

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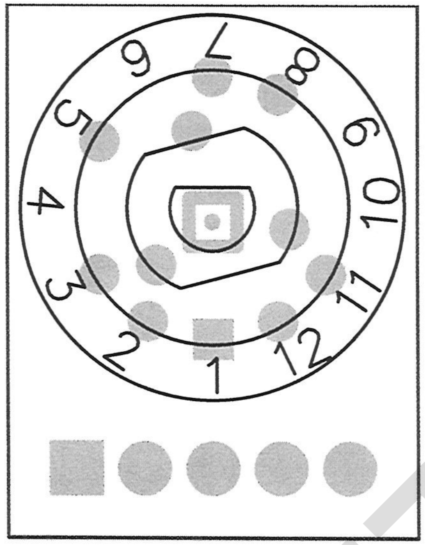
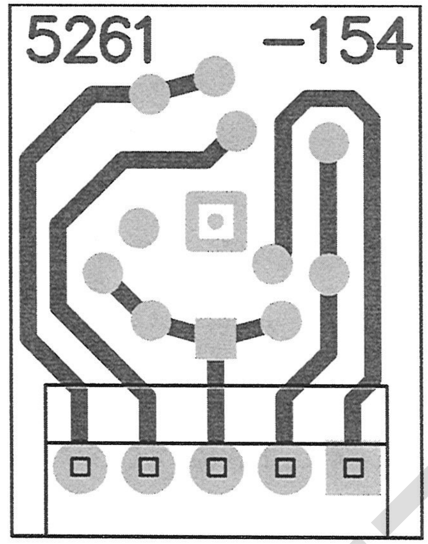


LUDLUM MEASUREMENTS, INC.

PO Box 810
501 Oak Street
Sweetwater, TX 79556
U.S.A. 1-800-622-0828

Title: BCD Board				
Drawn: CKB	03/27/01	**Model:** 2360		
Design: PW	10/30/96	**Board#:** 5261-154		
Approve: RDS	18 NOV 15	**Rev:** 2		
Print Date: 1/14/2014	2:08:01 PM	**SCALE: 1.00** Top Overlay	**Series** 261	**Sheet** 105 A
W:\Projects\LMI\M 2360\5261-154\Rev2.0\261154R2_Assy.PcbDoc				



PX
640456-5

DRAFT

LUDLUM MEASUREMENTS, INC.

PO Box 810
501 Oak Street
Sweetwater, TX 79556
U.S.A. 1-800-622-0828

Title: BCD Board

Drawn:	CKB	03/27/01	**Model:**	2360	
Design:	PW	10/30/96	**Board#:**	5261-154	
Approve:	RDS	18 Nov 15	**Rev:**	2	
Print Date: 1/14/2014		2:08:04 PM	**SCALE: 1.00** Bottom Overlay	**Series** 261	**Sheet** 105 A

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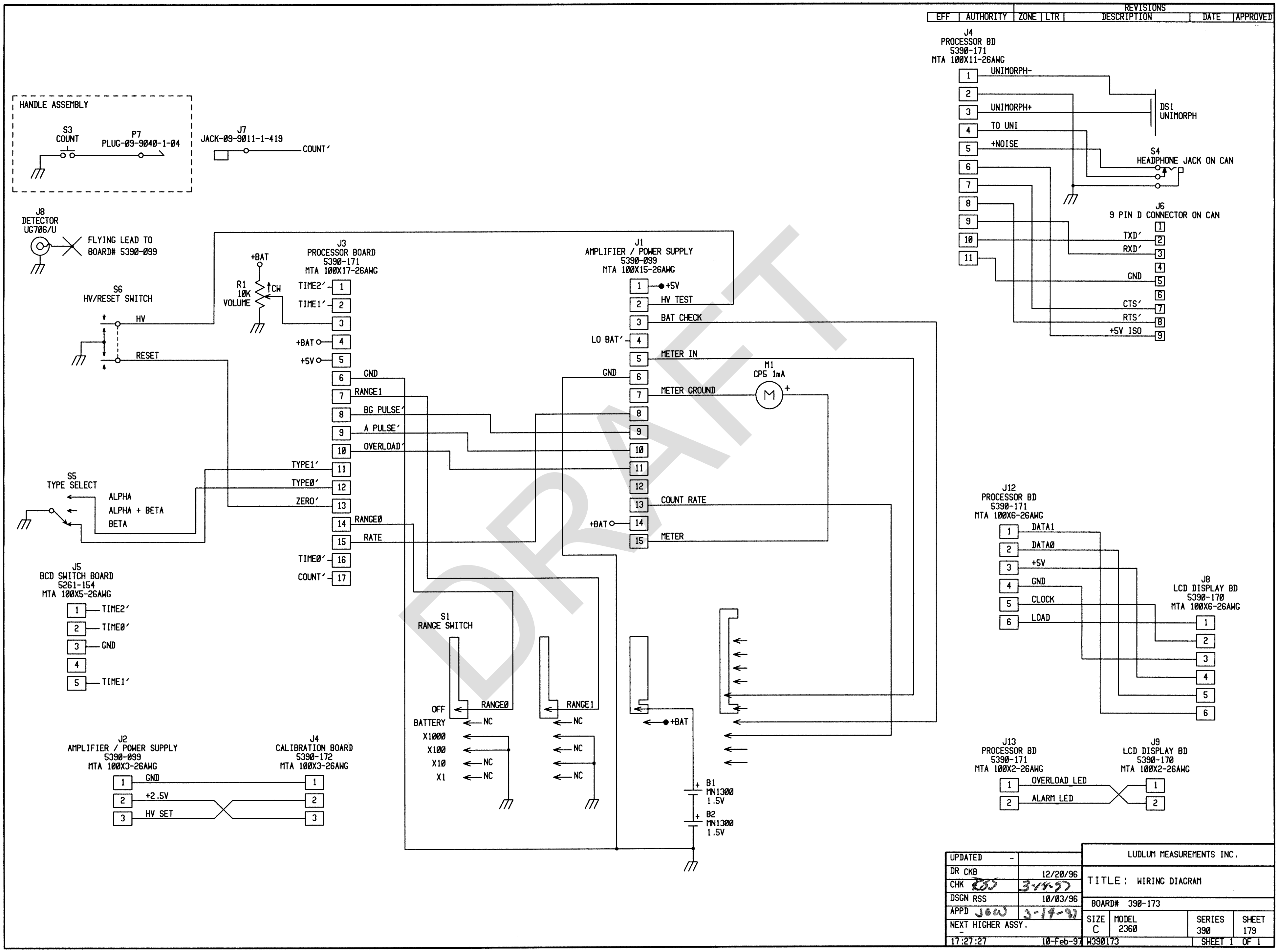

REVISIONS
EFF
AUTHORITY
ZONE
LTR
DESCRIPTION
DATE
APPROVED
J4
PROCESSOR BD
5390-171
MTA 100X11-26AWG
UNIMORPH-
UNIMORPH+
TO UNI
+NOISE
DS1
UNIMORPH
S4
HEADPHONE JACK ON CAN
J6
9 PIN D CONNECTOR ON CAN
TXD'
RXD'
GND
CTS'
RTS'
+5V ISO
HANDLE ASSEMBLY
S3
COUNT
P7
PLUG-09-9040-1-04
J7
JACK-09-9011-1-419
COUNT'
J8
DETECTOR
UG706/U
FLYING LEAD TO
BOARD# 5390-099
S6
HV/RESET SWITCH
HV
RESET
+BAT
R1
10K
VOLUME
CW
J3
PROCESSOR BOARD
5390-171
MTA 100X17-26AWG
TIME2'
TIME1'
+BAT
+5V
GND
RANGE1
BG PULSE'
A PULSE'
OVERLOAD'
TYPE1'
TYPE0'
ZERO'
RANGE0
RATE
TIME0'
COUNT'
J1
AMPLIFIER / POWER SUPPLY
5390-099
MTA 100X15-26AWG
+5V
HV TEST
BAT CHECK
LO BAT'
METER IN
GND
METER GROUND
COUNT RATE
+BAT
METER
M1
CP5 1mA
S5
TYPE SELECT
ALPHA
ALPHA + BETA
BETA
J5
BCD SWITCH BOARD
5261-154
MTA 100X5-26AWG
TIME2'
TIME0'
GND
TIME1'
S1
RANGE SWITCH
OFF
BATTERY
X1000
X100
X10
X1
RANGE0
RANGE1
NC
+BAT
B1
MN1300
1.5V
B2
MN1300
1.5V
J2
AMPLIFIER / POWER SUPPLY
5390-099
MTA 100X3-26AWG
GND
+2.5V
HV SET
J4
CALIBRATION BOARD
5390-172
MTA 100X3-26AWG
J12
PROCESSOR BD
5390-171
MTA 100X6-26AWG
DATA1
DATA0
+5V
GND
CLOCK
LOAD
J8
LCD DISPLAY BD
5390-170
MTA 100X6-26AWG
J13
PROCESSOR BD
5390-171
MTA 100X2-26AWG
OVERLOAD LED
ALARM LED
J9
LCD DISPLAY BD
5390-170
MTA 100X2-26AWG
DRAFT
UPDATED -
DR CKB 12/20/96
CHK RSS 3-14-97
DSGN RSS 10/03/96
APPD JGW 3-14-97
NEXT HIGHER ASSY.
17:27:27 10-Feb-97
LUDLUM MEASUREMENTS INC.
TITLE: WIRING DIAGRAM
BOARD# 390-173
SIZE C
MODEL 2360
SERIES 390
SHEET 179
W390173
SHEET 1 OF 1

MiniRAE 3000
User's Guide

RAE SYSTEMS
by Honeywell

Rev. F
February 2016
P/N 059-4020-000

FCC Information

Contains FCC ID: PI4411B or SU3RM900

The enclosed device complies with part 15 of the FCC rules. Operation is subject to the following conditions: (1) This device may not cause harmful interference, and (2) This device must accept any interference received, including interference that may cause undesired operation.

Wireless Approval For UAE In Middle East

TRA REGISTERED No: ER36153/14 or ER36153/15
DEALER No.: HONEYWELL INTERNATIONAL MIDDLE EAST – LTD – DUBAI BR

Wireless Approval For QATAR In Middle East

ictQATAR
Type Approval Reg. No.: R-4466 or R-4635

contém o módulo wireless: RM900

ANATEL

2781-14-6496

(01)07898911288364

Este equipamento opera em caráter secundário, isto é, não tem direito a proteção contra interferência prejudicial, mesmo de estações do mesmo tipo, e não pode causar interferência a sistemas operando em caráter primário.

Contents

Read Before Operating

This manual must be carefully read by all individuals who have or will have the responsibility of using, maintaining, or servicing this product. The product will perform as designed only if it is used, maintained, and serviced in accordance with the manufacturer's instructions. The user should understand how to set the correct parameters and interpret the obtained results.

CAUTION!

To reduce the risk of electric shock, turn the power off before removing the instrument cover. Disconnect the battery before removing sensor module for service. Never operate the instrument when the cover is removed. Remove instrument cover and sensor module only in an area known to be non-hazardous.

Special Notes

When the instrument is taken out of the transport case and turned on for the first time, there may be some residual organic or inorganic vapor trapped inside the detector chamber. The initial PID sensor reading may indicate a few ppm. Enter an area known to be free of any organic vapor and turn on the instrument. After running for several minutes, the residual vapor in the detector chamber will be cleared and the reading should return to zero.

The battery of the instrument discharges slowly even if it is turned off. If the instrument has not been charged for 5 to 7 days, the battery voltage will be low. Therefore, it is a good practice to always charge the instrument before using it. It is also recommended to fully charge the instrument for *at least 10 hours* before first use. Refer to this User Guide’s section on battery charging for more information on battery charging and replacement.

WARNINGS

STATIC HAZARD: Clean only with damp cloth.

For safety reasons, this equipment must be operated and serviced by qualified personnel only. Read and understand instruction manual completely before operating or servicing.

Use only RAE Systems battery packs, part numbers 059-3051-000, 059-3052-000, and 059-3054-000. This instrument has not been tested in an explosive gas/air atmosphere having an oxygen concentration greater than 21%. Substitution of components may impair intrinsic safety. Recharge batteries only in non-hazardous locations.

Do not mix old and new batteries or batteries from different manufacturers.

The calibration of all newly purchased RAE Systems instruments should be tested by exposing the sensor(s) to known concentration calibration gas before the instrument is put into service.

For maximum safety, the accuracy of the instrument should be checked by exposing it to a known concentration calibration gas before each day's use.

Do not use USB/PC communication in hazardous locations.

AVERTISSEMENT

DANGER RISQUE D'ORIGINE ELECTROSTATIQUE: Nettoyer uniquement avec un chiffon humide.

Pour des raisons de sécurité, cet équipment doit être utilisé, entretenu et réparé uniquement par un personnel qualifié. Étudier le manuel d'instructions en entier avant d'utiliser, d'entretenir ou de réparer l'équipement.

Utiliser seulement l'ensemble de batterie RAE Systems, la reference 059-3051-000 au 059-3052-000 au 059-3054-000. Cet instrument n'a pas été essayé dans une atmosphère de gaz/air explosive ayant une concentration d'oxygène plus élevée que 21%. La substitution de composants peut compromettre la sécurité intrinsique. Ne charger les batteries que dans emplacements désignés non-dangereuse.

Ne pas melanger les anciennes et les nouvelles batteries, ou bien encore les batteries de differents fabriquants.

La calibration de toute instruments de RAE Systems doivent être testé en exposant l'instrument a une concentration de gaz connue par une procédure diétalonnage avant de mettre en service l'instrument pour la première fois.

Pour une securite maximale, la sensibilité du l'instrument doit être verifier en exposant l'instrument a une concentration de gaz connue par une procédure diétalonnage avant chaque utilisation journalière.

Ne pas utiliser de connection USB/PC en zone dangereuse.

Standard Contents

Instrument
Calibration Kit
Charging Cradle
AC/DC Adapter
Alkaline Battery Adapter
Data Cable
CD-ROM With User's Guide, Quick Start Guide, and related materials

General Information

The compact instrument is designed as a broadband VOC gas monitor and datalogger for work in hazardous environments. It monitors Volatile Organic Compounds (VOC) using a photoionization detector (PID) with a 9.8 eV, 10.6 eV, or 11.7 eV gas-discharge lamp. Features are:

Lightweight and Compact

- Compact, lightweight, rugged design
- Built-in sample draw pump

Dependable and Accurate

- Up to 16 hours of continuous monitoring with rechargeable battery pack
- Designed to continuously monitor VOC vapor at parts-per-million (ppm) levels

User-friendly

- Preset alarm thresholds for STEL, TWA, low- and high-level peak values.
- Audio buzzer and flashing LED display are activated when the limits are exceeded.

Datalogging Capabilities

- 260,000-point datalogging storage capacity for data download to PC

The instrument consists of a PID with associated microcomputer and electronic circuit. The unit is housed in a rugged case with a backlit LCD and 3 keys to provide easy user interface. It also has a built-in flashlight for operational ease in dark locations.

Physical Description

The main components of the portable VOC monitoring instrument include:

- Three keys for user to interact with the instrument: 3 operation/programming keys for normal operation or programming
- LCD display with back light for direct readout and calculated measurements
- Built-in flashlight for illuminating testing points in dark environments
- Buzzer and red LEDs for alarm signaling whenever exposures exceed preset limits
- Charge contacts for plugging directly to its charging station
- Gas entry and exit ports
- USB communication port for PC interface
- Protective rubber cover

Specifications

Size:	9.25" L x 3.6" W x 2.9" H
Weight:	28 oz with battery pack
Detector:	Photoionization sensor with 9.8, 10.6, or 11.7 eV UV lamp
Battery:	A 3.7V rechargeable Lithium-Ion battery pack (snap in, field replaceable, at non-hazardous location only)
	Alkaline battery holder (for 4 AA batteries)
Battery Charging:	Less than 8 hours to full charge
Operating Hours:	Up to16 hours continuous operation
Display:	Large dot matrix screen with backlight

Measurement range & resolution

Lamp	Range	Resolution
10.6 eV	0.1 ppm to 15,000 ppm	0.1 ppm
9.8 eV	0.1 ppm to 5,000 ppm	0.1 ppm
11.7 eV	0.1 ppm to 2,000 ppm	0.1 ppm

Response time (T_{90}): 2 seconds

Accuracy (Isobutylene): 10 to 2000 ppm: ±3% at calibration point.

PID Detector: Easy access to lamp and sensor for cleaning and replacement

Correction Factors: Over 200 VOC gases built in (based on RAE Systems Technical Note TN-106)

Calibration: Two-point field calibration of zero and standard reference gases

Calibration Reference: Store up to 8 sets of calibration data, alarm limits and span values

Inlet Probe: Flexible 5" tubing

Radio module: Bluetooth (2.4GHz) or RF module (433MHz, 868MHz , 915MHz, or 2.4GHz)

Keypad: 1 operation key and 2 programming keys; 1 flashlight switch

Direct Readout: Instantaneous, average, STEL, TWA and peak value, and battery voltage

Intrinsic Safety: US and Canada: Class I, Division 1, Groups A, B, C, D

Europe: ATEX (0575 Ex II 2G Ex ia IIC/IIB T4 Gb)
KEMA 07 ATEX 0127
Complies with EN60079-0:2009, EN60079-11:2007

	IECEx CSA 10.0005 Ex ia IIC/IIB T4 Gb Complies with IEC 60079-0:2007, IEC 60079-11:2006 (IIC: 059-3051-000 Li-ion bat pack or 059-3054-000 NiMH bat pack; IIB: 059-3052-000 alkaline bat pack)
EM Interference:	Highly resistant to EMI/RFI. Compliant with EMC R&TTE (RF Modules)
Alarm Setting:	Separate alarm limit settings for Low, High, STEL and TWA alarm
Operating Mode:	Hygiene or Search mode
Alarm:	Buzzer 95dB at 30cm and flashing red LEDs to indicate exceeded preset limits, low battery voltage, or sensor failure
Alarm Type:	Latching or automatic reset
Real-time Clock:	Automatic date and time stamps on datalogged information
Datalogging:	260,000 points with time stamp, serial number, user ID, site ID, etc.
Communication:	Upload data to PC and download instrument setup from PC via USB on charging station.
Sampling Pump:	Internally integrated. Flow rate: 450 to 550 cc/min.
Wireless Network:	Mesh RAE Systems Dedicated Wireless Network (or WiFi network for WiFi-equipped instruments)
Wireless Frequency:	ISM license-free band, 902 to 907.5 MHz and 915 to 928 MHz, FCC Part 15, CE R&TTE, IEEE 802.11 b/g bands (2.4 GHz)
Modulation:	802.15.4 DSSS BPSK
RF Power (Tx):	10dBm
Temperature:	-20º C to 50º C (-4º to 122º F)

Humidity:	0% to 95% relative humidity (non-condensing)
Housing (including rubber boot):	Polycarbonate, splashproof and dustproof Battery can be changed without removing rubber boot.

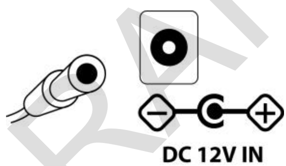
Charging The Battery

Always fully charge the battery before using the instrument. The instrument's Li-ion battery is charged by placing the instrument in its cradle. (The battery can also be charged by placing the instrument in an AutoRAE 2 Cradle.) Contacts on the bottom of the instrument meet the cradle's contacts, transferring power without other connections.

Note: Before setting the instrument into its charging cradle, visually inspect the contacts to make sure they are clean. If they are not, wipe them with a soft cloth. Do not use solvents or cleaners.

Follow this procedure to charge the instrument:

1. Plug the AC/DC adapter's barrel connector into the instrument's cradle.



2. Plug the AC/DC adapter into the wall outlet.
3. Place the instrument into the cradle, press down, and lean it back. It locks in place and the LED in the cradle glow

The instrument begins charging automatically. The "Primary" LED in the cradle blinks green to indicate charging. During charging, the diagonal lines in the battery icon on the instrument's display are animated and you see the message "Charging..."

When the instrument's battery is fully charged, the battery icon is no longer animated and shows a full battery. The message "Fully charged!" is shown. The cradle's LED glows continuously green.

Note: If you see the "Battery Charging Error" icon (a battery outline with an exclamation mark inside), check that the

instrument or rechargeable battery has been set into the cradle properly. If you still receive the message, check the Troubleshooting section of this guide.

Note: If the instrument or battery has been in the cradle for more than 10 hours and you see the "Battery Charging Error" icon and a message that says, "Charging Too Long," this indicates that the battery is not reaching a full charge. Try changing the battery and make sure the contacts between the instrument (or battery) are meeting the cradle. If the message is still shown, consult your distributor or RAE Systems Technical Services.

Charging A Spare Rechargeable Battery

A rechargeable Li-ion battery can be charged when it is not inside the monitor. The charging cradle is designed to accommodate both types of charging. Contacts on the bottom of the battery meet the contacts on the cradle, transferring power without other connections, and a spring-loaded capture holds the battery in place during charging.

1. Plug the AC/DC adapter into the monitor's cradle.
2. Place the battery into the cradle, with the gold-plated contacts on top of the six matching charging pins.
3. Plug the AC/DC adapter into the wall outlet.

The battery begins charging automatically. During charging, the Secondary LED in the cradle blinks green. When charging is complete, it glows steady green.

Release the battery from the cradle by pulling it back toward the rear of the cradle and tilting it out of its slot.

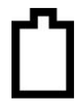
Note: If you need to replace the Li-ion battery pack, replacements are available from RAE Systems. The part number is 059-3051-000.

Note: An Alkaline Battery Adapter (part number 059-3052-000), which uses four AA alkaline batteries (Duracell MN1500), may be substituted for the Li-Ion battery.

WARNING!

To reduce the risk of ignition of hazardous atmospheres, recharge and replace batteries only in areas known to be non-hazardous. Remove and replace batteries only in areas known to be non-hazardous.

Low Voltage Warning



When the battery's charge falls below a preset voltage, the instrument warns you by beeping once and flashing once every minute, and the "empty battery" icon blinks on and off once per second. You should turn off the instrument within 10 minutes and either recharge the battery by placing the instrument in its cradle, or replace the battery with a fresh one with a full charge.

Clock Battery

An internal clock battery is mounted on one of the instrument's printed circuit boards. This long-life battery keeps settings in memory from being lost whenever the Li-ion battery or alkaline batteries are removed. This backup battery should last approximately five years, and must be replaced by an authorized RAE Systems service technician. It is not user-replaceable.

Data Protection While Power Is Off

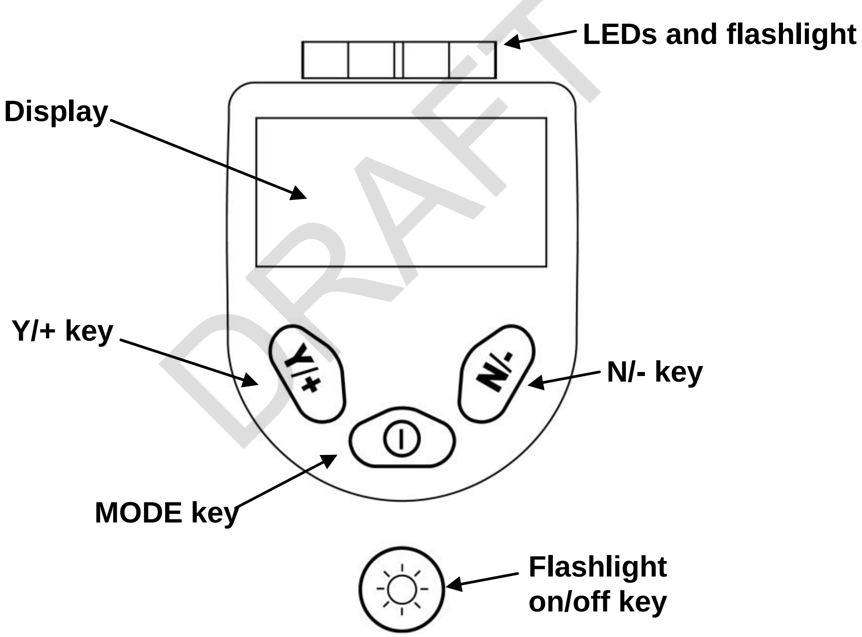
When the instrument is turned off, all the current real-time data including last measured values are erased. However, the datalog data is preserved in non-volatile memory. Even if the battery is disconnected, the datalog data will not be lost.

User Interface

The instrument's user interface consists of the display, LEDs, an alarm transducer, and four keys. The keys are:

Y/+
MODE
N/-
Flashlight on/off

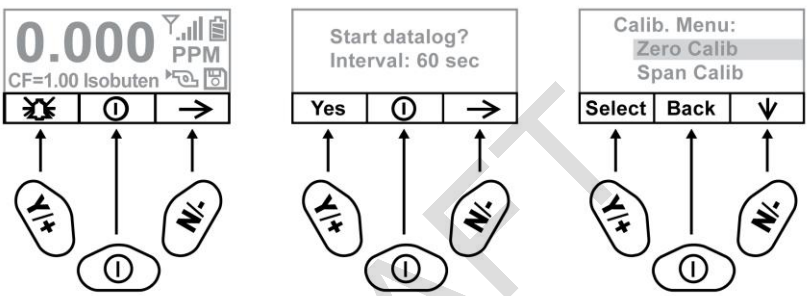
The LCD display provides visual feedback that includes the reading, time, battery condition, and other functions.



In addition to their labeled functions, the keys labeled Y/+, MODE, and N/- act as "soft keys" that control different parameters and make different selections within the instrument's menus. From menu to menu, each key controls a different parameter or makes a different selection.

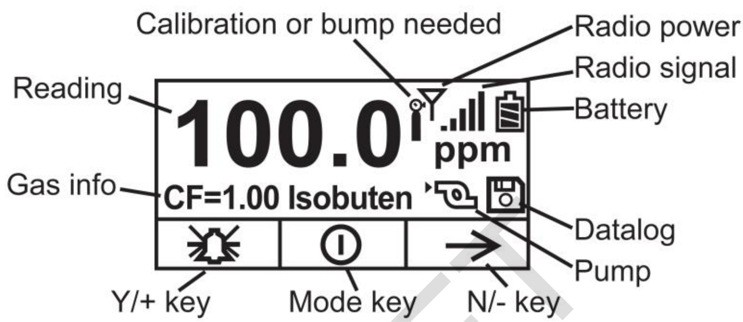
Three panes along the bottom of the display are “mapped” to the keys. These change as menus change, but at all times the left pane corresponds to the [Y/+] key, the center pane corresponds to the [MODE] key, and the right pane corresponds to the [N/-] key. Here are three examples of different menus with the relationships of the keys clearly shown:

RELATIONSHIP OF BUTTONS TO CONTROL FUNCTIONS



Display

The display shows the following information:



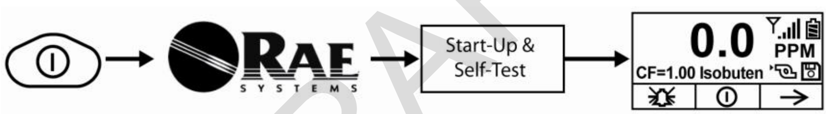
Gas info	Tells the Correction Factor and type of calibration gas
Reading	Concentration of gas as measured by the instrument
Calibration or bump needed	Dark icon indicates that calibration should be performed; light icon indicates bump should be performed
Radio power	Indicates whether radio (Mesh wireless or Bluetooth) connection is on or off
Radio signal	Indicates signal strength in 5-bar bargraph
Battery	Indicates battery level in 3 bars
Pump	Indicates that pump is working
Datalog	Indicates whether datalog is on or off
Y/+	Y/+ key’s function for this screen
MODE	MODE key’s function for this screen
N/-	N/- key’s function for this screen

Operating The Instrument

The instrument is designed as a broadband VOC gas monitor and datalogger for work in hazardous environments. It gives real-time measurements and activates alarm signals whenever the exposure exceeds preset limits. Prior to factory shipment, the instrument is preset with default alarm limits and the sensor is pre-calibrated with standard calibration gas. However, you should test the instrument and verify the calibration before the first use. After the instrument is fully charged and calibrated, it is ready for immediate operation.

Turning The Instrument On

1. With the instrument turned off, press and hold [MODE].
2. When the display turns on, release the [MODE] key.



The RAE Systems logo should appear first. (If the logo does not appear, there is likely a problem and you should contact your distributor or RAE Systems Technical Support.) The instrument is now operating and performs self tests. If any tests (including sensor and memory tests fail), refer to the Troubleshooting section of this guide.

Once the startup procedure is complete, the instrument shows a numerical reading screen with icons. This indicates that the instrument is fully functional and ready to use.

Turning The Instrument Off

1. Press and hold the Mode key for 3 seconds. A 5-second countdown to shutoff begins.
2. Once the countdown stops, the instrument is off. Release the Mode key.
3. When you see "Unit off..." release your finger from the [MODE] key. The instrument is now off.

Note: You must hold your finger on the key for the entire shutoff process. If you remove your finger from the key during the countdown, the shutoff operation is canceled and the instrument continues normal operation.

Operating The Built-In Flashlight

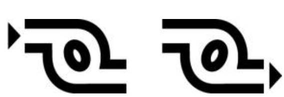
The instrument has a built-in flashlight that helps you point the probe in dark places. Press the flashlight key to turn it on. Press it again to turn it off.

Note: Using the flashlight for extended periods shortens the battery's operating time before it needs recharging.

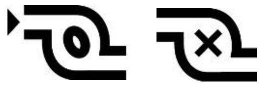
Pump Status

IMPORTANT!

During operation, make sure the probe inlet and the gas outlet are free of obstructions. Obstructions can cause premature wear on the pump, false readings, or pump stalling. During normal operation, the pump icon alternately shows inflow and outflow as shown here:



During duty cycling (PID lamp cleaning), the display shows these icons in alternation:



If there is a pump failure or obstruction that disrupts the pump, you will see this icon blinking on and off:

If you see this blinking icon, consult the Troubleshooting section of this guide.

Calibration Status

The instrument displays this icon if it requires calibration:

Calibration is required (and indicated by this icon) if:

- The lamp type has been changed (for example, from 10.6 eV to 9.8 eV).
- The sensor has been replaced.
- It has been 30 days or more since the instrument was last calibrated.
- If you have changed the calibration gas type without recalibrating the instrument.

Bump Status

The instrument displays this icon if it requires a bump test:

A bump test is required (and indicated by this icon) if:

- The defined period of time between bump tests has been exceeded (bump test overdue).
- The sensor has failed a previous bump test.
- The sensor(s) should be challenged on a periodic basis.

Policy Enforcement

The MiniRAE 3000 can be configured to enforce a facility/company's requirements that calibration and/or bump testing be performed at specified intervals, and to explicitly prompt the user that calibration/bump testing is required. Depending on how Policy Enforcement features are configured, the user may be required to perform a bump test or calibration prior to being able to use the instrument. That is, it can be set to not allow normal operation of the instrument unless calibration or bump testing is performed.

If the instrument has been bump tested and calibrated in compliance with the policy settings, a check-mark icon is included along the top of the MiniRAE 3000 screen:

If Policy Enforcement is enabled, then after startup the MiniRAE 3000 displays a screen that informs the user that the instrument requires either a bump test or a calibration. If both are required, then they are shown in sequence.

Note: Policy enforcement features are disabled by default.

Setting Policy Enforcement

You must use ProRAE Studio II to make changes to Policy Enforcement settings. You must use an AutoRAE 2 Cradle, a MiniRAE 3000 Travel Charger, or a MiniRAE 3000 Desktop Cradle. Policy violations are captured in the datalog.

Using The Travel Charger, Desktop Charger, or AutoRAE 2 Automatic Test And Calibration System

To program a MiniRAE 3000 via an AutoRAE 2, you need ProRAE Studio II Instrument Configuration and Data Management Software, the AutoRAE 2 connected to a power source, and a USB PC communications cable.

1. Connect a USB cable between a PC with ProRAE Studio II and the AutoRAE 2 Cradle, Travel Charger, or Desktop Cradle.
2. Apply power to the AutoRAE 2 Cradle, Travel Charger, or Desktop Cradle.
3. Turn off the MiniRAE 3000 (or put the MiniRAE 3000 into AutoRAE 2 Mode or Communication Mode) and set it in the cradle.
4. Start ProRAE Studio II software on the PC.
5. Select "Administrator" and input the password (the default is "rae").
6. Click "Detect the instruments automatically" (the magnifying glass icon with the letter "A" in it). After a few seconds, the AutoRAE 2 Cradle is found and it is shown, along with its serial number.
7. Click on the icon to highlight it, and then click "Select."
8. In ProRAE Studio II, the instrument or AutoRAE 2 Cradle is shown, including its Serial Number, under "Online."
9. Expand the view to show the instrument or to show the instrument in the AutoRAE 2 Cradle by clicking the "+" to the left of the image of the AutoRAE 2 Cradle.
10. Double-click on the icon representing the MiniRAE 3000.
11. Click "Setup."
12. In the menu that now appears on the left side, click "Policy Enforcement." It is highlighted, and the Policy Enforcement pane is shown. For "Must Calibrate" and "Must Bump," you have the options of no enforcement or enforcement (including "Can't Bypass," and "Can Bypass").

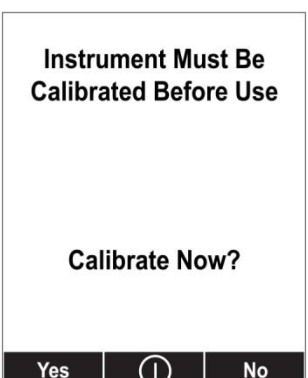
Must Calibrate. The user is prompted to calibrate the instrument when calibration is due (as set by the calibration interval). There are two programmable options:

- **Can’t Bypass.** Unless calibration is performed, the instrument cannot be used, and the only option is to turn off the instrument.
- **Can Bypass.** If calibration is due but the user does not want to perform a calibration, the instrument can still be used. In this case, the instrument records that the user has bypassed the calibration requirement in a Policy Violation report.

Must Bump. The user is prompted to bump test the instrument when a bump test is due (as set by the bump test interval). There are two programmable options:

- **Can’t Bypass.** Unless a bump test is performed, the instrument cannot be used, and the only option is to turn off the instrument.
- **Can Bypass.** If a bump test is due but the user does not want to perform one, the instrument can still be used. In this case, the instrument records that the user has bypassed the bump testing requirement in a Policy Violation report.

These are the screens that are shown on a MiniRAE 3000 after startup if “Can Bypass” is selected:



If "Can't Bypass" is selected, the display looks like this, and only allows the options of performing the test or shutting down:

16. Once you have made your selections in ProRAE Studio II, you must upload the changes to the instrument. Click the icon labeled "Upload all settings to the instrument."

17. A confirmation screen is shown. Click "Yes" to perform the upload, or "No" to abort.
    Uploading takes a few seconds, and a progress bar is shown. You can abort the upload by clicking "Cancel."

18. Exit ProRAE Studio II.

19. Press [Y/+] on the MiniRAE 3000 to exit Communication Mode.

Operating Modes

Your instrument operates in different modes, depending on the model and its factory default settings. In some cases, you can change modes using a password and using the instrument's navigation. In other cases, you must use ProRAE Studio software.

The default setting for your instrument is:

User Mode: Basic
Operation Mode: Hygiene

This is outlined in detail on page 83.

The other options, covered later in this guide, are:

User Mode: Advanced (page 86)
Operation Mode: Hygiene

User Mode: Advanced (page 90)
Operation Mode: Search

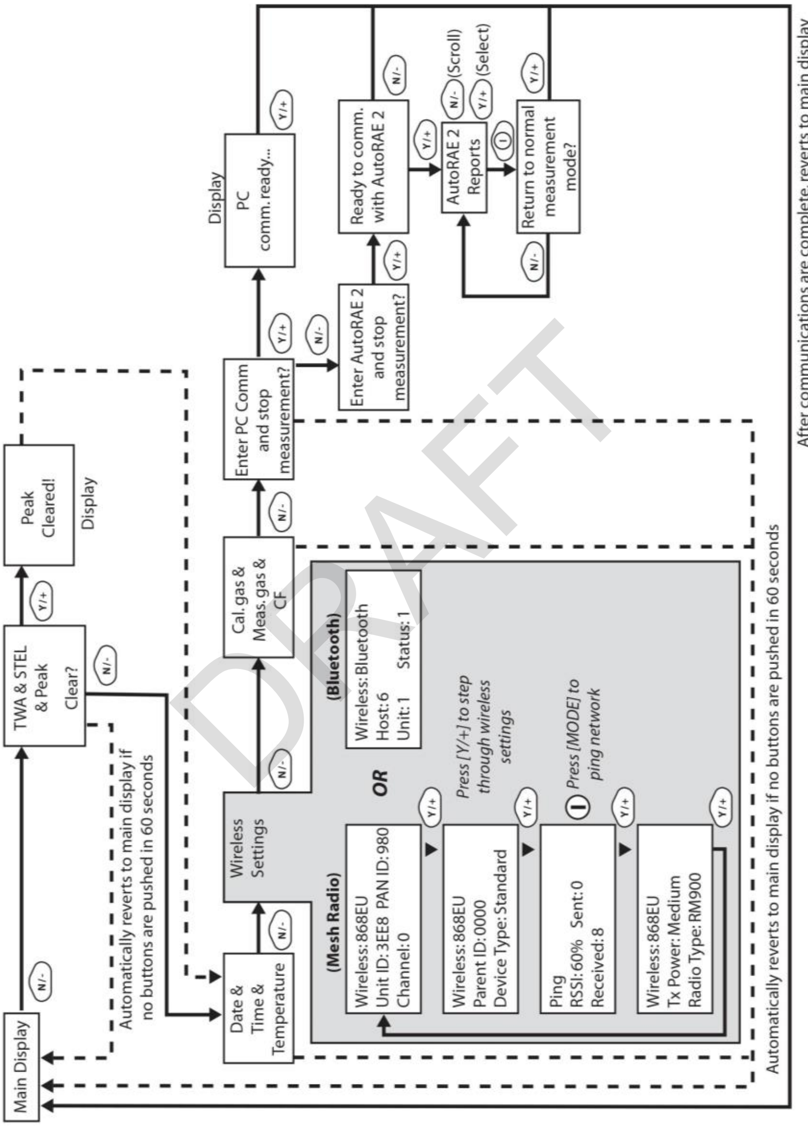
Using ProRAE Studio allows access to other options. In addition, Diagnostic Mode (page 91) is available for service technicians.

Basic User Level/Hygiene Mode (Default Settings)

The instrument is programmed to operate in Basic User Level/Hygiene Mode as its default. This gives you the most commonly needed features while requiring the fewest parameter adjustments.

Pressing [N/-] steps you from one screen to the next, and eventually return to the main display. If you do not press a key within 60 seconds after entering a display, the instrument reverts to its main display.

Note: While viewing any of these screens, you can shut off your instrument by pressing [MODE].



Note: Dashed line indicates automatic progression.

After the instrument is turned on, it runs through the start-up menu. Then the message "**Please apply zero gas…**" is displayed.

At this point, you can perform a zero air (fresh air) calibration. If the ambient air is clean, you can use that. Otherwise, use a cylinder of zero air. Refer to Zero Calibration on page 44 for a more detailed description of zero calibration.

Start zero calibration by pressing Start. You see the message "Zeroing…" followed by a 30-second countdown.

Note: You can press [MODE] to quit, bypassing the zero air calibration.

When zero calibration is complete, you see the message:

Zeroing is done!

Reading = 0.0 ppm

The instrument is now sampling and collecting data.

Note: At the Average & Peak, Date & Time & Temperature, Calibration Gas & Measurement Gas & Correction Factor, and PC Communications screens, the instrument automatically goes to the main display after 60 seconds if you do not push a key to make a selection.

Alarm Signals

During each measurement period, the gas concentration is compared with the programmed alarm limits (gas concentration alarm limit settings). If the concentration exceeds any of the preset limits, the loud buzzer and red flashing LED are activated immediately to warn you of the alarm condition.

In addition, the instrument alarms if one of the following conditions occurs: battery voltage falls below a preset voltage level, failure of the UV lamp, or pump stall.

Alarm Signal Summary

Message	Condition	Alarm Signal
HIGH	Gas exceeds "High Alarm" limit	3 beeps/flashes per second*
OVR	Gas exceeds measurement range	3 beeps/flashes per second*
MAX	Gas exceeds electronics' maximum range	3 beeps/flashes per second*
LOW	Gas exceeds "Low Alarm" limit	2 beeps/flashes per second*
TWA	Gas exceeds "TWA" limit	1 Beep/flash per second*
STEL	Gas exceeds "STEL" limit	1 Beep/flash per second*
Pump icon flashes	Pump failure	3 beeps/flashes per second
Lamp	PID lamp failure	3 beeps/flashes per second plus "Lamp" message on display
Battery icon flashes	Low battery	1 flash, 1 beep per minute plus battery icon flashes on display
CAL	Calibration failed, or needs calibration	1 beep/flash per second
NEG	Gas reading measures less than number stored in calibration	1 beep/flash per second

* Hygiene mode only. In Search mode, the number of beeps per second (1 to 7) depends upon the concentration of the sampled gas. Faster rates indicate higher concentrations.

Preset Alarm Limits & Calibration

The instrument is factory calibrated with standard calibration gas, and is programmed with default alarm limits.

Cal Gas (Isobutylene)	Cal Span	unit	Low	High	TWA	STEL
MiniRAE 3000	100	ppm	50	100	10	25

Testing The Alarm

You can test the alarm whenever the main (Reading) display is shown. Press [Y/+], and the audible and visible alarms are tested.

Integrated Sampling Pump

The instrument includes an integrated sampling pump. This diaphragm-type pump that provides a 450 to 550 cc per minute flow rate. Connecting a Teflon or metal tubing with 1/8" inside diameter to the gas inlet port of the instrument, this pump can pull in air samples from 100' (30 m) away horizontally or vertically.

Note: In Search Mode, the pump turns on when a sample measurement is started, and turns off when the sample is manually stopped.

If liquid or other objects are pulled into the inlet port filter, the instrument detects the obstruction and immediately shuts down the pump. The alarm is activated and a flashing pump icon is displayed.

You should acknowledge the pump shutoff condition by clearing the obstruction and pressing the [Y/+] key while in the main reading display to restart the pump.

Backlight

The LCD display is equipped with an LED backlight to assist in reading the display under poor lighting conditions.

Datalogging

During datalogging, the instrument displays a disk icon to indicate that datalogging is enabled. The instrument stores the measured gas concentration at the end of every sample period (when data logging is enabled). In addition, the following information is stored: user ID, site ID, serial number, last calibration date, and alarm limits. All data are retained (even after the unit is turned off) in non-volatile memory so that it can be down- loaded at a later time to a PC.

Datalogging event

When Datalogging is enabled, measurement readings are being saved. These data are stored in "groups" or "events." A new event is created and stored each time the instrument is turned on and is set to automatic datalogging, or a configuration parameter is changed, or datalogging is interrupted. The maximum time for one event is 24 hours or 28,800 points. If an event exceeds 24 hours, a new event is automatically created. Information, such as start time, user ID, site ID, gas name, serial number, last calibration date, and alarm limits are recorded.

Datalogging sample

After an event is recorded, the unit records a shorter form of the data. When transferred to a PC running ProRAE Studio, this data is arranged with a sample number, time, date, gas concentration, and other related information.

Auto/Manual/Snapshot Datalogging

The instrument has three datalog types:

Auto	Default mode. Collects datalog information when the instrument is sampling.
Manual	Datalogging occurs only when the instrument's datalogging is manually started (see page 63 for details).
Snapshot	Datalogs only during snapshot (single-event capture, initiated by pressing [MODE]) sampling. See page 65 for details.

Note: You can only choose one datalog type to be active at a time.

Accessories

The following accessories are included with the instrument:

- An AC Adapter (Battery Charger)
- Alkaline battery adapter
- External Filter
- Organic Vapor Zeroing kit

Hard-case kits also include these accessories:

- Calibration adapter
- Calibration regulator and Flow controller

Standard Kit & Accessories

AC Adapter (Battery Charger)

WARNING

To reduce the risk of ignition of hazardous atmospheres, recharge battery only in area known to be non-hazardous. Remove and replace battery only in area known to be non-hazardous.

Ne charger les batteries que dans emplacements designés non-dangereuses.

A battery charging circuit is built into the instrument cradle. It only needs a regular AC to 12 VDC adapter (wall-mount transformer, part number 500-0114-000) to charge the instrument.

To charge the battery inside the instrument:

1. Power off the instrument.
2. Connect the AC adapter to the DC jack on the instrument's cradle. If the instrument is off, it automatically turns on.
3. While charging, the display message shows "Charging." The Primary LED on the cradle flashes green when charging.
4. When the battery is fully charged, the LED changes to glowing green continuously, and the message "Fully charged" appears on the

display. If there is a charging error, the LED glows red continuously.

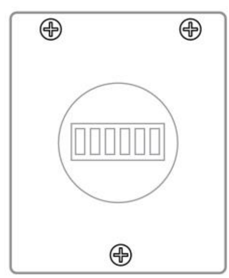
A completely discharged instrument can be charged to full capacity within 8 hours. Batteries drain slowly even if an instrument is off. Therefore, if the instrument has been in storage or has not been charged for several days or longer, check the charge before using it.

The factory-supplied battery is designed to last for 16 hours of normal operation (no alarm), for a new battery under the optimum circumstances. As the battery becomes older or is subject to adverse conditions (such as cold ambient temperature), its capacity will be significantly reduced.

Alkaline Battery Adapter

An alkaline battery adapter is supplied with each instrument. The adapter (part number 059-3052-000) accepts four AA alkaline batteries (use only Duracell MN1500) and provides approximately 12 hours of operation. The adapter is intended to be used in emergency situations when there is no time to charge the Li-ion battery pack.

To insert batteries into the adapter:



1. Remove the three Philips-head screws to open the compartment in the adapter.
2. Insert four fresh AA batteries as indicated by the polarity (+/-) markings.
3. Replace the cover. Replace the three screws.

To install the adapter in the instrument:

1. Remove the Li-ion battery pack from the instrument by sliding the tab and tilting out the battery.
2. Replace it with the alkaline battery adapter
3. Slide the tab back into place to secure the battery adapter.

IMPORTANT!

Alkaline batteries cannot be recharged. The instrument's internal circuit detects alkaline batteries and will not allow recharging. If you place the instrument in its cradle, the alkaline battery will not be recharged. The internal charging circuit is designed to prevent damage to alkaline batteries and the charging circuit when alkaline batteries are installed inside the instrument. If you try to charge an alkaline batteries installed in the instrument, the instrument's display will say, "Alkaline Battery," indicating that it will not charge the alkaline batteries.

Note: When replacing alkaline batteries, dispose of old ones properly.

WARNING!

To reduce the risk of ignition of hazardous atmospheres, recharge the battery only in areas known to be non-hazardous. Remove and replace the battery only in areas known to be non-hazardous.

External Filter

The external filter is made of PTFE (Teflon®) membrane with a 0.45 micron pore size to prevent dust or other particles from being sucked into the sensor manifold, which would cause extensive damage to the instrument. It prolongs the operating life of the sensor. To install the external filter, simply connect it to the instrument's inlet tube.

Optional Accessories

Calibration Adapter

The calibration adapter for the instrument is a simple 6-inch Tygon tubing with a metal adapter on one end. During calibration, simply insert the metal adapter into the regular gas inlet probe of the instrument and the tubing to the gas regulator on the gas bottle.

Calibration Regulator

The Calibration Regulator is used in the calibration process. It regulates the gas flow rate from the Span gas cylinder into the gas inlet of the instrument during calibration process. The maximum flow rate allowed by the flow controller is about 0.5L/min (500 cc per min.). Alternatively, a demand-flow regulator or a Tedlar gas bag may be used to match the pump flow precisely.

Organic Vapor Zeroing Kit

The Organic Vapor Zeroing Kit is used for filtering organic air contaminants that may affect the zero calibration reading. To use the Organic Vapor Zeroing Kit, simply connect the filter to the inlet port of the instrument.

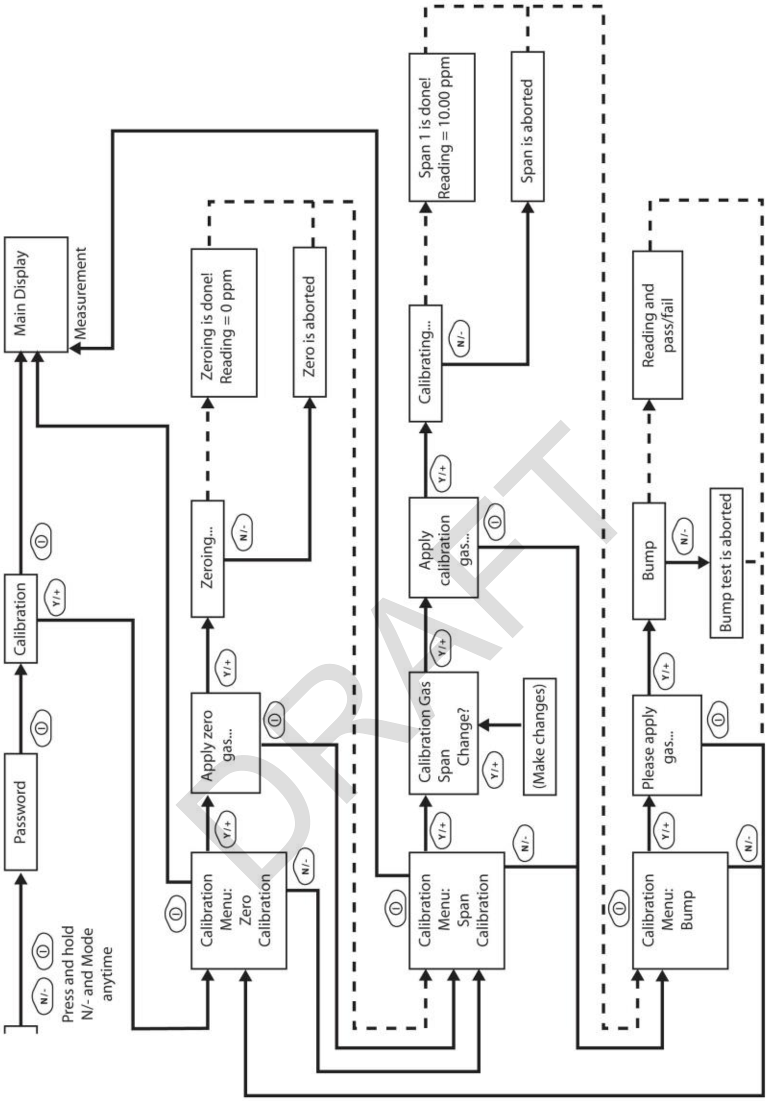
AutoRAE 2 Automatic Test & Calibration System

The AutoRAE 2 Automatic Test and Calibration System for RAE Systems portable gas monitors makes compliance with monitor test and calibration requirements as easy as pressing a button. Simply cradle the monitor and the system will take care of all calibration, testing, and recharging.

The AutoRAE 2 is a flexible, modular system that can be configured to meet your calibration requirements effectively and efficiently. An AutoRAE 2 system can be as simple as a single cradle deployed in standalone mode to calibrate one instrument at a time, or as powerful as a networked, controller-based system supporting ten monitors and five distinct calibration gas cylinders.

Standard Two-Point Calibration (Zero & Span, Optional Bump)

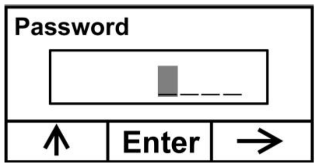
The following diagram shows the instrument's calibrations in Basic/Hygiene mode.



Note: Dashed line indicates automatic progression.

Entering Calibration

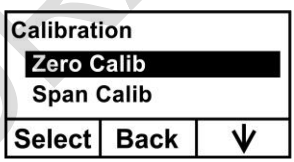
1. Press and hold [MODE] and [N/-] until you see the Password screen.



2. In Basic User Level, you do not need a password to perform calibrations. Instead of inputting a password, enter calibration by pressing [MODE].

   Note: If you inadvertently press [Y/+] and change any of the numbers, simply press [MODE] and you will be directed to the calibration menu.

The Calibration screen is now visible with Zero Calibration highlighted.



These are your options:

- Press [Y/+] to select the highlighted calibration (Zero Calib or Span Calib).
- Press [MODE] to exit calibration and return to the main display and resume measurement.
- Press [N/-] to toggle the highlighted calibration type.

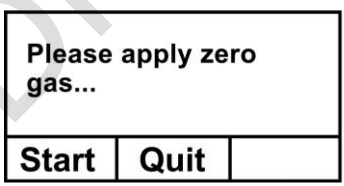
Zero (Fresh Air) Calibration

This procedure determines the zero point of the sensor calibration curve. To perform a fresh air calibration, use the calibration adapter to connect the instrument to a “fresh” air source such as from a cylinder or Tedlar bag (optional accessory). The “fresh” air is clean, dry air without organic impurities and an oxygen value of 20.9%. If such an air cylinder is not available, any clean ambient air without detectable contaminants or a charcoal filter can be used.

At the Zero Calibration menu, you can proceed to perform a Zero calibration or bypass Zero calibration and perform a Span calibration. You may also go back to the initial Calibration menu if you want to exit calibration.

- Press [Y/+] to start calibration.
- Press [MODE] to quit and return to the main calibration display.

If you have pressed [Y/+] to enter Zero calibration, then you will see this message:



1. Turn on your Zero calibration gas.
2. Press [Y/+] to start calibration.

   Note: At this point, you may press [MODE] if you decide that you do not want to initiate calibration. This will take you directly to the Calibration menu, highlighted for Span calibration.

3. Zero calibration starts a 30-second countdown and displays this message:

   Zeroing...

During the zeroing process, the instrument performs the Zero calibration automatically and does not require any action on your part.

Note: To abort the zeroing process at any time and proceed to Span calibration, press [N/-] at any time while zeroing is being performed. You will see a confirmation message that says "Zero aborted!" and then the Span calibration menu appears.

When Zero calibration is complete, you see this message:

Zeroing is done!
Reading = 0.0 ppm

The instrument will then show the Calibration menu on its display, with Span Calib highlighted.

Span Calibration

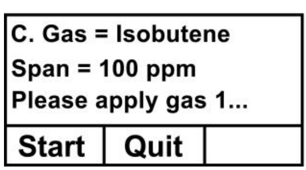
This procedure determines the second point of the sensor calibration curve for the sensor. A cylinder of standard reference gas (span gas) fitted with a 500 cc/min. flow-limiting regulator or a flow-matching regulator is the simplest way to perform this procedure. Choose the 500 cc/min. regulator only if the flow rate matches or slightly exceeds the flow rate of the instrument pump. Alternatively, the span gas can first be filled into a Tedlar bag or delivered through a demand-flow regulator. Connect the calibration adapter to the inlet port of the instrument, and connect the tubing to the regulator or Tedlar bag.

Another alternative is to use a regulator with >500 cc/min flow but allow the excess flow to escape through a T or an open tube. In the latter method, the span gas flows out through an open tube slightly wider than the probe, and the probe is inserted into the calibration tube.

At the Span Calibration menu, you perform a Span calibration. You may also go back to the Zero calibration menu or to the initial Calibration menu if you want to exit calibration.

- Press [Y/+] to enter Span calibration.
- Press [N/-] to skip Span calibration and return to Zero calibration.
- Press [MODE] to exit Span calibration and return to the top calibration menu.

If you have pressed [Y/+] to enter Span calibration, then you will see the name of your Span gas (the default is isobutylene) and the span value in parts per million (ppm). You will also see this message that prompts you:



1. Turn on your span calibration gas.
2. Press [Y/+] to initiate calibration.

Note: You may press [MODE] if you decide that you do not want to initiate calibration. This will abort the span calibration and take you directly to the Calibration menu for Zero calibration.

3. Span calibration starts and displays this message:

Calibrating...

During the Span calibration process, there is a 30-second countdown and the instrument performs the Span calibration automatically. It requires no actions on your part.

Note: If you want to abort the Span calibration process, press [N/-] at any time during the process. You will see a confirmation message that says "Span is aborted!" and then the Zero calibration menu appears. You can then proceed to perform a Zero calibration, perform a Span calibration, or exit to the topmost Calibration menu.

When Span calibration is complete, you see a message similar to this (the value is an example only):

Span 1 is done!
Reading = 100.0 ppm

The instrument then exits Span calibration and shows the Zero calibration menu on its display.

Note: The reading should be very close to the span gas value.

Exiting Two-Point Calibration In Basic User Level

When you are done performing calibrations, press [MODE], which corresponds with "Back" on the display. You will see the following message:

Updating settings…

The instrument updates its settings and then returns to the main display. It begins or resumes monitoring.

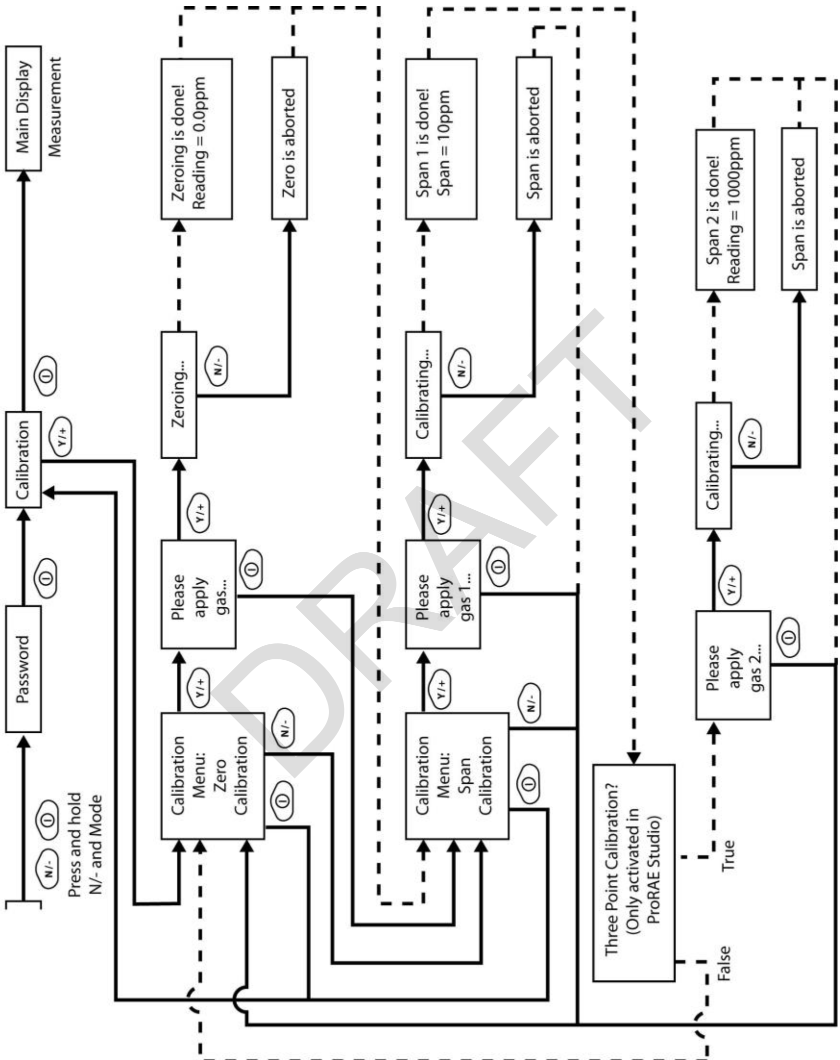
Three-Point Calibration

For enhanced accuracy, it is possible to perform a second Span calibration in addition to the Zero and Span calibrations outlined in the previous section. Your instrument first must be set to allow this third calibration. This requires using ProRAE Studio software and a PC, as well as a higher concentration of calibration gas.

Note: Once the third calibration is set, you do not need to use ProRAE Studio to allow future 3-point calibrations. Also, you can only disable 3-point calibration capability by using ProRAE Studio again.

Perform the Zero and Span calibrations. After the first Span calibration (Span 1) is completed, the display a second Span calibration (Span 2) can be performed. The process is identical to the first calibration. As in the Span 1 calibration, you may exit and return to the Zero calibration screen if you choose not to perform this calibration or to abort it.

Note: If a bump test is available, it appears after the last calibration in the menu. See "Two-Point Calibration," page 38, for details. Also, refer to page 53 for details on how to perform a bump test.



Note: Dashed line indicates automatic progression.

Span 2 Calibration

A cylinder of standard reference gas (span gas) fitted with a 500 cc/min. flow-limiting regulator or a flow-matching regulator is the simplest way to perform this procedure.

Note: This gas should be of a higher concentration than the gas used for Span 1 calibration.

Choose the 500 cc/min. regulator only if the flow rate matches or slightly exceeds the flow rate of the instrument pump. Alternatively, the span gas can first be filled into a Tedlar bag or delivered through a demand-flow regulator. Connect the calibration adapter to the inlet port of the instrument, and connect the tubing to the regulator or Tedlar bag.

Another alternative is to use a regulator with >500 cc/min flow but allow the excess flow to escape through a T or an open tube. In the latter method, the span gas flows out through an open tube slightly wider than the probe, and the probe is inserted into the calibration tube.

At the Span Calibration menu, you perform a Span calibration. You may also go back to the Zero calibration menu or to the initial Calibration menu if you want to exit calibration.

- Press [Y/+] to enter Span 2 calibration.
- Press [N/-] to skip Span calibration and return to Zero calibration.
- Press [MODE] to exit Span calibration and return to the top calibration menu.

If you have pressed [Y/+] to enter Span calibration, then you will see the name of your Span gas (the default is isobutylene) and the span value in parts per million (ppm). You will also see this message that prompts you:

Please apply gas...

4. Turn on your span calibration gas.
5. Press [Y/+] to initiate calibration.

Note: You may press [MODE] if you decide that you do not want to initiate calibration. This will take you directly to the Calibration menu for Zero calibration.

6. Span calibration starts a 30-second countdown and displays this message:

Calibrating...

During the Span calibration process, the instrument performs the Span calibration automatically and does not require any action on your part.

Note: If you want to abort the Span calibration process, press [N/-] at any time during the process. You will see a confirmation message that says "Span is aborted!" and then the Zero calibration menu will appear. You can then proceed to perform a Zero calibration, perform a Span calibration, or exit to the topmost Calibration menu.

When Span calibration is complete, you will see a message similar to this (the value shown here is for example only):

Span 2 is done!
Reading = 1000 ppm

The instrument then exits Span calibration and shows the Zero calibration menu on its display.

Note: The reading should be very close to the span gas value.

Exiting Three-Point Calibration

When you are done performing calibrations, press [MODE], which corresponds with "Back" on the display. You will see the following message:

Updating settings…

The instrument updates its settings and then returns to the main display. It begins or resumes monitoring.

Bump Test

RAE Systems recommends that a bump test be conducted prior to each day's use. The purpose of a bump test is to ensure that the instrument's sensors respond to gas and all the alarms are enabled and functional.

- The MiniRAE 3000 must be calibrated if it does not pass a bump test when a new sensor is installed, after sensor maintenance has been performed, or at least once every 180 days, depending on use and sensor exposure to poisons and contaminants.
- Calibration and bump test intervals and procedures may vary due to national legislation and company policy.

To perform a bump test (functional challenge), follow these steps:

1. Select "Bump."
2. Install the calibration adapter and connect it to a source of calibration gas.
3. Verify that the displayed calibration value meets the concentration specified on the gas cylinder.
4. Start the flow of calibration gas.
5. Press [Y/+] to start the bump test.
6. You can abort the calibration at any time during the countdown by pressing [N/-].

7. If the calibration is not aborted, the display shows reading and then tells you whether the bump test passed or failed. If the bump test failed, then it automatically advances to the Calibration screen.

Important!

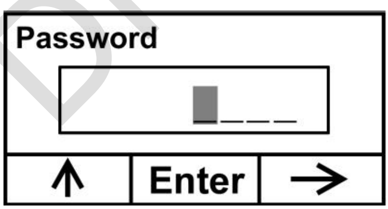
Anytime a bump test fails, you should perform a full calibration of the instrument.

Programming Mode

Programming Mode can be entered from either Hygiene Mode or Search Mode. If the current user mode is Basic, you must provide a 4-digit password to enter.

Entering Programming Mode

1. Press and hold [MODE] and [N/-] until you see the Password screen.



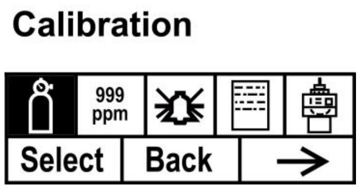
2. Input the 4-digit password:

- Increase the number from 0 through 9 by pressing [Y/+].
- Step from digit to digit using [N/-].
- Press [MODE] when you are done.

If you make a mistake, you can cycle through the digits by pressing [N/-] and then using [Y/+] to change the number in each position.

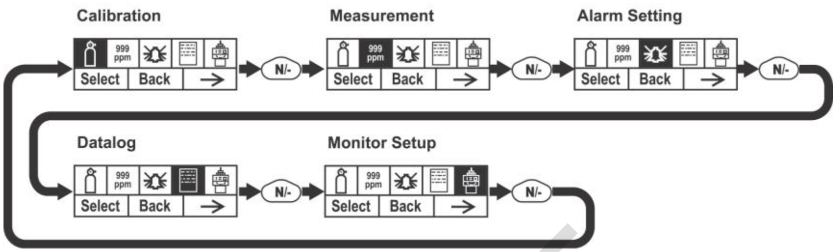
Note: The default password is 0000.

When you have successfully entered Programming Mode, you see this screen:



Note: The password can only be changed by connecting the instrument to a PC running ProRAE Studio software. Follow the instructions in ProRAE Studio to change it.

The Calibration label is shown and its icon is highlighted, but you can press [N/-] to step from one programming menu to the next, with the name of the menu shown at the top of the display and the corresponding icon highlighted. As you repeatedly press [N/-], the selection moves from left to right, and you see these screens:

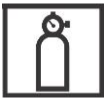
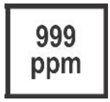
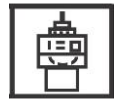


Note: When you reach Monitor Setup and press [N/-], the menu cycles back to Calibration.

Programming Mode Menus

The Programming Mode allows anyone with the password to change the instrument's settings, calibrate the instrument, modify the sensor configuration, enter user information, etc. Programming Mode has five menus. Each menu includes several sub-menus to perform additional programming functions.

This table shows the menus and sub-menus:

				
Calibration	**Measurement**	**Alarm Setting**	**Datalog**	**Monitor Setup**
Zero Calibration	Meas. Gas	High Alarm	Clear Datalog	Radio Power
Span Calibration	Meas. Unit	Low Alarm	Interval	Op Mode
Bump		STEL Alarm	Data Selection	Site ID
		TWA Alarm	Datalog Type	User ID
		Alarm Mode		User Mode
		Buzzer & Light		Date
				Time
				Pump Duty Cycle
				Pump Speed
				Temperature Unit
				Language
				Real Time Protocol
				Power On Zero
				Unit ID
				LCD Contrast
				Lamp ID
				PAN ID
				Mesh Channel
				Mesh Interval

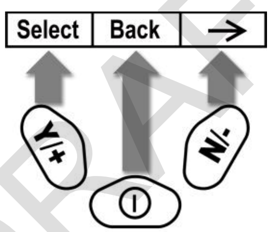
Once you enter Programming Mode, the LCD displays the first menu, Calibration. Each subsequent menu is accessed by pressing [N/-] repeatedly until the desired menu is displayed. To enter a sub-menu of a menu, press [Y/+].

Exiting Programming Mode

To exit Programming Mode and return to normal operation, press [MODE] once at any of the programming menu displays. You will see "Updating Settings…" as changes are registered and the mode changes.

Navigating Programming Mode Menus

Navigating through the Programming Mode menus is easy and consistent, using a single interface format of "Select," "Back" and "Next" at the top level. The three control buttons correspond to these choices as shown:



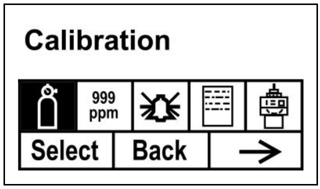
Note: Pressing [MODE] in the Programming Mode's top level causes the instrument to exit Programming Mode and return to monitoring.

The three keys perform the following functions in Programming Mode:

Key	Function in Programming Mode
[MODE]:	Exit menu when pressed momentarily or exit data entry mode
[Y/+]:	Increase alphanumerical value for data entry or confirm (yes) for a question
[N/-]:	Provides a "no" response to a question

Calibration

Two types of calibration are available: Zero (fresh air) and Span.



Select Zero or Span Calibration by pressing [N/+]. Once your choice is highlighted, press [Y/+].

Zero Calibration

The procedure for performing a zero calibration is covered on page 41.

Span Calibration

The procedure for performing a basic span calibration is covered on page 41.

Bump

The procedure for performing a bump calibration is covered on page 53.

A bump test can be performed either manually or using the AutoRAE 2 Automatic Test and Calibration System. When a bump test is done manually, the instrument makes a pass/fail decision based on sensor performance, but the user still has the responsibility to make sure all the alarms are enabled and functional.

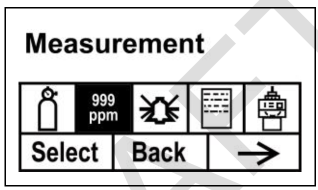
Note: Bump testing and calibration can be performed using an AutoRAE 2 Automatic Test & Calibration System. An AutoRAE 2 bump test takes care of both the sensor and alarm tests. Consult the AutoRAE 2 User's guide for details.

IMPORTANT!

If the instrument does not pass a bump test, perform a full calibration. If calibration also fails, the PID sensor or lamp may require cleaning or replacement. If the instrument repeatedly fails to calibrate, turn it off and refer it for servicing.

Measurement

The sub-menus for Measurement are Measurement Gas and Measurement Unit.



Meas. Gas

Measurement gases are organized in four lists:

- My List is a customized list of gases that you create. It contains a maximum of 10 gases and can only be built in ProRAE Studio on a PC and transferred to the instrument. **Note:** The first gas in the list is always isobutylene (it cannot be removed from the list).
- Last Ten is a list of the last ten gases used by your instrument. The list is built automatically and is only updated if the gas selected from Custom Gases or Library is not already in the Last Ten. This ensures that there is no repetition.
- Gas Library is a library that consists of all the gases found in RAE Systems' Technical Note TN-106 (available online at www.raesystems.com).
- Custom Gases are gases with user-modified parameters. Using ProRAE Studio, all parameters defining a gas can be modified,

including the name, span value(s), correction factor, and default alarm limits.

1. Scroll through each list by pressing [N/-].
2. Press [Y/+] to select one (My List, Last Ten, Gas Library, or Custom Gases).
3. Once you are in one of the categories, press [N/-] to scroll through its list of options and [Y/+] to select one. (If you press [MODE], you exit to the next submenu.)
4. Press [Y/+] to save your choice or [N/-] to undo your selection.

Leave the sub-menu and return to the Programming Mode menus by pressing [MODE].

Meas. Unit

Standard available measurement units include:

Abbreviation	**Unit**	**MiniRAE 3000**
ppm	parts per million	Yes
ppb	parts per billion	
mg/m3	milligrams per cubic meter	Yes
ug/m3	micrograms per cubic meter	

- Scroll through the list by pressing [N/-].
- Select by pressing [Y/+].
- Save your selection by pressing [Y/+] or undo your selection by pressing [N/-].

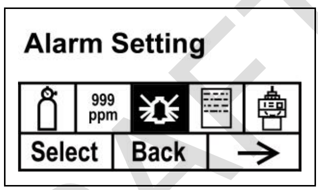
Leave the sub-menu and return to the Programming Mode menus by pressing [MODE].

Alarm Setting

During each measurement period, the gas concentration is compared with the programmed alarm limits (gas concentration alarm limit settings: Low, High, TWA and STEL). If the concentration exceeds any of the preset limits, the loud buzzer and red flashing LED are activated immediately to warn of the alarm condition.

An alarm signal summary is shown on page 33.

In this menu, you can change the High and Low alarm limits, the STEL limit, and the TWA. Press [Y/+] to to enter the Alarm Setting menu. **Note:** All settings are shown in ppb (parts per billion), or µg/m^3 (micrograms per cubic meter), depending on your setting.



1. Scroll through the Alarm Limit sub-menu using the [N/-] key until the display shows the desired limit to be changed (High Alarm, Low Alarm, STEL Alarm, and TWA Alarm)
2. Press [Y/+] to select one of the alarm types. The display shows a flashing cursor on the left-most digit of the previously stored alarm limit.
3. Press [Y/+] to increase each digit's value.
4. Press [N/-] to advance to the next digit.
5. Again, use [Y/+] to increase the number.

Repeat this process until all numbers are entered.

Press [MODE] when you are done.

- Press [Y/+] to save the changes.
- Press [N/-] to undo the changes and revert to the previous settings.

When all alarm types have been changed or bypassed, press [MODE] to exit to the Programming Menu.

High Alarm

You can change the High Alarm limit value. The value is typically set by the instrument to match the value for the current calibration gas. It is expressed in parts per billion (ppb). **Note:** The default value depends on the measurement gas.

To change the High Alarm value:

1. Press [Y/+] to increase each digit's value.
2. Press [N/-] to advance to the next digit.
3. Again, use [Y/+] to increase the number.

Repeat this process until all numbers are entered.
When you have completed your selections, press [MODE]. You will see two choices: Save and Undo. You have the opportunity to register the new settings or to change your mind and revert to your previous settings.

Press [Y/+] to save the changes.
Press [N/-] to undo the changes and revert to the previous settings.

Low Alarm

You can change the Low Alarm limit value. The value is typically set by the instrument to match the value for the current calibration gas. It is expressed in parts per billion (ppb). **Note:** The default value depends on the measurement gas.

To change the Low Alarm value:

1. Press [Y/+] to increase each digit's value.
2. Press [N/-] to advance to the next digit.
3. Again, use [Y/+] to increase the number.

Repeat this process until all numbers are entered.

When you have completed your selections, press [MODE]. You will see two choices: Save and Undo. You have the opportunity to register the new settings or to change your mind and revert to your previous settings.

- Press [Y/+] to save the changes.
- Press [N/-] to undo the changes and revert to the previous settings.

STEL Alarm

You can change the STEL Alarm limit value. The value is typically set by the instrument to match the value for the calibration gas. It is expressed in parts per billion (ppb). **Note:** The default value depends on the measurement gas.

To change the STEL Alarm value:

1. Press [Y/+] to increase each digit's value.
2. Press [N/-] to advance to the next digit.
3. Again, use [Y/+] to increase the number.

Repeat this process until all numbers are entered.

When you have completed your selections, press [MODE]. You will see two choices: Save and Undo. You have the opportunity to register the new settings or to change your mind and revert to your previous settings.

- Press [Y/+] to save the changes.
- Press [N/-] to undo the changes and revert to the previous settings.

TWA Alarm

You can change the TWA (time-weighted average) Alarm limit value. The value is typically set by the instrument to match the value for the calibration gas. It is expressed in parts per billion (ppb). **Note:** The default value depends on the measurement gas.

To change the TWA Alarm value:

1. Press [Y/+] to increase each digit's value.
2. Press [N/-] to advance to the next digit.
3. Again, use [Y/+] to increase the number.

Repeat this process until all numbers are entered.

When you have completed your selections, press [MODE]. You will see two choices:

- Save
- Undo

You have the opportunity to register the new settings or to change your mind and revert to your previous settings.

- Press [Y/+] to save the changes.
- Press [N/-] to undo the changes and revert to the previous settings.

Alarm Mode

There are two selectable alarm modes:

Auto Reset	When the alarm condition is no longer present, the alarm stops and automatically resets itself.
Latch	When the alarm is triggered, you can manually stop the alarm. The latched setting only controls alarms for High Alarm, Low Alarm, STEL Alarm, and TWA alarm. **Note:** To clear an alarm when the instrument is set to "Latched," press [Y/+] when the main (Reading) display is shown.

1. Press **[N/-]** to step from one alarm type to the other.
2. Press **[Y/+]** to select an alarm type.

When you have completed your selections, press [MODE].

You will see two choices: Save and Undo. You have the opportunity to register the new settings or to change your mind and revert to your previous settings.

- Press [Y/+] to save the changes.
- Press [N/-] to undo the changes and revert to the previous settings.

Buzzer & Light

The buzzer and light alarms can be programmed to be on or off individually or in combination. Your choices are:

- Both on
- Light only
- Buzzer only
- Both off

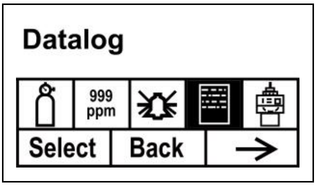
1. Press [N/-] to step from one option to the next.
2. Press [Y/+] to make your selection (the dark circle in the "radio button" indicates your selection).
3. When you have completed your selections, press [MODE].

   You will see two choices: Save and Undo. You have the opportunity to register the new settings or to change your mind and revert to your previous settings.

   - Press [Y/+] to save the changes.
   - Press [N/-] to undo the changes and revert to the previous settings.

Datalog

The instrument calculates and stores the concentration and ID of each sample taken. In the datalog sub-menu, a user can perform the tasks and functions shown below.



1. Scroll through the Datalog sub-menu using the [N/-] key until the display shows the desired parameter to be changed:

   Clear Datalog
   Interval
   Data Selection
   Datalog Type

2. Press [Y/+] to make your selection. Exit by pressing [MODE] for Back.

Clear Datalog

This erases all the data stored in the datalog.

Note: Once the datalog is cleared, the data cannot be recovered.

Press [Y/+] to clear the datalog. The display asks, "Are you sure?"

- Press [Y/+] if you want to clear the datalog. When it has been cleared, the display shows "Datalog Cleared!"
- Press [N/-] if you do not want to clear the datalog.

The display changes, and you are taken to the next sub-menu, Interval.

Interval

Intervals are shown in seconds. The default value is 60 seconds. The maximum interval is 3600 seconds.

1. Press [Y/+] to increase each digit's value.
2. Press [N/-] to advance to the next digit.
3. Again, use [Y/+] to increase the number.

Repeat this process until all numbers are entered.

When you have completed your selections, press [MODE].

You will see two choices: Save and Undo. You have the opportunity to register the new settings or to change your mind and revert to your previous settings.

- Press [Y/+] to save the changes.
- Press [N/-] to undo the changes and revert to the previous settings.

Data Selection

Data Selection allows you to select which types of data are stored and made available when you offload your datalog to a computer via ProRAE Studio software.

You can choose any or all of three types of data (you must choose at least one):

- Average
- Maximum
- Minimum

1. Press [N/-] to step from one option to the next. The highlighter indicates your choice.
2. Press [Y/+] to toggle your selection on or off (the check box indicates "on" with an "X").
3. When you have completed your selections, press [MODE].

You will see two choices: Save and Undo. You have the opportunity to register the new settings or to change your mind and revert to your previous settings.

- Press [Y/+] to save the changes.
- Press [N/-] to undo the changes and revert to the previous settings.

Datalog Type

The instrument has three datalog types:

Auto	Default mode. Collects datalog information when the instrument is sampling.
Manual	Datalogging occurs only when the instrument's datalogging is manually started (see below for details).
Snapshot	Datalogs only during single-event capture sampling.

Note: You can only choose one datalog type to be active at a time.

1. Press [N/-] to step from one option to the next.
2. Press [Y/+] to make your selection (the dark circle in the "radio button" indicates "on").
3. When you have completed your selection, press [MODE].

You will see two choices: Save and Undo. You have the opportunity to register the new settings or to change your mind and revert to your previous settings.

- Press [Y/+] to save the changes.

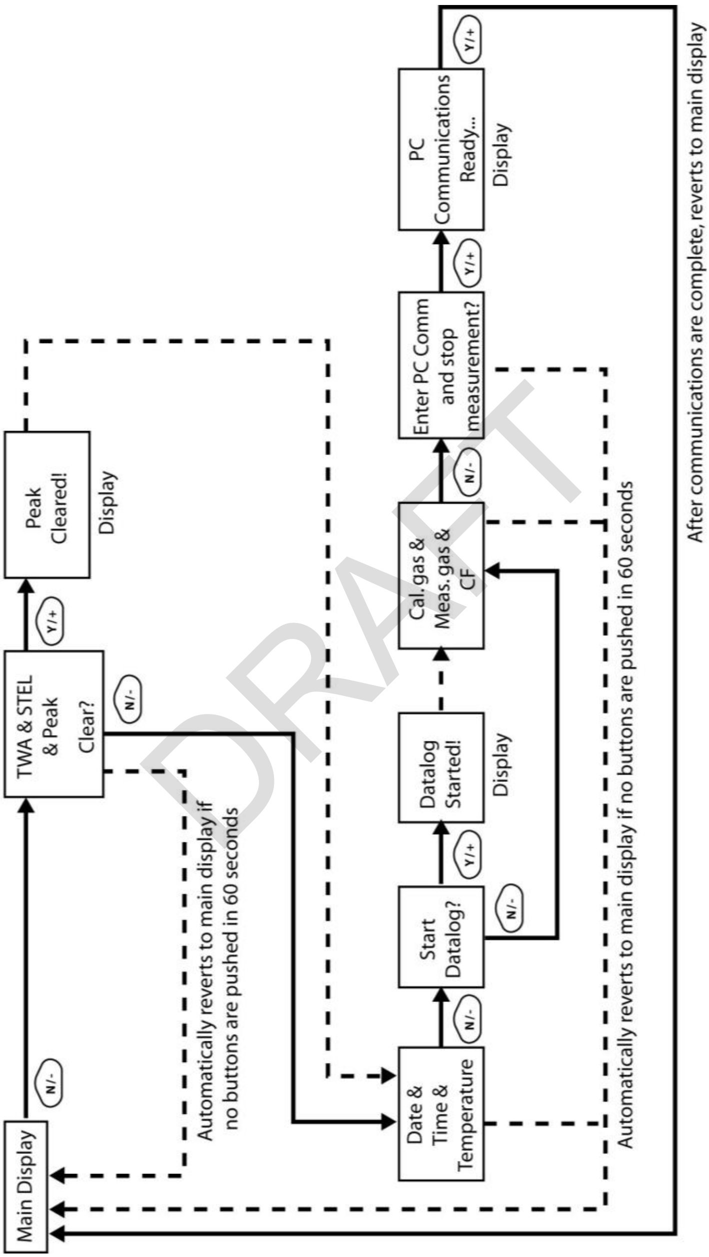
Press [N/-] to undo the changes and revert to the previous settings.

Manual Datalog

When the instrument is set to Manual Datalog, you turn datalogging on and off by stepping through the displays from the Main Display, and then pressing the keys to select datalog on/off functions.

- When you reach the screen that says "Start Datalog?" press [Y/+] to start it. You see "Datalog Started," confirming that datalogging is now on.

When you reach the screen that says "Stop Datalog?" press [Y/+] to stop it. You see "Datalog Stopped," confirming that datalogging is now off.



Note: Dashed line indicates automatic progression.

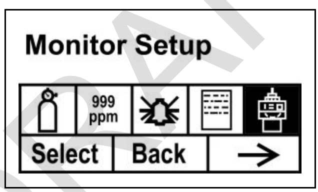
Snapshot Datalog

When the instrument is in Snapshot datalogging mode, it captures a single "snapshot" of the data at the moment of your choosing. Whenever the instrument is on and it is set to Snapshot, all you have to do is press [MODE] each time you want to capture a snapshot of the data at that instant.

When you send the data to a computer using ProRAE Studio, the data snapshots are uniquely identified by time and other parameters.

Monitor Setup

Many settings can be accessed in this menu, including setting the date and time and adjusting the pump's on/off duty cycle.



Radio Power

The radio connection can be turned on or off.

1. Press [N/-] to step from one option to the next (on or off).
2. Press [Y/+] to make your selection (the dark circle in the "radio button" indicates that the option is selected).
3. When you have completed your selection, press [MODE].

- Press [Y/+] to accept the new radio setting (on or off).
- Press [N/-] to discard the change and move to the next sub-menu.

Op Mode

Under Monitor Setup is "Op Mode."

Press [Y/+] to select.

You see two options (one is highlighted):

Hygiene
Search

The current mode is indicated by a dark circle within the circle in front of either Hygiene or Search.

1. Select Hygiene or Search by pressing [N/-]. The highlighting changes from one to the other each time you press [N/-].
2. Press [Y/+] to select that mode for the instrument.
3. Press [MODE] when you want to register your selection to place the instrument in the selected mode.
4. Press [Y/+] to commit the change and exit to the Monitor Setup screen, or press [N/-] to Undo (exit to the Monitor Setup screen without changing the Mode).

Site ID

Enter an 8-digit alphanumeric/character Site ID in the programming mode. This Site ID is included in the datalog report.

1. Press [Y/+] and the display shows the current site ID. Example: "RAE00001." Note that the left-most digit flashes to indicate it is the selected one.
2. Press [Y/+] to step through all 26 letters (A to Z) and 10 numerals (0 to 9).
   Note: The last four digits must be numerals.
3. Press [N/-] to advance to the next digit. The next digit to the right flashes.

Repeat this process until all eight digits of the new site ID are entered.

Press [MODE] to exit.

If there is any change to the existing site ID, the display shows "Save?" Press [Y/+] to accept the new site ID. Press [N/-] to discard the change and move to the next sub-menu.

User ID

Enter an 8-digit alphanumeric User ID in the programming mode. This User ID is included in the datalog report.

1. Press [Y/+] and the display shows the current User ID. Example: "RAE00001." Note that the left-most digit flashes to indicate it is the selected one.
2. Press [Y/+] to step through all 26 letters (A to Z) and 10 numerals (0 to 9).
3. Press [N/-] to advance to the next digit. The next digit to the right flashes.

Repeat this process until all eight digits of the new User ID are entered.

Press [MODE] to exit.

If there is any change to the existing User ID, the display shows "Save" Press [Y/+] to accept the new site ID. Press [N/-] to discard (undo) the change and move to the next sub-menu.

User Mode

The instrument has two user modes:

Basic Basic users can only see and use a basic set of functions.
Advanced Advanced users can see all screens and perform all available functions.

Note: The default value for User Mode is Basic.

To change the User Mode:

1. Press [N/-] to step from one option to the next. The highlighting changes each time you press [N/-].
2. Press [Y/+] to make your selection (the dark circle in the "radio button" indicates "on").
3. When you have completed your selection, press [MODE].
4. Press [Y/+] to accept the new User Mode. Press [N/-] to discard the change and move to the next sub-menu.

Date

The Date is expressed as Month/Day/Year, with two digits for each.

1. Press [Y/+] and the display shows the current date. Note that the left-most digit flashes to indicate it is selected.
2. Press [Y/+] to step through all 10 numerals (0 to 9).
3. Press [N/-] to advance to the next digit. The next digit to the right flashes.

   Repeat this process until all six digits of the new date are entered.

Press [MODE] to exit.

- Press [Y/+] to save the new date.
- Press [N/-] to undo the change and move to the next sub-menu.

Time

The Time is expressed as Hours/Minutes/Seconds, with two digits for each. The time is in 24-hour (military) format.

1. Press [Y/+] and the display shows the current time. Note that the left-most digit flashes to indicate it is selected.
2. Press [Y/+] to step through all 10 numerals (0 to 9).
3. Press [N/-] to advance to the next digit. The next digit to the right flashes.

   Repeat this process until all six digits of the new time are entered.

Press [MODE] to exit.

- Press [Y/+] to save the new date.
- Press [N/-] to undo the change and move to the next sub-menu.

Pump Duty Cycle

The pump's duty cycle is the ratio of its on time to off time. The duty cycle ranges from 50% to 100% (always on), and the period is 10 seconds. Therefore, a duty cycle of 60% means that the pump is on for 6 seconds and off for four seconds. Duty cycling is employed by the instrument to clean the PID. A lower duty cycle has a greater effect on keeping the PID clean than a higher duty cycle.

Important! Pump duty cycling is interrupted when the instrument senses a gas. The pump's duty cycle is disabled when the measurement is greater than the 2ppm threshold and is re-enabled when the reading falls below 90% of the threshold (1.8 ppm).

1. Press [Y/+] to increase the value.
2. When you have completed your selection, press [MODE].
   - Press [Y/+] to save the new duty cycle value.
   - Press [N/-] to undo the change and move to the next sub-menu.

Pump Speed

The pump can operate at two speeds, high and low. Running at low speed is quieter and conserves a small amount of power. There is almost no difference in sampling accuracy.

1. Press [N/-] to step from one option to the next.
2. Press [Y/+] to make your selection (the dark circle in the "radio button" indicates "on").
3. When you have completed your selection, press [MODE].
   - Press [Y/+] to save the new temperature unit.
   - Press [N/-] to undo the change and move to the next sub-menu.

Temperature Unit

The temperature display can be switched between Fahrenheit and Celsius units.

1. Press [N/-] to step from one option to the next.
2. Press [Y/+] to make your selection (the dark circle in the "radio button" indicates "on").
3. When you have completed your selection, press [MODE].
   - Press [Y/+] to save the new temperature unit.
   - Press [N/-] to undo the change and move to the next sub-menu.

Language

English is the default language, but other languages can be selected for the instrument.

1. Press [N/-] to step from one option to the next.
2. Press [Y/+] to make your selection (the dark circle in the "radio button" indicates "on").
3. When you have completed your selection, press [MODE].
   - Press [Y/+] to save your new language choice.
   - Press [N/-] to undo it and return to the previous language selection.

Real Time Protocol

Real Time Protocol is the setting for data transmission.

The choices are:

P2M (cable)	Point to multipoint. Data is transferred from the instrument to multiple locations using a wired connection. Default data rate: 19200 bps.
P2P (cable)	Point to point. Data is transferred only between the instrument and one other location, such as a computer. Default data rate: 9600 bps.
P2M (wireless)	Point to multipoint, wireless. Data is transferred wirelessly and can be received by multiple receivers.

1. Press [N/-] to step from one option to the next.
2. Press [Y/+] to make your selection (the dark circle in the "radio button" indicates "on").
3. When you have completed your selection, press [MODE].
   - Press [Y/+] to save the new real-time communications protocol.
   - Press [N/-] to undo the change and move to the next sub-menu.

Power On Zero

When Power On Zero is on, the instrument performs a zero calibration when it is turned on.

1. Press [N/-] to step from one option to the next.
2. Press [Y/+] to make your selection (the dark circle in the "radio button" indicates your selection).
3. When you have completed your selection, press [MODE].
    - Press [Y/+] to save the change.
    - Press [N/-] to discard the change and move to the next sub-menu.

Unit ID

This three-digit number keeps data separated by instrument when more than one instrument is used in a network. If multiple sensing units are attempting to communicate with the same Host, then the units must all have a different Unit ID.

1. Press [Y/+] to step through all 10 numerals (0 to 9). If you pass the numeral you want, keep pressing [Y/+]. After it counts up to 9, it starts counting up from 0 again.
2. Press [N/-] to advance to the next digit. The next digit to the right flashes.

Repeat this process until all three digits of the Unit ID are entered.

3. Press [MODE] when you are done.
    - Press [Y/+] to save the change.
    - Press [N/-] to discard the change and move to the next sub-menu.

LCD Contrast

The display's contrast can be increased or decreased from its default setting. You may not need to ever change the default setting, but sometimes you can optimize the display to suit extreme temperature and ambient brightness/darkness conditions.

- The minimum value is 20.
- The maximum value is 60.

1. Press [Y/+] to increase the value or [N/-] to decrease the value.
2. Press [MODE] to save your selection.
   - Press [Y/+] to save your new contrast value.
   - Press [N/-] to undo it and return to the previous value.

Lamp ID

The instrument must be set to the correct lamp value in order to function correctly. Always match the value that was installed in your instrument from the factory or the value of the PID lamp you are replacing.

1. Press [N/-] to step from one option to the next.
2. Press [Y/+] to make your selection (the dark circle in the "radio button" indicates "on").
3. When you have completed your selection, press [MODE].

PAN ID

The MiniRAE 3000 and any other devices that you want to interconnect wirelessly must have the same PAN ID. You can set the PAN ID in the instrument or through ProRAE Studio II.

1. Press [N/-] to advance through the digits from left to right.
2. Press [Y/+] to] to advance through the numbers (1, 2, 3, etc.).
3. Press [MODE] to register your choice when you are done.

Mesh Channel

Note: For mesh radio modems operating at 868MHz, only channel 0 is available. For other frequencies, channels 1 through 10 are allowed.

1. Press [Y/+] to increase the number and [N/-] to advance to the next digit.
2. After moving to the last digit and making changes, press [MODE].
    - Press [Y/+] to save the change.
    - Press [N/-] to undo the change.

Mesh Interval

Set the time interval at which the instrument's mesh radio sends out a signal. This can range from once every 10 seconds to once every four minutes (240 seconds). The transmission frequency is user-adjustable, but a rate of at least once every 30 seconds is recommended. **Note:** Shorter intervals reduce battery life.

1. Press [N/-] to step from one option to the next.
2. Press [Y/+] to make a selection.
3. When you are done, press [MODE].

Hygiene Mode

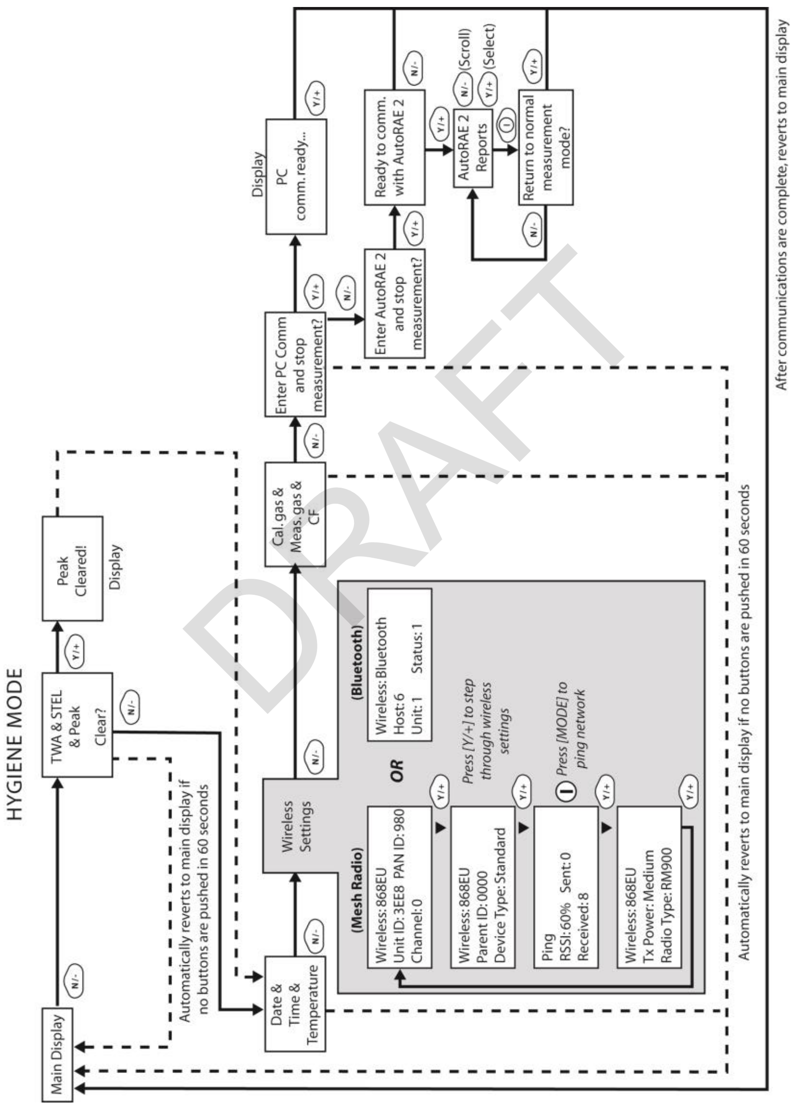
The instrument usually operates in Hygiene Mode, which provides basic functionality. However, it is possible to operate it in a second mode called Search Mode. Here are the primary differences:

Hygiene Mode: Automatic measurements, continuously running and datalogging, and calculates additional exposure values.

Search Mode: Manual start/stop of measurements and display of certain exposure values.

Basic User Level & Hygiene Mode

The default setting is navigated in the following way:



Note: Dashed line indicates automatic progression.

Pressing [N/-] steps you from screen to screen. Options include clearing the Peak value and turning on the instrument's PC Communications for data transfer to a PC.

Entering Search Mode From Hygiene Mode

In order to change the instrument's operational mode from Hygiene Mode to Search Mode, you must enter the password-protected Programming Mode:

1. Hold [MODE] and [N/-] until you see the password screen.
2. Use [Y/+] to increment to the number you want for the first digit. (If you pass by the desired number, press [Y/+] until it cycles through to 0 again. Then press [Y/+] until you reach the desired number.)
3. Press [N/-] to advance to the next digit.
4. Again press [Y/+] to increment the number.
5. Press [N/-] to advance to the next digit.

Continue the process until all four numbers of the password have been input. Then press [MODE] to proceed.

The screen changes to icons with the label "Calibration."

1. Press [N/-] to advance to "Monitor Setup."
2. Press [Y/+] to select Monitor Setup.

Under Monitor Setup, you will see "Op Mode."

Press [Y/+] to select.

You will see:

Hygiene
Search

The current mode is indicated by a dark circle within the circle in front of either Hygiene or Search.

1. Select Hygiene or Search by pressing [N/-].
2. Press [Y/+] to place the instrument into the selected mode.

3. Press [MODE] when you want to register your selection to place the instrument in the selected mode.
4. Press [Y/+] to commit the change and exit to the Monitor Setup screen, or press [N/-] to Undo (exit to the Monitor Setup screen without changing the Mode).

Advanced User Level (Hygiene Mode Or Search Mode)

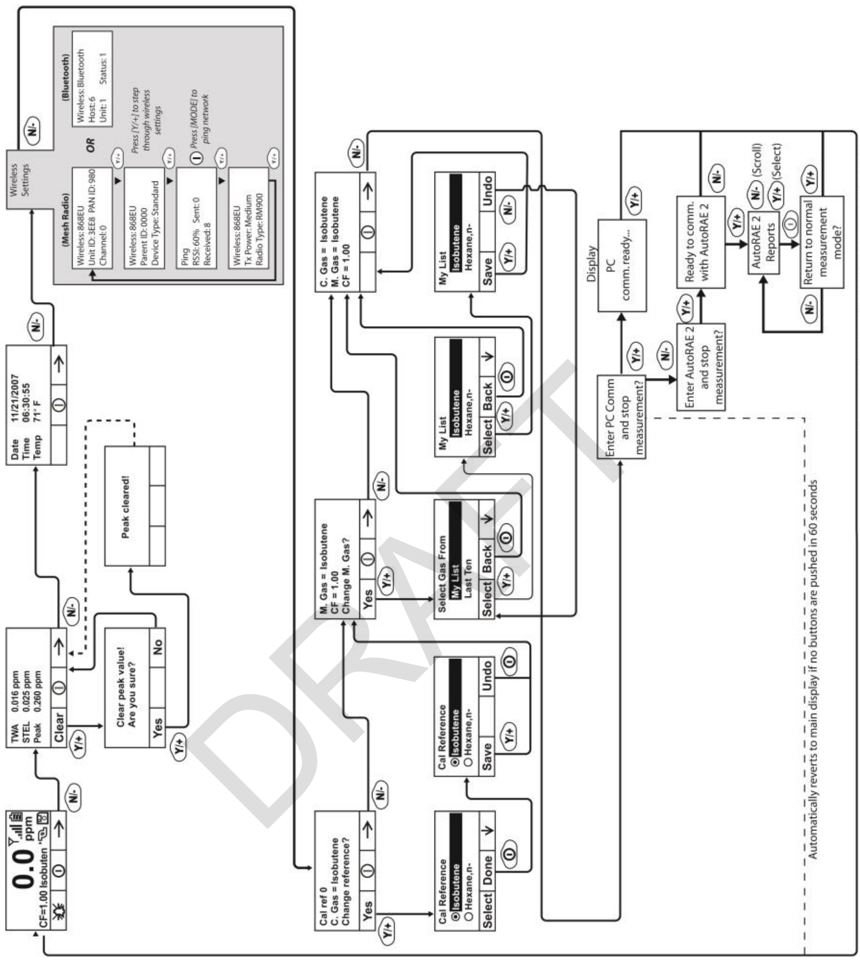
The User Mode called Advanced User Level allows a greater number of parameters to be changed than Basic User Level. It can be used with either of the Operation Modes, Hygiene Mode or Search Mode.

Advanced User Level & Hygiene Mode

With the instrument in Operation Mode: Hygiene Mode, enter User Mode: Advanced User Level (refer to the section called Monitor Mode for instructions).

Once you are in Advanced User Level and Hygiene Mode together, you can change the calibration reference and measurement gas, in addition to performing normal monitoring functions.

Pressing [N/-] progresses through the screens, while pressing [Y/+] selects options. Pressing [MODE] makes menu choices when it is shown for "Done" or "Back." Pressing and holding [Mode] whenever the circle with a vertical line in the middle is shown activates the countdown to shutoff.

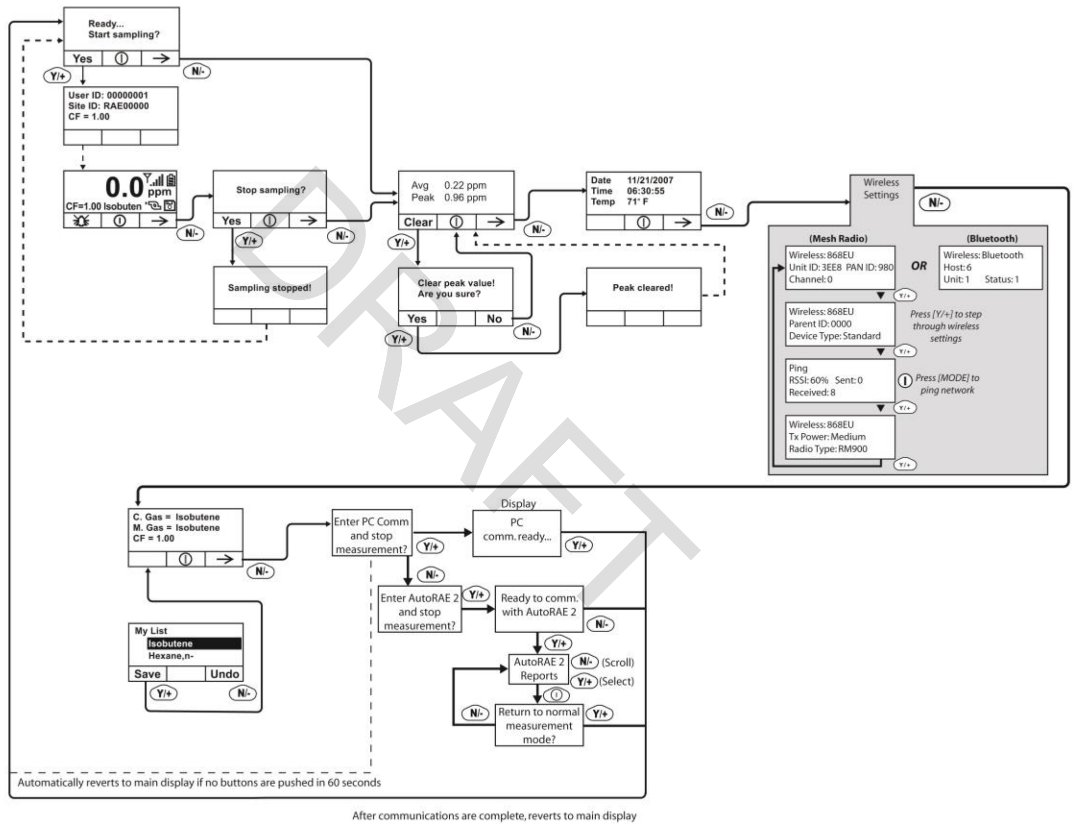


Note: Dashed line indicates automatic progression.

Basic User Level & Search Mode

With the instrument in Operation Mode: Search Mode, enter User Mode and select Basic User Level (refer to the section called User Mode for instructions).

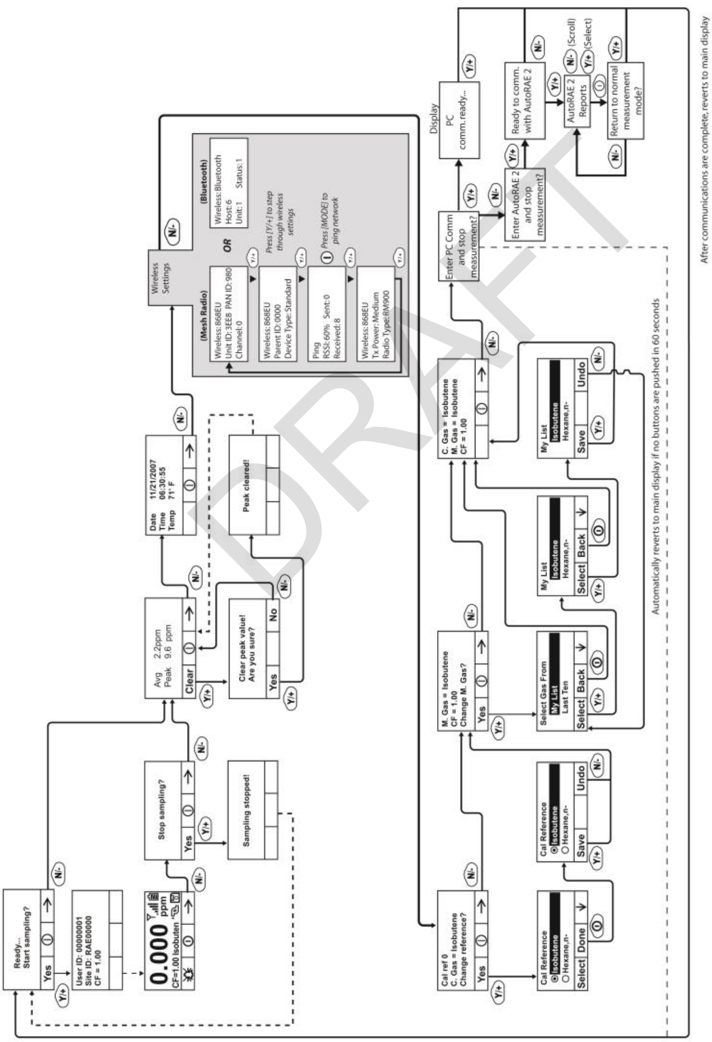
When the instrument is in Search Mode, it only samples when you activate sampling. When you see the display that says, "Ready…Start sampling?" press [Y/+] to start. The pump turns on and the instrument begins collecting data. To stop sampling, press [N/-] while the main display is showing. You will see a new screen that says, "Stop sampling?" Press [Y/+] to stop sampling. Press [N/-] if you want sampling to continue.



Note: Dashed line indicates automatic progression.

Advanced User Level & Search Mode

With the instrument in Operation Mode: Search Mode, enter User Mode and select Advanced User Level (refer to the section called Monitor Mode for instructions). Operation is similar to Basic User Level & Sampling Mode, but now allows you to change calibration and measurement reference gases. Refer to the section on measurement gases on page 60 for more details.



Note: Dashed line indicates automatic progression.

Diagnostic Mode

IMPORTANT! Diagnostic Mode is designed for servicing and manufacturing, and therefore is not intended for everyday use, even by advanced users. It provides raw data from sensors and about settings, but only allows adjustment of pump stall parameters, which should only be changed by qualified personnel.

Note: If the instrument is turned on in Diagnostic Mode and you switch to User Mode, datalog data remains in raw count form. To change to standard readings, you must restart the instrument.

Entering Diagnostic Mode

Note: To enter Diagnostic Mode, you must begin with the instrument turned off.

Press and hold [Y/+] and [MODE] until the instrument starts.

The instrument goes through a brief startup, and then displays raw data for the PID sensor. These numbers are raw sensor readings without calibration. The instrument is now in Diagnostic Mode.

Note: In Diagnostic Mode, the pump and lamp are normally on.

You can enter Programming Mode and calibrate the instrument as usual by pressing both [MODE] and [N/-] for three seconds.

You can enter Monitoring Mode by pressing [MODE] and [Y/+] together for three seconds.

Once the instrument is started up in Diagnostic Mode, you can switch between Diagnostic Mode and Monitoring Mode by pressing and holding [MODE] and [Y/+] simultaneously for two seconds.

In Diagnostic mode, you can step through parameter screens by pressing [MODE].

Adjusting The Pump Stall Threshold

If the gas inlet is blocked but the pump does not shut down, or the pump shuts down too easily with a slight blockage, the pump stall threshold value may be set too high or too low.

Use the following steps to adjust the pump stall threshold:

Pump High

In Diagnostic Mode, press the [MODE] key until "Pump High" is displayed. The display shows the maximum, minimum, and stall values for the pump at its high speed. Write down the "Max" reading.

Block the gas inlet and watch the pump current reading (labeled "I") increase. Write down its blocked reading. **Note:** If the pump current reading does not increase significantly (less than 10 counts), then there may be a leak in the gas inlet or the pump is weak or defective.

Add the two readings you wrote down. This is the average of the maximum block count and the maximum idle count. Divide that number by 2. Use the [Y/+] or [N/-] key to increase or decrease the stall value to equal that number.

Press the [MODE] key to exit this display.

Pump Low

In Diagnostic Mode, press the [MODE] key until "Pump Low" is displayed. The display shows the maximum, minimum, and stall values for the pump at its low speed. Write down the "Max" reading.

Block the gas inlet and watch the pump current reading (labeled "I") increase. Write down its blocked reading. **Note:** If the pump current reading does not increase significantly (less than 10 counts), then there may be a leak in the gas inlet or the pump is weak or defective.

Add the two readings you wrote down. This is the average of the maximum block count and the maximum idle count. Divide that number by 2. Use the [Y/+] or [N/-] key to increase or decrease the stall value to equal that number.

Press the [MODE] key to exit this display.

Exiting Diagnostic Mode

You can exit Diagnostic Mode and go directly to Programming Mode or Monitor Mode as outlined above, or you can exit Diagnostic Mode completely.

To exit Diagnostic Mode so that it cannot be re-entered without a restart:

Shut down the instrument. When it is off, restart it by holding the [MODE] key. Diagnostic Mode cannot be entered until the instrument is restarted as outlined in "Entering Diagnostic Mode."

Transferring Data To & From A Computer

Once you have connected your instrument cradle to the PC, you can can transfer data, including a download of the datalog to the computer and updates of firmware to the instrument (should this ever be necessary).

Downloading The Datalog To A PC

1. Connect the data cable to the PC and the cradle.
2. Place the instrument into its cradle. The charging LED should be illuminated.
3. Start ProRAE Studio on your PC.
4. From ProRAE Studio, select "Operation" and select Setup Connection.
5. Select the COM port to establish a communication link between the PC and the instrument.
6. To receive the datalog in the PC, select "Downlog Datalog."
7. When you see "Unit Information," click OK.

During the data transfer, the display shows a progress bar.

When the transfer is done, you will see a screen with the datalog information. You can now export this datalog for other use or printing.

Uploading Firmware To The instrument From A PC

Uploading new firmware to your instrument requires connecting the instrument and PC. Follow these steps to make the connection:

1. Connect the data cable to the PC and the cradle.
2. Place the instrument into its cradle. The charging LED should be illuminated.
3. Start RAEProgrammer 7000 on your PC.
4. From RAEProgrammer 7000, select "Operation" and select Setup Connection.
5. Select the COM port to establish a communication link between the PC and the instrument.
6. Select Operation → Download Firmware.

Once communication is established, follow the instructions that accompany RAEProgrammer 7000 and the firmware to upload the new firmware to your instrument.

Note: Check for the latest updates to ProRAEProgrammer 7000 at www.raesystems.com.

Maintenance

The major maintenance items of the instrument are:

- Battery pack
- Sensor module
- PID lamp
- Sampling pump
- Inlet connectors and filters

Note: Maintenance should be performed by qualified personnel only.

NOTE: The printed circuit board of the instrument is connected to the battery pack even if the power is turned off. Therefore, it is very important to disconnect the battery pack before servicing or replacing any components inside the instrument. Severe damage to the printed circuit board or battery may occur if the battery pack is not disconnected before servicing the unit.

Battery Charging & Replacement

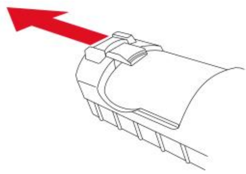
When the display shows a flashing empty battery icon, the battery requires recharging. It is recommended to recharge the instrument upon returning from fieldwork. A fully charged battery runs a instrument for 16 hours continuously. The charging time is less than 8 hours for a fully discharged battery. The battery may be replaced in the field (in areas known to be non-hazardous), if required.

WARNING!

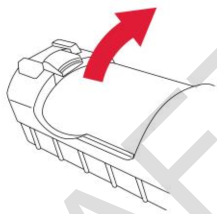
To reduce the risk of ignition of hazardous atmospheres, recharge battery only in area known to be non-hazardous. Remove and replace battery only in areas known to be non-hazardous.

Replacing The Li-ion Battery

1. Turn off the instrument.
2. Located on the rear of the instrument is a battery tab. Slide it down to unlock the battery.



3. Remove the battery pack from the battery compartment by tilting it out.



4. Replace a fully charged spare battery pack inside the battery compartment. Make sure the battery pack is oriented properly inside the compartment.
5. Slide the capture tab back up to its locked position.

Replacing The Alkaline Battery Adapter

An alkaline battery adapter is supplied with each instrument. The adapter (part number 059-3052-000) accepts four AA alkaline batteries (use only Duracell MN1500) and provides approximately 12 hours of operation. The adapter is intended to be used in emergency situations when there is no time to charge the Li-ion battery pack.

To insert batteries into the adapter:

1. Remove the three Philips-head screws to open the compartment.
2. Insert four fresh AA batteries as indicated by the polarity (+/-) markings.
3. Replace the cover. Replace the three screws.

To install the adapter in the instrument:

1. Remove the Li-ion battery pack from the battery compartment by sliding the tab and tilting out the battery.
2. Replace it with the alkaline battery adapter
3. Slide the tab back into place to secure the battery adapter.

IMPORTANT!

Alkaline batteries cannot be recharged. The instrument's internal circuit detects alkaline batteries and will not allow recharging. If you place the instrument in its cradle, the alkaline battery will not be recharged. The internal charging circuit is designed to prevent damage to alkaline batteries and the charging circuit when alkaline batteries are installed inside the instrument.

Note: When replacing alkaline batteries, dispose of old ones properly.

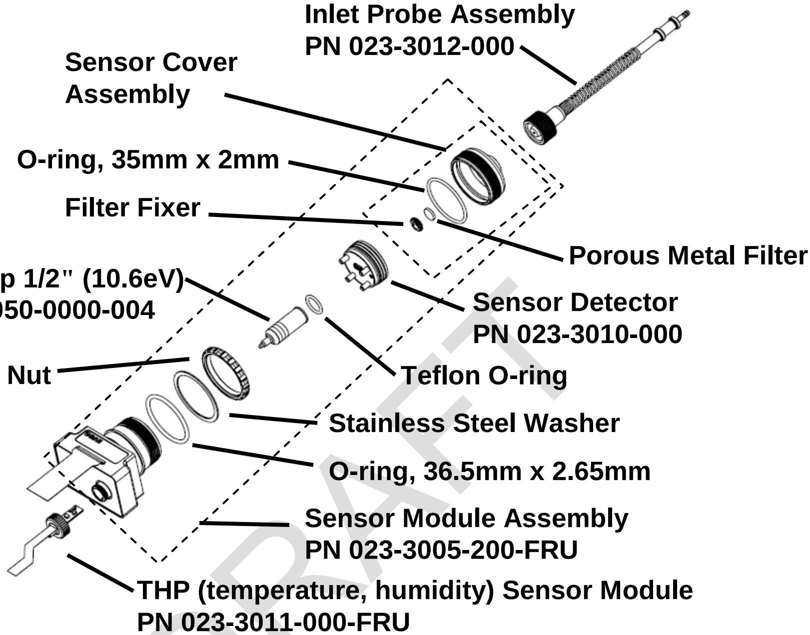
WARNING!

To reduce the risk of ignition of hazardous atmospheres, recharge the battery only in areas known to be non-hazardous. Remove and replace the battery only in areas known to be non-hazardous.

Note: The internal charging circuit is designed to prevent charging to alkaline batteries.

PID Sensor & Lamp Cleaning/Replacement

The sensor module is made of several components and is attached to the lamp-housing unit as shown below.



Sensor Components

Note: The cleaning procedure is not normally needed. Clean the PID sensor module, the lamp and the lamp housing only if:

1. The reading is inaccurate even after calibration.
2. The reading is very sensitive to air moisture.
3. A liquid has been sucked into the unit and damaged the unit.

Use of the external filter helps to prevent contamination of the sensor.

To access the sensor components and lamp, gently unscrew the lamp-housing cap, remove the sensor adapter with the gas inlet probe and the metal filter all together. Then hold the PID sensor and pull it straight out. A slight, gentle rocking motion helps release the sensor.

Cleaning The PID Sensor

Place the entire PID sensor module into GC grade methanol. It is highly recommended that an ultrasound bath to be used to clean the sensor for at least 15 minutes. Then dry the sensor thoroughly. Never touch the electrodes of the sensor by hand.
Also use a methanol-soaked cotton swab to wipe off the lamp housing where it contacts the sensor when the sensor is installed.

Turn over the sensor so that the pins point up and the sensor cavity is visible. Examine the sensor electrodes for any corrosion, damage, or bending out of alignment. The metal sensor electrode "fingers" should be flat and straight. If necessary, carefully bend the sensor fingers to ensure that they do not touch the Teflon portions and that they are parallel to each other. Make sure that the nuts on the sensor pins are snug but not overtight. If the sensor is corroded or otherwise damaged, it should be replaced.

Cleaning The Lamp Housing Or Changing The Lamp

If the lamp does not turn on, the instrument will display an error message to indicate replacement of the lamp may be required.

1. If the lamp is operational, clean the lamp window surface and the lamp housing by wiping it with GC grade methanol using a cotton swab using moderate pressure. After cleaning, hold the lamp up to the light at an angle to detect any remaining film. Repeat the process until the lamp window is clean. Never use water solutions to clean the lamp. Dry the lamp and the lamp housing thoroughly after cleaning.

   CAUTION: Never touch the window surface with the fingers or anything else that may leave a film. Never use acetone or aqueous solutions.

2. If the lamp does not turn on, remove the lamp from the lamp housing. Place the lamp O-ring onto the new lamp. Insert the new lamp, avoiding contact with the flat window surface.

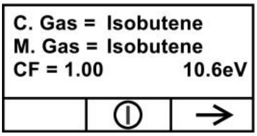
3. Reinstall the PID sensor module.

4. Tighten the Lamp Housing Cap.

Determining The Lamp Type

The monitor can accommodate three lamp values: 10.6eV (standard), 9.8eV, and 11.7eV. Always make sure you are using the correct lamp value and that the instrument is set to use that lamp.

Also, when the monitor is running, the lamp type is shown along with the calibration and measurement gas and Correction Factor:



Note: This screen can be accessed from the reading screen by pressing [N/-] four times.

You can manually determine the lamp type, too:

1. Turn off the instrument and remove the lamp. Now look at the serial number. The following identify the lamp type:
   - 10.6eV SN: 106 2Nxxxxx
   - 9.8eV SN: 098 2Nxxxxx
   - 11.7eV SN: 117 2Nxxxxx

Programming The Lamp ID

The correct measurement gas library is used by the instrument when you ensure that the right lamp value is programmed.

To manually select the Lamp ID:

1. Enter the Programming menu.
2. Select Monitor Setup.
3. Scroll down and select the Lamp ID sub-menu.
4. Press [N/-] to scroll down to the desired Lamp ID.
5. Press [Y/+] to select.
6. Press [MODE] to select Done.
7. Select "Save."
8. Return to the main menu.

Recalibrate the instrument before returning it to service.

Sampling Pump

When approaching the end of the specified lifetime of the pump, it will consume higher amount of energy and reduce its sample draw capability significantly. When this occurs, it is necessary to replace or rebuild the pump. When checking the pump flow, make sure that the inlet connector is tight and the inlet tubing is in good condition. Connect a flow meter to the gas inlet probe. The flow rate should be above 450 cc/min when there is no air leakage.

If the pump is not working properly, refer the instrument to qualified service personnel for further testing and, if necessary, pump repair or replacement.

Cleaning The Instrument

Occasional cleaning with a soft cloth is recommended. Do not use detergents or chemicals.

Visually inspect the contacts at the base of the instrument, on the battery, and on the charging cradle to make sure they are clean. If they are not, wipe them with a soft, dry cloth. Never use solvents or cleaners.

Ordering Replacement Parts

If you need replacement parts, contact your local RAE Systems distributor. A list is available online:

http://www.raesystems.com

In the U.S., you can order sensors, replacement batteries, and other accessories online at:

http://istore.raesystems.com/

Special Servicing Note

If the instrument needs to be serviced, contact either:

1. The RAE Systems distributor from whom the instrument was purchased; they will return the instrument on your behalf.

   or

2. The RAE Systems Technical Service Department. Before returning the instrument for service or repair, obtain a Returned Material Authorization (RMA) number for proper tracking of your equipment. This number needs to be on all documentation and posted on the outside of the box in which the instrument is returned for service or upgrade. Packages without RMA Numbers will be refused at the factory.

Troubleshooting

Problem	Possible Reasons & Solutions	
Cannot turn on power after charging the battery	**Reasons:** **Solutions:**	Discharged battery. Defective battery. Charge or replace battery.
Lost password	**Solutions:**	Call Technical Support at +1 408-752-0723 or toll-free at +1 888-723-4800
Reading abnormally High	**Reasons:** **Solutions:**	Dirty filter. Dirty sensor module. Excessive moisture and water condensation. Incorrect calibration. Replace filter. Blow-dry the sensor module. Calibrate the unit.
Reading abnormally Low	**Reasons:** **Solutions:**	Dirty filter. Dirty sensor module. Weak or dirty lamp. Incorrect calibration. Replace filter. Remove Calibration Adapter. Calibrate the unit. Check for air leakage.
Buzzer Inoperative	**Reasons:** **Solutions:**	Bad buzzer. Check that buzzer is not turned off. Call authorized service center.

Inlet flow too low	**Reasons:**	Pump diaphragm damaged or has debris. Flow path leaks.
	Solutions:	Check flow path for leaks; sensor module O-ring, tube connectors, Teflon tube compression fitting. Call Technical Support at +1 408-752-0723 or toll-free at +1 888-723-4800
"Lamp" message during operation	**Reasons:**	Lamp drive circuit. Weak or defective PID lamp, defective.
	Solutions:	Turn the unit off and back on. Replace UV lamp

Technical Support

To contact RAE Systems Technical Support Team:

Monday through Friday, 7:00AM to 5:00PM Pacific (US) Time
Phone (toll-free): +1 888-723-4800
Phone: +1 408-952-8461
Email: tech@raesystems.com

RAE Systems Contacts

RAE Systems by Honeywell
World Headquarters
3775 N. First St.
San Jose, CA 95134-1708 USA
Phone: 408.952.8200
Toll-Free: 888.723.4800
Fax: 408.952.8480

E-mail (technical support): RAE-tech@honeywell.com
Web Site: www.raesystems.com

WORLDWIDE SALES OFFICES

USA/Canada 1.877.723.2878

Europe +800.333.222.44/+41.44.943.4380

Middle East +971.4.450.5852

China +86.10.5885.8788-3000

Asia Pacific +852.2669.0828

Controlled Part of Manual

Intrinsic Safety:
US and Canada: Class I, Division 1, Groups A,B,C,D T4

Europe: ATEX (0575 Ex II 2G Ex ia IIC/IIB T4 Gb)
KEMA 07 ATEX 0127
Complies with EN60079-0:2009, EN60079-11:2007
IECEx CSA 10.0005 Ex ia IIC/IIB T4 Gb
Complies with IEC 60079-0:2007, IEC 60079-11:2006

Temperature: -20º C to 50º C (-4º to 122º F)

Humidity: 0% to 95% relative humidity (non-condensing)

Basic Operation

Turning The Instrument On

1. With the instrument turned off, press and hold [MODE].
2. When the display turns on, release the [MODE] key.

The instrument is now operating and performs self tests. Once the self tests are complete, the display shows a graph or numerical gas reading. This indicates that the instrument is fully functional and ready to use.

Turning The Instrument Off

1. Press and hold the Mode key for 3 seconds. A 5-second countdown to shutoff begins.
2. When you see "Unit off..." release your finger from the [MODE] key. The instrument is now off.

Note: You must hold your finger on the key for the entire shutoff process. If you remove your finger from the key during the countdown, the shutoff operation is canceled and the instrument continues normal operation.

Alarm Signals

During each measurement period, the gas concentration is compared with the programmed alarm limits (gas concentration alarm limit settings). If the concentration exceeds any of the preset limits, the loud buzzer and red flashing LED are activated immediately to warn you of the alarm condition.

In addition, the instrument alarms if one of the following conditions occurs: battery voltage falls below a preset voltage level, failure of the UV lamp, pump stall, or when the datalog memory is full.

Alarm Signal Summary

Message	Condition	Alarm Signal
HIGH	Gas exceeds "High Alarm" limit	3 beeps/flashes per second*
OVR	Gas exceeds measurement range	3 beeps/flashes per second*
MAX	Gas exceeds electronics' maximum range	3 beeps/flashes per second*
LOW	Gas exceeds "Low Alarm" limit	2 beeps/flashes per second*
TWA	Gas exceeds "TWA" limit	1 Beep/flash per second*
STEL	Gas exceeds "STEL" limit	1 Beep/flash per second*
Pump icon flashes	Pump failure	3 beeps/flashes per second
Lamp	PID lamp failure	3 beeps/flashes per second plus "Lamp" message on display

Battery icon flashes	Low battery	1 flash, 1 beep per minute plus battery icon flashes on display
CAL	Calibration failed, or needs calibration	1 beep/flash per second
NEG	Gas reading measures less than number stored in calibration	1 beep/flash per second

Preset Alarm Limits & Calibration

The instrument is factory calibrated with standard calibration gas, and is programmed with default alarm limits.

Cal Gas (Isobutylene)	Cal Span	unit	Low	High	TWA	STEL
ppbRAE 3000	10	ppm	10	25	10	25
MiniRAE 3000	100	ppm	50	100	10	25
MiniRAE Lite	100	ppm	50	100	10	25
UltraRAE 3000	100	ppm	50	100	10	25

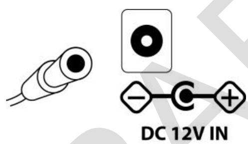
Charging The Battery

Always fully charge the battery before using the instrument. The instrument's Li-ion/NiMH battery is charged by placing the instrument in its cradle. Contacts on the bottom of the instrument meet the cradle's contacts, transferring power without other connections.

Note: Before setting the instrument into its charging cradle, visually inspect the contacts to make sure they are clean. If they are not, wipe them with a soft cloth. Do not use solvents or cleaners.

Follow this procedure to charge the instrument:

1. Plug the AC/DC adapter's barrel connector into the instrument's cradle.



2. Plug the AC/DC adapter into the wall outlet.
3. Place the instrument into the cradle, press down, and lean it back. It locks in place and the LED in the cradle glows.

Note: To release the instrument, press down and tilt the top out of the cradle and lift up.

The instrument begins charging automatically. The LED on the front of the cradle marked "Primary" blinks during charging. During charging, the diagonal lines in the battery icon on the instrument's display are animated and you see the message "Charging..."

When the instrument's battery is fully charged, the battery icon is no longer animated and shows a full battery. The message "Fully charged!" is shown and the Primary LED on the cradle glows continuously green.

Note: A spare Li-ion battery (059-3051-000) or NiMH(059-3054-000) can be charged by placing it directly in the charging port on the back of the cradle. It can be charged at the same time as the instrument. Press the battery in place, sliding it slightly toward the front of the cradle. This locks it in the cradle. To release the battery, slide it forward again and tilt it up.

Note: An Alkaline Battery Adapter (part number 059-3052-000), which uses four AA alkaline batteries (Duracell MN1500), may be substituted for the Li-Ion battery.

WARNING!

To reduce the risk of ignition of hazardous atmospheres, recharge and replace batteries only in areas known to be non-hazardous. Remove and replace batteries only in areas known to be non-hazardous.

Low Voltage Warning

When the battery's charge falls below a preset voltage, the instrument warns you by beeping once and flashing once every minute, and the battery icon blinks once per second. You should turn off the instrument within 10 minutes and either recharge the battery by placing the instrument in its cradle, or replace the battery with a fresh one with a full charge.

Clock Battery

An internal clock battery is mounted on one of the instrument's printed circuit boards. This long-life battery keeps settings in memory from being lost whenever the Li-ion, NiMH, or alkaline batteries are removed. This backup battery should last approximately five years, and must be replaced by an authorized RAE Systems service technician. It is not user-replaceable.

WARNING

To reduce the risk of ignition of hazardous atmospheres, recharge battery only in area known to be non-hazardous. Remove and replace battery only in an area known to be non-hazardous.

Replacing Rechargeable Li-Ion or NiMH Battery

Caution: Turn off the instrument before removing or replacing the battery.

Alkaline Battery Adapter

An alkaline battery adapter is supplied with each instrument. The adapter (part number 059-3052-000) accepts four AA alkaline batteries (use only Duracell MN1500).

Do not mix old and new batteries or different type batteries.

Troubleshooting

Problem	Possible Reasons & Solutions	
Cannot turn on power after charging the battery	**Reasons:** **Solutions:**	Discharged battery. Defective battery. Charge or replace battery.
Lost password	**Solutions:**	Call Technical Support at +1 408-752-0723 or toll-free at +1 888-723-4800
Reading abnormally High	**Reasons:** **Solutions:**	Dirty filter. Dirty sensor module. Excessive moisture and water condensation. Incorrect calibration. Replace filter. Blow-dry the sensor module. Calibrate the unit.
Reading abnormally Low	**Reasons:** **Solutions:**	Dirty filter. Dirty sensor module. Weak or dirty lamp. Incorrect calibration. Replace filter. Remove Calibration Adapter. Calibrate the unit. Check for air leakage.
Buzzer Inoperative	**Reasons:** **Solutions:**	Bad buzzer. Check that buzzer is not turned off. Call authorized service center.

Inlet flow too low	**Reasons:**	Pump diaphragm damaged or has debris. Flow path leaks.
	Solutions:	Check flow path for leaks; sensor module O-ring, tube connectors, Teflon tube compression fitting. Call Technical Support at +1 408-752-0723 or toll-free at +1 888-723-4800
"Lamp" message during operation	**Reasons:**	Lamp drive circuit. Weak or defective PID lamp, defective.
	Solutions:	Turn the unit off and back on. Replace UV lamp

RAE Systems by Honeywell
World Headquarters
3775 N. First St.
San Jose, CA 95134-1708 USA
Phone: 408.952.8200
Toll-Free: 888.723.4800
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E-mail (technical support): RAE-tech@honeywell.com
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Rev. F
February 2016
P/N 059-4020-000

MultiRAE

User's Guide

Rev C
May 2013
P/N: M01-4003-000

IMPORTANT!

This User's Guide covers instruments with application firmware version 1.14 and sensor firmware version 1.04.

Product Registration

Register your product online by visiting:

http://www.raesystems.com/support/product-registration

By registering your product, you can:

- Receive notification of product upgrades or enhancements
- Be alerted to Training classes in your area
- Take advantage of RAE Systems special offers and promotions

Contents

⚠ WARNINGS ⚠

Read Before Operating

This manual must be carefully read by all individuals who have or will have the responsibility of using, maintaining, or servicing this product. The product will perform as designed only if it is used, maintained, and serviced in accordance with the manufacturer's instructions.

CAUTION!

Never operate the monitor when the cover is removed. Remove the monitor rear cover or battery only in an area known to be non-hazardous.

ANY RAPID UP-SCALE READING FOLLOWED BY A DECLINING OR ERRATIC READING MAY INDICATE A GAS CONCENTRATION BEYOND UPPER SCALE LIMIT, WHICH MAY BE HAZARDOUS.

TOUTE LECTURE RAPIDE ET POSITIVE, SUIVIE D'UNE BAISSE SUBITE AU ERRATIQUE DE LA VALEUR, PEUT INDIQUER UNE CONCENTRATION DE GAZ HORS GAMME DE DÉTECTION QUI PEUT ÊTRE DANGEREUSE

ONLY THE COMBUSTIBLE GAS DETECTION PORTION OF THIS INSTRUMENT HAS BEEN ASSESSED FOR PERFORMANCE.

UNIQUMENT, LA PORTION POUR DÉTECTOR LES GAZ COMBUSTIBLES DE CET INSTRUMENT A ÉTÉ ÉVALUÉE.

CAUTION: BEFORE EACH DAY'S USAGE, SENSITIVITY OF THE LEL SENSOR MUST BE TESTED ON A KNOWN CONCENTRATION OF METHANE GAS EQUIVALENT TO 20 TO 50% OF FULL-SCALE CONCENTRATION. ACCURACY MUST BE WITHIN 0 AND +20% OF ACTUAL. ACCURACY MAY BE CORRECTED BY CALIBRATION PROCEDURE.

ATTENTION: AVANT CHAQUE UTILISATION JOURNALIERE, VERIFIER LA SENSIBILITE DU CAPTEUR DE LIE AVEC UNE CONCENTRATION CONNUE DE METHANE EQUIVALENTE DE 20 A 50% DE LA PLEINE ECHELLE. LA PRECISION DOIT ETRE COMPRISE ENTRE 0 ET 20% DE LA VALEUR VRAIE ET PEUT ETRE CORRIGEE PAR UNE PROCEDURE D'ETALONNAGE.

CAUTION: HIGH OFF-SCALE READINGS MAY INDICATE AN EXPLOSIVE CONCENTRATION.

ATTENTION: DES LECTURES HAUTES ET HORS D'ECHELLE PEUVENT INDIQUER DES CONCENTRATIONS DE GAZ INFLAMMABLES

CAUTION: SUBSTITUTION OF COMPONENTS MAY IMPAIR INTRINSIC SAFETY.

Note: Users are recommended to refer to ISA-RP12.13, Part II-1987 for general information on installation, operation, and maintenance of combustible gas detection instruments.

The MultiRAE multi-gas detector must be calibrated if it does not pass a bump test, or at least once every 180 days, depending on use and sensor exposure to poisons and contaminants.

SPECIAL CONDITIONS FOR SAFE USE

1. The PGM-62xx shall only be fitted with RAE Systems Battery Pack type M01-3051-000 or M01-3053-000 or Battery Adapter M01-3052-000 or M01-3054-000 fitted with Duracell MN1500 batteries.
2. The PGM62xx shall only be charged outside hazardous areas.
3. No precautions against electrostatic discharge are necessary for portable equipment that has an enclosure made of plastic, metal, or a combination of the two, except where a significant static-generating mechanism has been identified. Activities such as placing the item in a pocket or on a belt, operating a keypad or cleaning with a damp cloth, do not present a significant electrostatic risk. However, where a static-generating mechanism is identified, such as repeated brushing against clothing, then suitable precautions shall be taken, e.g., the use of anti-static footwear.

The model PGM62xx is certified according to the IECEx scheme, ATEX and cCSAus (for US and Canada). PGM62xx is intrinsically safe and may be used in hazardous locations. SUBSTITUTION OF COMPONENTS MAY IMPAIR INTRINSIC SAFETY.

MARKING

The product is marked with the following information:

RAE SYSTEMS
3775 N. 1st. St., San Jose
CA 95134, USA

Type PGM62x0, PGM 62x6, PGM 62x8
Serial No/matrix: XXX-XXXX-000

IECEx SIR 11.0069X, Ex ia IIC T4 Ga (PGM62x0/PGM62x6) Ex ia d IIC T4 Gb (PGM62x8)	CE 0575 SIRA 11ATEX2152X Ex II 1G Ex ia IIC T4 Ga (PGM62x0/PGM62x6) Ex II 2G Ex ia d IIC T4 Gb (PGM62x8)	CSA c us Exia Cl I, Dv 1 Gr. A, B, C, D, T4 C22.2 No 152-1984 ISA-12.13.01-2000

Warnings: Understand manual first before operating.
Warning: Do not change batteries in hazardous location.
Do not mix old/new or different type of batteries

PGM62x0: Use only RAE Systems battery pack, PN: M01-3051-000 or M01-3052-000.
PGM62x6/62x8: Use only RAE Systems battery pack, PN: M01-3053-000 or M01-3054-000.
Um: 20V
-20º C ≤ Tamb ≤ +50º C

FCC Part 15 Statement

This device complies with Part 15 of the FCC rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Operation Area and Conditions

Hazardous Areas classified by Zones

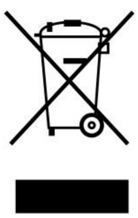
PGM62x0/PGM62x6 are intended to be used in hazardous areas zone 0, zone 1 or zone 2, and PGM62x8 in hazardous areas zone 1 or zone 2 within the temperature range of -20º C to +50º C, where gases of explosion groups IIA, IIB or IIC and T4 may be present.

Hazardous Areas classified by Divisions

PGM62x0/PGM62x6/PGM62x8 are intended to be used in hazardous areas classified for Class I Div. 1 or 2, within the temperature range of -20º C to +50º C, where gases of explosion groups A, B, C or D and temperature class T4 may be present.

WARNINGS:
1. NDIR sensors shall not be installed in PGM62x0 or PGM 62x6 models.
2. NDIR LEL sensors shall not be installed in PGM62x8 diffusion models bearing **cCSAus** logo.

Proper Product Disposal At End Of Life



The Waste Electrical and Electronic Equipment (WEEE) directive (2002/96/EC) is intended to promote recycling of electrical and electronic equipment and their components at end of life. This symbol (crossed-out wheeled bin) indicates separate collection of waste electrical and electronic equipment in the EU countries. This product may contain one or more Nickel-metal hydride (NiMH), Lithium-ion, or Alkaline batteries. Specific battery information is given in this user guide. Batteries must be recycled or disposed of properly.

At the end of its life, this product must undergo separate collection and recycling from general or household waste. Please use the return and collection system available in your country for the disposal of this product.

Sensor Specifications, Cross-Sensitivities, And Calibration Information

For information on sensor specifications, cross-sensitivities, and calibration information, refer to RAE Systems Technical Note TN-114: Sensor Specifications And Cross-Sensitivities (available for free download from www.raesystems.com/downloads/tech-notes). All specifications presented in this Technical Note reflect the performance of stand-alone sensors. Actual sensor characteristics may vary when the sensor is installed in different instruments. As sensor performance may change over time, specifications provided are for brand-new sensors.

1 Standard Contents

The MultiRAE is available in four configurations, each with different kits, outlined below.

MultiRAE Pro	MultiRAE
MultiRAE Pro monitor with pump, sensors, battery, and wireless options as specified and protective black rubber boot, external filter, and belt clip installed	MultiRAE monitor with pump, sensors, battery, and wireless options as specified and protective rubber boot, filter, and belt clip installed
Travel Charger / PC communications adapter	Travel Charger / PC communications adapter
Desktop charging / PC communications cradle	
PC communication cable	PC communication cable
AC adapter	AC adapter
Calibration adapter	Calibration adapter
6" flexible probe	6" flexible probe
Alkaline battery adapter	Alkaline battery adapter
3 spare external filters	3 spare external filters
PID sensor cap removal tool	PID sensor cap removal tool
PID zeroing charcoal filter	Toolkit
Toolkit	QuickStart Guide
QuickStart Guide	CD with documentation
CD with ProRAE Studio II instrument configuration and data management software	CD with ProRAE Studio II instrument configuration and data management software
CD with documentation	Calibration and test certificate
Calibration and test certificate	Warranty / registration card
Technical Note TN-106 with ionization energies and correction factors for 300+ VOCs	Technical Note TN-106 with ionization energies and correction factors for 300+ VOCs
Warranty / registration card	10 charcoal filters (reduce CO sensor's cross-sensitivity to VOCs)
10 charcoal filters (reduce CO sensor's cross-sensitivity to VOCs)	Ships in a hard transport case
Ships in a Pelican case	

MultiRAE Lite Diffusion	MultiRAE Lite Pumped
MultiRAE Lite monitor with sensors, battery, and wireless options as specified and protective rubber boot installed	MultiRAE Lite monitor with pump, sensors, battery, and wireless options as specified and protective rubber boot, filter, and belt clip installed
Travel Charger / PC communications adapter	Travel Charger / PC communications adapter
PC communication cable	PC communication cable
AC adapter	AC adapter
Calibration adapter	Calibration adapter
Alkaline battery adapter (included with rechargeable configurations only)	Alkaline battery adapter (included with rechargeable configurations only)
Toolkit	3 spare filters
QuickStart Guide	PID sensor cap removal tool
CD with documentation	Toolkit
CD with ProRAE Studio II instrument configuration and data management software	QuickStart Guide
Calibration and test certificate	CD with documentation
Warranty / registration card	10 charcoal filters (reduce CO sensor's cross-sensitivity to VOCs)
Ships in a cardboard box with a colorful sleeve	CD with ProRAE Studio II instrument configuration and data management software
	Calibration and test certificate
	Warranty / registration card
	Ships in a cardboard box with a colorful sleeve

2 General Information

The MultiRAE is a family of multi-threat gas detectors that combine continuous monitoring capabilities for volatile organic compounds (VOCs), toxic and combustible gases, and radiation, with Man Down Alarm functionality in one highly portable instrument. MultiRAE monitors offer an industry-leading selection of interchangeable field-replaceable electrochemical, combustible, infrared, PID (photoionization detector), and gamma radiation sensors to fit a wide variety of applications. The MultiRAE family's wireless capability elevates worker protection to the next level by providing safety officers real-time access to instrument readings and alarm status from any location for better visibility and faster response.

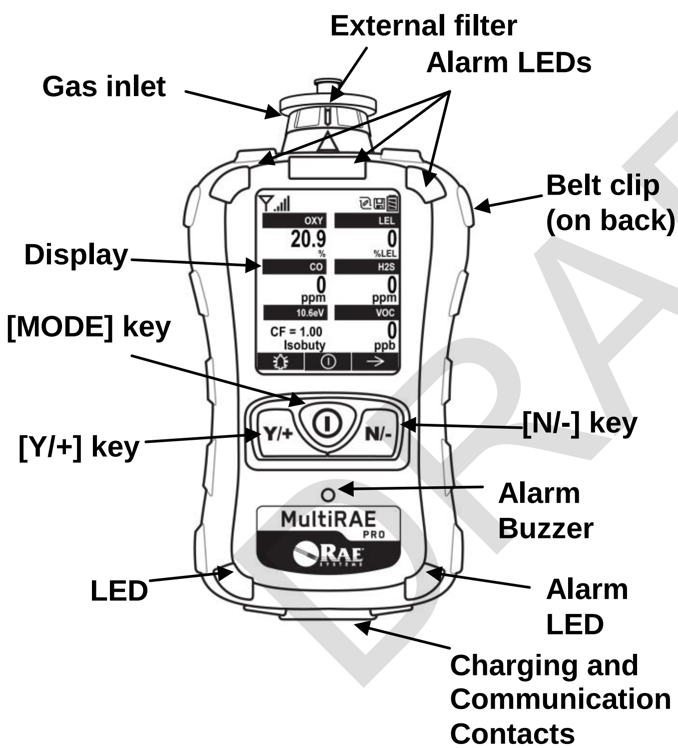
Notes:

- NDIR combustible sensors are not supported on the diffusion version with CSA certification.
- The PID sensor requires a pumped configuration.
- If a %Vol. NDIR sensor is installed in an instrument, a catalytic bead %LEL sensor must also be installed in the instrument for CSA certification.

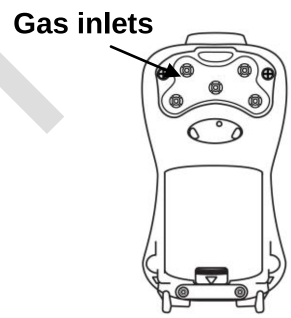
2.1 Key Features

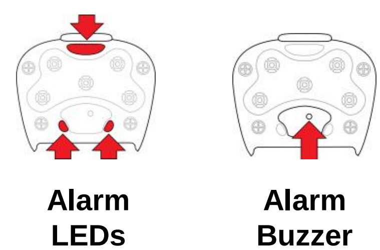
- All-in-one continuous monitoring capabilities for gamma radiation, VOCs, oxygen, toxic and combustible gases, for a total of up to six threats at a time
- Highly customizable with over 25 field-interchangeable intelligent sensor options
- Wireless access to real-time instrument readings and alarm status from any location through ProRAE Guardian Real-Time Wireless Safety System
- Unmistakable five-way local and remote wireless notification of alarm conditions, including Man Down Alarm
- Large graphical display with easy-to-use, icon-driven user interface
- Simple maintenance with easily accessible sensors, pump, and plug-and-play battery
- Fully automated charging, data management, bump testing and calibration with AutoRAE 2

MultiRAE With Pump, front view

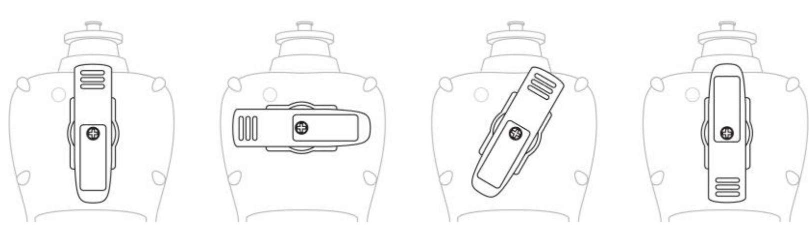


MultiRAE Lite Diffusion Model, rear view





Note: The front of the diffusion model of the MultiRAE Lite is the same as the pumped model, but instead of a single gas inlet at the top, there are five inlets on the back side, as well as an extra alarm buzzer and LEDs.



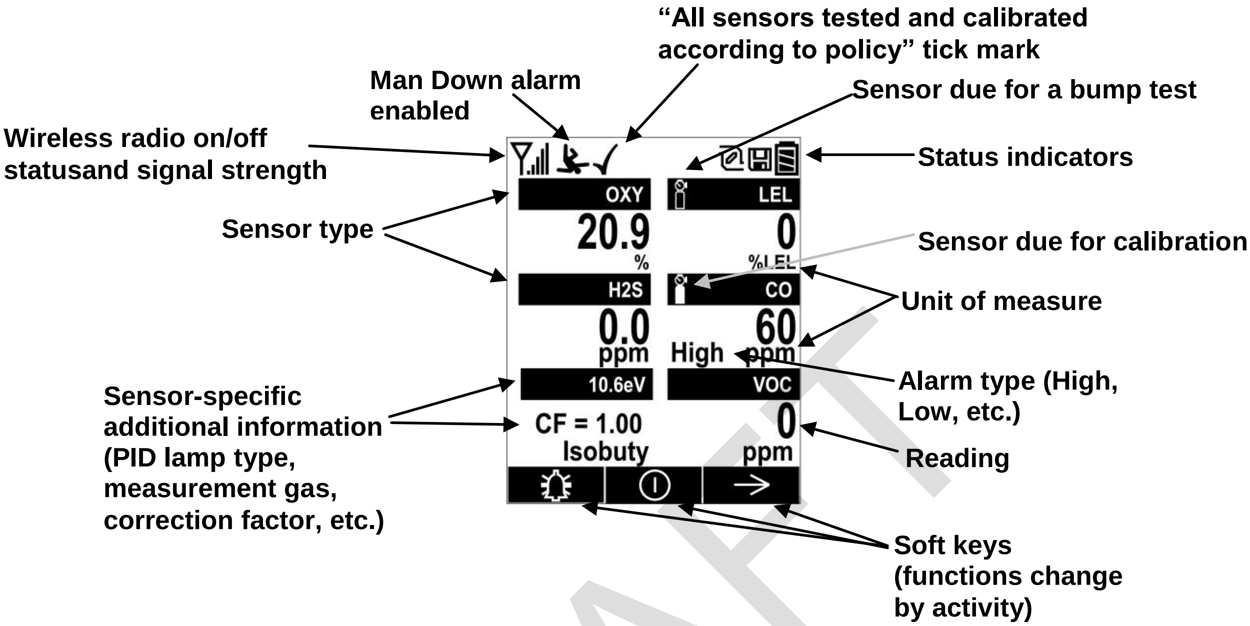
The belt clip on the back of the pump-equipped MultiRAE can be swiveled for carrying it at different angles.

3 User Interface

The MultiRAE's user interface consists of the display, alarm LEDs, an alarm buzzer, and three keys.

3.1 Display Overview

The LCD display provides visual feedback that includes the sensor types, readings, alarm status, battery condition, and other information.



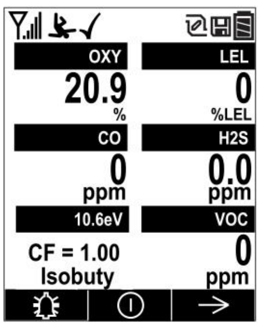
3.1.1 Status Indicator Icons

Along the top of most screens are status indicators that tell you whether a function is operating and/or its strength or level.

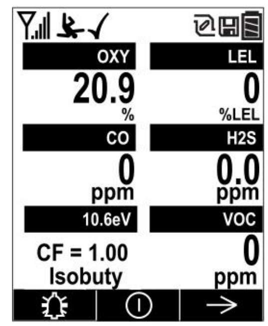
Icon	Function
	Wireless status: the radio is on
	Wireless status: the radio is off
	The instrument is not equipped with a radio (no icon)
	Wireless strength (0 to 5 bars)
	Pump status (only on pump-equipped models)
	Datalogging status (shown when datalogging is on, blank when off)
	Battery status (three segments show battery charge level)
	Man Down alarm enabled
	Sensor due for calibration
	Sensor due for a bump test
	"All sensors tested and calibrated to policy" tick mark (all sensors have been bump tested and calibrated; no sensor is overdue for a bump test or calibration according to the intervals configured on the instrument)

3.1.2 LCD Flip

The MultiRAE senses its vertical/horizontal orientation, and can automatically flip the display 180 degrees, making it easy to read if the MultiRAE is upside down. (You can turn this feature on or off in Programming Mode, under "Monitor/LCD Flip.")



As the MultiRAE is tilted, the gravity sensor detects its orientation and inverts the screen when it is past its horizontal position.



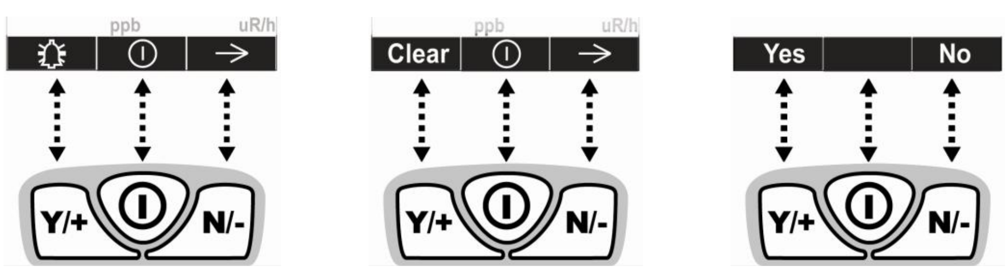
3.1.3 Keys And Interface

The MultiRAE has three keys:

Y/+ MODE N/-

In addition to their labeled functions, [Y/+], [MODE], and [N/-] act as "soft keys" that control different parameters and make different selections within the instrument's menus. From menu to menu, each key controls a different parameter or makes a different selection.

Three panes along the bottom of the display are "mapped" to the keys. These change as menus change, but at all times the left pane corresponds to the [Y/+] key, the center pane corresponds to the [MODE] key, and the right pane corresponds to the [N/-] key. Here are examples that show the relationships of the keys and functions:

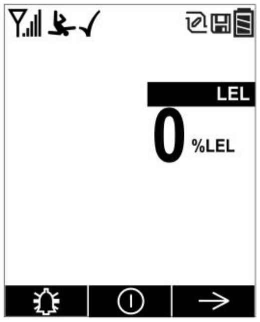


In addition to the functions described above, any of the keys can be used to manually activate display backlighting. Press any key when the backlighting is off to turn it on. A subsequent key press is required to carry out an actual function corresponding to that key.

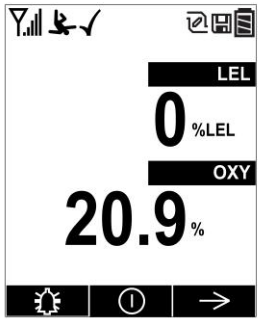
3.2 Screen Display For Various Numbers Of Active Sensors

The MultiRAE family of instruments can display readings from one to six sensors (including dual sensors), depending on the configuration. In order to maximize readability and the amount of information shown, the display is automatically reconfigured, according to the number and types of sensors in the MultiRAE.

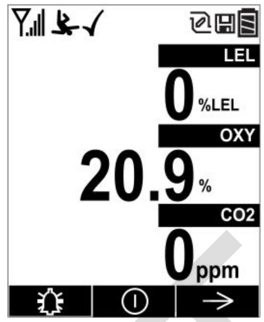
If the configuration includes five sensors, and one of them is a PID, then the lamp value (9.8eV or 10.6eV) is shown, along with the currently applied correction factor (CF) and measurement gas.



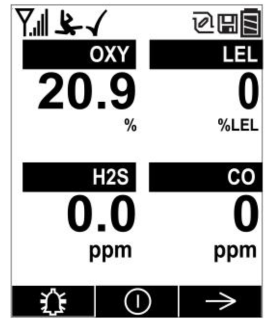
One sensor.



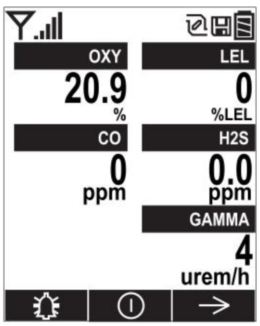
Two sensors.



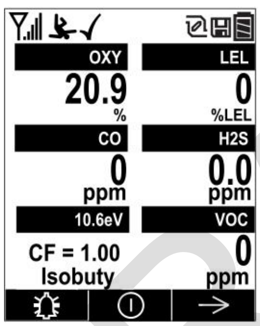
Three sensors.



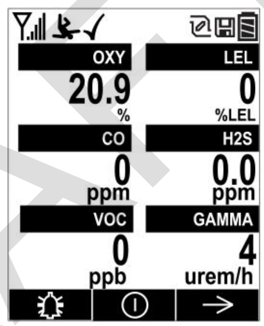
Four sensors.



Five sensors, including Gamma radiation sensor.



Five sensors, including PID, showing lamp type, correction factor, and measurement gas.



Six-sensor configuration with $CO+H_2S$ combo sensor.

3.3 Menus

The reading menus are easy to step through by pressing the [N/-] key.

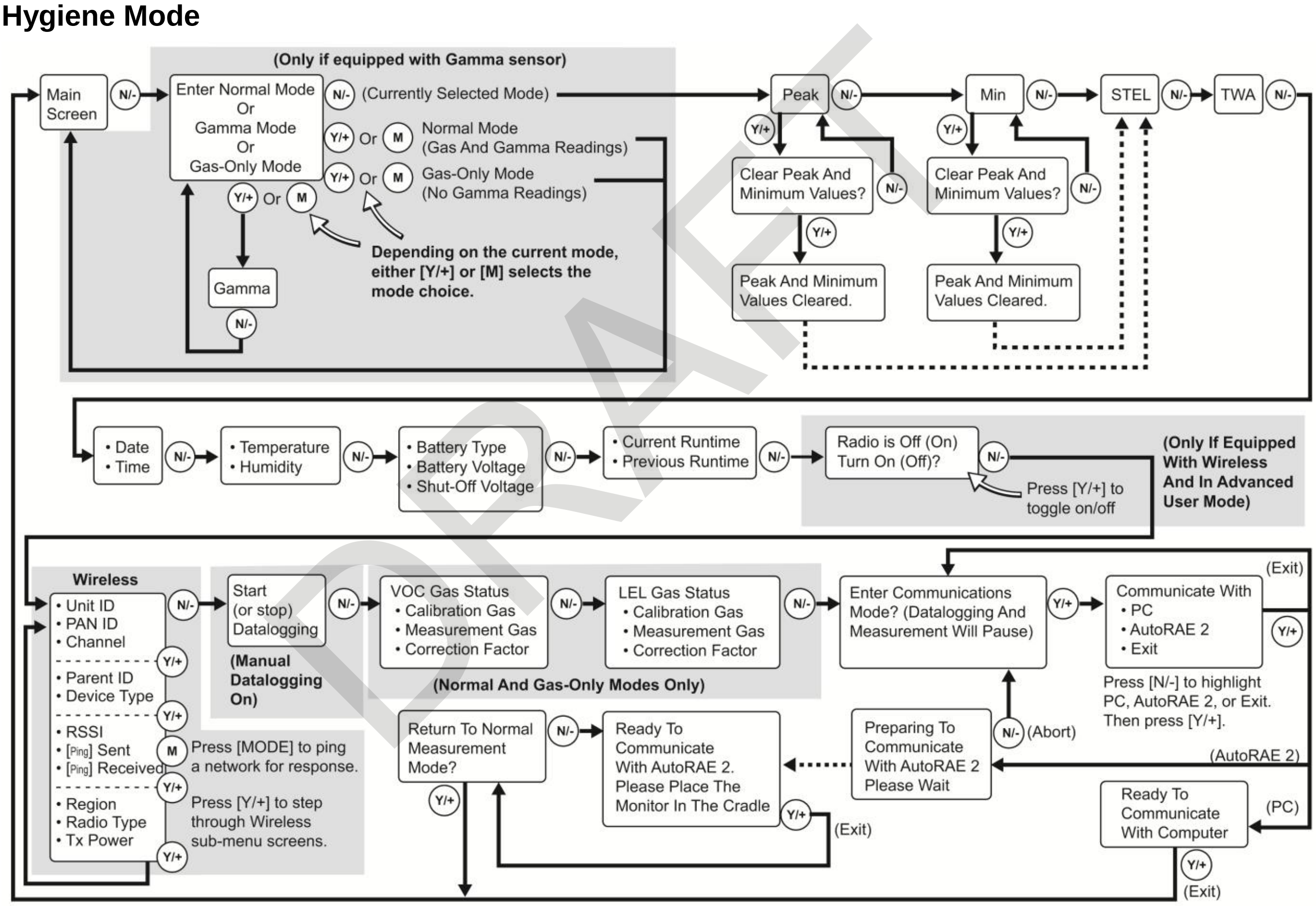
Hygiene Mode: Sampling is continuous, and Hygiene Mode allows you to clear peak and minimum values at any time.

Search Mode: Samples only when you tell it to sample. This allows you to save sample readings as individual events in the datalog. You can also clear peak and minimum values.

Note: You can switch between Hygiene and Search modes via the Programming Menu (Select Monitor and then Operation Mode).

Note: If the instrument is not equipped with a VOC sensor (PID), or is not equipped with an LEL sensor, then screens for those sensors (VOC Gas Status and LEL Gas Status, respectively) are not shown.

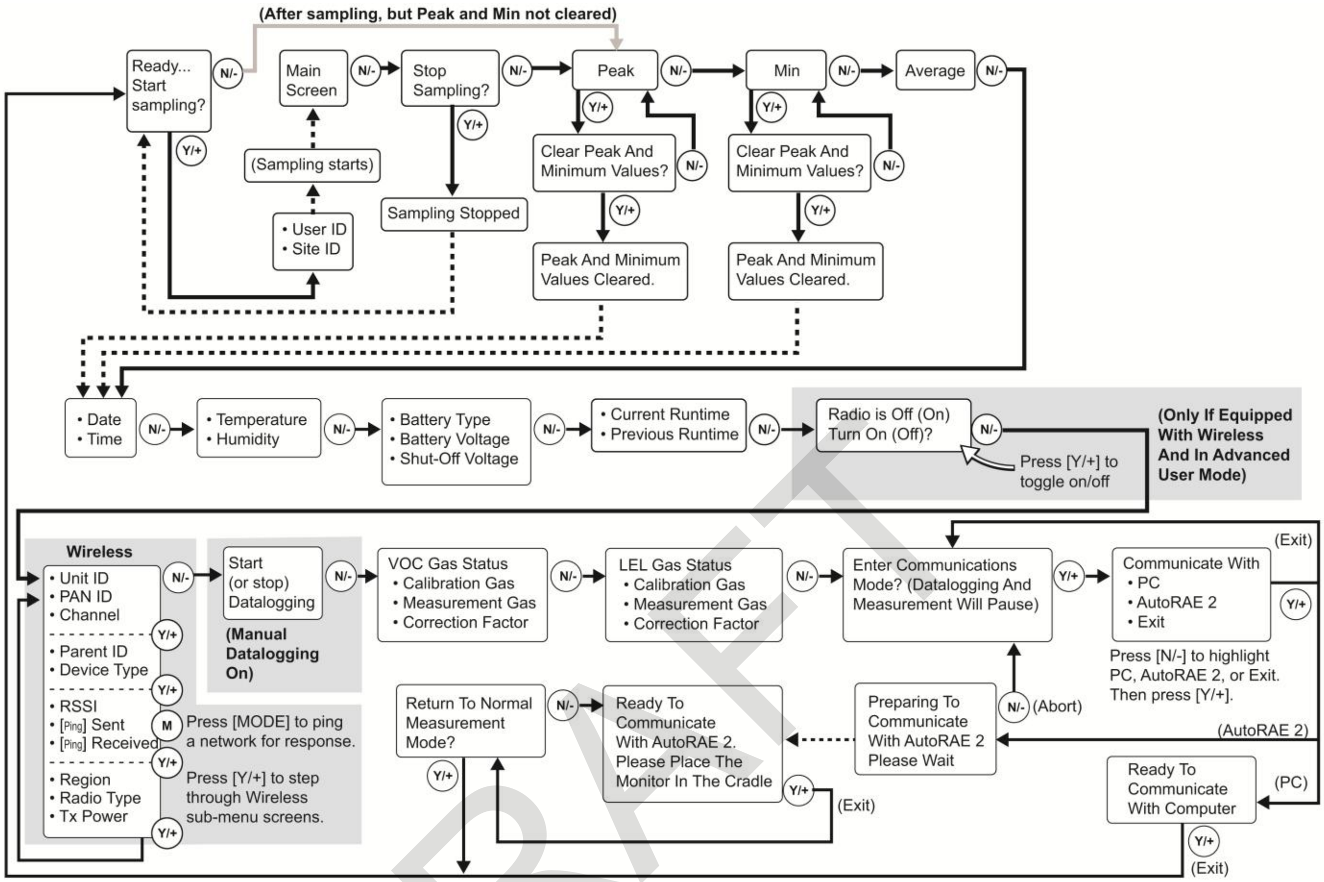
Hygiene Mode



Note: Dashed line indicates automatic progression.

Search Mode

Note: If the instrument is not equipped with a VOC sensor (PID), or is not equipped with an LEL sensor, then screens for those sensors (VOC Gas Status and LEL Gas Status, respectively) are not shown.

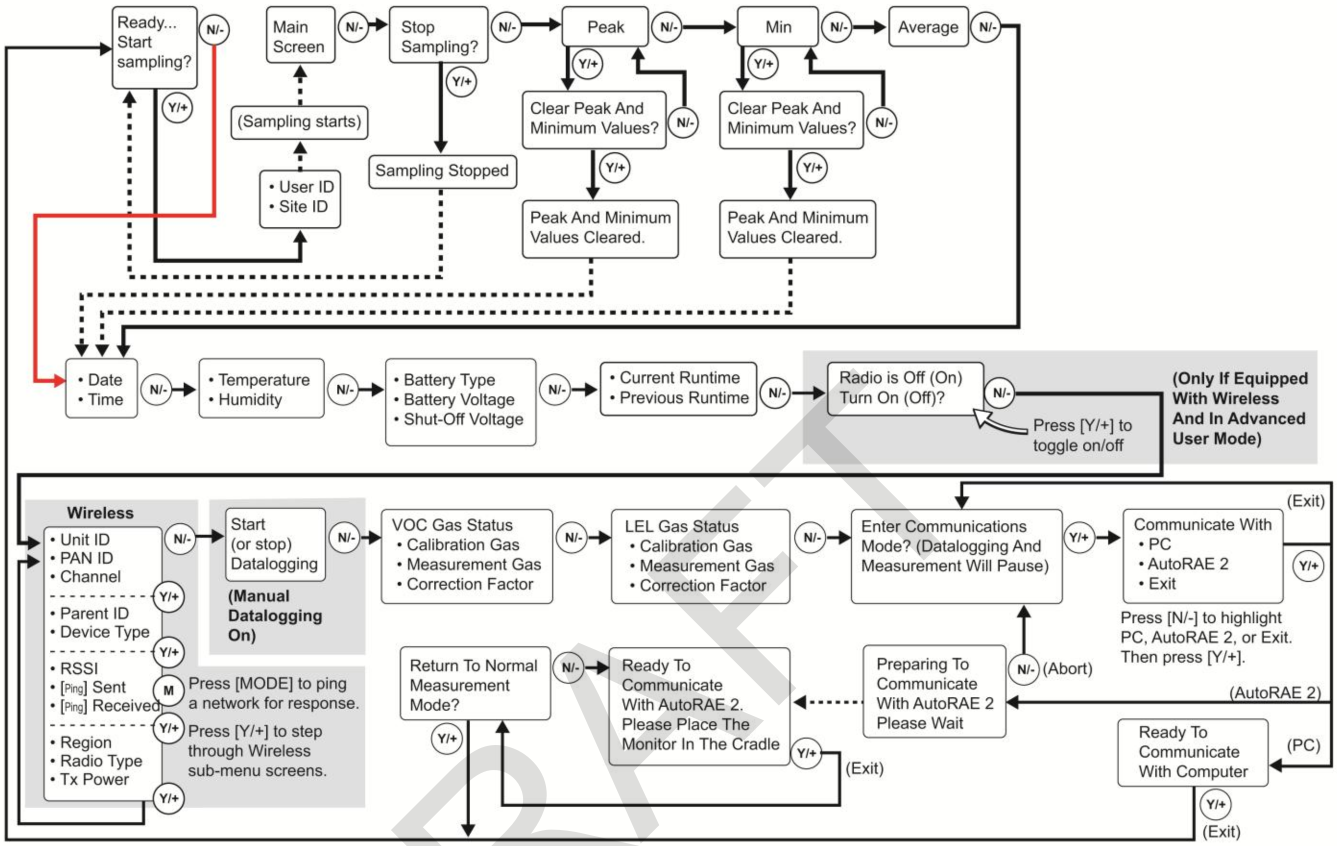


Note: Dashed line indicates automatic progression.

WARNING!

Gamma readings are not taken in Search Mode.

Note: If the Peak or Min is cleared, the Average is also cleared. In addition, each cycle through the main screen after they are cleared will route from "Ready… Start sampling?" directly to Date and Time if you press [N/-] (see red line in diagram below), until you perform a new sample. Also, if you start sampling again and stop sampling, clear the Peak, or clear the Min, it advances to Date and Time, as well.



Note: Dashed line indicates automatic progression.

WARNING!

Gamma readings are not taken in Search Mode.

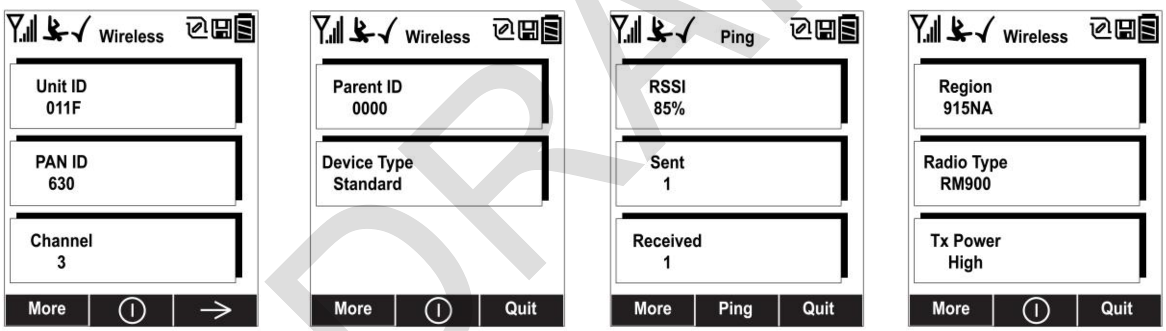
4 Wireless Control And Submenus

When you step through the main menu, as shown in the previous three diagrams, there are two screens for wireless communication.

Note: These are only present if the MultiRAE is equipped with a wireless module.

At the Radio On/Off screen, you can turn the radio on or off, if the MultiRAE is in Advanced User Mode. The radio turns off instantly, but turning on the radio takes a few seconds, so you see a screen that indicates the radio is being turned on. If the instrument is in Basic User Mode, the option for turning the radio on or off does not appear (you can turn it on or off in Programming Mode).

At the Wireless screen, you can check communication with other wireless devices and get other useful information about the wireless settings. The Wireless menu is divided into a sequence of four "pages," each presenting different information. As you press [Y/+] on each of the "pages," you advance to the next one.



Unit ID (unique identifier of the instrument's radio), Pan ID, and Channel are read-only parameters that help you to check whether the instrument's wireless settings are correct (very helpful for troubleshooting).

The next "page," Parent ID and Device Type are also read-only. The Parent ID (the ID of the "Parent" wireless device to which the monitor is connected) is not changeable. The device type tells you that it is "Standard," meaning it transmits and receives.

The third "page" is labeled "Ping," where you can check the signal strength via RSSI (received signal strength indication) and "ping" the network to confirm an active two-way communication network. Each time you press [MODE] to "ping" the network, a number of sends is included under "Sent." If the network receives the signal and sends one back, which is in turn received by the MultiRAE, then a number is added under "Received."

The fourth "page" includes the type of transmitter (Region), Radio Type (model), and Tx Power (transmission power). These are primarily for diagnostics and troubleshooting.

When you reach the fourth "page," you can wrap around to the first one by pressing [Y/+]. Otherwise, you can press [N/-] to quit, which advances to the next screen.

5 Battery

Always make sure the batteries are fully charged before using the MultiRAE. Three battery options are available for the MultiRAE:

1. Standard duration rechargeable Li-ion battery (PN: M01-3053-000)
2. Extended-duration rechargeable Li-ion battery delivering 50% more runtime than the standard battery (PN: M01-3055-000)
3. Alkaline battery pack for four standard AA-sized batteries (PN: M01-3054-000)

Its standard or extended-duration batteries are charged inside the instrument by placing the MultiRAE in its cradle or using the Travel Charger. Contacts on the bottom of the instrument meet the cradle's contact pins, transferring power.

Note: Before setting the MultiRAE into its MultiRAE Desktop Cradle or attaching its Travel Charger, visually inspect the contacts to make sure they are clean. If they are not, wipe them with a soft, dry cloth. Do not use solvents or cleaners.

WARNING

To reduce the risk of ignition of hazardous atmospheres, recharge, remove or replace the battery only in an area known to be non-hazardous! Do not mix old and new batteries or batteries from different manufacturers.

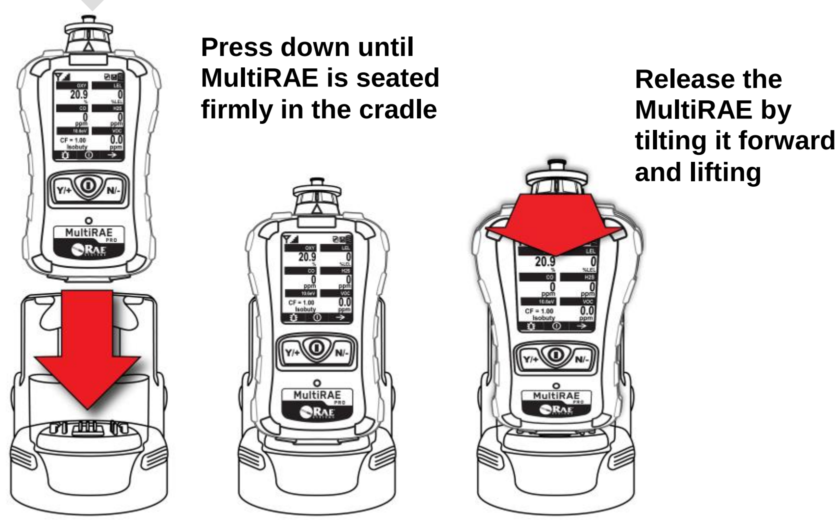
5.1 Charging With The MultiRAE Desktop Cradle

Follow this procedure to charge the MultiRAE:

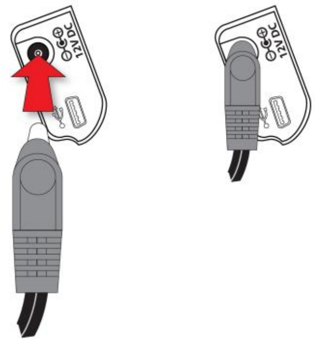
1. Plug the AC/DC adapter into the MultiRAE's Desktop Cradle.
2. Plug the AC/DC adapter into the wall outlet.
3. Place the MultiRAE into the cradle (make sure the bottom of the instrument and the alignment pins on the cradle mate properly) and press down until it is locked in place.

The MultiRAE begins charging automatically. The LED in the cradle should glow red to indicate charging. When charging is complete, the LED in the cradle glows green.

To remove the MultiRAE from the Desktop Cradle, tilt it toward you until it releases, and then lift it up.



Next, put the plug from the power supply into the jack on the side of the Desktop Cradle:



Plug the other end of the charger into a power source.

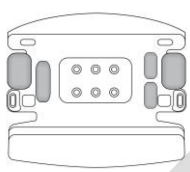
Automatic PID Lamp Cleaning

When a MultiRAE equipped with a PID (photoionization detector) is placed in the Desktop Cradle, its PID is automatically cleaned. During the first four hours of charging, continuous lamp auto-cleaning is performed. After that, cleaning stops. The battery continues to be charged, if necessary.

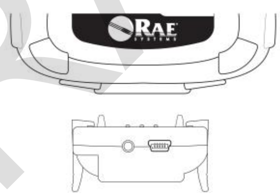
5.2 Charging With The Travel Charger

The Travel Charger is a lightweight portable alternative to the Desktop Cradle for charging and PC communications. Follow these steps to use the Travel Charger.

Before attaching the Travel Charger, check that it is aligned correctly with the base of the MultiRAE. There are two alignment pins on one side and one alignment pin on the other side, designed to mate with matching points on the bottom of the MultiRAE:



1. Check bottom of MultiRAE Travel Charger's alignment pins for correct orientation with the MultiRAE.

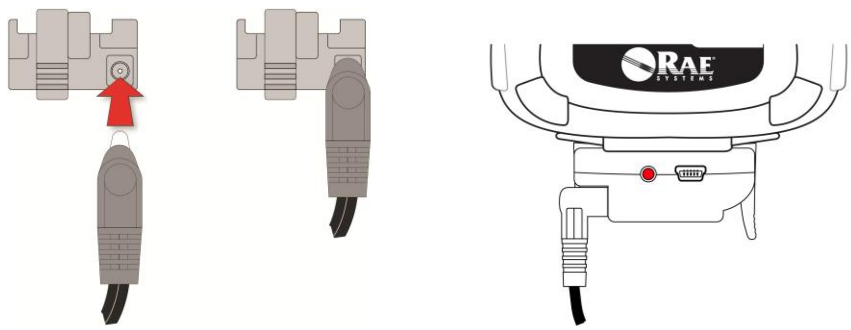


2. Align Travel Charger with bottom of MultiRAE.

3. Press Travel Charger onto bottom of MultiRAE.

4. Make sure the Travel Charger clicks into place and attaches firmly.

Next, put the plug from the power supply into the jack on the side of the Travel Charger:



Plug the other end of the charger into a power source (AC outlet or 12VDC mobile power port, depending on the model). When power is applied and the MultiRAE’s battery is charging, the LED glows red. The LED glows green when the battery is fully charged.

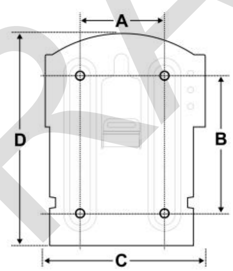
5.3 Carrying The MultiRAE In A Vehicle

The MultiRAE Truck Mount, used in conjunction with the front part of the Desktop Cradle, provides an NFPA requirement-compliant way to mount and carry the MultiRAE in a vehicle.

Truck Mount Installation

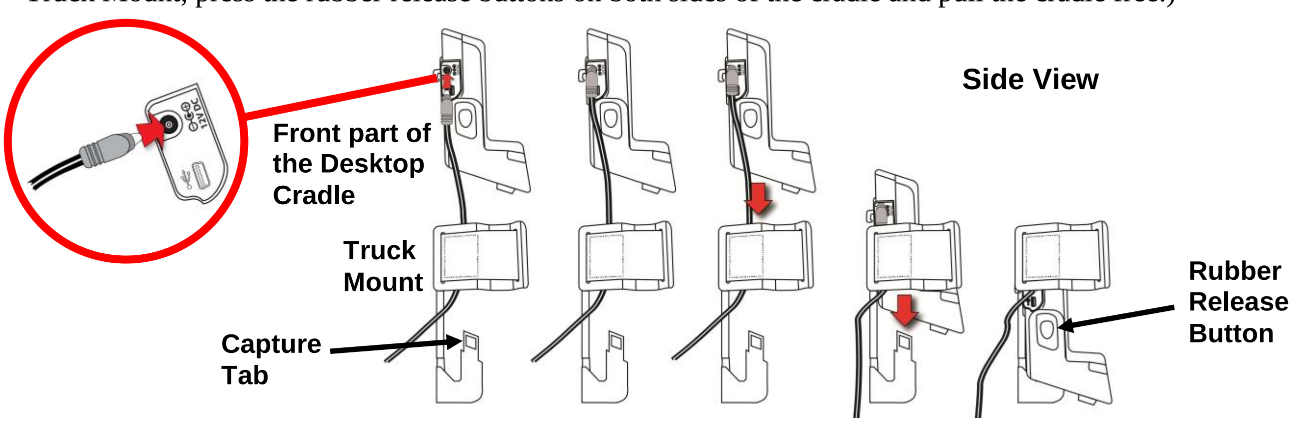
The Truck Mount must be used in conjunction with the front part of the MultiRAE Desktop Cradle. Follow the guidelines below to select the correct mounting hardware for the Truck Mount and install it in your vehicle. Use these dimensions to pre-drill a flat surface to accept the Truck Mount. The maximum screw diameter must not exceed 6.4mm (0.25"). Vertical clearance should be at least 26cm (10").

Letter	Measurement
A	61.6 mm (2.42")
B	96 mm (3.8")
C	113 mm (4.5")
D	150.8 mm (6")

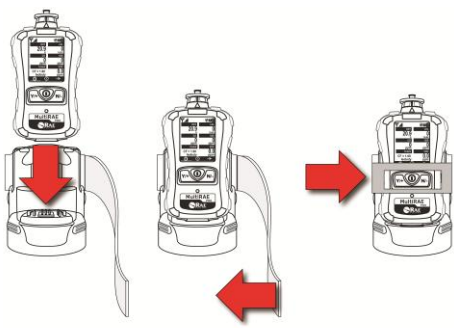


Important!
Make sure that there is sufficient clearance around and above the mounting plate so that the MultiRAE can be easily placed in the cradle and removed.

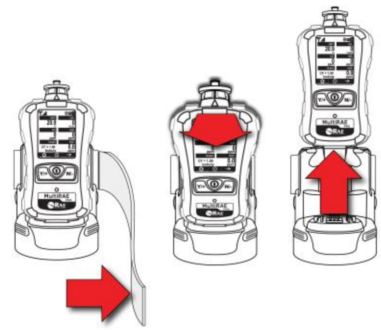
Once the Truck Mount is attached, disconnect the front part of the Desktop Cradle from its base by pressing on the rubber release buttons on both sides of the cradle. Next, insert the plug from the power supply into the jack on the side of the front part of the Desktop Cradle. Then slide the cradle into the Truck Mount as shown below. The capture tabs on both sides of the Truck Mount slip into the cradle and lock it in place. Make sure the cradle sits securely in the Truck Mount. (To separate the cradle from the Truck Mount, press the rubber release buttons on both sides of the cradle and pull the cradle free.)



Place the MultiRAE into the cradle (make sure the bottom of the instrument and the alignment pins on the cradle mate properly) and press down until it is locked in place. Then wrap the Velcro strap around the MultiRAE and fasten its end to the mating Velcro on the side of the Truck-Mount.



To secure: Press the MultiRAE into the cradle and fasten the Velcro strip.



To remove: Unfasten the Velcro strip, tilt the MultiRAE forward, and lift it out

Plug the other end of the charger into a power source. When power is applied and the MultiRAE's battery is charging, the LEDs on the left and right sides of the front of the cradle glow red. The LEDs glow green when the battery is fully charged.

5.4 Charging With The AutoRAE 2

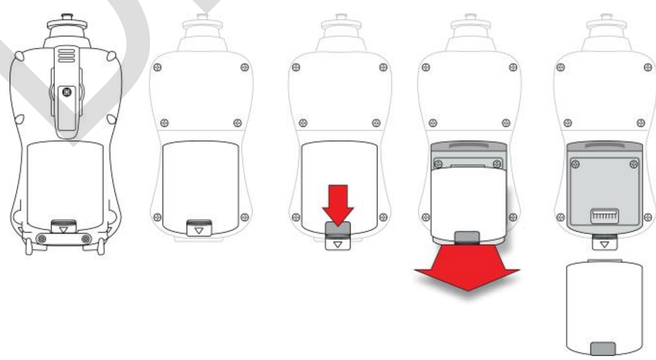
A MultiRAE's battery can be charged by placing the monitor in an AutoRAE 2 Cradle. Details are covered in the AutoRAE 2 User's Guide.

5.5 Replacing A Battery

The MultiRAE battery packs are plug-and-play, and can be replaced on the go without tools. To replace the MultiRAE battery:

1. Remove the battery from the instrument by sliding the tab and tilting out the adapter.

   Note: The belt clip and rubber boot are removed in the illustration for clarity. They can be left on while replacing a battery.



2. Tilt a fully charged battery (or alkaline battery adapter) into the battery compartment and place it in the instrument.
3. Slide the tab back into place to secure the battery.

5.6 Battery States

The battery icon on the display shows how much charge is in the battery and alerts you to any charging problems.

Full charge	2/3 charge	1/3 charge	Low charge	Battery alert

When the battery's charge falls below a preset voltage, the instrument warns you by beeping once and flashing once every minute, and the "empty battery" icon blinks on and off once per second. The instrument automatically powers down within 10 minutes, after which you will need to either recharge the battery, or replace it with a fresh one with a full charge.

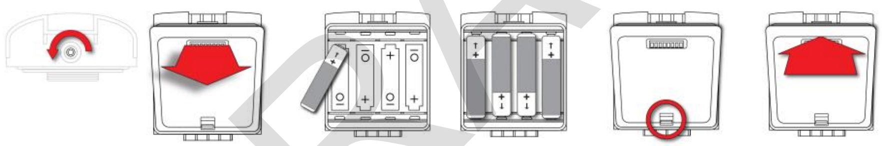
5.7 Alkaline Battery Pack

An alkaline battery adapter is supplied with each instrument. The adapter (part number M01-3054-000) is installed and removed just like the rechargeable battery. It accepts four AA alkaline batteries (use only Duracell MN1500) and provides approximately 8 hours of normal operation.

Note: The vibration alarm is disabled whenever the alkaline adapter is used.

To replace the alkaline adapter's batteries:

1. Remove the hex-socket screw at the end of the adapter.
2. Lift the cover off the battery compartment.
3. Insert four fresh AA batteries as indicated by the polarity (+/-) markings.
4. Replace the cover and replace the hex screw.



IMPORTANT!

Alkaline batteries cannot be recharged. The instrument's internal circuit detects alkaline battery pack and will not allow recharging. If you try to charge alkaline batteries installed in the instrument, the Charging Cradle or Travel Charger's charging LED does not glow, indicating that it will not charge them.

The alkaline battery adapter accepts four AA alkaline batteries (use only Duracell MN1500). Do not mix old and new batteries or batteries from different manufacturers.

Note: When replacing alkaline batteries, properly dispose of old ones.

6 Turning The MultiRAE On And Off

6.1 Turning The MultiRAE On

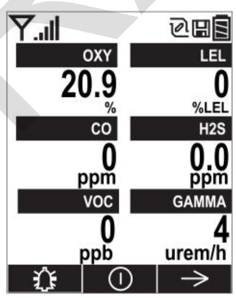
With the instrument turned off, press and hold the [MODE] key until the beep sounds and the display and LED alarm lights turn on, and then release.

A RAE Systems logo (or a company name) should appear first. This is followed by a progression of screens that tell you the MultiRAE's current settings:

- Product name and model number, air flow type, and serial number
- Application firmware version, build date, and build time
- Sensor firmware, build date, build time
- Installed sensors (including serial number/production/expiration/calibration date and alarm limit settings)
- Current date, time, temperature, and relative humidity
- User mode and operation mode
- Battery type, voltage, shutoff voltage
- Alarm mode and alarm settings
- Datalog period (if it is activated) and interval
- Policy Enforcement settings (whether calibration and/or bump testing are enforced)

Note: To speed up the startup time, the number of screens shown on startup can be reduced by enabling the Fast Startup option under Programming/Monitor.

Then the MultiRAE's main reading screen appears. It may take a few minutes for sensors to show a reading, so if any have not warmed up by the time the main screen is shown, you will see "- - -" instead of a numerical value until the sensor provides data (typically less than 2 minutes). Then it displays instantaneous readings similar to the following screen (depending on the sensors installed) and is ready for use.



Note: If the battery is completely empty, then the display briefly shows the message "Battery Fully Discharged," and the MultiRAE shuts off. You should charge the battery or replace it with a fully charged battery before turning it on again.

6.2 Turning The MultiRAE Off

Press and hold [MODE]. A 5-second countdown to shutoff begins. You must hold your finger on the key for the entire shutoff process until the MultiRAE is powered off.

6.3 Testing Alarm Indicators

Under normal-operation mode and non-alarm conditions, the buzzer, vibration alarm, LED, and backlight can be tested at any time by pressing [Y/+] once.

IMPORTANT!

If any of the alarms does not respond to this test, check the Alarm Settings in Programming Mode. It is possible that any or all of the alarms have been turned off. If all of the alarms are turned on, but one or more of them (buzzer, LED lights, or vibration alarm) does not respond to this test, do not use the instrument. Contact your RAE Systems distributor for technical support.

6.4 Pump Status

IMPORTANT!

During operation, make sure the probe inlet and the gas outlet are free of obstructions. Obstructions can cause premature wear on the pump, false readings, or pump stalling. During normal operation, the pump icon alternately shows inflow and outflow as shown here:

If there is a pump failure or obstruction that disrupts the pump, the alarm sounds and you see this icon blinking on and off:

Once the obstruction is removed, you can try to restart the pump by pressing the [Y/+]. If the pump does not restart, and the pump stall alarm continues, consult the Troubleshooting section of this guide or contact RAE Systems Technical Support.

It is advisable to perform a pump stall test periodically, to make sure the pump is working properly and there are no leaks in the system. To perform a pump stall test, simply block the gas inlet with your finger. To pass the test, the instrument should go into a pump alarm. Press [Y/+] to disable the alarm and return to normal operation.

Note: Pump Status is not indicated on diffusion MultiRAEs.

6.5 Calibration Status

The instrument displays this icon next to the sensor that requires calibration:

Calibration is required (and indicated by this icon) if:

- The lamp type has been changed (for example, from 10.6 eV to 9.8 eV).
- The sensor module has been replaced with one whose calibration is overdue.
- The defined period of time between calibrations has been exceeded.
- If you have changed the calibration gas type without recalibrating the instrument.
- The sensor has failed a previous calibration.

6.6 Bump Status

The instrument displays this icon next to the sensor that requires bump test:

A bump test is required (and indicated by this icon) if:

- The defined period of time between bump tests has been exceeded (bump test overdue).
- The sensor has failed a previous bump test.
- The sensor(s) should be challenged on a periodic basis.

7 Modes Of Operation

The MultiRAE has two operation modes and two user modes.

7.1 Hygiene Operation Mode

Hygiene Mode provides continuous monitoring.

7.2 Search Operation Mode

Search Mode provides monitoring only when monitoring is initiated. This allows specific samples to be taken at different times, rather than continuously.

7.3 Basic User Mode

In Basic User Mode, some restrictions are applied, including password protection that guards against entering Programming Mode by unauthorized personnel.

7.4 Advanced User Mode

In Advanced User Mode, there are no access restrictions (you do not need a password), and MultiRAE provides the indications and data you need most for typical monitoring applications.

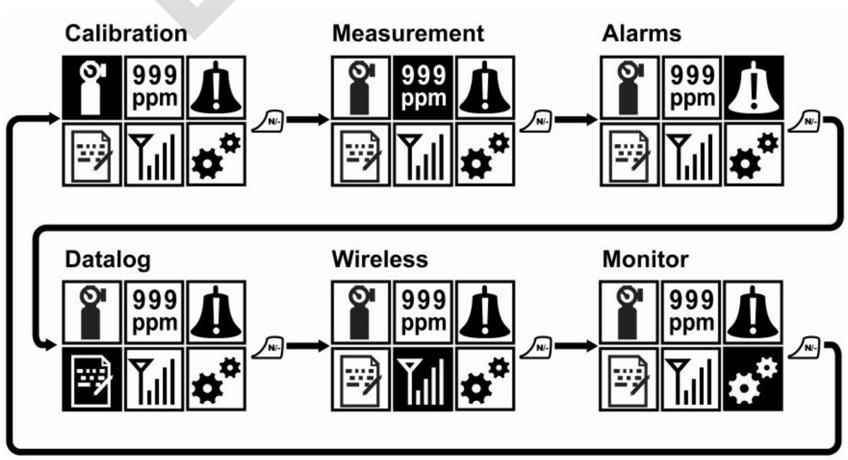
8 Programming

The menu in Programming Mode is to adjust settings, calibrate sensors, and initiate communication with a computer. It has the following submenus:

- Calibration
- Measurement
- Alarms
- Datalog
- Wireless
- Monitor

8.1 Enter Programming In Advanced Mode

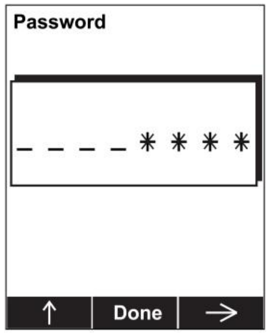
1. To enter Programming Mode, press and hold [MODE] and [N/-] until you see the Calibration screen. No password is necessary in Advanced Mode.
2. Press [N/-] to step through the programming screens.



To enter a menu and view or edit parameters in its submenus, press [Y/+].

8.2 Enter Programming In Basic Mode

1. To enter Programming Mode, press and hold [MODE] and [N/-] until you see the Password screen.



2. Input the 4-digit password:

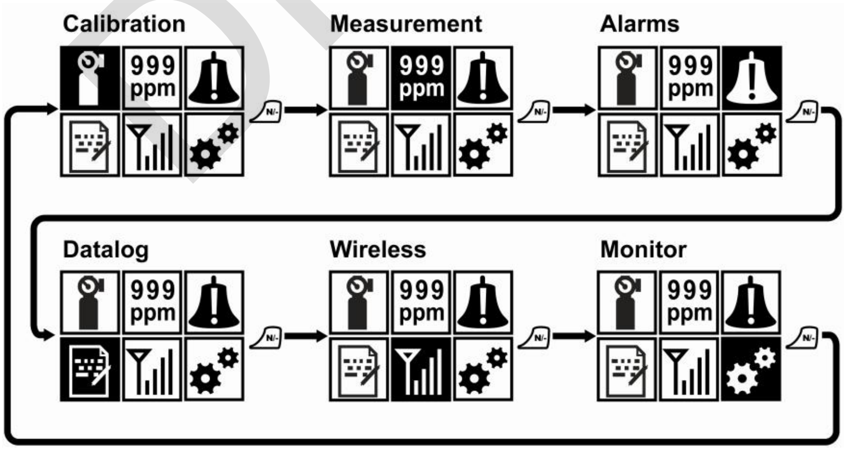
- Increase the number from 0 through 9 by pressing [Y/+].
- Step from digit to digit using [N/-].
- Press [MODE] when you are done.

If you make a mistake, you can cycle through the digits by pressing [N/-] and then using [Y/+] to change the number in each position.

Note: The default password is 0000.

Note: The password screen only appears when you enter the Programming Mode the first time after turning the instrument on in Basic Mode. If you have input the correct password, you do not have to input it again to enter Programming Mode until you turn the instrument off and on again.

Once you enter Programming Mode, the Calibration menu is highlighted. Press [N/-] to step through the programming screens.



To enter a menu and view or edit parameters in its submenus, press [Y/+].

8.3 Menus And Submenus

In Programming Mode, menus and submenus are organized as shown here:

Calibration	Measurement	Alarms	Datalog	Wireless*	Monitor
Fresh Air	Sensor On/Off	Alarm Limits	Clear Datalog	Radio ON/OFF	LCD Contrast
Multi Sensor Span	Change Meas. Gas	Alarm Mode	Datalog Interval	PAN ID	Operation Mode
Single Sensor Zero	Measurement Units	Alarm Settings	Sensor Selection	Channel	Pump Speed**
Single Sensor Span		Comfort Beep	Data Selection	Join Network	Zero At Start
Multi Sensor Bump		Man Down Alarm	Datalog Type	Interval	Fast Startup
Single Sensor Bump			Memory Full Action	Off Network Alarm	Temperature Units
Cal. Reference				Factory Reset	Language
Change Cal. Gas					Site ID
Multi Cal. Select					User ID
Change Span Value					Date Format
Change Span2 Value***					Date
					Time Format
					Time
					User Mode
					Backlight
					LCD Flip

* This menu is available on wirelessly equipped instruments only.
** Pump-equipped version only.
*** This menu item is shown only if a 3-point calibration is enabled. Change Span2 Value menu item is only shown if a 3-point calibration is enabled on the instrument. Three-point calibration is disabled by default, but can be enabled on MultiRAE and MultiRAE Pro instruments with 10.6eV PID sensors, including high-range ppm and ppb PID sensors. The MultiRAE Lite PID sensor only supports 2-point calibration.

8.3.1 Editing And Selecting Parameters And Sensors

There are a few basic ways to edit parameters, select sensors, and perform other activities in the MultiRAE. The actions performed by pressing keys always match 1-to-1 with the boxes along the bottom of the display and the three keys. Some parameters are edited by scrolling and selecting individual items (black bars behind white text act as highlighters). Some include a choice via "radio buttons," where only one item in a list can be selected, while other menus use boxes for you to "check" with an "X," and these allow for multiple items in a list to be selected. In all cases of editing, you can save or undo your choice.

8.3.2 Calibration

Use this menu to perform a bump test or zero or span calibration for one or more sensors, and change the gas concentration value used in bump tests and span calibration, as well as choose which sensors will be calibrated at the same time.

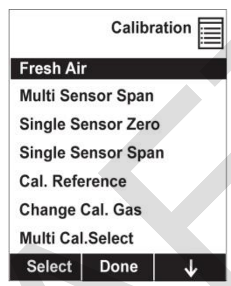
8.3.2.1 Fresh Air

This procedure determines the zero point of the sensor calibration curve for all the sensors that require a zero calibration. For the oxygen sensor, Fresh Air calibration sets the point equal to the concentration of oxygen in ambient air (approximately 20.9% volume).

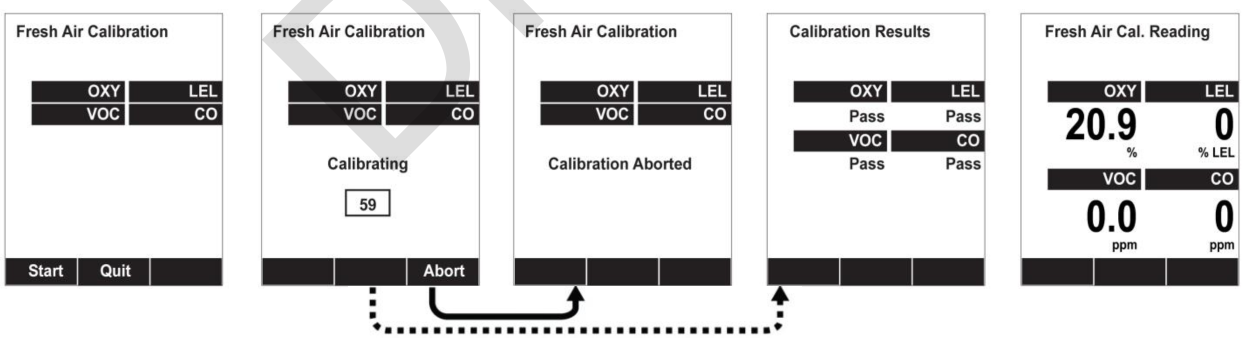
Note: Fresh air calibration is performed on all enabled gas sensors at the same time.

To perform Fresh Air calibration on multiple sensors:

1. If using dry air, install the calibration adapter and connect it to a source of dry air. Otherwise do not use calibration adapter to perform fresh air calibration.
2. At the Calibration Menu, select "Fresh Air." Press [Y/+] once to enter the fresh air calibration sub-menu.



3. Start the flow of dry air, if used.
4. Press [Y/+] to start fresh air calibration.
5. A countdown screen appears. You can abort the calibration at any time during the countdown by pressing [N/-].



Note: Dotted line indicates automatic progression.

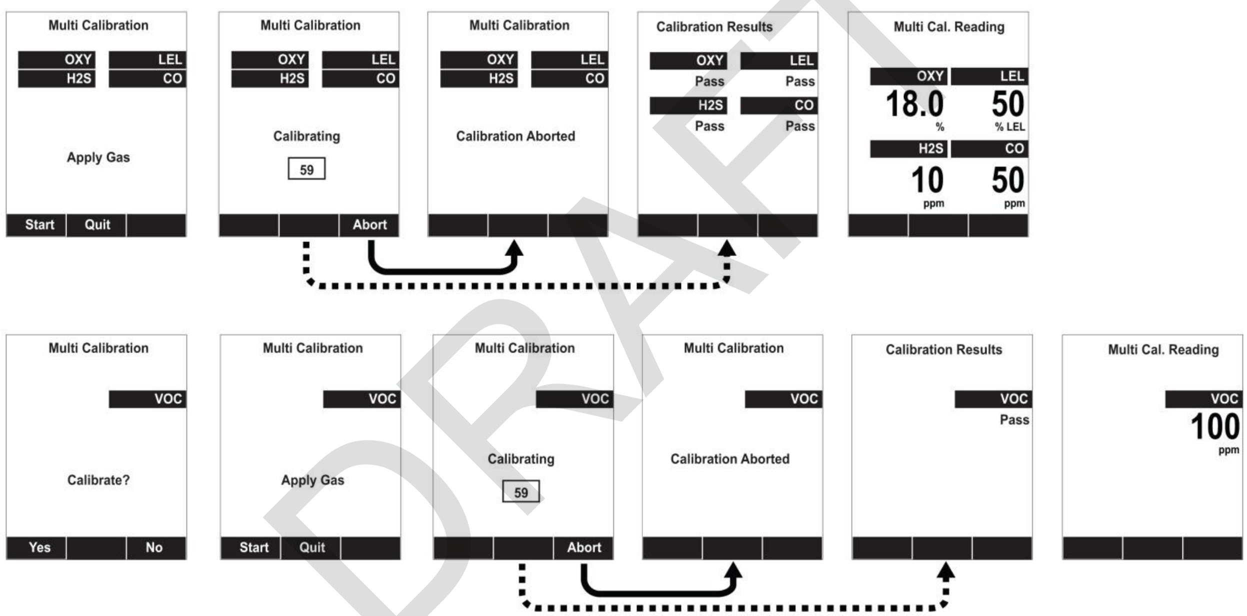
6. If the calibration is not aborted, the display shows the sensor names and tells you whether the fresh air calibration passed or failed, followed by the sensors' fresh air readings.

8.3.2.2 Multi Sensor Span

Depending on the configuration of your MultiRAE and span gas you have, you can perform a span calibration simultaneously on multiple sensors. You can define which sensors are calibrated together using the Multi Cal Select menu described in section 8.3.2.9.

In case all sensors in the instrument cannot be calibrated with the same gas, the MultiRAE will intelligently split the span calibration process into several steps and will provide menu prompts accordingly.

1. At the Calibration Menu, select “Multi Sensor Span.”
2. Install the calibration adapter and connect it to a source of calibration gas.
3. Start the flow of calibration gas.
4. Press [Y/+] to start calibrating or wait for calibration to start automatically.
5. A countdown screen is shown. You can abort the calibration at any time during the countdown by pressing [N/-].



Note: Dotted line indicates automatic progression.

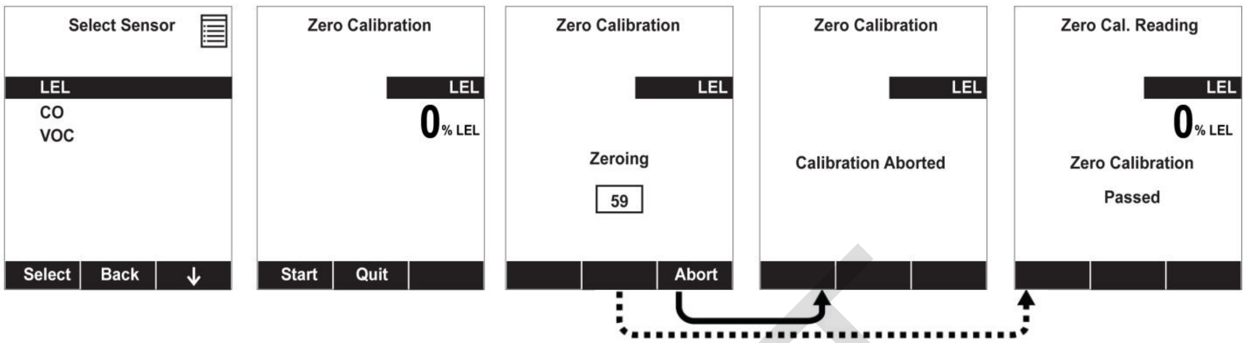
6. If the calibration is not aborted, the display shows the sensor names and tells you whether the calibration passed or failed, followed by the sensor readings.

8.3.2.3 Single Sensor Zero

This allows you to perform zero (fresh air) calibration on individual sensors. Even though most toxic gas sensors can be zeroed in fresh air, sensors such as the CO_2 and parts-per-billion PID sensor for volatile organic compounds (VOCs) should not be zeroed in fresh air. Both CO_2 gas and VOCs are normally present in ambient air, so zeroing these sensors in ambient air will not allow for a true zero to be set for such sensors. The CO_2 sensor should be zeroed in 99.9% nitrogen, and the parts-per-billion PID sensor with ambient air using a charcoal filter or a VOC zeroing tube.

1. If you are using a charcoal filter, connect it to the instrument.
2. If you are using dry air, install the calibration adapter and connect it to a source of dry air.

3. At the Calibration Menu, select "Single Sensor Zero." Press [Y/+] once to enter the zero calibration sub-menu.
4. Start the flow of dry air, if used.
5. Press [Y/+] to start zero calibration.
6. A countdown screen appears. You can abort the calibration at any time during the countdown by pressing [N/-].



Note: Dotted line indicates automatic progression.

7. If the calibration is not aborted, the display shows the sensor names and tells you whether the zero calibration passed or failed, followed by the sensors' zero calibration readings.

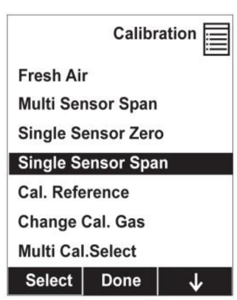
8.3.2.4 Single Sensor Span

Instead of performing a span calibration on multiple sensors simultaneously, you can select a single sensor and perform a span calibration.

Note: If a calibration icon (bottle with bottom portion filled in) is shown next to any of the sensors, it means that the sensor is due for a full calibration.

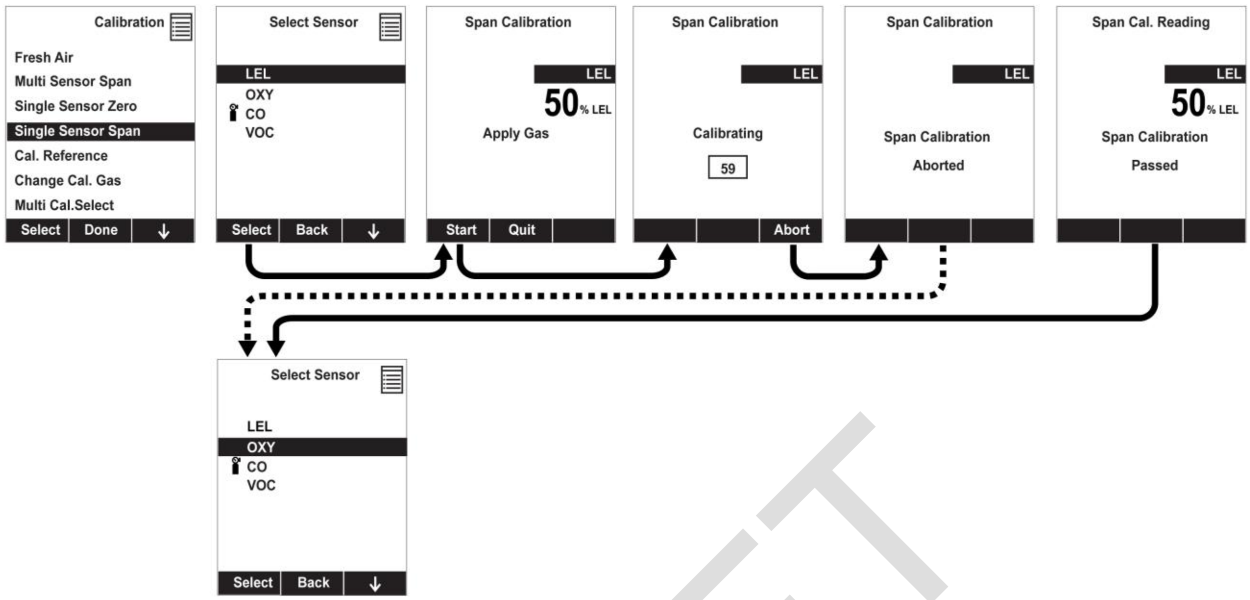
To perform span calibration of an individual sensor, follow these steps:

1. At the Calibration Menu, select "Single Sensor Span."
2. Select a sensor to calibrate from the list.
3. Install the calibration adapter and connect it to a source of calibration gas.
4. Verify that the displayed calibration value meets the concentration specified on the gas cylinder.
5. Start the flow of calibration gas.



6. Press [Y/+] to start calibrating or wait for calibration to start automatically.

7. A countdown screen appears. You can abort the calibration at any time during the countdown by pressing [N/-].



Note: Dotted line indicates automatic progression.

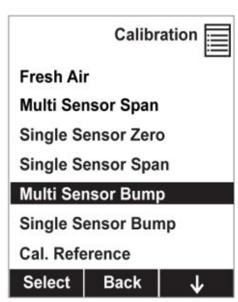
8. If the calibration is not aborted, the display shows the sensor names and tells you whether the calibration passed or failed, followed by the sensor readings.

Note: The gamma radiation sensor comes pre-calibrated from the factory and does not require routine calibration. However, you can check it by placing a check-source on the rear of the MultiRAE equipped with a gamma sensor to check the readings. There is a raised dot on the rubber boot that marks where the sensor is located inside the instrument.

8.3.2.5 Multi Sensor Bump

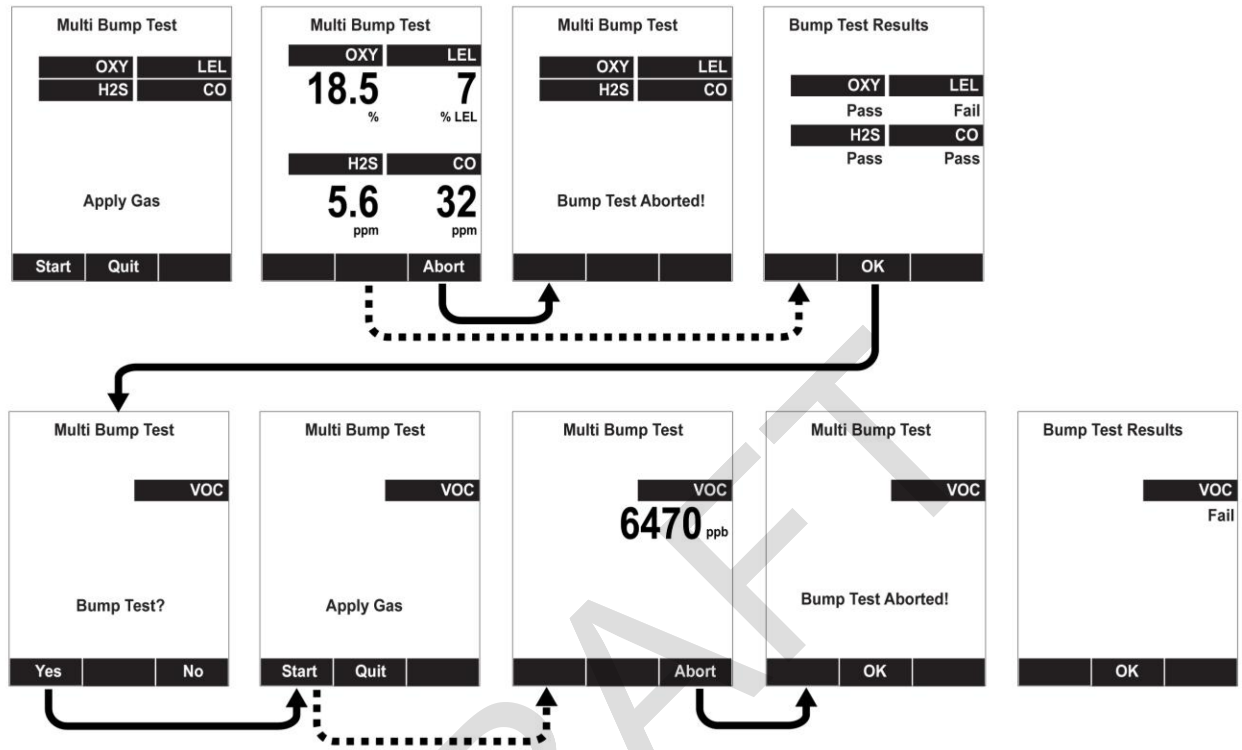
Depending on the configuration of your MultiRAE and span gas you have, you can perform a bump test simultaneously on multiple sensors. Which sensors are bump tested simultaneously is defined in the Multi Cal Select menu. Refer to section 8.3.2.9 for more information.

In case all sensors in the instrument cannot be calibrated with the same gas, the MultiRAE will intelligently split the span calibration process into several steps and will provide menu prompts accordingly.



1. At the Calibration Menu, select "Multi Sensor Bump."
2. Install the calibration adapter and connect it to a source of calibration gas.

3. Start the flow of calibration gas.
4. Press [Y/+] to start calibrating or wait for calibration to start automatically.
5. A countdown screen is shown. You can abort the calibration at any time during the countdown by pressing [N/-].



Note: Dotted line indicates automatic progression.

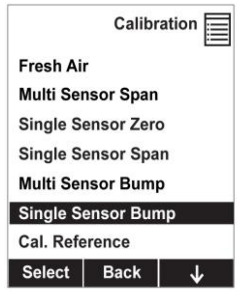
6. If the calibration is not aborted, the display shows the sensor names and tells you whether the calibration passed or failed, followed by the sensor readings.
7. If a sensor requires different gas (such as a PID for VOCs), you are prompted. Change the calibration gas, and when you are ready, start bump testing by pressing [Y/+].

Note: You can quit the bump calibration procedure and exit to the menu whenever you see "Quit." Press [MODE] to quit.

8.3.2.6 Single Sensor Bump

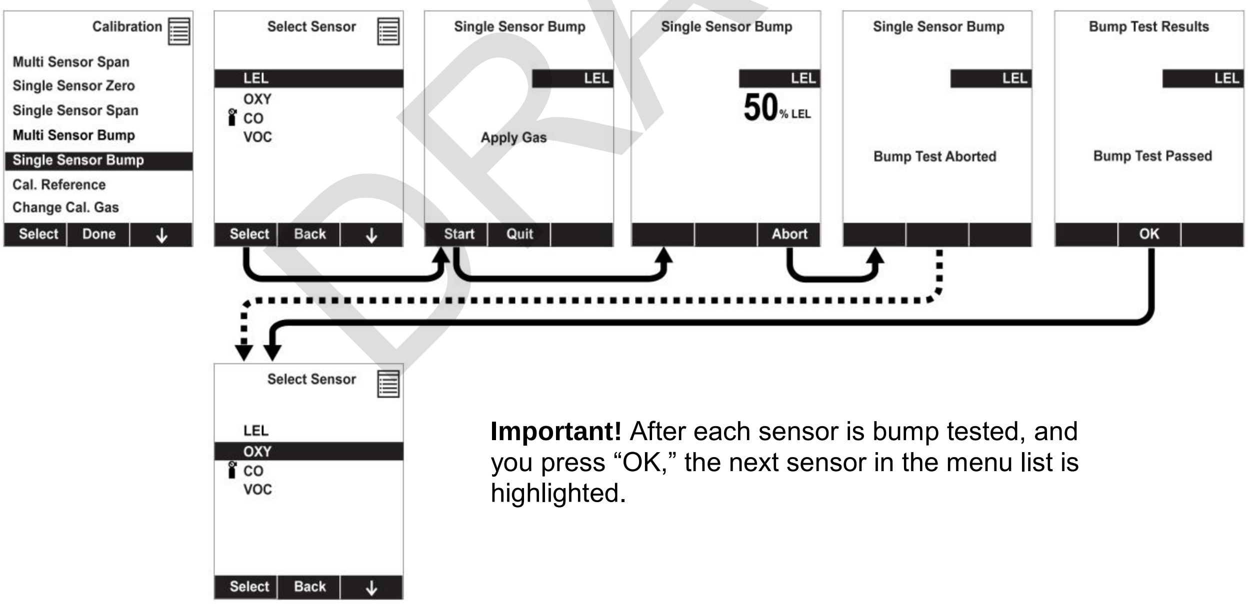
This menu allows a bump test to be performed on an individual sensor of your choice.

Note: If a bump test icon (bottle with bottom portion not filled in) is shown next to any of the sensors, it means that the sensor is due for a bump test.



To perform a bump test on an individual sensor, follow these steps:

1. At the Calibration Menu, select "Single Sensor Bump."
2. Scroll down the list using [N/-], and then press [Y/+] to select a sensor to calibrate.
3. Install the calibration adapter and connect it to a source of calibration gas.
4. Verify that the displayed calibration value meets the concentration specified on the gas cylinder.
5. Start the flow of calibration gas.



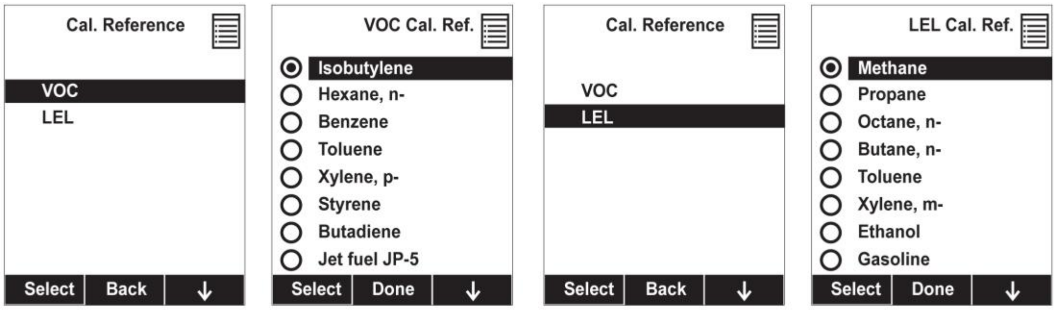
Important! After each sensor is bump tested, and you press "OK," the next sensor in the menu list is highlighted.

Note: Dotted line indicates automatic progression.

6. Press [Y/+] to start calibrating or wait for calibration to start automatically.
7. A countdown screen appears. You can abort the calibration at any time during the countdown by pressing [N/-].
8. If the calibration is not aborted, the display shows the sensor names and tells you whether the calibration passed or failed, followed by the sensor readings.

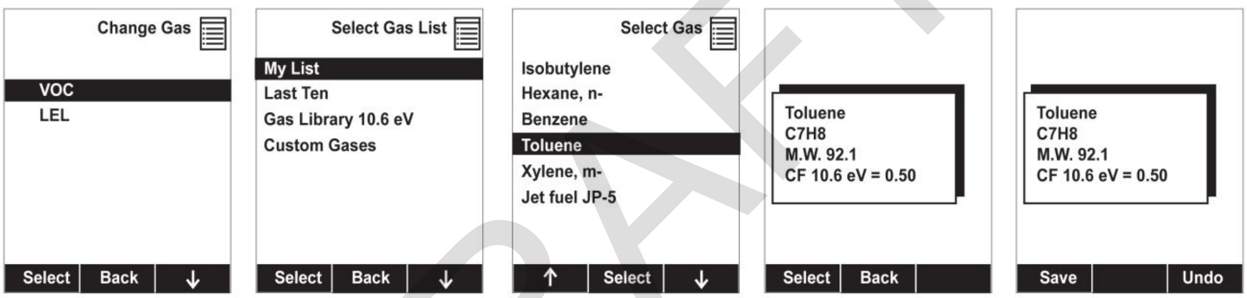
8.3.2.7 Cal. Reference

It is sometimes desirable to calibrate a sensor (PID for VOC, and LEL) with a specific gas for best response to a gas you are surveying. The Cal. Reference library contains calibration curves for the PID and LEL sensors for select gases. Choose the sensor, and then select from the list of reference gases.



8.3.2.8 Change Cal. Gas

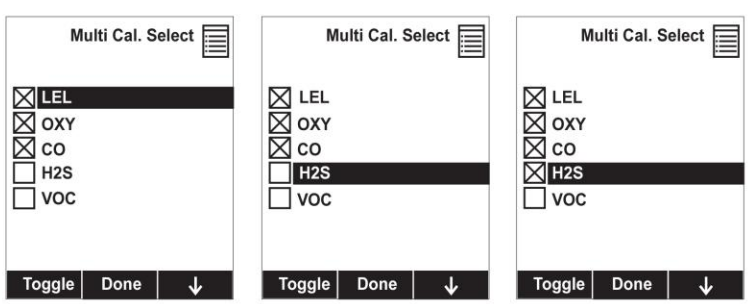
You can change the calibration gas for the MultiRAE's PID and LEL sensors. Select from a custom list that you create (My List), the last ten gases used, the built-in gas library for your PID lamp, and user-defined custom gases. Each gas is shown in the list for selection and the screen automatically changes to show its full name, chemical formula, molecular weight (M.W.) and correction factor (CF).



8.3.2.9 Multi Cal Select

This menu allows you to define a group of sensors to be bump tested and span calibrated together. Simultaneous testing and calibration of multiple sensors shortens the bump test and calibration processes and reduces the number of individual gas cylinders you need. For example, it may be more efficient to use a single cylinder with a four-gas mix including 50% LEL Methane, 18% O_2, 10 ppm H_2S, and 50 ppm CO, to calibrate the LEL, O_2, CO, and H_2S sensors at one time, compared to using four distinct gas cylinders and calibrate these sensors individually in sequence. In order for sensors to be calibrated together, all of them must be selected using Multi Cal. Select.

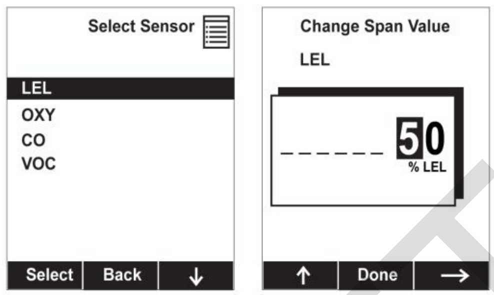
1. Scroll down the list of sensors using the [N/-] key.
2. Add or remove that gas from the list by pressing [Y/+]. An "X" in a box to the left of a sensor's name indicates it is selected.
3. Once you have made all your selections, press [MODE] for "Done."



8.3.2.10 Change Span Value

You can individually set the span gas concentration for each sensor. This concentration setting will also be used for a bump test. The units of measure (ppm, %LEL, etc.) are shown on the display.

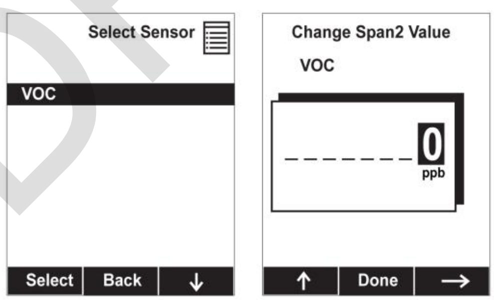
1. Scroll down the list of sensors using the [N/-] key.
2. Press [Y/+] to select it.
3. Press [N/-] to step through the digits.
4. Press [Y/+] to increase the number from 0 through 9. Once the number 9 is reached, pressing [Y/+] causes the numbers to “wrap around” to 0 and count up again.
5. Once you have set the desired value, press [MODE] for “Done.” This registers the new span value.



8.3.2.11 Change Span2 Value

If your MultiRAE is equipped with a high-range, or parts-per billion, PID sensor, you can set the span gas value for a third calibration point (Span2). The unit of measure is shown on the display.

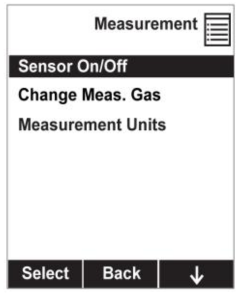
1. Press [Y/+] to select the highlighted sensor (VOC).
2. Press [N/-] to step through the digits.
3. Press [Y/+] to increase the number from 0 through 9. Once the number 9 is reached, pressing [Y/+] causes the numbers to “wrap around” to 0 and count up again.
4. Once you have set the desired value, press [MODE] for “Done.” This registers the new Span 2 value.



Note: Three-point calibration is disabled by default, but can be enabled on MultiRAE and MultiRAE Pro instruments with 10.6eV PID sensors, including high-range ppm and ppb PID sensors. The MultiRAE Lite PID sensor only supports 2-point calibration.

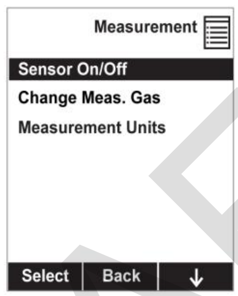
8.3.3 Measurement

The submenus for Measurement include Sensor On/Off, Change Measurement Gas, and VOC and Gamma (if equipped) Measurement Units.

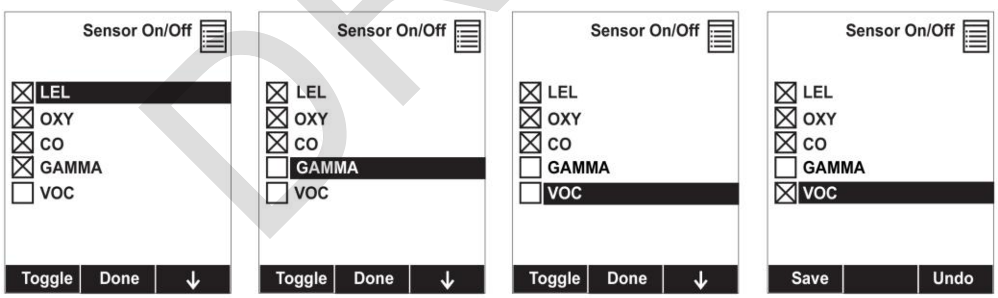


8.3.3.1 Sensor On/Off

You can turn sensors on or off via this submenu. An "X" in a box to the left of a sensor's name indicates it is turned on.

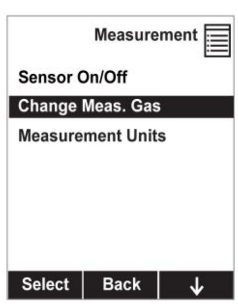


1. Scroll down the list of sensors using the [N/-] key.
2. Add or remove that gas from the list by pressing [Y/+]. An "X" in a box to the left of a sensor's name indicates it is selected.
3. Once you have made all your selections, press [MODE] for "Done."



8.3.3.2 Change Meas. Gas

The MultiRAE has extensive onboard gas libraries for combustible gases and VOCs that you can use to configure your MultiRAE to automatically apply the appropriate correction factors and produce readings in the units of the desired combustible gas or VOC.

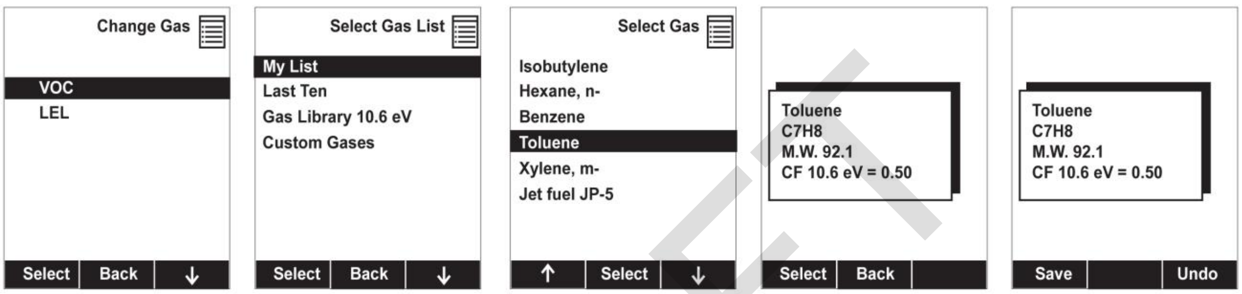


Measurement gases are organized in four lists:

- **My List** is a customized list of gases that you create. It contains a maximum of 10 gases and can only be built in ProRAE Studio II on a PC and transferred to the instrument.

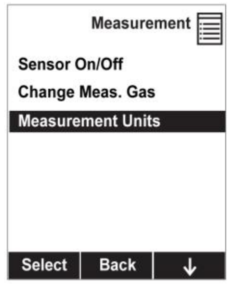
  Note: The first gas in the list is always isobutylene (it cannot be removed from the list).

- **Last Ten** is a list of the last ten gases used by your instrument. The list is built automatically and is only updated if the gas selected from Custom Gases or Library is not already in the Last Ten. This ensures that there is no repetition.
- **Gas Library** is a library that consists of more than 200 gases for the PID sensor and more than 50 for the catalytic LEL sensor.
- **Custom Gases** are gases with user-modified parameters. Using ProRAE Studio II, all parameters defining a gas can be modified, including the name, span value(s), correction factor, and default alarm limits.



8.3.3.3 Measurement Units

In some cases, the measurement unit for displaying data from sensors can be changed.

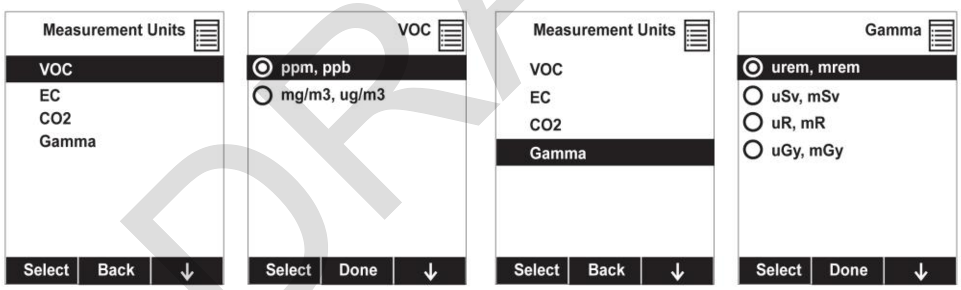


Standard available measurement units include:

Abbreviation	Unit	Sensor Type
ppm, ppb	parts per million, parts per billion	PID for VOC
mg/m3, ug/m3	milligrams per cubic meter, micrograms per cubic meter	PID for VOC
ppm, mg/m3	parts per million, milligrams per cubic meter	EC (electrochemical)
ppm Only, %VOL only, Auto Range	parts per million, percent by volume, automatically switch from ppm to %VOL at 10,000 ppm and higher*	CO_2
urem, mrem	microrems and millirems	Gamma
uSv, mSv	microSieverts and milliSieverts	Gamma
uR, mR	microRoentgens and milliRoentgens	Gamma
uGy, mGy	microGrays and milliGrays	Gamma

* The CO_2 switch point from ppm to %VOL can be changed via ProRAE Studio 2.

Here are two examples of menu hierarchies (select the sensor type and then the measurement unit):



8.3.4 Alarms

Use this menu to change high, low, STEL, and TWA alarm limits - the points at which alarms are triggered. The Alarms menu also allows changing alarm mode (latched or automatic reset) and alarm output methods (combinations of light, buzzer, and vibration alarm indications).

8.3.4.1 Alarm Limits

There are four groups of alarm settings that you can adjust for each individual sensor for which a particular alarm type is available.

Settings:

- High Alarm
- Low Alarm
- STEL (Short-Term Exposure Limit) Alarm
- TWA (Time-Weighted Average) Alarm

Note: Some alarm settings are not applicable to all sensors. If a setting is irrelevant to a sensor (for example, STEL for a gamma radiation sensor), then that sensor does not appear in the list.

8.3.4.2 Alarm Mode

You can program the MultiRAE so that there are two ways to shut off an alarm:

Auto Reset	When the alarm condition is no longer present, the alarm stops automatically.
Latch	You must manually turn off an alarm when one is triggered. The latched setting only controls alarms for High Alarm, Low Alarm, STEL Alarm, and TWA Alarm.

8.3.4.3 Alarm Settings

You can enable/disable any combination of light (visible), buzzer (audible), and vibration alarms.

Settings:

- All Enabled
- Light
- Vibration
- Buzzer
- Buzzer & Light
- Buzzer & Vibration
- Vibration & Light
- All Disabled

8.3.4.4 Comfort Beep

A Comfort Beep is a single beep of the audible alarm at 60-second intervals that informs the person using the MultiRAE that it is functioning. It can be turned on or off.

8.3.4.5 Man Down Alarm

The Man Down Alarm is a critical and potentially lifesaving feature of every MultiRAE. The Man Down Alarm is based on the premise that if the instrument is motionless when it is not supposed to be, something wrong may be happening to its user. If that is the case, a wirelessly enabled MultiRAE not only goes into alarm locally on the instrument to notify people in the vicinity, but also remotely, over the RAE Systems Dedicated Wireless Network, to transmit the alarm to remote safety officers at a command center, that a person is down, so that help can be dispatched quickly.

Whenever the Man Down feature is enabled, the main screen displays a Man Down icon along the top to indicate it is active:

The MultiRAE has a 3D gravity sensor that can track the slightest motion of the instrument in any direction. If the instrument is not moved during that time, then a pre-alarm is activated to alert the user, and shows the "Are You OK?" screen. Pressing [Y/+] clears the alarm and returns the MultiRAE to its normal operation. Pressing [N/-] sets it into Man Down Alarm (and if wireless connectivity is enabled, a Man Down message is sent in real time to remote observers). If neither key is pressed, then after the count-down, it goes into Man Down Alarm (again sending a message to remote observers if wirelessly enabled).

Settings are available for:

- Off/On (off by default)
- Motionless Time: time the instrument is motionless before initiating a pre-alarm (30 seconds by default)
- Motion Sensitivity: set to low, medium, or high to compensate for ambient vibration or motion (medium by default)
- Warning Time: countdown, in seconds, from pre-alarm to Man Down alarm (30 seconds by default)

When the Man Down pre-alarm is activated, the buzzer sounds and LEDs flash twice per second, and a countdown begins.

- If the MultiRAE’s user presses [Y/+] for “Yes” in response to the “Are You OK?” question on the screen before the countdown reaches zero, the Man Down alarm stops and the main reading screen is displayed.
- If the person does not press [Y/+] for “Yes” in response to the “Are You OK?” question on the screen before the countdown reaches zero, the Man Down alarm is triggered.
- If the person presses [N/-] during the countdown, answering the “Are You OK?” question with “No,” the Man Down alarm starts.

If wireless connectivity is enabled, a Man Down message is also sent to remote observers.

IMPORTANT!

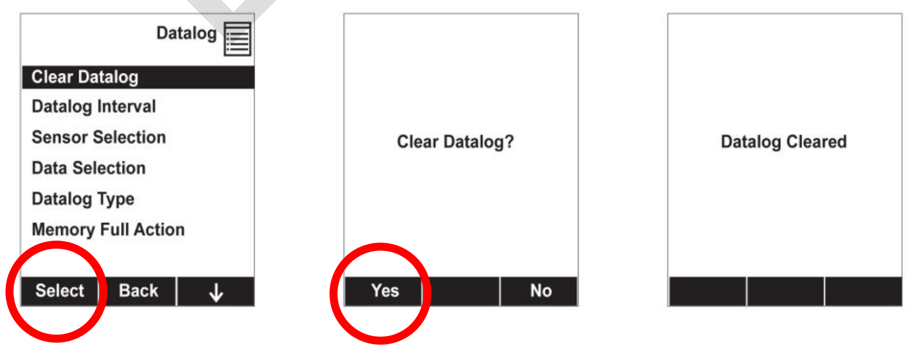
When gas or radiation alarm conditions exist at the same time as the Man Down is activated, the pre-alarm stage is skipped and the instrument goes straight into a Super Alarm (gas or radiation and Man Down) with four beeps/flashes per second.

8.3.5 Datalog

The instrument displays a floppy disk icon to indicate that a datalog is being recorded. The instrument stores the measured gas concentration for each sensor, date and time for each measurement, Site ID, User ID, and other parameters. The MultiRAE memory is sufficient to record six months’ worth of data for five sensors at one-minute intervals, 24/7. All data are retained (even after the unit is turned off) in non-volatile memory so that they can be downloaded at a later time to a PC.

8.3.5.1 Clear Datalog

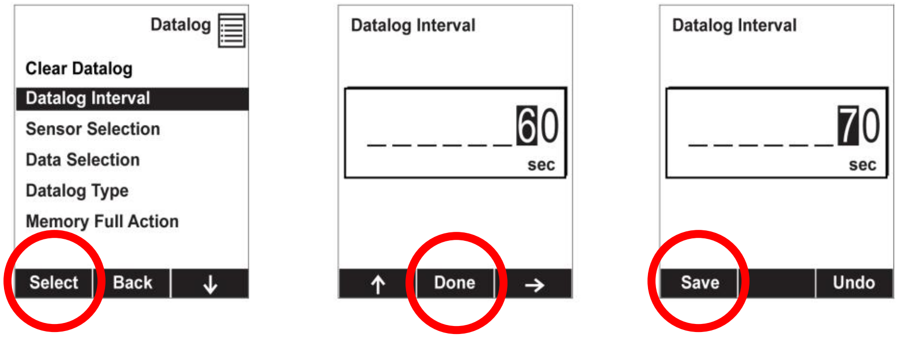
This operation erases all data stored in the datalog. Select “Clear Datalog,” and then “Yes.”



Note: Once the datalog is cleared, the data cannot be recovered.

8.3.5.2 Datalog Interval

Intervals are shown in seconds. The default value is 60 seconds. The maximum interval is 3600 seconds, and the minimum is 1 second.



8.3.5.3 Sensor Selection

You can choose which sensors' data are included in the datalog. The entire list of installed sensors is shown, and you can individually select whether their data is included.

Note: Turning a sensor off in the list does not change or erase its settings.

8.3.5.4 Data Selection

Data Selection allows you to select which types of data are stored and made available when you download your datalog to a computer via ProRAE Studio II (version 1.04 or higher) software.

You can choose any or all of four types of data (you must choose at least one):

- Minimum
- Average
- Maximum
- Real Time

8.3.5.5 Datalog Type

The instrument offers three options for starting the datalogging process:

Auto	Automatically collects datalog information every time the instrument is sampling until the datalog memory is full.
Manual	Datalogging occurs only when you manually initiate it (see below for details).
Snapshot	Captures a single event when you press [MODE].

Note: You can only choose one datalog type to be active at a time.

About Manual Datalogging

When the instrument is set to Manual Datalog, you can turn datalogging on and off by repeatedly pressing [N/-] and stepping through the screens from the main display until you reach the screen that says "Start Datalog?"

- When you reach the screen that says "Start Datalog?" press [Y/+] to start it. You see "Datalog Started," confirming that datalogging is now on. You can turn it off by pressing [Y/+] again.
- If datalogging is running, you can leave it running. However, if you want to turn it off, follow this procedure:

> Press [N/-] repeatedly to step through the screens until you reach the screen that says, "Stop Datalog?" Press [Y/+] to stop datalogging. The screen displays "Datalog Stopped" for a few seconds, before displaying "Start Datalog?" and the datalog interval. You can restart it anytime by pressing [Y/+] from that screen.

About Snapshot Datalogging

When the instrument is in Snapshot datalogging mode, it captures a single "snapshot" of the data at the moment of your choosing. All you have to do is press [MODE] each time you want to capture a snapshot of the data at that instant.

No snapshot.

Press [MODE] for a snapshot.

Datalog icon is shown momentarily during a snapshot

8.3.5.6 Memory Full Action

When the internal datalog memory is full, the MultiRAE can either stop collecting data (Stop when full) or go back to the beginning and overwrite the data from the first entry, second entry, etc. (Wraparound).

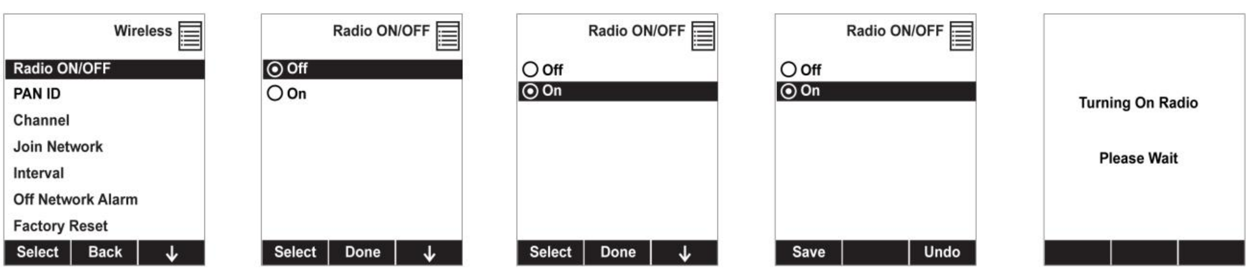
8.3.6 Wireless

When a MultiRAE is equipped with a wireless modem, its settings are controlled via the menu items under "Wireless."

8.3.6.1 Radio ON/OFF

Turn the radio on or off via this menu.

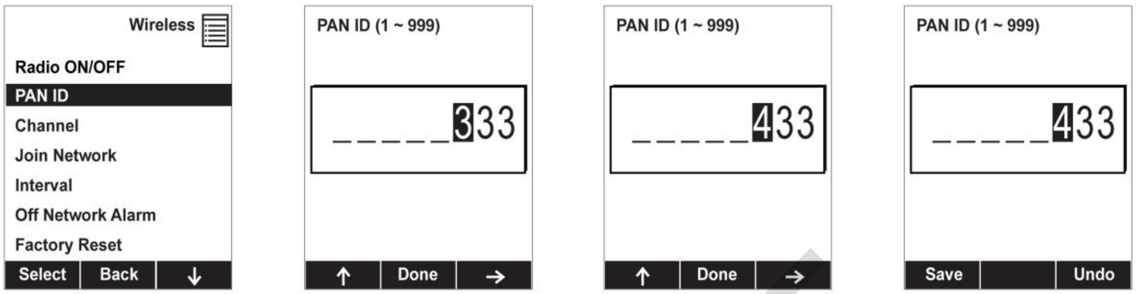
1. Choose between "On" and "Off" by pressing [N/-].
2. Select the highlighted state by pressing [Y/+].
3. Save or register the change:
   - Press [Y/+] to save the change.
   - Press [N/-] to undo the change.



8.3.6.2 PAN ID

The MultiRAE and any other devices that you want to interconnect wirelessly must have the same PAN ID.

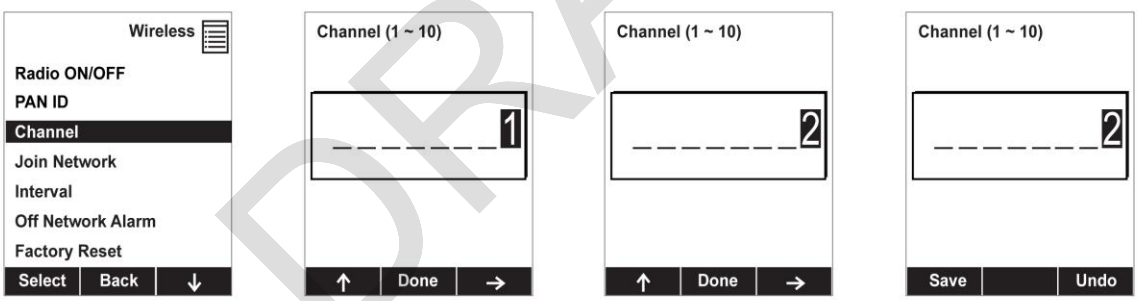
1. Press [Y/+] to increase the number and [N/-] to advance to the next digit.
2. After moving to the last digit and making changes, press [MODE].
   - Press [Y/+] to save the change.
   - Press [N/-] to undo the change.



8.3.6.3 Channel

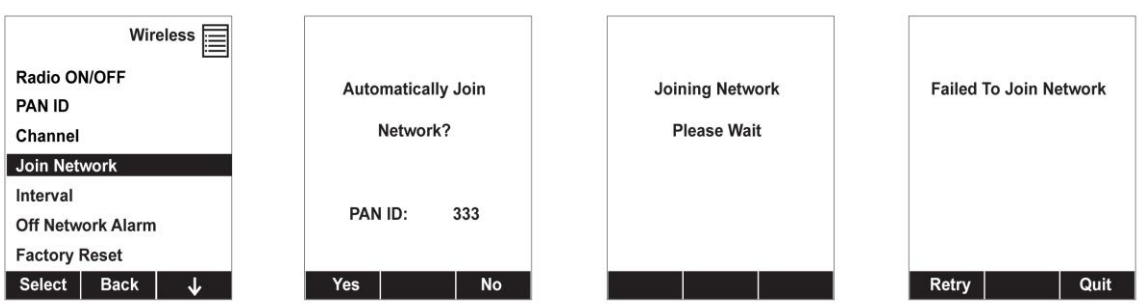
The MultiRAE and any other devices that you want to interconnect wirelessly must be operating on the same channel.

1. Press [Y/+] to increase the number and [N/-] to advance to the next digit.
2. After moving to the last digit and making changes, press [MODE].
   - Press [Y/+] to save the change.
   - Press [N/-] to undo the change.



8.3.6.4 Join Network

You can tell the MultiRAE to automatically join a network with a certain PAN ID without having to specify the communications channel. The PAN ID is shown for reference (if it is incorrect, you can change it, as described above). Press [Y/+] to join.



While it is searching for a network to join, the display shows this message:

Joining Network
Please Wait

If it is unsuccessful, you will see this message:

Failed To Join Network

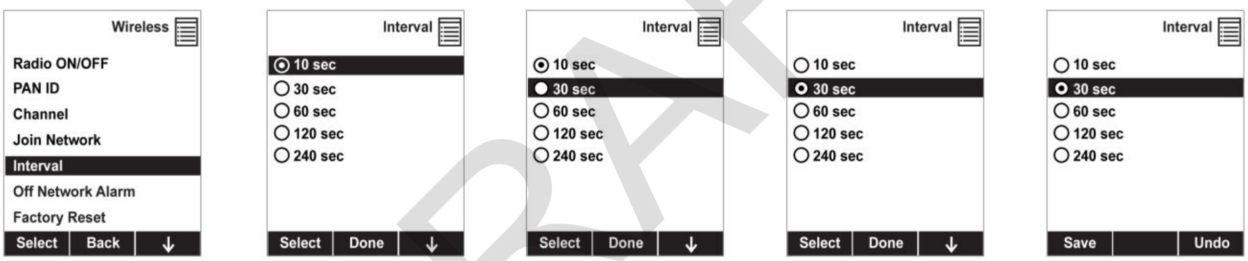
Check your other settings, as well as those of the network you are trying to join.

You can press [Y/+] to retry or [N/-] to quit.

8.3.6.5 Interval

This menu allows you to change the interval between wireless transmissions. The interval can be set to 10, 30, 60, 120, or 240 seconds.

1. Scroll down the list of intervals by pressing [N/-] until the interval you want is highlighted.
2. Select the highlighted interval by pressing [Y/+].
3. Save or register the change:
    - Press [Y/+] to save the change.
    - Press [N/-] to undo the change.

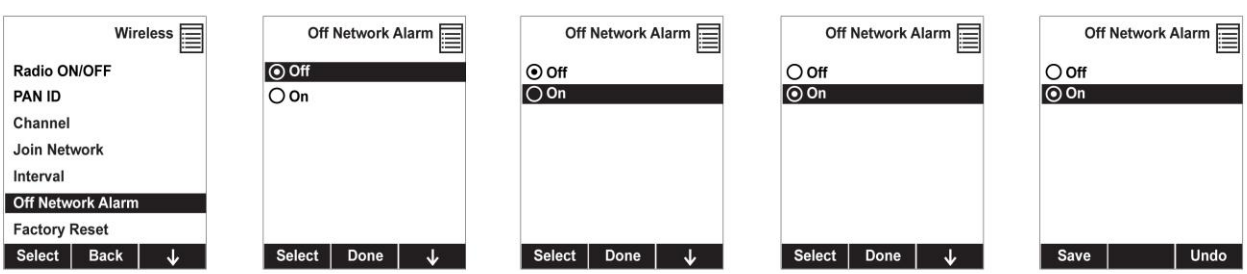


Note: The default interval is 30 seconds.

8.3.6.6 Off Network Alarm

If you would like the MultiRAE to notify you when it loses connection with a network, turn this on.

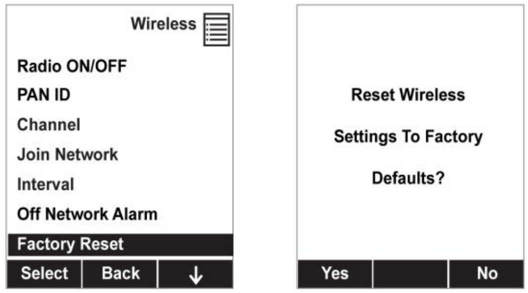
1. Choose between "On" and "Off" by pressing [N/-].
2. Select the highlighted state by pressing [Y/+].
3. Register the change.
    - Press [Y/+] to save the change.
    - Press [N/-] to undo the change.



8.3.6.7 Factory Reset

Restore all the wireless settings to their original factory defaults.

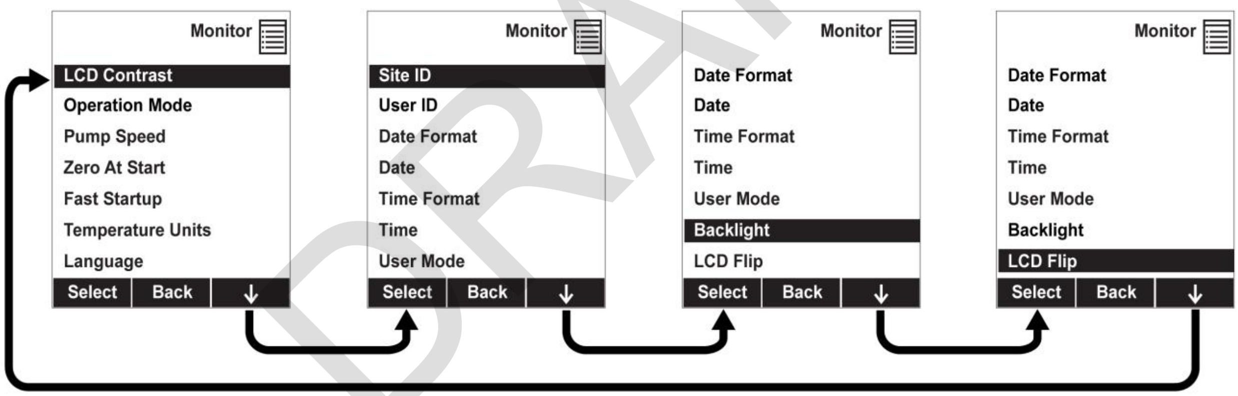
Caution! Once you reset the wireless settings, you cannot retrieve any of the settings deleted by performing this reset.



- Press [Y/+] to reset the wireless settings.
- Press [N/-] to exit without resetting the wireless settings.

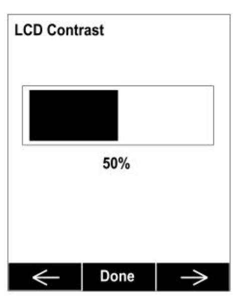
8.3.7 Monitor

The submenus under "Monitor" control the LCD's contrast, operation mode, pump speed, and other parameters. Press [N/-] to advance through the submenus, and when you reach the last one, it returns to the first selection.



8.3.7.1 LCD Contrast

The display's contrast can be increased or decreased from its default setting. You may not need to ever change the default setting, but sometimes you can optimize the display to suit extreme temperature and ambient brightness/darkness conditions.



Use the [Y/+] and [N/-] keys to decrease or increase LCD contrast, respectively (the bar graph aids in setting it). When you are done, press [MODE] to select "Done." If you have not made a change, it exits to the submenu's next selection. If you have made a change, you are prompted at the next screen to press [Y/+] to save the change or [N/-] to undo the change and exit to the next submenu selection.

8.3.7.2 Operation Mode
There are two operation modes, outlined below.

Hygiene Mode
When the MultiRAE is in Hygiene Mode, it continuously monitors, and if datalogging is on, it saves data continuously. Refer to page 25 for more information on operation in Hygiene Mode.

Search Mode
When the instrument is in Search Mode, it only samples when you activate sampling. When you see the display that says, "Ready…Start sampling?" press [Y/+] to start. The instrument automatically assigns a new Site ID to each measurement you take. The pump turns on and the instrument begins collecting data. To stop sampling, press [N/-] while the main display is showing. You will see a new screen that says, "Stop sampling?" Press [Y/+] to stop sampling. Press [N/-] if you want sampling to continue. Refer to page 25 for more information on operation in Search Mode.

8.3.7.3 Pump Speed
If the MultiRAE is equipped with a pump, the pump can operate at two speeds, high and low. Running at low speed is quieter, extends pump lifespan, and conserves a small amount of power. There is almost no difference in sampling accuracy.

8.3.7.4 Zero At Start
If your MultiRAE has been configured to perform a zero (fresh air) calibration upon startup, called Zero At Start, then the startup routine is interrupted so that you can perform a fresh air calibration for all sensors prior to using the instrument.

If you do not want to perform a zero calibration, press [MODE] to bypass it. If you start a zero calibration and want to abort it, press [N/-], and the calibration stops and the main display is shown.

8.3.7.5 Fast Startup
Fast Startup reduces the amount of time between when the instrument is turned on and is ready for use. It skips showing you many settings and is best suited to environments where the MultiRAE is turned on and off very often during a given day. If Fast Startup is not selected, then when the instrument starts, it shows you details of each sensor, including calibration information, high and low alarm settings, etc.

8.3.7.6 Temperature Units
The display unit of the internal temperature sensor can be switched between Fahrenheit and Celsius.

8.3.7.7 Language
English is the default language, but other languages can also be selected for the instrument.

8.3.7.8 Site ID
Choose and enter an 8-digit Site ID to uniquely identify the particular site where the instrument is to be used. The first four digits can be an alphabet letter or number, while the last four digits can only be numbers. This Site ID is included in the datalog report.

Note: Advance through the alphabet and numbers (0 through 9) by one with each press of the [Y/+] key. To scroll quickly, hold down the [Y/+] key for as long as you want it to scroll rapidly.

8.3.7.9 User ID
Enter an 8-digit alphanumeric User ID to uniquely identify a user. This User ID is included in the datalog report. The first four characters of a customized User ID act as an identifier for the monitor on the screen of the EchoView Host Wireless Mini-Controller to which the MultiRAE is wirelessly connected.

Note: Advance through the alphabet and numbers (0 through 9) by one with each press of the [Y/+] key. To scroll quickly, hold down the [Y/+] key for as long as you want it to scroll rapidly.

8.3.7.10 Date Format

Month (MM) and Day (DD) have two digits each, while the year (YYYY) uses four digits. The Date can be expressed in three different formats:

- MM/DD/YYYY
- DD/MM/YYYY
- YYYY/MM/DD

8.3.7.11 Date

Set the date according to the format selected in Date Format.

8.3.7.12 Time Format

The time format can be either of these two options:

- 12 Hour (AM/PM)
- 24 Hour

8.3.7.13 Time

Regardless of the Time Format you select, the MultiRAE's time must be set using the 24-hour format, following hours, minutes, and seconds (HH:MM:SS).

8.3.7.14 User Mode

Two User Modes are available: Advanced and Basic. The Advanced User Mode allows a greater number of parameters to be changed than Basic User Mode. It can be used with either of the Operation Modes, Hygiene or Search. No password is required to enter the Programming Menu when in Advanced User Mode.

8.3.7.15 Backlight

The display's backlight can be set to illuminate either automatically, based on ambient light conditions, or manually, or it can be shut off. If manual backlighting is selected, when the backlight is turned off, pressing any key turns backlighting on. A key needs to be pressed again to perform its main function.

8.3.7.16 LCD Flip

The display can be configured to flip 180° automatically when the MultiRAE is turned upside-down. The LCD Flip feature can be set to On or Off.

9 Policy Enforcement

The MultiRAE can be configured to enforce a facility/company's requirements that calibration and/or bump testing be performed at specified intervals, and to explicitly prompt the user that calibration/bump testing is required. Depending on how Policy Enforcement features are configured, the user may be required to perform a bump test or calibration prior to being able to use the instrument. That is, it can be set to not allow normal operation of the instrument unless calibration or bump testing is performed.

If the instrument has been bump tested and calibrated in compliance with the policy settings, a check-mark icon is included along the top of the MultiRAE screen:

√

If Policy Enforcement is enabled, then after startup the MultiRAE displays a screen that informs the user that the instrument requires either a bump test or a calibration. If both are required, then they are shown in sequence.

Note: Policy enforcement features are disabled by default.

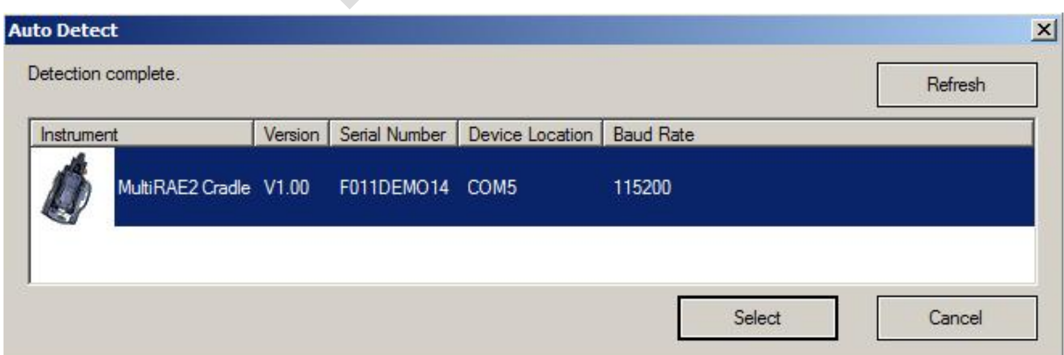
9.1 Setting Policy Enforcement

You must use ProRAE Studio II to make changes to Policy Enforcement settings. The procedure differs, depending on whether you are using an AutoRAE 2, a MultiRAE Travel Charger, or a MultiRAE Desktop Cradle. Policy violations are captured in the datalog.

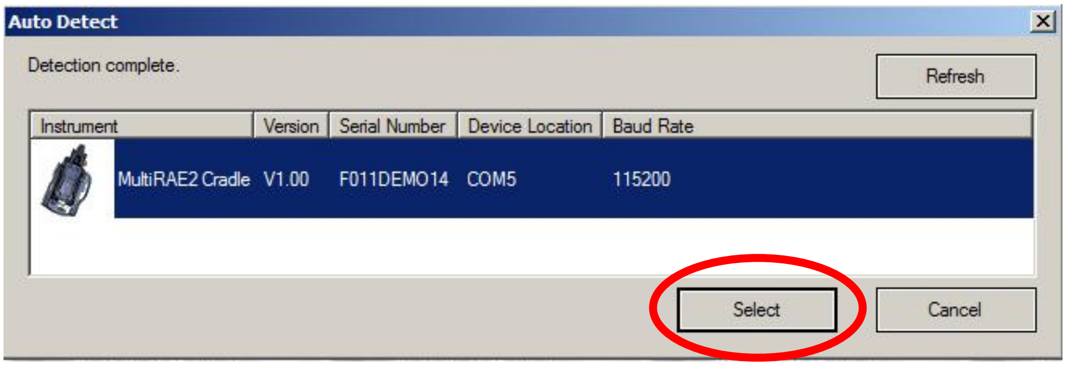
9.1.1 Using The AutoRAE 2 Automatic Test And Calibration System

To program a MultiRAE via an AutoRAE 2, you need ProRAE Studio II Instrument Configuration and Data Management Software, the AutoRAE 2 connected to a power source, and a USB PC communications cable.

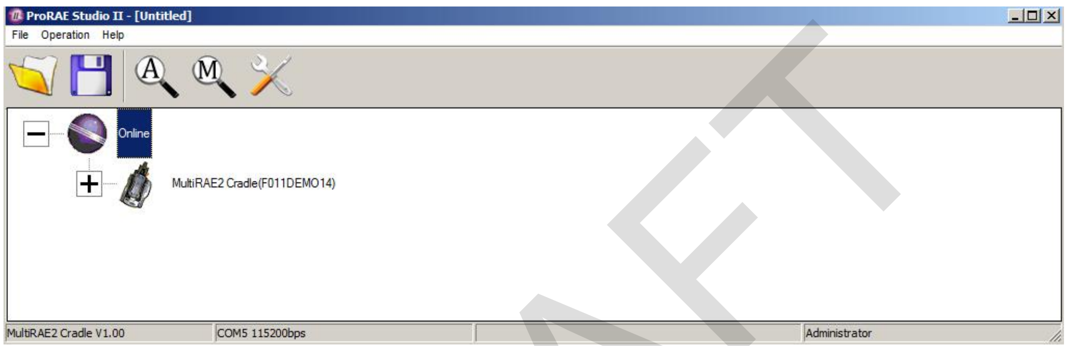
1. Connect a USB cable between a PC with ProRAE Studio II and the AutoRAE 2.
2. Apply power to the AutoRAE 2.
3. Turn off the MultiRAE (or put the MultiRAE into AutoRAE 2 Mode) and set it in the cradle.
4. Start ProRAE Studio II software on the PC.
5. Select "Administrator" and input the password (the default is "rae").
6. Click "Detect the instruments automatically" (the magnifying glass icon with the letter "A" in it). After a few seconds, the AutoRAE 2 Cradle is found and it is shown, along with its serial number:



7. Click on the icon to highlight it, and then click "Select."



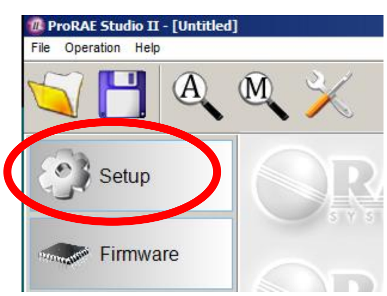
8. In ProRAE Studio II, the AutoRAE 2 Cradle is shown, including its Serial Number, under "Online":



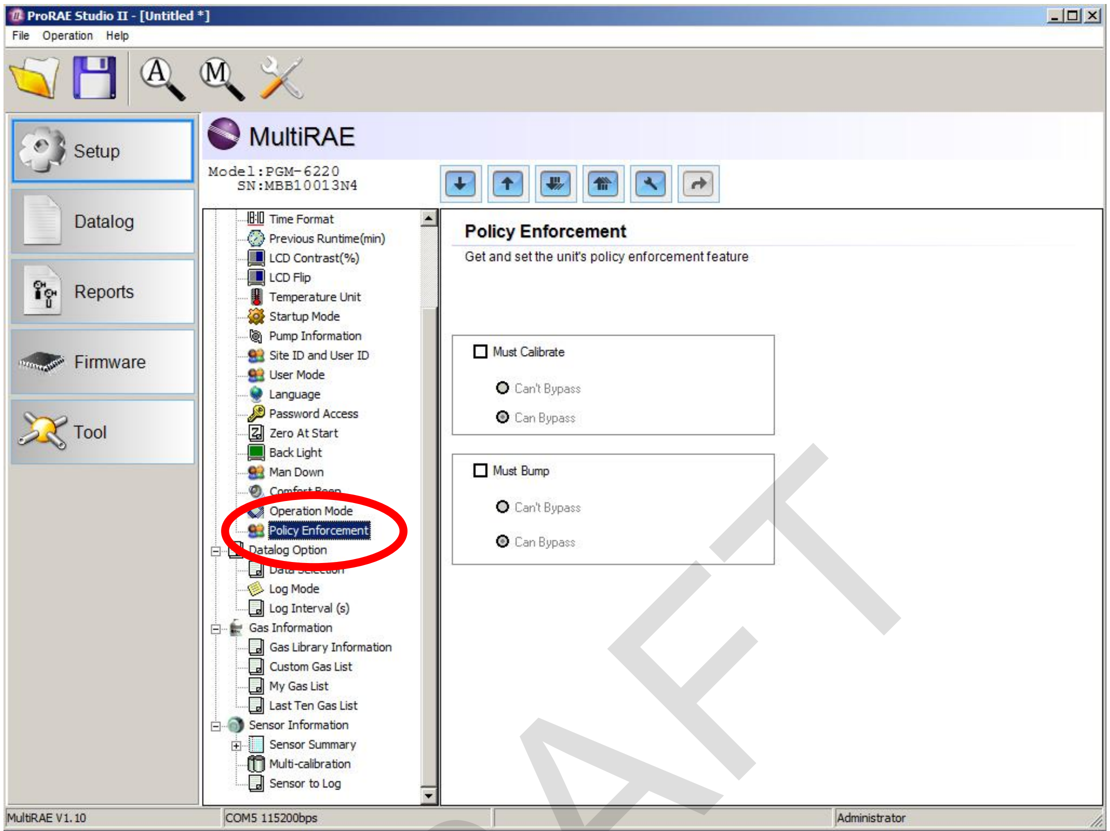
9. Expand the view to show the MultiRAE in the AutoRAE 2 Cradle by clicking the "+" to the left of the image of the AutoRAE 2 Cradle:

10. Double-click on the icon representing the MultiRAE.

11. Click "Setup."



12. In the menu that now appears on the left side, click "Policy Enforcement." It is highlighted, and the Policy Enforcement pane is shown:



For "Must Calibrate" and "Must Bump," you have the options of no enforcement or enforcement (including "Can't Bypass," and "Can Bypass").

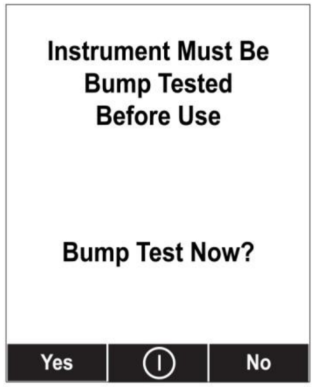
Must Calibrate. The user is prompted to calibrate the instrument when calibration is due (as set by the calibration interval). There are two programmable options:

- **Can't Bypass.** Unless calibration is performed, the instrument cannot be used, and the only option is to turn off the instrument.
- **Can Bypass.** If calibration is due but the user does not want to perform a calibration, the instrument can still be used. In this case, the instrument records that the user has bypassed the calibration requirement in a Policy Violation report.

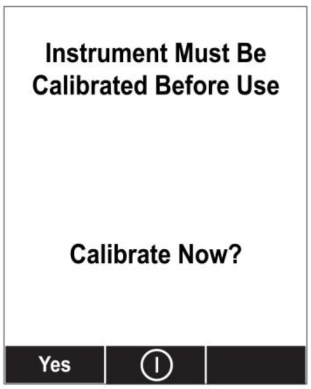
Must Bump. The user is prompted to bump test the instrument when a bump test is due (as set by the bump test interval). There are two programmable options:

- **Can't Bypass.** Unless a bump test is performed, the instrument cannot be used, and the only option is to turn off the instrument.
- **Can Bypass.** If a bump test is due but the user does not want to perform one, the instrument can still be used. In this case, the instrument records that the user has bypassed the bump testing requirement in a Policy Violation report.

These are the screens that are shown on a MultiRAE after startup if "Can Bypass" is selected:



If "Can't Bypass" is selected, the display looks like this, and only allows the options of performing the test or shutting down:



16. Once you have made your selections in ProRAE Studio II, you must upload the changes to the instrument. Click the icon labeled "Upload all settings to the instrument."

17. A confirmation screen is shown. Click "Yes" to perform the upload, or "No" to abort. Uploading takes a few seconds, and a progress bar is shown. You can abort the upload by clicking "Cancel."

18. Exit ProRAE Studio II.

19. Press [Y/+] on the MultiRAE to exit Communication Mode.

9.1.2 Using The MultiRAE Desktop Cradle Or Travel Charger

Make sure the AC adapter is connected and that a USB cable is connected to a computer running ProRAE Studio II.

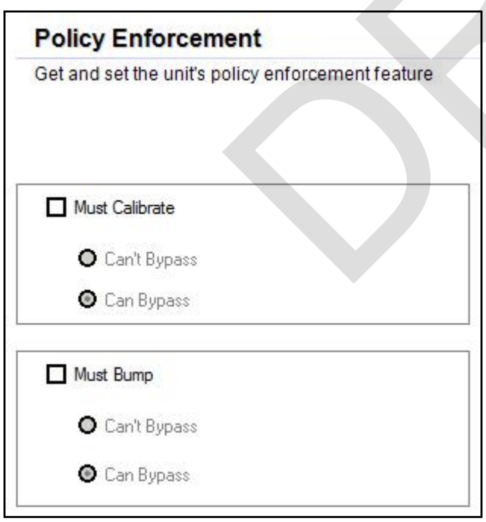
1. Turn on the MultiRAE.
2. Hold down [MODE] and [N/-] to enter Programming Mode.
3. Provide the password.
4. Press [N/-] until "Enter Communications Mode?" is displayed.
5. Press [Y/+]. The screen shows three options:

    - PC
    - AutoRAE 2
    - Exit

6. With "PC" highlighted, press [Y/+] to select it.
   The screen now displays: "Ready To Communicate With Computer."

7. Start ProRAE Studio II.
8. Select "Administrator."
9. Input the password (the default is "rae").
10. Click "OK."
11. Click "A" (detects instruments automatically).
12. Click on the instrument's icon when it appears to highlight it.
13. Click "Select."
14. Click "Setup."
15. Click "Policy Enforcement."

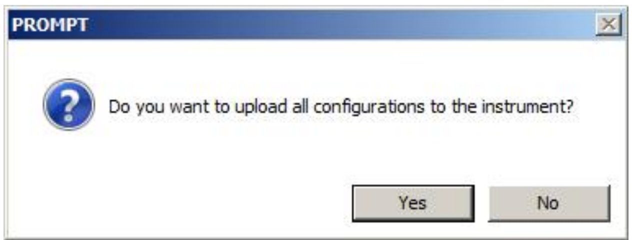
The Policy Enforcement pane is shown:



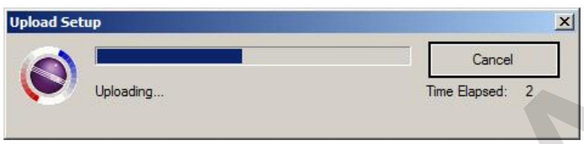
You can select "Must Calibrate" and/or "Must Bump" and then set whether the user must perform the selected operation in order to use the instrument.

16. Once you have made your selections in ProRAE Studio II, you must upload the changes to the instrument. Click the icon labeled "Upload all settings to the instrument."

17. A confirmation screen is shown. Click "Yes" to perform the upload, or "No" to abort.



Uploading takes a few seconds, and this progress bar is shown. You can abort the upload by clicking "Cancel."



18. Exit ProRAE Studio II.
19. Press [Y/+] on the MultiRAE to exit Communication Mode.

9.2 Deactivating Policy Enforcement

9.2.1 AutoRAE 2 Cradle

To deactivate Policy Enforcement when using an AutoRAE 2 Cradle, follow the procedure for changing settings. See page 48 for details.

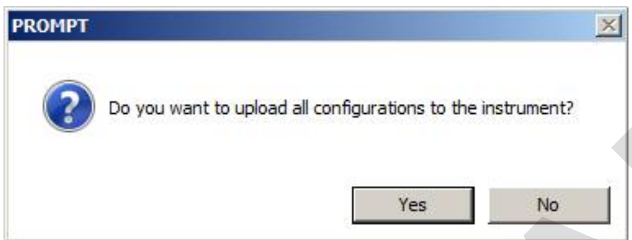
9.2.2 MultiRAE Desktop Cradle Or Travel Charger

If the MultiRAE screen displays the message that it must be bump tested or calibrated, and if the option to bypass bump testing or calibration is not available, you should shut off the instrument and follow the procedure outlined here if you want to change the Policy Enforcement settings:

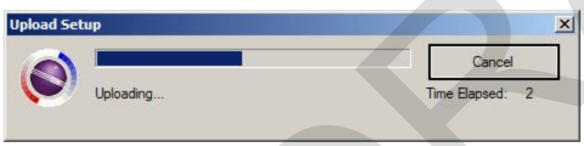
1. Use a USB cable to connect the MultiRAE in its Travel Charger or Desktop Cradle to a computer running ProRAE Studio II.
2. Enter Diagnostic Mode on the MultiRAE (with the instrument turned off, press and hold [Y/+] and [MODE] until it starts up.
3. After startup, enter the password when prompted (default is "0000") and press [MODE].
4. Press [N/-] repeatedly until you see the "Enter Communications Mode?" screen.
5. Press [Y/+] to enter Communications Mode.
6. Start ProRAE Studio II.
7. Select "Administrator."

8. Input the password (the default is "rae").
9. Click "OK."
10. Click "A" (detect instruments automatically).
11. Click on the instrument's icon when it appears.
12. Click "Select."
13. Click "Setup."
14. Click "Policy Enforcement." The Policy Enforcement pane is shown.
15. Deselect Policy Enforcement features you do not wish to use.
16. Click "Upload all settings to the instrument."

17. When you see this confirmation. Click "Yes."



Uploading will take a few seconds, and this progress bar is shown:



18. When the upload is done, exit ProRAE Studio II.
19. Press [Y/+] on the MultiRAE to exit Communication Mode.

10 Calibration And Testing

10.1 Manual Alarms Test

Under Normal Operation Mode and non-alarm conditions, the buzzer (audible alarm), vibration, visible alarms, and backlight can all be tested anytime by pressing [Y/+] twice. If any alarm does not respond, check the alarm settings in the Programming Menu to make sure all alarms are enabled (selected setting under Programming/Alarms/Alarm Settings should be "All Enabled"). If any alarms are enabled but not functional, the instrument should not be used.

10.2 Bump Testing And Calibration

RAE Systems recommends that a bump test be conducted prior to each day's use. The purpose of a bump test is to ensure that the instrument's sensors respond to gas and all the alarms are enabled and functional.

- The MultiRAE multi-gas detector must be calibrated if it does not pass a bump test when a new sensor is installed, after sensor maintenance has been performed, or at least once every 180 days, depending on use and sensor exposure to poisons and contaminants.
- Calibration and bump test intervals and procedures may vary due to national legislation.

A bump test or calibration can be performed either manually or using the AutoRAE 2 Automatic Test and Calibration System. When a bump test or calibration is done manually, the instrument makes a pass/fail decision based on sensor performance, but the user still has the responsibility to make sure all the alarms are enabled and functional.

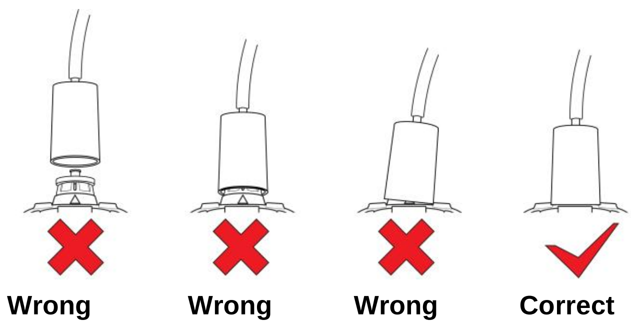
An AutoRAE 2 bump test or calibration takes care of both the sensor and alarm tests. Consult the AutoRAE 2 User's Guide for details.

10.2.1 MultiRAE Equipped With A Pump

With its pump speed setting of low or high, a MultiRAE normally draws in air at a flow rate of between 200 cc/min and 300 cc/min. RAE Systems recommends that a calibration cap used with calibration gas flow rates from 500 cc/min to 1000 cc/min.

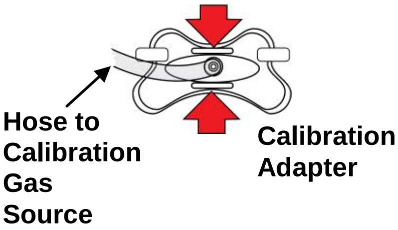
Installing The Calibration Adapter

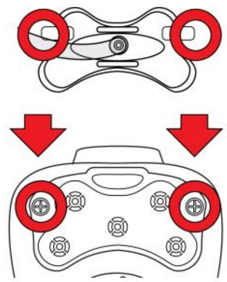
WARNING: Make sure the calibration cap clips on and stays in the correct position during calibration, as illustrated below. Otherwise, the calibration cap must be manually held in the correct position.

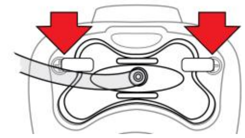


10.2.2 MultiRAE Lite Diffusion Model (No Pump)

Because there is no single inlet on the diffusion (non-pumped) version of the MultiRAE, a Calibration Adapter is used for supplying calibration gas to all sensors at one time. Follow these steps for attaching the Calibration Adapter.







Grasp the small handles on the Calibration Adapter.

Align the Calibration Adapter's two connectors with the screws on both sides of the MultiRAE's gas inlets.

Make sure the connectors are securely in place before starting the flow of calibration gas. (The Calibration Adapter has small grooves on its underside to allow gas to escape after passing over the sensors.

10.2.3 Bump (Functional) Testing

A bump test can be performed on an individual sensor (Single Sensor Bump) or a group of sensors (Multi Sensor Bump) combined into Multi Cal. Select. The same gas is used for a bump test as for calibration. Typically, two cylinders of calibration gas are needed to perform a bump test or calibration on an instrument with a PID sensor and electrochemical and LEL sensors. This may require one gas cylinder with Isobutylene or another VOC test gas to test the PID sensor, and another with a 4-gas mix to test electrochemical (such as CO, H_2S, and O_2) and LEL sensors. As with calibration, the instrument intelligently splits the process into two consecutive steps: first, the wizard prompts for testing electrochemical and LEL sensors, and then it tests the PID sensor.

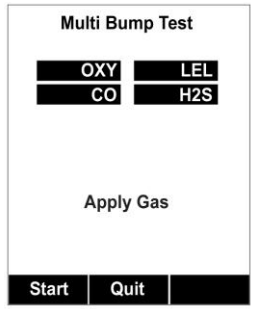
For a manual bump test, a constant-flow regulator producing 0.5 to 1 liters per minute should be used, and the calibration cap must be installed on the instrument. Testing and calibration with an AutoRAE 2 must be performed using demand-flow regulators. A calibration cap must not be used. Teflon tubing must be used to test or calibrate the PID sensor. Follow the steps described here to perform a manual bump test:

1. Turn on your MultiRAE by pressing and holding [MODE] (the middle button) and allow the instrument to boot up fully until the main measurement screen with sensor names and readings is shown.

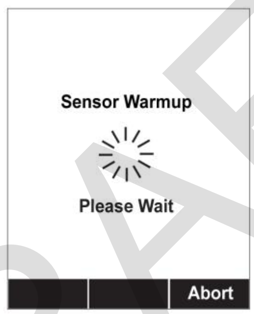
Important! Make sure all of the instrument's sensors have warmed up before performing the bump test. The instrument will take the time to warm up the sensors prior to enabling access to bump test menus. You can tell a sensor has warmed up if you see a reading next to it name on the display. If it has not warmed up, you see three dashes ("---") next to it.

2. Enter the Bump Test menu. It is accessible either through Programming Menu/Calibration or using the following easy shortcut:

   With the instrument running in Normal Mode and the main measurement screen shown, press both [Y/+] and [N/-] at the same time and hold them for 5 seconds. If all the sensors have warmed up, the Multi-Bump Test menu then appears:



   Otherwise, the menu appears after the warm-up is complete (while it is warming up, the screen indicates that you must wait for the sensors to warm up).



   Note: If you do not apply gas within a couple of minutes, the screen changes briefly to indicate gas has not been applied, and then the instrument returns to its normal reading screen.

3. Install the calibration cap on the MultiRAE and connect it to the calibration gas. Turn on the gas to initiate flow.

4. Press [Y/+] to start the bump test. While the bump test is being performed, the readings for each sensor are shown. Once the bump test completes, pass/fail test results and readings are shown for each sensor.

   Note: If a PID or other sensors are installed in the instrument require a dedicated cylinder of gas to calibrate, the instrument will prompt for calibrating such sensors at this point.

5. If a PID or other sensors installed in the instrument require a dedicated gas cylinder to calibrate, the instrument will prompt to calibrate such sensors at this point. Disconnect the gas cylinder and connect the next (for example, 100 ppm Isobutylene for a PID).

6. Press "OK" to proceed to the PID sensor test. Turn on the gas and press Start ([Y/+] button). While the bump test is being performed, PID sensor readings are shown. Once the bump test completes, pass/fail test results and readings are shown for the PID sensor.

   Note: If other installed sensors require a dedicated cylinder of gas to calibrate, the instrument prompts for calibrating these sensors at this point.

Important! If one or more sensors fails a bump test, be sure to calibrate those sensors.

7. The bump test is now complete. Press Exit to return to the main measurement screen.

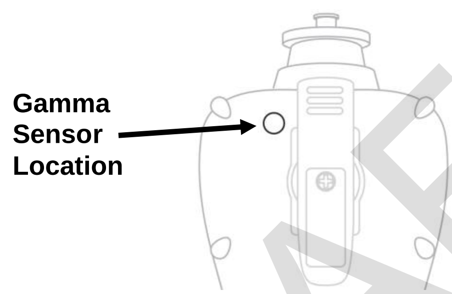
8. Now perform a manual alarms test, as described in section 10.1.

If all the alarms and all sensors have passed and no sensor is due for a calibration, the instrument is now ready for use.

Note: When a manual bump test is performed, the readings shown are in the equivalent units of the calibration gas, and not the measurement gas (if different).

10.2.4 Testing The Gamma Radiation Sensor

The gamma radiation sensor does not require user calibration. You can check it by placing a check-source on the rear of the MultiRAE equipped with a gamma sensor to check the readings. A raised dot on the rubber boot marks where the sensor is located inside the instrument.



10.3 Zero/Fresh Air Calibration

This operation sets the zero point of the sensor calibration curve for clean air. It should be performed before other calibrations.

IMPORTANT!

Even though most toxic gas sensors can be zeroed in fresh air, sensors such as the CO_2 and the parts-per-billion PID sensor for volatile organic compounds (VOCs) should not be zeroed in fresh air. Both CO_2 gas and VOCs are normally present in ambient air, so zeroing these sensors in ambient air will not allow for a true zero to be set for such sensors. The CO_2 sensor should be zeroed in 99.9% nitrogen and the parts-per-billion PID sensor should be zeroed with ambient air using a charcoal filter or a VOC zeroing tube.

Note: If you use a zero air or other gas cylinder, you must use the MultiRAE Calibration Adapter. A calibration adapter is not necessary for calibration in fresh air.

10.3.1 Zero Calibration For A CO_2 Sensor

Important! If your MultiRAE is equipped with a CO_2 sensor, it must be zero calibrated using 100% Nitrogen (N_2), which is inert, instead of fresh air or zero air.

10.3.2 Zero Calibration For Parts-Per-Billion (ppb) Sensor

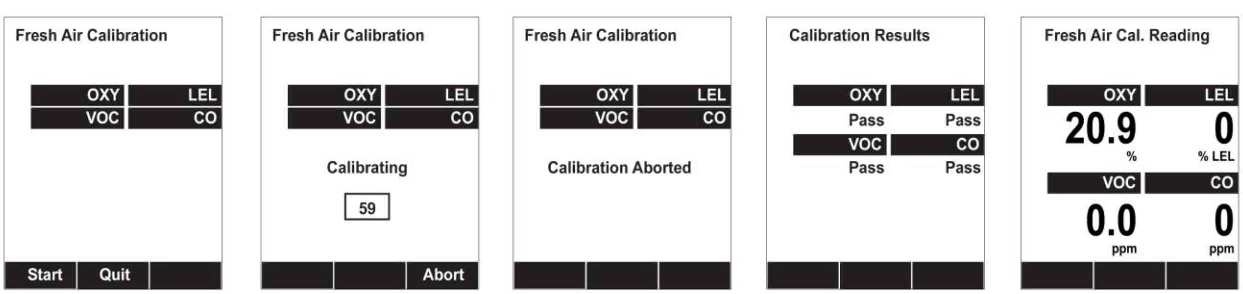
Important! The parts-per-billion PID sensor for volatile organic compounds (VOCs) should not be zeroed in fresh air. VOCs are normally present in ambient air, so zeroing the sensor in ambient air will not allow for a true zero to be set. The parts-per-billion PID sensor should be zeroed with ambient air using a charcoal filter or a VOC zeroing tube.

10.3.3 Fresh Air Calibration

This procedure determines zero points of most sensors. The MultiRAE should be zero-calibrated in clean air with 20.9% oxygen or with a cylinder of clean zero air.

At the Calibration menu, select "Fresh Air" by pressing [Y/+] once to enter fresh air calibration.

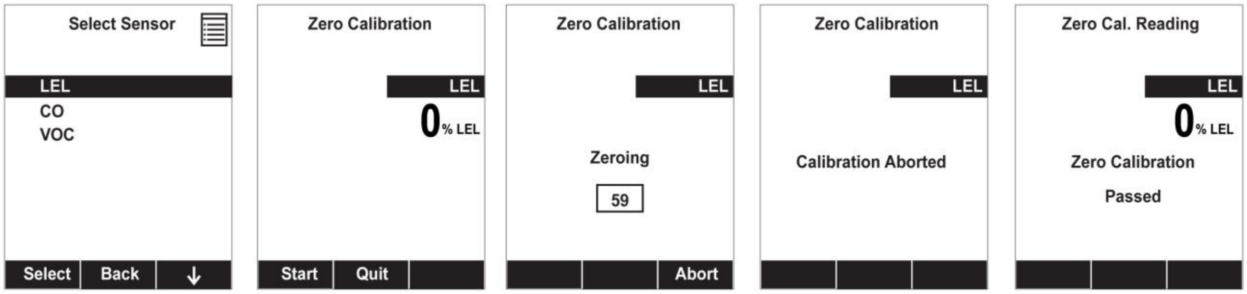
After a timer countdown, the zero calibration is done. The LCD displays the sensor names and tells you whether each calibration passed or failed, followed by the sensor readings.



Note: You can abort the calibration at any time during the countdown by pressing [N/-].

10.3.4 Single-Sensor Zero Calibration

Select the sensor and then start the calibration by pressing [Y/+]. You can abort the procedure anytime by pressing [N/-].



10.4 Span Calibration

This procedure determines the second point of the sensor calibration curve for the sensor.

Note: When a manual calibration is performed, the readings shown are in the equivalent units of the calibration gas, and not the measurement gas.

10.5 Three-Point Calibration For Enhanced Linearity With Extended-Range And ppb PID Sensors

For better linearity at higher concentrations when a MultiRAE is equipped with a PID sensor, a 3-point calibration can be performed.

IMPORTANT!

Three-point calibration is disabled by default, but can be enabled using ProRAE Studio II Instrument Configuration and Data Management software on MultiRAE and MultiRAE Pro instruments with 10.6eV PID sensors, including high-range ppm and ppb PID sensors. The MultiRAE Lite PID sensor does not support three-point calibration.

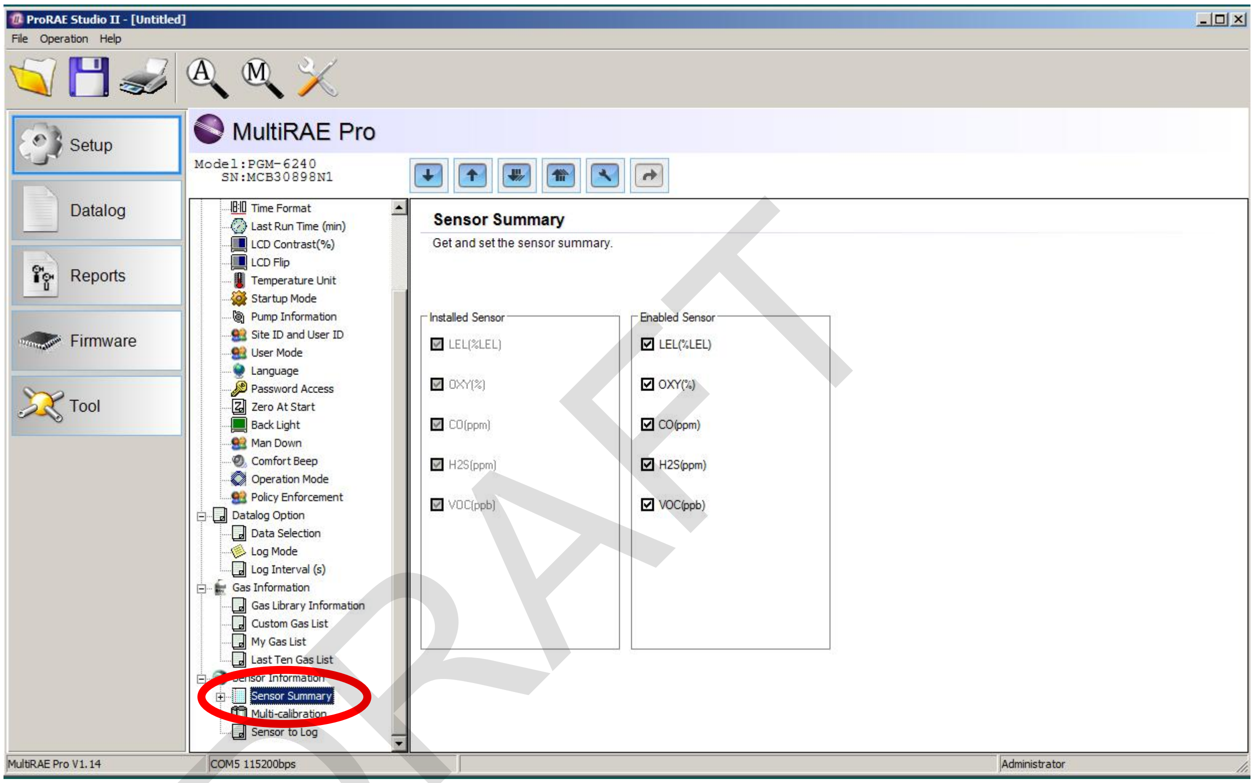
Default calibration gas settings for MultiRAE PID sensors are as follows:

Sensor	Specifications	Zero	Span	Span 2 (Third calibration point, if enabled)
MultiRAE Pro parts-per-billion (ppb) PID	0 to 2,000 ppm range, 10 ppb resolution	With a charcoal filter or VOC zeroing tube	10 ppm Isobutylene	100 ppm Isobutylene
MultiRAE extended-range ppm PID	0 to 5,000 ppm range, 0.1 ppm resolution	Fresh air or dry air	100 ppm Isobutylene	1,000 ppm Isobutylene
MultiRAE Lite PID (same as the ToxiRAE Pro Safety Configuration PID)	0 to 1,000 ppm range, 1 ppm resolution	Fresh air or dry air	100 ppm Isobutylene	Not supported

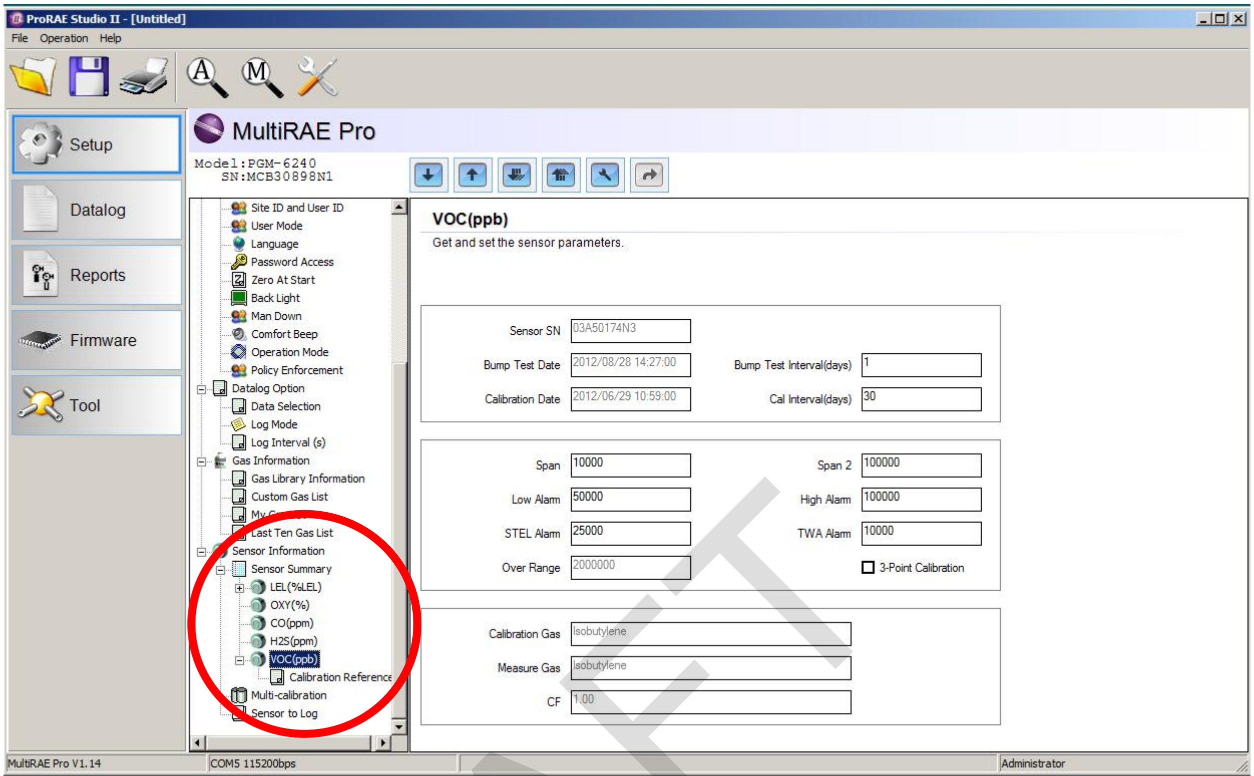
10.5.1 Enabling 3-Point Calibration Via ProRAE Studio II

The MultiRAE must be connected to a PC through the supplied Desktop Cradle, Travel Charger, or AutoRAE 2 and must be in the PC or AutoRAE 2 communications mode.

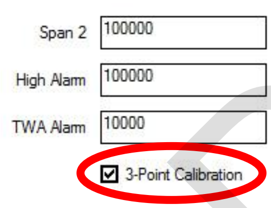
1. Start up the ProRAE Studio II software, enter a password, and detect the instrument following the directions provided in the ProRAE Studio II User's Manual.
2. Click "Setup" to download the MultiRAE's current configuration information.
3. Click "Sensor Summary" to show the list of installed sensors.



4. Click "VOC(ppm)" or "VOC(ppb)" to get and set sensor parameters.



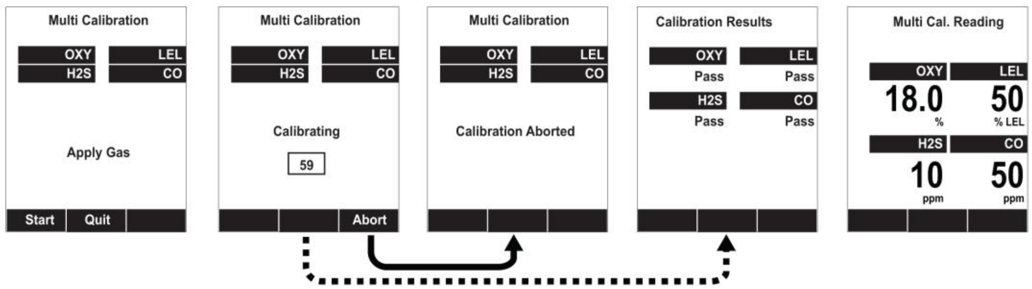
5. Click 3-Point Calibration (the check mark should now be showing).

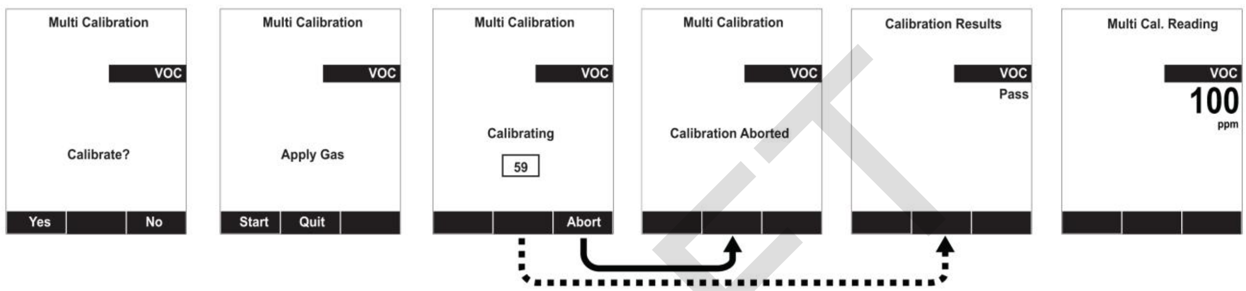


6. Click the "Upload all settings to the instrument" icon. You will be asked whether you want to upload all configurations to the instrument. Click "Yes."
7. When you are done, quit ProRAE Studio II and then press [Y/+] on the MultiRAE to exit the PC communications mode. The instrument returns to operating in Normal mode.

10.5.2 Multi-Sensor Span Calibration

This lets you perform a span calibration on multiple sensors simultaneously. It requires using the appropriate span gas and that the concentration labeled on the gas cylinder matches the concentration programmed in the MultiRAE.





For a multi-sensor span calibration, a constant-flow regulator producing 0.5 to 1 liters per minute should be used, and the calibration cap must be installed on the instrument. Testing and calibration with an AutoRAE 2 must be performed using demand-flow regulators. A calibration cap must not be used. Teflon tubing must be used to test or calibrate the PID sensor. Follow the steps described here to perform a multi-sensor span calibration:

1. Attach the calibration adapter and connect gas to the MultiRAE.
2. Start the flow of gas and then either press [Y/+] to begin calibration or wait for calibration to start automatically once the sensor "senses" the gas. A countdown screen is shown. You can abort the calibration at any time during the countdown by pressing [N/-].

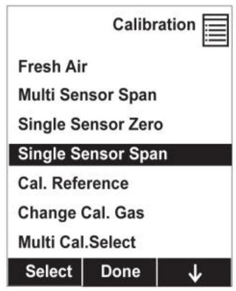
If the calibration reaches its conclusion, it shows the sensor names and tells you whether the calibration passed or failed, followed by the sensor readings.

Note: If there are other sensors to be calibrated at this stage, the screens will guide you through the process.

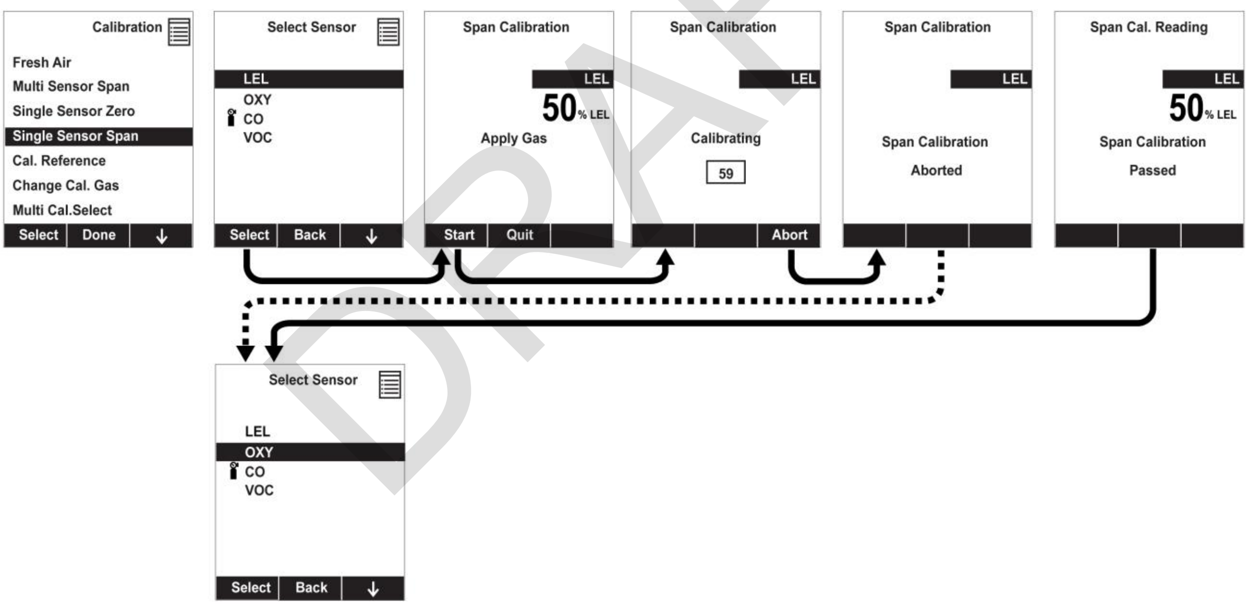
10.5.3 Single-Sensor Span Calibration

To perform span calibration of an individual sensor, follow these steps:

1. At the Calibration Menu, select "Single Sensor Span."
2. Select a sensor from the list.
3. Connect the calibration adapter and connect it to a source of calibration gas.
4. Verify that the displayed calibration value meets the concentration label on the gas cylinder.
5. Start the flow of calibration gas.



6. Press [Y/+] to start calibrating. You can abort the calibration at any time during the countdown by pressing [N/-].



After a timer countdown, the span calibration is done. The LCD will display whether the calibration was successful and the reading for that calibration gas.

Note: If the sensor calibration fails, try again. If calibration fails repeatedly, turn off the instrument and then replace the sensor.

WARNING: Do not replace sensors in hazardous locations.

11 MultiRAE Pro Multi-Threat & Gamma Operation

MultiRAE Pro monitors equipped with a gamma radiation sensor in addition to one or more sensors for detecting chemical threats can operate in three measurement modes:

- **Multi-threat mode**, in which the instrument monitors for both chemical threats and radiation on a sequential basis
- **Radiation-only mode**, in which the instrument continuously monitors for gamma radiation and does not monitor for chemical threats
- **Gas-only mode**, in which the instrument continuously monitors for gaseous threats and not for radiation

The specifics of each operating mode are described in the following sections.

11.1 Multi-Threat Mode For Simultaneous Radiation & Gaseous Threat Measurements

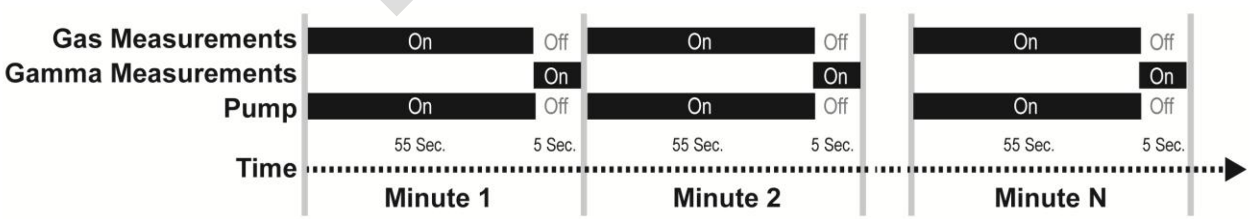
Multi-threat mode is the default mode of MultiRAE Pro's operation. Multi-threat mode is only available on MultiRAE Pro monitors equipped with a gamma radiation sensor, provided the gamma sensor is enabled. The minimum instrument firmware requirements for the gamma sensor are:

- Application firmware: v.1.14 or higher
- Sensor firmware: v.1.04 or higher

When the monitor is turned on, it boots up in multi-threat mode to monitor for both gamma radiation and gaseous threats. Measurements are done in sequence: Gas measurements are taken first, followed by gamma radiation measurements.

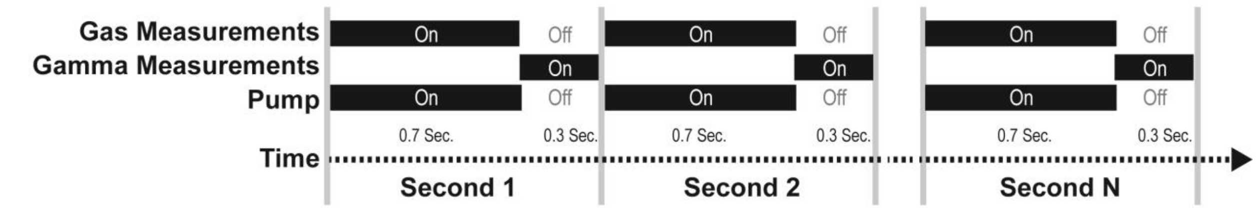
Under alarm-free conditions, gas measurements are taken during 55 consecutive seconds out of every minute, followed by gamma radiation measurements that are taken during the remaining 5 consecutive seconds. When gas measurements are taken, the instrument's internal sampling pump is turned on, and when radiation measurements are taken, the pump is always turned off.
In other words, out of every minute of alarm-free operation, the instrument monitors for gas during the first 55 seconds, followed by the 5 seconds of gamma radiation monitoring, as illustrated below:

MultiRAE Pro Operation in Multi-Threat Mode under Alarm-Free Conditions



If gas or radiation alarm conditions exist (High, Low, Max, Over, STEL, or TWA alarms), the operation pattern switches to a much shorter, one-*second*-long cycle in which gas measurements are taken for 0.7 seconds followed by gamma radiation measurements that are taken during the remaining 0.3 seconds. Like under non-alarm conditions, the pump stays on when gas measurements are taken, but it is turned off when gamma radiation is measured.

MultiRAE Pro Operation in Multi-Threat Mode in Alarm Conditions



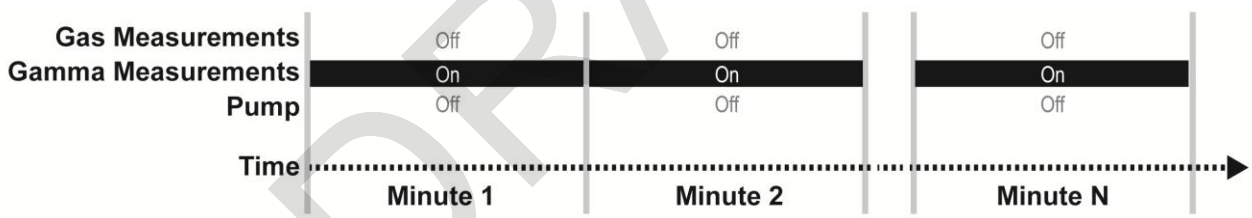
Once alarm conditions subside, the operation pattern returns to the "55 sec. gas / 5 sec. radiation" cycle.

Note: Because of the MultiRAE Pro's intermittent pump operation in multi-threat mode, during the part of the cycle in which the pump is turned off, the PID sensor lamp is automatically cleaned by ozone that forms above the PID lamp crystal (this ozone is removed by the air flow when the pump is running.) This auto-clean feature reduces PID sensor maintenance frequency.

11.2 Gamma Radiation-Only Measurement Mode

When the instrument is in gamma-only mode, gas sensors are not shown on the display and gas measurements are not taken. The pump remains off and gamma radiation is measured all the time in all cases, as illustrated below:

MultiRAE Pro Operation in Gamma-Only Mode



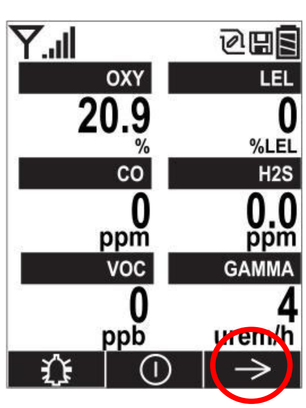
WARNING

Toxic and combustible gases cannot be detected by the MultiRAE when it is operated in gamma-only mode.

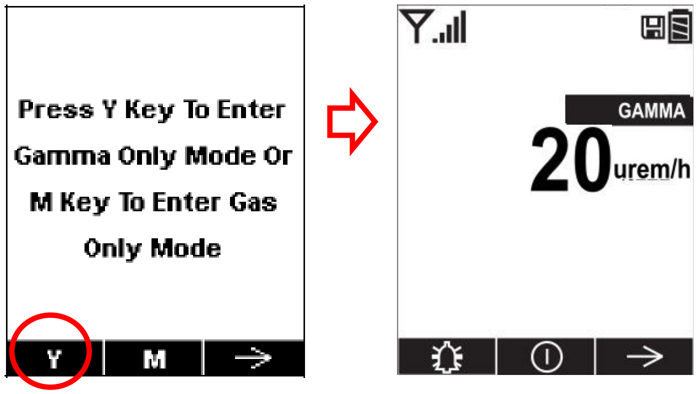
Activating Gamma-Only Measurement Mode

To activate gamma-only measurement mode:

1. Press [N/-] when the instrument is running in normal (multi-threat) mode:



2. Press [Y/+] when the following screen appears:

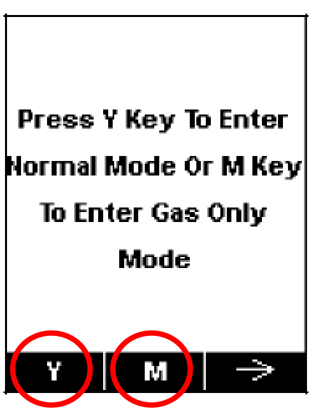


Exiting Gamma-Only Measurement Mode

To exit gamma-only mode and either switch back to multi-threat mode (where both gamma radiation and gaseous threats are measured) or to gas-only mode:

1. Press [N/-] when the instrument is running in gamma-only mode:

2. The following screen appears:



- Press [Y/+] to enter normal (multi-threat) mode.
- Press [MODE] to enter gas-only mode.

11.3 Gas-Only Measurement Mode

The MultiRAE Pro can be switched to gas-only measurement mode. When in this mode, the gamma radiation sensor is not displayed and gamma radiation measurements are not taken. The pump runs constantly, as illustrated below:

MultiRAE Pro Operation in Gas-Only Mode

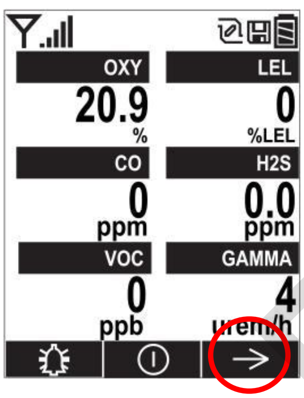
WARNING

Gamma radiation cannot be detected by the MultiRAE when it is operated in gas-only mode.

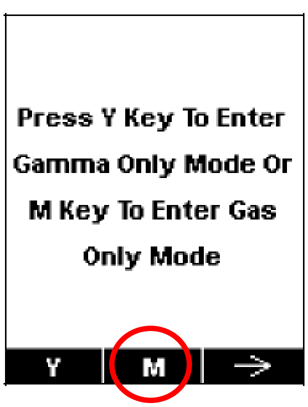
Activating Gas-Only Measurement Mode

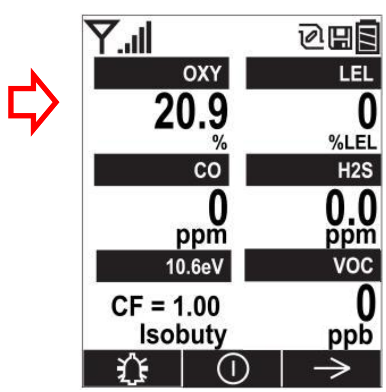
To activate gas-only measurement mode:

1. Press [N/-] when the instrument is running in normal (multi-threat) mode:



2. Press [MODE] when the following screen appears:

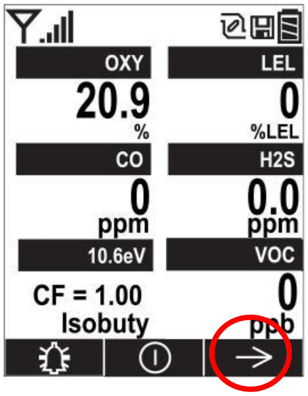




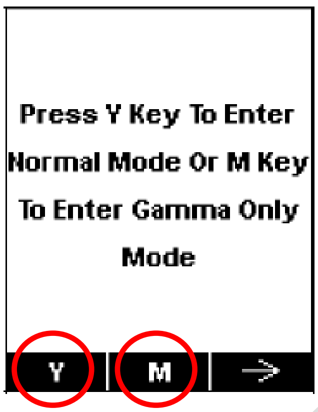
Exiting Gas-Only Measurement Mode

To exit gas-only mode and either switch back to multi-threat mode (where both gamma radiation and gaseous threats) are measured or to gamma-only mode:

1. Press [N/-] when the instrument is running in gas-only mode:



2. The following screen appears:



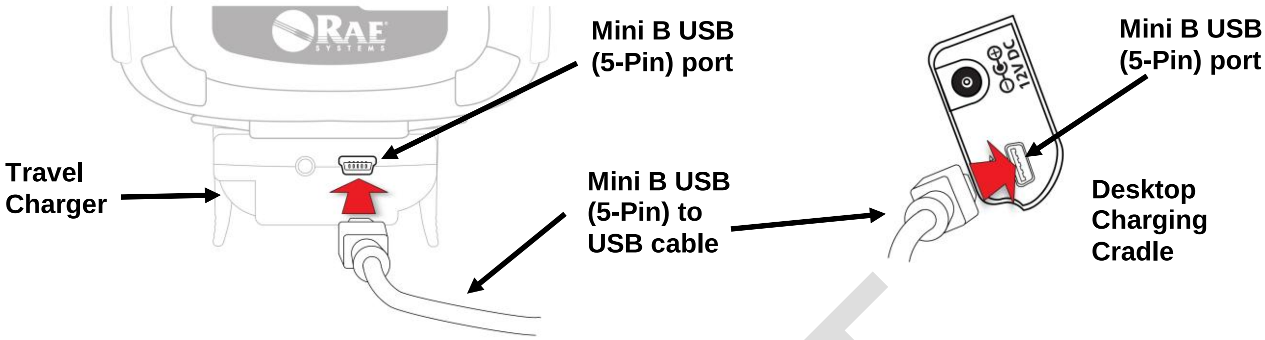
- Press [Y/+] to enter normal (multi-threat) mode.
- Press [MODE] to enter gamma-only mode.

Notes:

- The gamma radiation sensor is always disabled when the MultiRAE Pro is used in Search Mode.
- Radiation dose is not calculated for the gamma sensor.
- If the monitor runs in gamma-only mode for over 20 minutes, TWA is not calculated for gas sensors.
- STEL is reset for gas sensors when the instrument exits gamma-only mode.
- PID sensor auto-cleaning is only performed in multi-threat mode and is not available in either gamma-only or gas-only mode (PID auto-cleaning is done automatically for any MultiRAE with a PID sensor when the monitor is turned off and docked in the desktop charging cradle.)

12 Datalog Transfer, Monitor Configuration, and Firmware Upgrades Via Computer

Datalogs can be downloaded from the MultiRAE to a computer, and firmware updates can be uploaded to the MultiRAE via the USB port on the Travel Charger, Desktop Cradle, or AutoRAE 2. Use the included Mini B USB (5-pin)-to-USB cable to connect the Travel Charger or Desktop Cradle to a computer running ProRAE Studio II or a USB A to USB B cable to connect the AutoRAE 2.



12.1 Downloading Datalogs And Performing PC-Based Instrument Configuration And Firmware Upgrades

The MultiRAE communicates with a PC running ProRAE Studio II Instrument Configuration and Data Management software to download datalogs, configure the instrument, or upgrade the instrument's firmware.

Note: The most recent version of ProRAE Studio II Instrument Configuration and Data Management software is available for a free-of-charge download at: http://www.raesystems.com/downloads/product-software

The MultiRAE must be connected to a PC through the supplied Desktop Cradle, Travel Charger, or AutoRAE 2 and must be in the PC or AutoRAE 2 communications mode.

Desktop Cradle or Travel Charger

1. Use the supplied PC Communications Cable (USB to mini-USB cable) to connect the Desktop Cradle or Travel Charger to a PC.
2. Turn on the MultiRAE. Make sure it is running in Normal mode (with the main measurement screen showing).
3. Insert the MultiRAE in the Desktop Cradle or connect it to the Travel Charger.
4. Activate the PC communications mode on the MultiRAE by pressing [N/-] repeatedly, starting from the main measurement screen until you reach the "Communicate With Computer?" screen.
5. Press [Y/+]. Measurement and datalogging stop, and the instrument is now ready to communicate with the PC. The display now says "Ready To Communicate With Computer."
6. Start up the ProRAE Studio II software, enter a password, and detect the instrument following the directions provided in the ProRAE Studio II User's Guide.
7. Follow the instructions in the ProRAE Studio II User's Guide to download the datalog, configure the instrument settings, or update the MultiRAE's firmware.
8. When you are done, press [Y/+] to exit the PC communications mode on the MultiRAE. The instrument returns to operating in Normal mode.

AutoRAE 2

1. Follow the instructions in the AutoRAE 2 User's Guide to connect the AutoRAE 2 and the PC using the included cable.
2. Make sure the monitor is either turned off or is in AutoRAE 2 Communications Mode.
3. Place the instrument into the cradle face-down, making sure that it is aligned correctly with the contacts on the AutoRAE 2 Cradle's charging port. There are two alignment points on one side and one alignment point on the other side, designed to mate with matching points on the bottom of the MultiRAE.
4. Press in on the capture mechanism to lock the MultiRAE in place.
5. Start up the ProRAE Studio II software, enter a password, and detect the instrument following the directions provided in the ProRAE Studio II User's Guide.
6. Follow the instructions in the ProRAE Studio II User's Guide to download the datalog, configure the instrument settings, or to update the MultiRAE's firmware.
7. When you are done, press [Y/+] to exit the AutoRAE 2 Communications Mode on the MultiRAE. The instrument returns to operating in Normal mode.

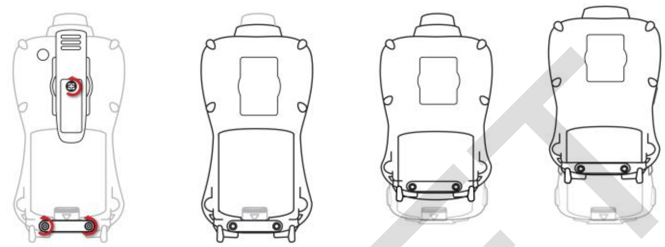
13 Maintenance

The MultiRAE requires little maintenance, aside from replacing sensors, the filter, and the battery. If the instrument is equipped with a pump, it may need replacement, as well. If the instrument has a PID, then the PID sensor lamp and sensor electrode panel may require periodic cleaning.

13.1 Removing/Installing The Rubber Boot

In order to open the MultiRAE, it is necessary to remove the belt clip and the rubber boot. Note that there are two hex screws on the bottom rear side that secure the boot.

1. Remove the belt clip by unscrewing the Philips screw (pumped version only).
2. Remove the two hex screws located below the battery area.
3. Pull the bottom of the boot back over the rear side of the instrument.
4. Carefully slide the boot upward, and slide it over the D-ring and clamp.



13.2 Replacing The Filter(s)

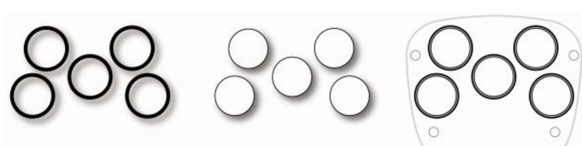
Pumped Version

If a filter is dirty or clogged, remove it by unscrewing it from the black gas inlet adapter. Discard it and replace it with a new filter. Perform a pump stall test to make sure the inlet and the external filter are installed properly so that there are no leaks in the system.

Diffusion Version

If the filters appear dirty, remove the sensor compartment cover to access them (this requires removing the rubber boot first).

Remove the four screws holding the sensor compartment cover in place.

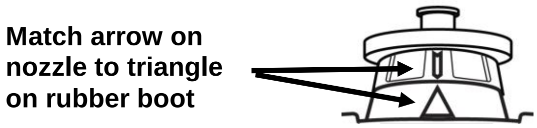


Remove the O-rings and then remove the filters. Replace them with new filters (press around the perimeter of each to ensure that the adhesive holds them firmly) and install the O-rings in their proper locations. O-rings may need to be replaced as well if they appear worn down, cracked, or dirty

Replace the sensor compartment cover and tighten the four screws.

13.3 Replacing The Gas Inlet Adapter (Pumped Versions Only)

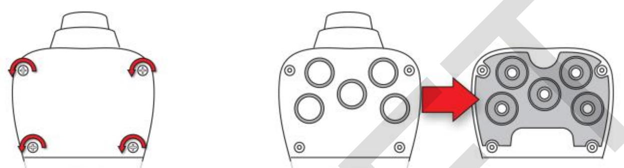
When you remove the black gas inldet adapter, unscrew it in the same manner as the external filter. When replacing it, make sure that the arrow on the front points to the triangle on the rubber boot. Perform a pump stall test to make sure the inlet and the external filter are installed properly so that there are no leaks in the system.



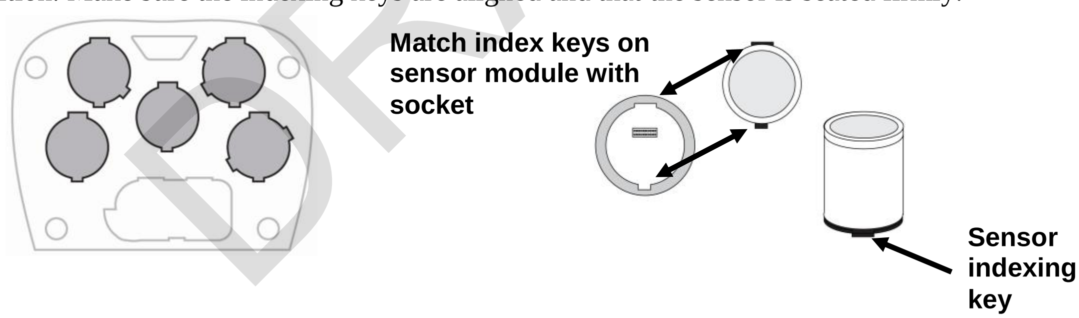
13.4 Removing/Cleaning/Replacing Sensor Modules

WARNING! Do not replace sensors in hazardous locations.

All sensors are located inside the sensor compartment in the upper half of the MultiRAE. They are accessed by removing the cover that is held on by four screws.



1. Turn off the instrument.
2. Remove the four screws holding the sensor compartment.
3. Remove the cover. The sensors are plugged into the slots.
4. Gently lift out the desired sensor module with your fingers.
5. Install the replacement sensor. It can only go into its slot one way. The connector inside the MultiRAE and the indexing guides are good visual indicators of how to set the sensor into position. Make sure the indexing keys are aligned and that the sensor is seated firmly.



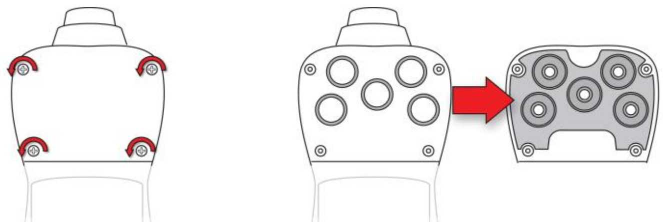
WARNING!

If you are removing a sensor and not replacing it, the slot cannot be left empty. A MultiRAE "dummy" sensor must be installed in such slot.

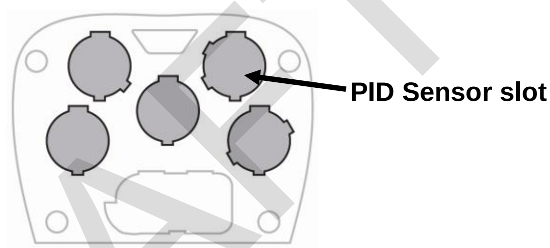
13.5 Removing/Cleaning/Replacing A PID (Pumped Versions Only)

Note: If you need to access a PID for cleaning or replacement, you must remove the rubber boot and belt clip first.

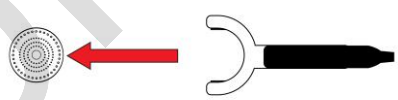
1. Turn off the instrument.
2. Remove the four screws holding the MultiRAE sensor compartment cover in place.
3. Remove the cover to expose the sensors.



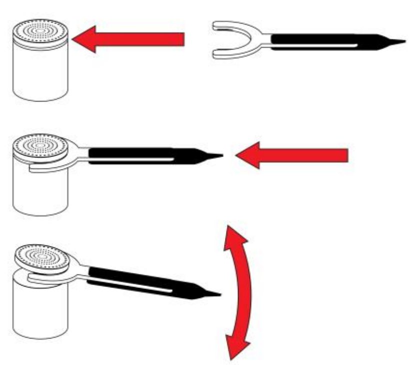
4. Gently lift out the PID module with your fingers.
5. If the module requires replacement (for example, because the lamp does not illuminate, or the sensor repeatedly fails calibrations), place a new module into the slot, being careful to match the indexing keys. The sensor can only go into its slot one way.



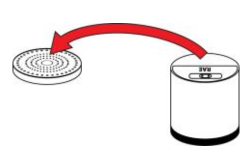
6. If you want to open the sensor module to inspect and clean the lamp and sensor electrode panel, you must use the special tool (part number G02-0306-003, package of three). Its "C"-shaped end has small "teeth" inside. Slide the tool so that the teeth slip into the notch between the module's cap and body:



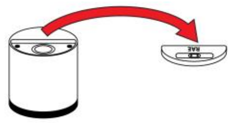
7. Gently pry up the cap using a rocking motion:



8. Once the cap is removed, set it aside.

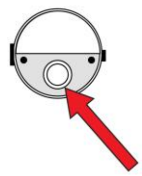


9. Now lift the sensor electrode panel from the module:

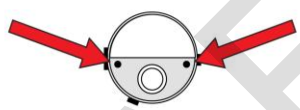


10. Clean the sensor electrode panel (crystal) in a solution of isopropanol or methanol lamp cleaner (included, along with cleaning swabs, in a PID Lamp Cleaning Kit, sold separately), and allow it to dry.

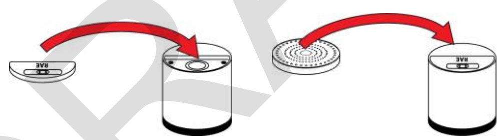
11. Clean the lamp's window with a cleaning swab dipped in isopropanol or methanol lamp cleaner, and allow it to dry. Do not touch the lamp window with your fingers, as the residual oils will affect its performance and shorten its life.



12. Inspect the electrical contacts. Clean them with a swab dipped in lamp cleaner if they appear to need cleaning:



13. Reassemble the sensor module by placing the sensor electrode panel back in place and firmly pressing the cap back onto the top.



14. Place the sensor module back into the MultiRAE. Make sure the index points are aligned (it can only go in one way).
15. Reinstall the rear cover.
16. Tighten all four screws.

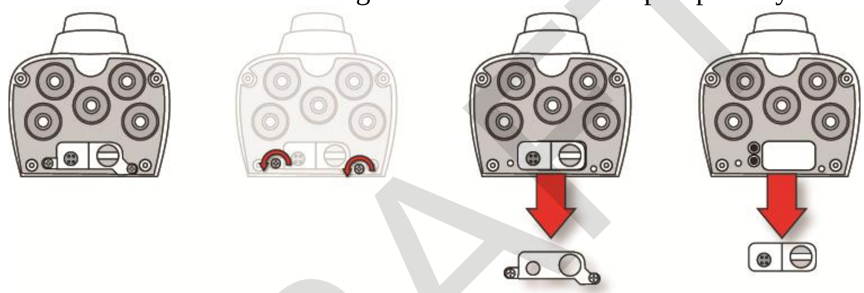
Note: Always calibrate the MultiRAE after replacing the sensor module.

13.6 Replacing The Pump

If your MultiRAE has a pump and it requires replacement, follow these steps. Make sure the rubber boot and the battery are removed before proceeding.

1. Remove the sensor compartment cover.

   Turn it upside down and set it on a soft flat surface.
2. The pump is to the sensor compartment cover by a metal bracket and two Philips screws. Remove the two screws.
3. Lift off the metal bracket.
4. Pressing down on the gas plate with one hand, disconnect the pump from internal tubing by gently pulling it out. It has an inlet and outlet
   that are held in the two holes with rubber gaskets to the left of the pump cavity.



5. Press a new pump into place (a small amount of wiggling helps), making sure that both the inlet and outlet from the pump go into the two holes.
6. Place the metal bracket over the pump.
7. Insert and tighten the two screws that attach the bracket to the housing.
8. Replace the cover.
9. Turn on the instrument and check for proper pump operation.

14 Alarms Overview

The MultiRAE provides an unmistakable five-way alarm notification system that combines local alarms on the device with real-time remote wireless alarm notification (if the instrument is equipped with the optional wireless functionality) to take worker safety to the next level. Local alarms include audible buzzer alarm, visible alarm via bright LED lights, vibration alarm, and an alarm notification on the display. These can be selectively turned on or off.

Note: The vibration alarm is automatically disabled whenever the instrument is run on alkaline batteries.

14.1 Alarm Signals

During each measurement period, the gas concentration and radiation levels are compared with the programmed alarm limits for Low, High, TWA, STEL, and other alarms, as applicable. If the concentration exceeds any of the preset limits, the alarms are activated immediately to warn both the MultiRAE user and a remote safety officer (if wireless is enabled) of the alarm condition. In addition to gas and radiation alarms, Man Down and other alarms are available.

Furthermore, the MultiRAE alarms if one or more of the following conditions occurs: battery voltage low, pump blocked, PID lamp failed, etc.

When the low battery alarm occurs, there may be approximately 10 minutes of operating time remaining. In this case, it is recommended that you promptly change or charge the battery in a non-hazardous location.

14.2 Changing The Alarm Mode

Your choices are Auto Reset and Latched. A latched alarm stays on until you acknowledge the alarm by pressing a button. An auto-reset alarm turns off when the condition that set off the alarm is no longer present (for instance, a high H_2S reading that exceeds the preset threshold and triggers an alarm, but then lowers below that threshold, turning the alarm off).

1. Enter the Alarm Mode sub-menu of the Alarms section under the Programming Menu.
2. Select Auto Reset or Latched by pressing [N/-] to select, and [Y/+] to confirm the choice.
3. Press [Y/+] to save your selection.

14.3 Alarm Signal Summary

Hygiene Mode

Alarm Type	Buzzer & LED	Display	Vibration	Reading	Backlight	Priority
Super Alarm	4 beeps/sec	"Super Alarm" screen	400ms	-	On	Highest
Man Down Alarm	3 beeps/sec	"Man Down Alarm" screen	400ms	-	On	
Man Down Warning	2 beeps/sec	"Are you OK" screen	400ms	-	On	
Fail	3 beeps/sec	"Lamp" at PID location "Off" at LEL location	400ms	Blinking reading	On	
Pump	3 beeps/sec	Blinking pump symbol	400ms	Reading	On	
Max	3 beeps/sec	"Max" at sensor location	400ms	Blinking reading	On	
Over Range	3 beeps/sec	"Over" at sensor location	400ms	Blinking 9999	On	
High	3 beeps/sec	"High" at sensor location	400ms	Reading	On	
Low	2 beeps/sec	"Low" at sensor location	400ms	Reading	On	
Negative	1 beep/sec	"Neg" at sensor location	400ms	0	On	
STEL	1 beep/sec	"STEL" at sensor location	400ms	Reading	On	
TWA	1 beep/sec	"TWA" at sensor location	400ms	Reading	On	
Calibration Fail	1 beep/sec	"Cal" at sensor location	400ms	Reading	On	
Bump Fail	1 beep/sec	"Bump" at sensor location	400ms	Reading	On	
Datalog Full	1 beep/sec	Blinking datalog symbol	400ms	Reading	On	
Calibration Required	-	"Full" Bottle symbol	-	Reading	-	
Bump Required	-	"Empty" Bottle symbol	-	Reading	-	
Battery	1 beep/min	Blinking battery symbol	400ms	Reading	Stays as is	
Nwk Lost	1 beep/min	Blinking RF offline symbol	400ms	Reading	On	
Nwk Joined	1 beep	RF symbol with RSSI	400ms	Reading	On	
Comfort Beep	1 beep/min no LED flash	-	-	Reading	-	Lowest

Notes

"Negative" means that the true sensor reading is below zero, even though a zero reading is shown for the sensor.

"Nwk Lost" means "Network Lost." This indicates that the MuliRAE has lost wireless connectivity with its network.

"Nwk Joined" means that the MultiRAE has joined a wireless network.

Search Mode

Alarm Type		Buzzer & LED	Display	Vibration	Reading	Backlight	Priority
Super Alarm		4 beeps/sec	"Super Alarm" screen	400ms	-	On	Highest
Man Down Alarm		3 beeps/sec	"Man Down Alarm" screen	400ms	-	On	↑
Man Down Warning		2 beeps/sec	"Are You OK?" screen	400ms	-	On	
Fail		3 beeps/sec	"Lamp" at PID location "Off" at LEL location	400ms	Blinking reading	On	
Pump		3 beeps/sec	Blinking pump symbol	400ms	Reading	On	
Max		3 beeps/sec	"Max" at sensor location	400ms	Blinking reading	On	
Over Range		3 beeps/sec	"Over" at sensor location	400ms	Blinking 9999	On	
Geiger Counter-style Alarm	G7 (>High)	7 beeps(30ms)/sec	No change	400ms	Reading	On	
	G6	6 beeps(40ms)/sec					
	G5	5 beeps(50ms)/sec					
	G4	4 beeps(60ms)/sec					
	G3	3 beeps(70ms)/sec					
	G2	2 beeps(80ms)/sec					
	G1 (>Low)	1 beep(90ms)/sec					
Negative		1 beep/sec	"Neg" at sensor location	400ms	0	On	
STEL		1 beep/sec	"STEL" at sensor location	400ms	Reading	On	
TWA		1 beep/sec	"TWA" at sensor location	400ms	Reading	On	
Calibration Fail		1 beep/sec	"Cal" at sensor location	400ms	Reading	On	
Bump Fail		1 beep/sec	"Bump" at sensor location	400ms	Reading	On	
Datalog Full		1 beep/sec	Blinking datalog symbol	400ms	Reading	On	
Calibration Required		-	"Full" bottle symbol	-	Reading	-	
Bump Required		-	"Empty" bottle symbol	-	Reading	-	
Battery		1 beep/min	Blinking battery symbol	400ms	Reading	Stays as is	
Nwk Lost		1 beep/min	Blinking RF offline symbol	400ms	Reading	On	
Nwk Joined		1 beep	RF symbol with RSSI	400ms	Reading	On	↓
Comfort Beep		1 beep/min No LED flashing	-	-	Reading	-	Lowest

General Alarms

Message	Condition	Alarm Indications
HIGH	Gas exceeds "High Alarm" limit	3 beeps/flashes per second
OVR	Gas exceeds sensor's measurement range	3 beeps/flashes per second
MAX	Gas exceeds electronic circuit's maximum range	3 beeps/flashes per second
LOW	Gas exceeds "Low Alarm" limit*	2 beeps/flashes per second
TWA	Gas exceeds "TWA" limit	1 Beep/flash per second
STEL	Gas exceeds "STEL" limit	1 Beep/flash per second
Crossed pump icon flashes	Inlet blocked or pump failure	3 beeps/flashes per second
"Lamp" flashes	PID lamp failure	3 beeps/flashes per second
Empty battery icon flashes	Low battery	1 flash, 1 beep per minute
CAL	Calibration failed, or needs calibration	1 beep/flash per second
NEG	True sensor reading is below zero, even though a zero reading is shown for the sensor.	1 beep/flash per second

* For oxygen, "low alarm limit" means a concentration is lower than the low alarm limit.

15 Troubleshooting

Problem	Possible Reasons & Solutions
Cannot turn on power after charging the battery	**Reasons:** Defective charging circuit. Defective battery. **Solutions:** Replace battery or charger. Try another charge of battery.
Lost password	**Solutions:** Call Technical Support at +1 408-952-8461 or toll-free at +1 888-723-4800
Buzzer, LED lights, and vibration motor inoperative	**Reasons:** Buzzer and/or other alarms disabled. Bad buzzer, LED lights, PCB, or vibration motor(s). **Solutions:** Check under "Alarm Settings" in Programming Mode that buzzer and/or other alarms are not turned off. Call authorized service center.
"Lamp" message when power on. Lamp alarm.	**Reasons:** Low ion concentration inside PID lamp especially in cold environment when first powered on. Defective PID lamp or defective circuit. **Solutions:** Turn the unit off and back on. Replace UV lamp.
Pump failed message. Pump alarm.	**Reasons:** Inlet probe blocked. Direct connection to a gas outlet while the gas value is turned off. Water trap filter sucks in water. Water trap filter too dirty. Water condensed along the inlet probe. Bad pump or pump circuit. **Solutions:** Remove the blocking objects and then press [Y/+] key to reset the pump alarm. Replace contaminated water trap filter. Be careful not to allow water condensation inside the unit. Replace the pump.

If you need replacement parts, a list is available online:

www.raesystems.com

16 Specifications

Instrument Specifications

Size	7.6" H x 3.8" W x 2.6" D (193 x 96.5 x 66 mm)
Weight	Pumped models: 31 oz. (880 g) Diffusion models: 26.8 oz. (760 g)
Sensor	Over 25 intelligent interchangeable field-replaceable sensors, including Gamma radiation, ppb and ppm PIDs, electrochemicals for toxics and oxygen, combustible LEL and NDIR, and CO_2 NDIR
Battery Options	• Rechargeable Li-ion (over 12 hours runtime, pumped/over 18 hours, diffusion; < 6 hours recharge time) • Extended-duration rechargeable Li-ion (over 18 hours runtime, pumped; over 27 hours, diffusion) • Alkaline adapter for 4 x AA batteries (approximately 6 hours runtime, pumped/ 8 hours, diffusion)
Display	• Monochrome graphical LCD display (128 x 160) with backlighting (activated automatically in dim ambient lighting conditions, when monitor is in alarm, or with a button press) • Automatic screen flipping.
Display Readout	• Real-time reading of gas concentrations; PID measurement gas and correction factor; battery status; datalogging on/off; wireless on/off and reception quality. • STEL, TWA, peak, and minimum values • Various instrument status-related information
Keypad	3 operation and programming keys (MODE, Y/+, and N/-)
Sampling	Built-in pump or diffusion. Average flow rate, pumped: 250 cc/min. Auto shutoff in low-flow conditions
Calibration	Automatic with AutoRAE 2 Test and Calibration Station or manual
Alarms	• Wireless remote alarm notification; multi-tone audible (95 dB @ 30 cm), vibration, visible (flashing bright red LEDs), and on-screen indication of alarm conditions • Man Down Alarm with pre-alarm and real-time remote wireless notification
Datalogging	• Continuous datalogging (six months for 5 sensors at 1-minute intervals, 24/7) • User-configurable datalogging interval (from 1 to 3,600 seconds)
Communication and Data Download	• Data download and instrument set-up and upgrades on PC via charging and PC communication cradle, Travel Charger, or AutoRAE 2 Automated Test and Calibration Station[1] • Wireless data and status transmission via built-in RF modem (optional)
Wireless Network	RAE Systems Dedicated Wireless Network
Wireless Frequency	ISM license-free bands
EM Immunity	No effect when exposed to $0.43 mW/cm^2$ RF interference (5-watt transmitter at 12")
Operating Temperature	-4° to 122° F (-20° to 50° C)

Instrument Specifications

continued

Humidity	0% to 95% relative humidity (non-condensing)
Dust and Water Resistance	IP-65 (pumped), IP-67 (diffusion)
Hazardous Location Approvals	Exia Class I, Division 1, Groups A, B, C, D, T4 SIRA 11ATEX2152X, 0575 II 1G Ex ia IIC T4 Ga (for PGM62x0/PGM62x6) SIRA 11ATEX2152X, 0575 II 2G Ex ia d IIC T4 Gb (for PGM62x8) UM=20V IECEx SIR 11.0069X, Ex ia IIC T4 Ga (for PGM62x0/PGM62x6) IECEx SIR 11.0069X, Ex ia d IIC T4 Gb (for PGM62x8)
CE Compliance (European Conformity)	EMC directive: 2004/108/EC R&TTE directive: 1999/5/EC ATEX directive: 94/9/EC
FCC Compliance	FCC Part 15
Performance Tests	LEL CSA C22.2 No. 152; ISA-12.13.01
Languages	Arabic, Chinese, Czech, Danish, Dutch, English, French, German, Indonesian, Italian, Japanese, Korean, Norwegian, Polish, Portuguese, Russian, Spanish, Swedish, and Turkish
Warranty	• Two years on non-consumable components and catalytic LEL, CO, H_2S, and O_2 sensors • One year on all other sensors, battery, and other consumable parts

Specifications are subject to change.

Sensor Specifications

Radiation Sensor	Range	Resolution
Gamma	0 to 20,000 µRem/h	1 µRem/h
PID Sensors	**Range**	**Resolution**
VOC 10.6 eV (HR) VOC 10.6 eV (LR)* VOC 10.6 eV (ppb) VOC 9.8 eV	0.1 to 5,000 ppm 1 to 1,000 ppm 10 ppb to 2,000 ppm 0.1 to 1,000 ppm	0.1 ppm 1 ppm 10 ppb 0.1 ppm
Combustible Sensors	**Range**	**Resolution**
Catalytic bead LEL NDIR (0-100% LEL Methane) NDIR (0-100% Vol. Methane)	0 to 100% LEL 0 to 100% LEL 0 to 100% Vol.	1% LEL 1% LEL 0.1% Vol.
Carbon Dioxide Sensor	**Range**	**Resolution**
Carbon Dioxide (CO_2) NDIR	0 to 50,000 ppm	100 ppm
Electrochemical Sensors	**Range**	**Resolution**
Ammonia (NH_3)	0 to 100 ppm	1 ppm
Carbon Monoxide (CO) Carbon Monoxide (CO), Ext. Range Carbon Monoxide (CO), H_2-comp. Carbon Monoxide (CO) + Hydrogen Sulfide (H_2S) Combo	0 to 500 ppm 0 to 2,000 ppm 0 to 2,000 ppm 0 to 500 ppm 0 to 200 ppm	1 ppm 10 ppm 10 ppm 1 ppm 0.1 ppm
Chlorine (Cl_2)	0 to 50 ppm	0.1 ppm
Chlorine Dioxide (ClO_2)	0 to 1 ppm	0.03 ppm
Ethylene Oxide (EtO-A) Ethylene Oxide (EtO-B) Ethylene Oxide (EtO-C), Ext. Range	0 to 100 ppm 0 to 10 ppm 0 to 500 ppm	0.5 ppm 0.1 ppm 10 ppm
Formaldehyde (HCHO)	0 to 10 ppm	0.01 ppm
Hydrogen (H_2)**	0 to 1,000 ppm	2 ppm
Hydrogen Sulfide	0 to 100 ppm	0.1 ppm
Hydrogen Sulfide (H_2S), Ext. Range*	0 to 1,000 ppm	1 ppm
Hydrogen Cyanide (HCN)	0 to 50 ppm	0.5 ppm
Methyl Mercaptan (CH_3-SH)	0 to 10 ppm	0.1 ppm
Nitric Oxide (NO)	0 to 250 ppm	0.5 ppm
Nitrogen Dioxide (NO_2)	0 to 20 ppm	0.1 ppm
Oxygen (O_2)	0 to 30% Vol.	0.1% Vol.
Phosphine (PH_3)	0 to 20 ppm	0.1 ppm
Sulfur Dioxide (SO_2)	0 to 20 ppm	0.1 ppm

* Supported in MultiRAE Lite Pumped version only.
** Supported in Diffusion version only.

All specifications are subject to change without notice.

LEL Range, Resolution & Response Time

LEL 0-100% 1 % 15 sec

LEL Cross-Sensitivity

Compound	LEL Relative Sensitivity*	LEL CF
Methane	100	1.0
Propane	62	1.6
Propene	67	1.5
n-Butane	50	2.0
Isobutylene	67	1.5
n-Pentane	45	2.2
n-Hexane	43	2.3
Cyclohexane	40	2.5
Benzene	45	2.2
Toluene	38	2.6
n-Heptane	42	2.4
n-Octane	34	2.9
Turpentine	34	2.9
Leaded Gasoline	48	2.1
Methanol	67	1.5
Ethanol	59	1.7
Isopropanol	38	2.6
Acetone	45	2.2
Methyl Ethyl Ketone	38	2.6
Ethyl Acetate	45	2.2
Carbon Monoxide	75	1.2
Hydrogen	91	1.1
Ammonia	125	0.80

* Response of the RAE Systems LEL sensor to a range of gases at the same LEL, expressed as percent of methane response (=100). These figures are for guidance only and are rounded to the nearest 5%. For the most accurate measurements, the instrument should be calibrated with the gas under investigation. See RAE Systems Technical Note TN-156 for more details and other compounds.

Caution:
Refer to RAE Systems Technical Note TN-144 for LEL sensor poisoning.

Year Of Manufacture

To identify the year of manufacture, refer to the serial number of the instrument.

The second to last digit in the serial number indicates the year of manufacture. For example, "M" indicates the manufacturing year is 2010.

First digit	Year
J	2008
K	2009
M	2010
N	2011
P	2012
Q	2013
R	2014
S	2015
T	2016
U	2017
V	2018
W	2019

17 Technical Support

To contact RAE Systems Technical Support Team:

Monday through Friday, 7:00AM to 5:00PM Pacific (US) Time
Phone (toll-free): +1 888-723-4800
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Email: tech@raesystems.com

Critical after-hours support is available:
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18 RAE Systems Contacts

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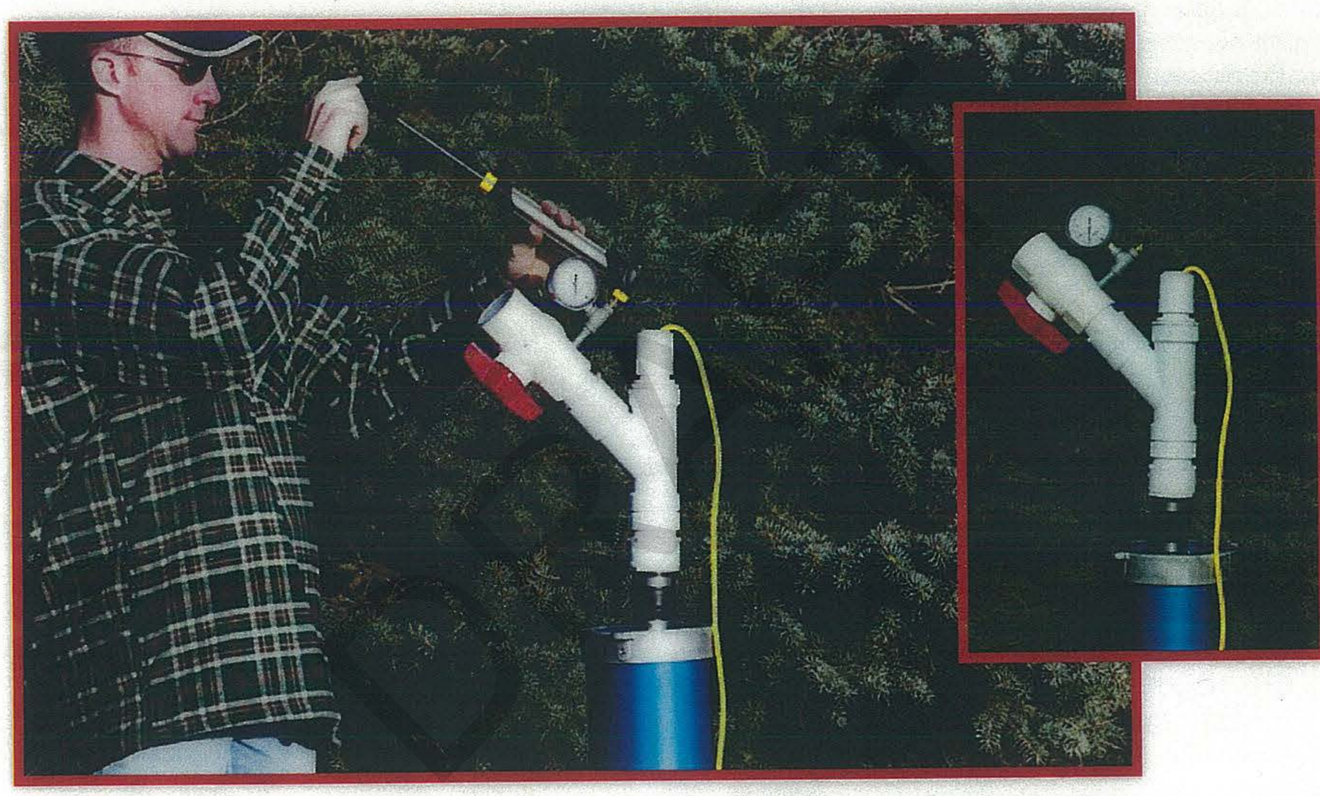
Web Site: www.raesystems.com

Rev C
May 2013
P/N: M01-4003-000

General Instructions for Using Pneumatic Slug to Run a Slug Test

1. The Pneumatic Slug uses air pressure to displace water in a well for a slug test.
2. The Pneumatic Slug can only be used if the water level extends above the top of the screen and remains above the top of the screen throughout the test.
3. The Pneumatic Slug can only be used to conduct rising head slug tests.
4. The Pneumatic Slug works best for slug tests in wells that recover quickly.



EQUIPMENT LIST

1. PNEUMATIC SLUG ASSEMBLY
2. VALVE ASSEMBLY WITH GAUGE (in. or cm.)
3. COMPRESSION COUPLING ASSEMBLY
4. PIPE CLAMPS (4 INCH, 2 INCH AND 3/4 INCH OPTIONS)
5. OFFSET SCREWDRIVER
6. TEFLON TAPE
7. HAND PUMP
8. CARRYING CASE
9. INSTRUCTION SHEET

Users agree to defend, indemnify and hold harmless Midwest GeoSciences Group, its owners, managers, officers, directors, agents, and affiliates from any damages or charges resulting from the use of the equipment. Users liability shall include all losses, costs, damages, or expenses arising from any use, accident, bodily injury, or other occurrences to any persons or properties, including the users and their agents which arise from the equipment, proper use or otherwise.

Step 1 - Assembly

ASSEMBLY AND OPERTING INSTUCTIONS

1. Apply Teflon tape to the male threads of the parts to be assembled.
2. Thread the Valve Assembly onto the Pneumatic Slug Assembly.
3. Choose the proper size Well Coupling Assembly to match the well casing diameter. The unit can fit a 4-inch, 2-inch and ¾-inch well pipe diameter.
4. Thread the Well Coupling Assembly onto the Pneumatic Slug Assembly.

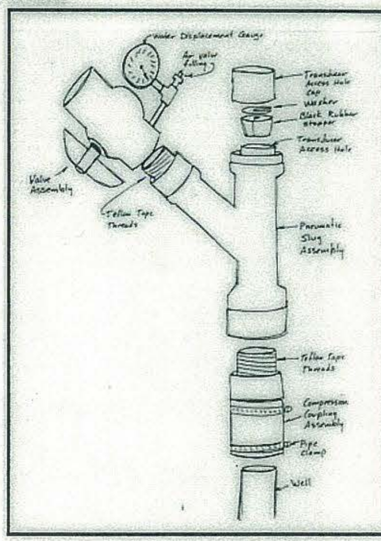
PNEUMATIC midwest GEOSCIENCES group www.midwestgeo.com HI-K SLUG tm

Step 2 - Attach the Pneumatic Slug to the Well

1. Loosen the pipe clamp and slide the Well Coupling Assembly onto the well.
2. Tighten the pipe clamp until secure and air tight.

Step 3 - Insert the Transducer

1. Unscrew the Transducer Access Hole Cap and remove the Rubber Stopper from the Transducer Access Hole.
2. Insert the transducer through the Transducer Access Hole Cap with the treaded end of the Transducer Access Hole Cap facing toward the Pneumatic Slug.
3. Insert the transducer into the Transducer Access Hole, and lower the transducer to the desired depth.
4. Insert the transducer cable into the hole in the Black Rubber Stopper so that the smaller end of the Black Rubber Stopper is facing the Pneumatic Slug. The Black Rubber Stopper has a slit in the side to allow the transducer cable to be inserted into the hole.
5. Insert the Black Rubber Stopper into the Transducer Access Hole.
6. Screw the Transducer Access Hole Cap over the Rubber Stopper to hold the stopper in place.
7. Read the transducer depth.
8. Set up the data logger as required to run the test.

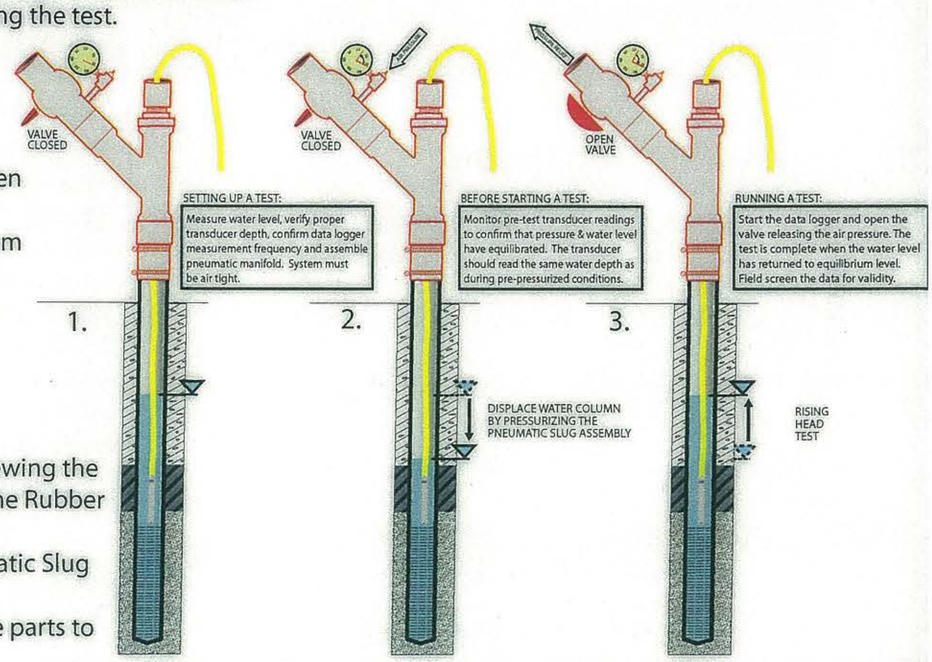


Step 4 - Displace Water Column in the Well

1. Close the valve.
2. Attach the Air Pump to the Air Valve Fitting.
3. Pump air into the well until the desired displacement is achieved. Note that the Water Displacement Gauge reads in inches of water. Do not apply too much pressure as it may damage the pressure gauge and may cause the pneumatic slug to be blown off the well.
4. Read the transducer. Once the pressure/water level has equilibrated, it should read the same water depth as during static conditions. If the transducer does not read the same depth, wait until it does to ensure static conditions prior to starting the test.
5. Remove the Air Pump.

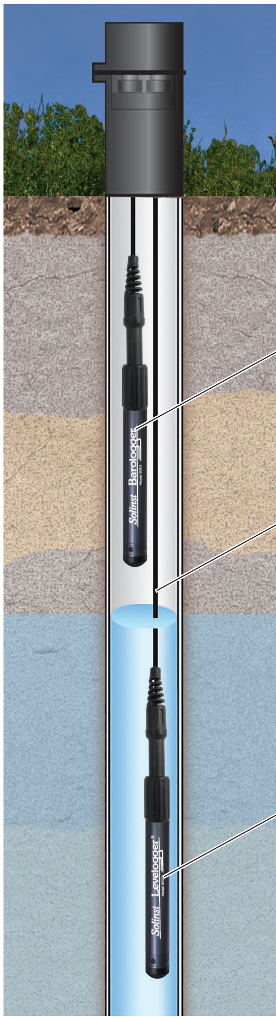
Step 5 - Run the Slug Test

1. Start the data logger and then immediately open the valve to release the air pressure.
2. When the water level has returned to equilibrium level, the test is complete.
3. Review the slug test data to ensure a valid test. Repeat the test as desired.



Step 6 - Remove the Pneumatic Slug

1. Remove the transducer from the well by unscrewing the Transducer Access Hole Cap, removing the Rubber Stopper, and removing the transducer.
2. Loosen the pipe clamp and remove the Pneumatic Slug from the well casing.
3. Disassemble the Pneumatic Slug and return the parts to the toolbox.



Barologger Suspended in Air

Typically 1 Barologger per 30 km (20 mile) radius and/or every 300 m (1000 ft.) of elevation change from well to well

Direct Read Cable

Lengths up to 1500 ft. (450 m)

Submerged Levelogger

Direct Read Cable Deployment

Use this method when you want direct communication with your Levelogger while it is deployed, and to view real-time readings. Deploy with Direct Read Cables using a Solinst 2" (4" with reducer) Lockable Well Cap.

Direct Read Communication

Pre-program Leveloggers in the office using an Optical Reader. In the field use a laptop and PC Interface Cable, to program, view or download data. **The Direct Read Communication Package** from Solinst includes an Optical reader, PC Interface Cable and Levelogger Software & User Guide CD.

The Solinst 2" Lockable Well Cap has openings for two Direct Read Cables and an opening for other monitoring equipment, such as a Water Level Meter.

Levelogger App Interface connected to a Direct Read Cable provides a wireless Bluetooth® connection between the Levelogger and the Solinst Levelogger App on your iOS or Android™ smart device, for programming or downloading data.

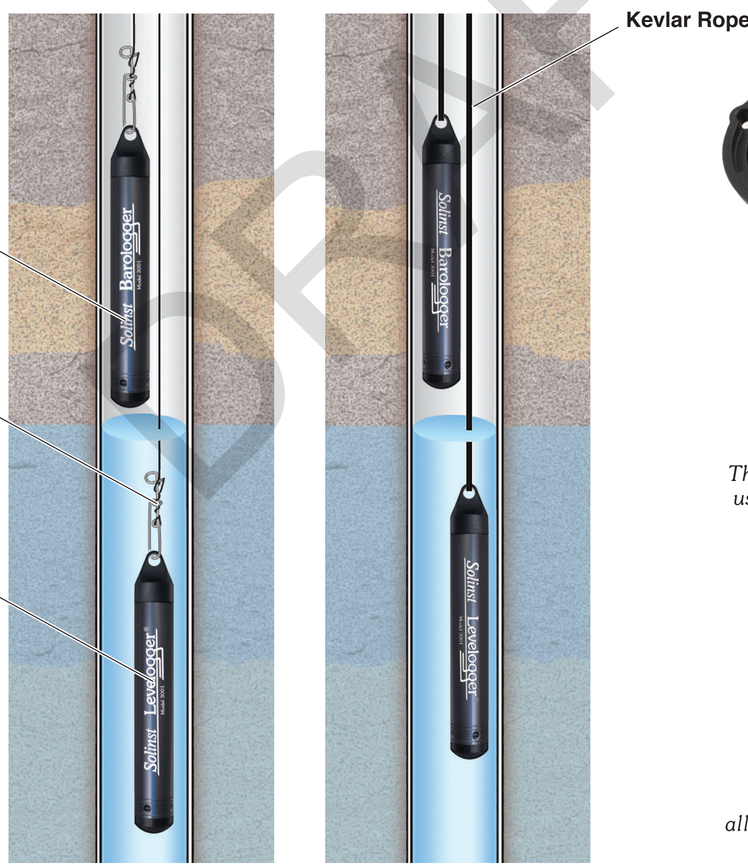
DataGrabber connected to a Direct Read Cable allows Levelogger data to be copied to a USB memory key.

Wireline/Rope Deployment

Use this method when you wish to minimize up front costs, and pre-program Leveloggers in the office. Lower into the well, suspended on wireline or Kevlar cord from a Solinst 2" (4" with reducer) Lockable Well Cap.

Standard Communication

To retrieve data or re-program, remove the Levelogger from the well and use an Optical Reader attached to a portable or office computer. **The Standard Communication Package** from Solinst includes an Optical Reader and Levelogger Software & User Guide CD.



The Solinst Lockable 2" Well Cap when used with a stainless steel wireline and hook, or a Kevlar Cord.

A Direct Read to Optical Adaptor allows direct connection of a Levelogger to a Levelogger App Interface or DataGrabber for programming or downloading data in the field.

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Quick Start Guide

Levelogger Series

High Quality Groundwater and Surface Water Monitoring Instrumentation

Solinst®

To begin using your Levelogger, download the newest version of Levelogger Software and User Guide by visiting: www.solinst.com/downloads/ or insert the software CD provided.

Installing the Software

1. To activate the software install, click on the 'setup.exe' file located on the software CD.
2. The Software Installation Wizard will guide you through the remaining installation process.

Installing the Hardware

3. Connect the communications device, either the Optical Reader or PC Interface Cable, to the computer.

Note: USB connections require installation of a driver to the assigned device. See the USB Installation Guide for details.

USB Installation Guide

Notes: 1. Levelogger Software comes preloaded with the necessary USB drivers.
2. The following steps are based on the Windows® 7 operating system, if using another operating system, refer to the Levelogger User Guide.

1. Plug the USB device into the computer, this will begin the 'Found New Hardware Wizard'. The USB driver installation may occur automatically, if not, follow steps 2-4 below.

Note: If the 'Found New Hardware Wizard' fails to start, refer to the Manual USB Installation instructions below.

2. Select "Browse my computer for driver software".
3. Click the 'Browse' button and choose this location:
   C:\Program Files\Solinst\Levelogger 4_1\USB Drivers
   Click, 'Next'.
4. A warning message may prompt that the software has not passed the Windows Logo Test. Select "Continue Anyway". This will complete the installation process. A system restart may be required. Repeating the steps may be necessary to complete the installation.

PC Interface Cable

Optical Reader Connection

Manual USB Installation

If your device is plugged in and the Found New Hardware Wizard fails to start, then follow these steps:

1. Open the Device Manager. Typically this is found through the path:
   Start > Control Panel > System > Hardware and Sound > Device Manager

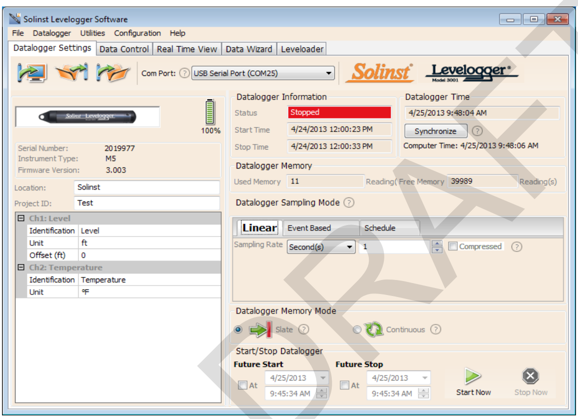
Note: If you are unsure which is the correct device in the list, with the screen visible, safely remove the device and then reconnect it. The list should automatically refresh accordingly.

2. Identify the Solinst device from the list. The device will be categorized under 'Other Devices' or 'Universal Serial Bus Controllers' (look for yellow warning icon).
3. Highlight the device in the list and right click. You will see an option to "Update the driver". This will start the 'Update Driver Software Wizard'. Follow steps 2-4 above to install the USB driver. You may have to repeat the steps to install the USB Serial Port.
4. Once installed, the Com Port number will appear in Device Manager under 'Ports (Com &LPT)'.

Programming the Levelogger

Note: Ensure the Levelogger is operating with the latest firmware, and that you are using the latest software. Visit the Solinst website or software update feature for assistance.

1. Connect the Levelogger to the communications device and start the Software.
2. Select the appropriate COM or USB port for the connected communications device from the centre drop-down menu.
3. Click the 'Retrieve Settings from Levelogger' icon. This will retrieve and display the current programmed settings for the connected Levelogger.
4. You can now customize the Levelogger including your Project ID, Location, Sampling Mode and Rate, and Future Stop and Start times.



Datalogger Settings Window

Note: Clicking on the ? embedded in the software will provide you with a short explanation of that feature, e.g. Com Port, Slate Mode, Time Synchronization, etc.

Starting and Stopping the Levelogger

1. If desired, enter a Future Start and/or Future Stop Time.
2. When the 'Start' icon is selected, all settings are applied to the Levelogger and it will start logging at the specified time.
3. To start logging immediately, do not fill in the Future Start field, and click the 'Start Now' icon.

Note: When the 'Start' icon is selected, a window will pop-up as an alert that the previous data will be erased.

4. To stop the Levelogger immediately, click the 'Stop Now' icon.

Tip

If a number of Leveloggers are to be programmed with identical inputs, clicking the 'Save Default Settings' icon will create a template.

Rainlogger Programming

The Rainfall Calibration Constant 'value' of the tipping bucket rain gauge used with the Rainlogger is required when programming the Rainlogger. Consult the Levelogger User Guide for more information on programming the Rainlogger Edge.

LTC Calibration

Before deploying your LTC Levelogger Junior, be sure to calibrate the instrument. To begin calibration, open the 'Conductivity Cal' tab and follow the steps provided. Consult the Levelogger User Guide for more information.

Tip

The 'future start' and 'future stop' options are ideal for synchronizing the data collection of multiple Leveloggers.

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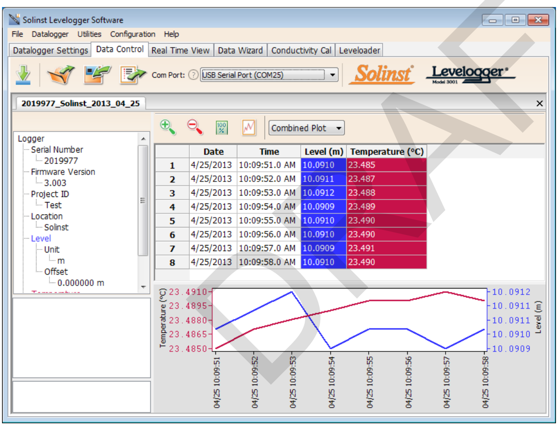
Downloading and Working with Data

1. Click the 'Data Control' tab to access the 'Data Control' window. This window is laid out in three sections: Levelogger settings, tabular data, and graphical data.
2. To download the data from a connected Levelogger, select the 'Download Data from Levelogger' icon. There are four options for downloading data. They are: All Data, Append Download, Partial Download and Recover Previous Log. The data will be presented in both tabular and graphical format.

> **Note:** The default directory for downloaded and saved data is in the 'Data' folder:
> <C:\Program\Files\Solinst\Levelogger 4_1\Data>.
> Data is saved as a .xle data file.

3. To save data, click the 'Save Data' icon and input desired name for the saved file.
4. To export the file for use in other software, click the 'Export' icon. The file can be exported to a *.csv or *.xml file.



Data Control Window

Note

To change the default directory for downloaded data, use the 'Configuration' menu at the top of the software window. Select 'Application Settings' and input or navigate to a different folder destination. Click 'OK'.

Tip

*The *.csv and *.xml file formats are supported and can be imported by most spreadsheet and database programs.*

*The data graph can be exported to a *.bmp file or a *.png file by clicking File > Export > Graph.*

DataGrabber

Connect a DataGrabber to an in-field Levelogger via a Direct Read Cable or Adaptor, and transfer data to a USB key.

Real Time View

Real Time View provides on-screen measurement as data is being recorded by the connected datalogger. A view rate is set independently of the logging period of the Levelogger and does not interfere with internal logging taking place. To take a reading at any specific time, click and that reading will be added to the displayed data. The data can be exported and saved.

Compensate the Data

Click the 'Data Wizard' tab to open the 'Data Wizard' window. In this window the 'Wizard' will guide you through Barometric Compensation, Manual Data Adjustments, and Parameter Adjustments on your open data files. There are two convenient options; Basic or Advanced compensation. This allows you to choose just one, two, or all three types of compensation. Multiple Levelogger files can be barometrically compensated at once, using one open Barologger file.

Tip

'Manual Data Adjustment' allows you to use manual water level measurements to adjust your data to depth to water readings.

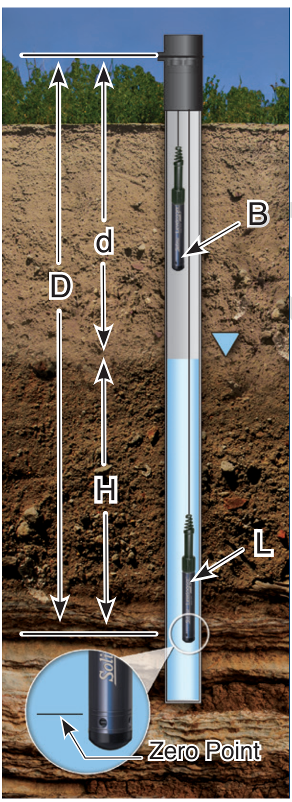
Levelogger Edge Field Measurement

Levelogger Edge Ranges

Each model of Levelogger is rated for a specific submergence depth (Table 1). The choice of model largely depends on the accuracy of the water level required and the submergence depth. The selection, however, should be based on the maximum anticipated water level fluctuation.

Model	Submergence Depth	Accuracy
Barologger	Air only	± 0.05 kPa
F15, M5	16.4 ft., 5 m	± 0.010 ft., 0.3 cm
F30, M10	32.8 ft., 10 m	± 0.016 ft., 0.5 cm
F65, M20	65.6 ft., 20 m	± 0.032 ft., 1 cm
F100, M30	98.4 ft., 30 m	± 0.064 ft., 1.5 cm
F300, M100	328.1 ft., 100 m	± 0.164 ft., 5 cm
F600, M200	656.2 ft., 200 m	± 0.328 ft., 10 cm

Table 1 - Levelogger Edge Ranges



Measurement Fundamentals

Leveloggers **(L)** measure the total pressure acting on a transducer at their zero point/sensor. The total pressure is caused by the column of water lying above the Levelogger pressure sensor AND the barometric (atmospheric) pressure acting on the water surface. To compensate for barometric pressure fluctuations and get true height of water column measurements **(H)**, a Barologger **(B)** is required, i.e.:

Levelogger Reading (L)
-
Barologger Reading (B)
=
Height of Water Column (H)

Verifying Readings

The best recommendation is to compare barometrically compensated Levelogger data **(H)** with a measured depth to water level value **(d)** (using a Water Level Meter). The deployment depth of the Levelogger **(D)**, minus the manual depth to water measurement **(d)**, should equal the compensated Levelogger reading, i.e.:

Deployment Depth (D)
-
Depth to Water (d)
=
Height of Water Column (H)

Note

The Levelogger Edge can withstand over-pressurization of 2 times the intended range, e.g. a Model M10/F30 can accommodate a fluctuation of 20 meters or 60 feet and still record pressure. However, over-range accuracy is not guaranteed.

Barologger Edge

A single Barologger can be used to compensate all Leveloggers on site, within a 20 mile/30 km radius and with every 1000 ft (300 m) change in elevation. Ensure that your Barologger will start logging within at least 3 hours of your Levelogger start time.

Tip

To adjust all readings in your Levelogger file to depth to water below a well casing **(d)**, *record a manual water level measurement using a water level meter. This reading should correspond in date and time with an actual Levelogger recording. Use this as a reference datum in the Manual Data Adjustment option in the Levelogger Software Data Wizard.*

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Levelogger Field Notes

Before Deployment

Before deployment, make sure you do the following:

- Program your Levelogger, using Levelogger Software, with the correct project identification, memory mode, sampling regime, time, etc.

> **Note:** It is useful to synchronize the times of all Leveloggers and Barologgers being used for the same project.

- Set a future start time, or start the Levelogger if deploying on a wireline/ Kevlar rope (Leveloggers can be started after deployment if using a Direct Read Cable)
- Determine borehole depth to ensure Levelogger does not touch the bottom of the well (avoid submergence in sediment)
- Record the deployment depth of your Levelogger
- Use a Solinst Model 101 or 102 Water Level Meter to take a manual depth to water measurement that will be used to verify Levelogger readings
- Determine the minimum and maximum expected water levels, as Leveloggers must remain submerged for the entire monitoring period, and Barologgers must not be submerged

Deployment

- Deploy your Levelogger and Barologger using a direct read cable for down-well communication, or use an inexpensive wireline or Kevlar cord.

> **Note:** For information on other types of installations, see the latest Levelogger User Guide.

- Install the Barologger in a similar thermal environment as the Levelogger
- The Barologger should be suspended beyond the frost line and deep enough to avoid large temperature fluctuations
- Ensure the Barologger location is vented to atmosphere

Wireline/Cord Deployment

Direct Read Deployment

Tip

It is recommended to take a manual water level measurement before installing a Levelogger, shortly after installation, periodically during your monitoring interval, and at the end of your measurement period. Use these measurements to verify Levelogger readings, and for data adjustments later on. Ensure you take manual readings as close in time as possible to a scheduled Levelogger reading.

Well Caps

The Model 3001 2" (or 4" with Adaptor) Well Cap Assembly provides a secure method of installing your Levelogger using wireline/Kevlar cord or Direct Read Cables.

After Deployment

After deployment, make sure you do the following:

- Take a manual depth to water measurement after the well has stabilized (approximately 10 minutes))
- Take another manual depth to water measurement just before removing the Levelogger from the well

In-field Communication

If you have installed your Levelogger using wireline/Kevlar cord, you can communicate with your Levelogger via an Optical Reader and Levelogger Software on a laptop PC.

If you have installed your Levelogger using a Direct Read Cable, you can communicate with your Levelogger via a PC Interface Cable and Levelogger Software on a laptop PC, or using a Levelogger App Interface and the Solinst Levelogger App on your mobile device, without removing the Levelogger from the well.

Note: A Direct Read to Optical Adaptor can be used to directly connect a Levelogger to an App Interface.

Optical Reader

PC Interface Cable

Solinst Levelogger App & Interface

Frequently Asked Questions (Also see http://www.solinst.com/Prod/3001/Levelogger-FAQ.php)

How can I protect my Levelogger from corrosive or marine environments?

The Levelogger Edge has a corrosion resistant Titanium-based coating. In harsher chemical environments, you can protect the Levelogger using a thick membrane balloon (e.g. helium) filled with non-corrosive/non-toxic fluid (tap water). As pressure changes, the fluid encasing the loggers will transmit the pressure differential to the logger's pressure transducer, without exposing it to corrosive conditions. Continual monitoring is recommended to assess the effectiveness of the protection at your site.

How do I install my Levelogger in a surface water application?

For installations within rivers, streams, wetlands, lakes and watershed or drainage basin monitoring, the shallow pressure range Levelogger Edge or Levelogger Junior Edge (M5/F15) should be considered. For installation in streams or rivers, stilling wells can be constructed which shield the instrument from the water turbulence. Alternatively, Leveloggers can be lowered into a protective pipe or casing and then attached to a permanent fixture such as a bridge, pier or hand driven marker/rod.

How do I protect my Levelogger from freezing?

To avoid icing/freezing and transducer damage, the easiest method is to lower the transducer to a point in the water column below the frost line or ice formation depth. In water bodies such as shallow streams, wetlands or ponds where icing/freezing may penetrate to the bottom, install the Levelogger in a vented stilling well imbedded into the bottom of the water body beyond the frost line.

If this is not possible, place the Levelogger inside a thick membrane balloon filled with a non-toxic, non-corrosive anti-freeze solution or saltwater solution. Place the balloon in a section of perforated, 1.25" (30 mm) ID pipe and install the logger in the monitored water. The antifreeze solution will protect the Levelogger from ice expansion at the pressure transducer, yet transmit any pressure and temperature fluctuations that occur.

How do I protect my Levelogger from biofouling? Use the Solinst Model 3001 Biofoul Screen.

Is Levelogger maintenance required?

Yes, consult the Solinst Technical Bulletin "Ensuring Proper Use and Maintenance of Leveloggers" to maintain the long life of your instrument, based on the monitoring environment specific to your application.

Troubleshooting Guide

Levelogger Software:

1. You must have administrator privileges to install software on a computer.
2. Windows XP, 7, 8, and 10 Operating Systems support Levelogger Software.

Levelogger data has been accidentally erased:

If the Levelogger has been restarted and the old data has not been saved, select the download option "Recover Previous Log". This will download your previous data set.

Communication Errors:

"Port Cannot Open", "Check Com Port"

1. Reason: Software was started before USB device was connected to computer.
   Solution: Restart computer, connect USB device, start software.
2. Reason: Incorrect Com Port is selected in Com Port selection menu.
   Solution: Check the Com Port location for the installed device, by accessing the 'Device Manager' (through the Control Panel), and selecting the "Ports" section. This will state the Com Port the device is installed on.
3. Reason: The correct Com Port is not available because the USB driver needs to be installed or updated.
   Solution: See the USB Installation Guide, or refer to Section 4.1.3 of the Levelogger User Guide.
4. Reason: Another device shares the same Com Port or is causing a communication conflict.
   Solution: Ensure that software for PDA or other devices, which automatically synchronize, are disabled. Ask your system administrator for assistance.
5. Reason: RS-232 Adaptor to USB converter is improperly installed.

Note: Not all converters are compatible with all makes and models of computers.

   Solution: Reinstall supplied driver for converter device.

"Communication Time-Out", "Communication Error"

1. Reason: Levelogger, Direct Read Cable, or communications device has failed.
   Solution: a) Narrow down the failure by using a different Levelogger, Direct Read Cable, or another communications device.
   b) Clean the optical "eyes" on the Levelogger and Optical Reader, or Direct Read Cable, with a soft cloth.
   c) Check that the communication cable is connected to the same Com Port that is chosen in the upper middle of the Levelogger Software window.

   Check the Com Port settings. They should be as follows:
   - Bits per second: 9600
   - Data bits: 8
   - Parity: None
   - Stop bits: 1
   - Flow control: None

   d) Try using a different computer, to see if this is the cause of the problem.
   e) If using a laptop (especially in conjunction with a Direct Read Cable) your Com Port may not be powered adequately to receive/transmit data. Try using a desktop computer to test this.
   f) If problem persists, contact Solinst.

Note: All Leveloggers should be deployed and stored with the installation cap or direct read cable attached. This prevents unnecessary battery drainage and protects the optical eyes.

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Solinst®

User Guide

Levelogger Series - Software Version 4.1.2

December 3, 2015

Solinst®

Levelogger®
Model 3001

1 Introduction

This User Guide focuses on the current Levelogger Series, which includes:

- Levelogger Edge
- Barologger Edge
- Levelogger Junior Edge
- LTC Levelogger Junior
- Rainlogger Edge

Software Version 4.1.2 is also compatible with Levelogger Gold, Barologger Gold, Levelogger Junior and Rainlogger dataloggers. For details on setting up these dataloggers, see Section 5.9. Software Version 4.1.2 is also compatible with the Leveloader Gold data transfer device, which has a separate User Guide.

This Windows based software provides many convenient features. You can view and program datalogger settings, begin logging sessions, monitor real-time readings, download data, manage data files, perform data compensations, and save and export data files. Depending on the type of datalogger, there will be differences in programming options. See below for a summary of the differences:

Datalogger Programming Options

Datalogger Type	Sampling Options	Memory Capacity	Battery Life
Levelogger Edge 	Linear (0.125 second to 99 hours), Compressed Linear, Event Based, Schedule, Repeat Schedule, Real Time View, Future Start/Stop	40,000 sets of readings or up to 120,000 Compressed. Slate or Continuous Mode (see note)	10 years based on 1 reading per minute
Barologger Edge 	Linear (0.125 second to 99 hours), Compressed Linear, Event Based, Schedule, Repeat Schedule, Real Time View, Future Start/Stop	40,000 sets of readings or up to 120,000 Compressed. Slate or Continuous Mode (see note)	10 years based on 1 reading per minute
Levelogger Junior Edge 	Linear (0.5 second to 99 hours), Real Time View, Future Start	40,000 sets of readings in Slate Mode	5 years based on 1 reading per minute
LTC Levelogger Junior 	Linear (5 seconds to 99 hours), Real Time View, Future Start	16,000 sets of readings in Slate Mode	5 years based on 1 reading every 5 minutes
Rainlogger Edge & Rainlogger  	Event Based (records tips from tipping-bucket rain gauge), Real Time View , Future Start	Up to 60,000 tip time logs in Slate Mode	10 years based on 2 parameters logged every 10 minutes
Levelogger Gold 	Linear (0.5 second to 99 hours), Event Based, Schedule, Real Time View, Future Start/Stop	40,000 sets of readings, Slate or Continuous Mode	10 years based on 1 reading per minute
Barologger Gold 	Linear (0.5 second to 99 hours), Event Based, Schedule, Real Time View, Future Start/Stop	40,000 sets of readings, Slate or Continuous Mode	10 years based on 1 reading per minute
Levelogger Junior 	Linear (0.5 second to 99 hours), Real Time View, Future Start	32,000 sets of readings in Slate Mode	5 years based on 1 reading per minute

NOTE

This version of software is not compatible with older models of the Levelogger (Made before Dec. 2005). To program and use the old versions, Levelogger 3.1.1 Software and User Guides can still be accessed at: www.solinst.com/downloads/ For Software version 2.0.3, contact Solinst.

NOTE

Let Solinst keep you up-to-date with each new software and firmware release. Register your software at: www.solinst.com/Registration/ to receive these updates automatically.

NOTE

To use the new compression algorithm, which enables up to 120,000 data points, the Levelogger Edge or Barologger Edge must be in linear sampling mode and slate memory mode.

! NOTE

Solinst recommends using the most recent firmware, Version 3.003, when using a Levelogger Edge with Software Version 4.1.2.

! NOTE

The Model number refers to the depth of submergence below water level that the pressure sensor can withstand. i.e.: The Levelogger Edge, which is available in F15 (M5), F30 (M10), F65 (M20), F100 (M30), F300 (M100), and F600 (M200) ranges has actual water level ranges of 16.40 ft (5 m), 32.80 ft (10 m), 65.60 ft (20 m), 98.40 ft (30 m), 328.0 ft (100 m), and 656.2 ft (200 m), respectively.

1.1 Levelogger Series

1.1.1 Levelogger Edge

The Levelogger Edge is an absolute (non-vented) datalogger, which measures groundwater and surface water levels and temperature. Water levels are displayed as temperature compensated pressure readings, and can be barometrically compensated with the aid of a Barologger Edge.

Levelogger Edge Technical Specifications	
Level Sensor:	Piezoresistive Silicon with Hastelloy Sensor
Ranges:	15, 30, 65, 100, 300, 600 ft. (5, 10, 20, 30, 100, 200 m)
Accuracy	± 0.05% FS
Normalization:	Automatic Temperature Compensation
Temperature Sensor:	Platinum Resistance Temperature Detector (RTD)
Temp. Sensor Accuracy:	± 0.05ºC
Temp. Sensor Resolution:	0.003ºC
Temp. Comp. Range:	0ºC to 50ºC
Battery Life:	10 years (based on 1 reading/minute)
Clock Accuracy:	± 1 minute/year (-20ºC to 80ºC)
Operating Temperature:	-20ºC to 80ºC
Maximum # Readings:	40,000 (up to 120,000 using data compression)
Memory:	FRAM, Continuous or Slate mode
Communication Speed:	9600 bps, 38,400 bps with USB optical reader
Com Interface:	Optical Infra-red: USB, RS-232, SDI-12
Size:	7/8" x 6.25" (22 mm x 159 mm)
Weight:	129 grams (4.5 oz.)
Corrosion Resistance:	Titanium based PVD coated body and superior corrosion resistant Hastelloy sensor
Other Wetted Materials:	Delrin®, Viton®, 316L Stainless Steel
Sampling Modes:	Linear, Event & User-Selectable Schedule with Repeat Mode, Future Start, Future Stop, Real Time View
Measurement Rates:	0.125 second to 99 hours
Barometric Compensation:	High accuracy, air-only, Barologger Edge

LT Edge Models	Full Scale	Accuracy
F15, M5	16.4 ft., 5 m	± 0.05% FS
F30, M10	32.8 ft., 10 m	± 0.05% FS
F65, M20	65.6 ft., 20 m	± 0.05% FS
F100, M30	98.4 ft., 30 m	± 0.05% FS
F300, M100	328.1 ft., 100 m	± 0.05% FS
F600, M200	656.2 ft, 200 m	± 0.05% FS

1.1.2 Barologger Edge

The Barologger Edge uses algorithms based on air pressure only. It measures and logs changes in atmospheric pressure, which are then used to compensate water level readings recorded by a Levelogger Edge, Levelogger Junior Edge, or LTC Levelogger Junior.

NOTE

Solinst recommends using the most recent firmware, Version 3.003, when using a Barologger Edge with Software Version 4.1.2.

Barologger Edge Technical Specifications	
Level Sensor:	Piezoresistive Silicon with Hastelloy Sensor
Accuracy	± 0.05 kPa
Normalization:	Automatic Temperature Compensation
Temperature Sensor:	Platinum Resistance Temperature Detector (RTD)
Temp. Sensor Accuracy:	± 0.05ºC
Temp. Sensor Resolution:	0.003ºC
Temp. Comp. Range:	-10ºC to 50ºC
Battery Life:	10 years (based on 1 reading/minute)
Clock Accuracy:	±1 minute/year (-20ºC to 80ºC)
Operating Temperature:	-20ºC to 80ºC
Maximum # Readings:	40,000 (120,000 using data compression)
Memory:	FRAM, Continuous or Slate mode
Communication Speed:	9600 bps, 38,400 bps with USB optical reader
Com Interface:	Optical Infra-red: USB, RS-232, SDI-12
Size:	7/8" x 6.25" (22 mm x 159 mm)
Weight:	129 grams (4.5 oz.)
Corrosion Resistance:	Titanium based PVD coated body and superior corrosion resistant Hastelloy sensor
Other Wetted Materials:	Delrin®, Viton®, 316L Stainless Steel
Sampling Modes:	Linear, Event & User-Selectable Schedule with Repeat Mode, Future Start, Future Stop, Real Time View
Measurement Rates:	0.125 second to 99 hours

LT Edge Models	Full Scale (FS)	Accuracy
Barologger	Air Only	±0.05 kPa

1.1.3 Levelogger Junior Edge

The Levelogger Junior Edge provides an inexpensive alternative for measuring groundwater and surface water levels and temperature.

> **NOTE**
> Solinst recommends using the most recent firmware, Version 3.003, when using a Levelogger Junior Edge with Software Version 4.1.2.

> **NOTE**
> The Levelogger Junior Edge looks very similar to the previous Levelogger Junior. To determine the difference, look at the serial number on the body of the Levelogger. If the fourth number in the serial number is 1, it is a Levelogger Junior. If the fourth number is a 2, it is a Levelogger Junior Edge.

Levelogger Junior Edge Technical Specifications	
Level Sensor:	Piezoresistive Silicon with Hastelloy Sensor
Ranges:	15, 30 ft. (5, 10 m)
Accuracy	± 0.1% FS
Normalization:	Automatic Temperature Compensation
Temperature Sensor:	Platinum Resistance Temperature Detector (RTD)
Accuracy:	± 0.1ºC
Resolution:	0.1ºC
Temp Compensation Range:	0ºC to 40ºC
Battery life:	5 years (based on 1 reading/minute)
Clock Accuracy:	± 1 minute / year (-20ºC to 80ºC)
Operating Temperature:	-20ºC to 80ºC
Memory:	FRAM, Slate mode
Maximum # Readings	40,000 (no data compression)
Com Interface:	Optical Infra-red: USB, RS-232, SDI-12
Communication Speed:	9600 bps
Size:	7/8" x 5.6" (22 mm x 142 mm)
Weight:	4.2 oz (119 grams)
Wetted Materials:	Delrin®, Viton®, 316L Stainless Steel, Hastelloy
Sampling Mode:	Linear, Future Start, Real Time View
Measurement Rates:	0.5 seconds to 99 hours
Barometric Compensation:	High accuracy, air-only, Barologger Edge

LT Models	Full Scale (FS)	Accuracy
F15, M5	16.4 ft., 5 m	± 0.1% FS
F30, M10	32.8 ft., 10 m	± 0.1% FS

1.1.4 LTC Levelogger Junior

The LTC Levelogger Junior provides an inexpensive and convenient method to measure level, temperature and conductivity all in one probe.

NOTE

Solinst recommends using the most recent firmware, Version 2.005, when using a LTC Levelogger Junior with Software Version 4.1.2.

LTC Levelogger Junior Technical Specifications	
Level Sensor:	Piezoresistive Silicon with Hastelloy Sensor
Ranges:	30, 100 ft. (10, 30 m)
Accuracy	± 0.1% FS
Normalization:	Automatic Temperature Compensation
Temperature Sensor:	Platinum Resistance Temperature Detector (RTD)
Accuracy:	± 0.1ºC
Resolution:	0.1ºC
Temp Compensation Range:	10ºC to 40ºC
Conductivity Sensor:	4-Electrode Platinum
Full Range:	0 to 80,000 µS/cm
Calibrated Range:	500 to 50,000 µS/cm
Accuracy:	± 2% of reading or 20 µS/cm
Resolution:	1 µS
Normalization:	Specific Conductance normalized to 25ºC for full range
User Calibration Points:	1413, 5000, 12,880 µS
Battery Life:	5 years (based on 1 reading/ 5 minutes)
Clock Accuracy:	± 1 minute / year
Operating Temperature:	-20ºC to 80ºC
Memory:	Non-volatile EEPROM, FRAM back-up, Slate mode only
Maximum Readings:	16,000
Communication Speed:	9600 bps
Com Interface:	Optical Infrared: USB, RS-232, SDI-12
Size:	7/8" x 7.5" (22 mm x 190 mm)
Weight:	200 g (7.05 oz.)
Wetted Materials:	Hastelloy, Delrin®, Viton®, 316L Stainless Steel, Platinum
Sampling Mode:	Linear, Future Start, Real Time View
Measurement Rates:	5 seconds to 99 hours
Altitude Input:	-980 to 16,400 ft. (-300 to 5,000 m)
Barometric Compensation:	High accuracy, air-only, Barologger

LTC Models	Full Scale (FS)	Accuracy
F30, M10	32.8 ft., 10 m	± 0.032 ft., 1.0 cm
F100, M30	98.4 ft., 30 m	± 0.098 ft., 3 cm

1.1.5 Rainlogger Edge

The Rainlogger Edge is designed for use with most standard tipping-bucket rain gauges with a reed switch output. It records each tip time from the tipping-bucket, and outputs the amount of rainfall per programmed time period (based on rainfall calibration constant).

Rainlogger Edge Technical Specifications	
Battery Life:	10 years (logging 2 parameters/10 minutes)
Clock Accuracy:	± 1 minute/year
Operating Temperature:	-20˚C to 80˚C
Maximum # Readings:	Up to 60,000 tip times
Memory:	FRAM, Slate mode only
Communication:	Optical infra-red: USB, RS-232, SDI-12
Measurement:	Records each tip by the tipping-bucket rain gauge and outputs the amount of rainfall
Sampling Mode:	Event Based, Future Start, Real TIme View
Size:	7/8" x 5.5" (22 mm x 140 mm)
Weight:	1.6 oz (44 grams)
Materials:	ABS, Delrin®, Viton®

NOTE

Solinst recommends using the most recent firmware, Version 3.001, when using a Rainlogger Edge with Software Version 4.1.2.

1.1.6 Leveloader Gold

The Leveloader Gold is a data transfer device for use with all versions of Leveloggers. It can be used to download, store, and transfer data from Levelogger to PC, as well as, save settings files for transfer to a Levelogger. Also allows real time viewing of Levelogger readings. The Leveloader is used with Levelogger Software, see separate Leveloader Gold User Guide.

NOTE

Solinst recommends using the most recent firmware, Version 2.002, when using a Leveloader Gold with Software Version 4.1.2.

NOTE

To use the Levelogger Gold with Software Version 4.1.2, ensure you are using version 2.007 firmware.

Contact Solinst if you need to upgrade your firmware from version 1.016 or lower.

1.1.7 Levelogger Gold

The Levelogger Gold is an absolute (non-vented) datalogger, which measures groundwater and surface water levels and temperature. Water levels are displayed as temperature compensated pressure readings, and can be barometrically compensated with the aid of a Barologger.

Levelogger Gold Technical Specifications	
Level Sensor:	Piezoresistive Silicon in 316L Stainless Steel
Accuracy	0.05% FS
Ranges:	15, 30, 65, 100, 300 ft. (5, 10, 20, 30, 100 m)
Normalization:	Automatic Temperature Compensation
Temperature Sensor:	Platinum Resistance Temperature Detector (RTD)
Temp. Sensor Accuracy:	± 0.05°C
Temp. Sensor Resolution:	0.003°C
Temp. Comp. Range:	10ºC to 40°C
Battery Life:	10 Years - based on one reading/min
Clock Accuracy:	± 1 minute/year
Operating Temperature:	-20°C to 80°C
Maximum # Readings:	40,000 of level and temperature
Memory:	EEPROM Slate, Continuous, and redundant backup of last 1200 readings
Communication:	Optical Infra-red: USB, RS-232, SDI-12
Communication Speed:	9600 bps
Size:	7/8" x 6" (22 mm x 154 mm)
Weight:	6.3 oz (179 grams)
Corrosion Resistance:	Zirconium Nitride (ZrN) Coating
Other Wetted Materials:	316L Stainless Steel, Delrin®, Viton®
Sampling Modes:	Linear, Event & User-Selectable with 30 separate line items, Future Start, Future Stop, Real Time View
Measurement Rates:	0.5 sec to 99 hrs
Barometric Compensation:	High accuracy, air-only, Barologger Gold

LT Models	Full Scale (FS)	Accuracy
F15, M5	16.4 ft., 5 m	± 0.010 ft., 0.3 cm
F30, M10	32.8 ft., 10 m	± 0.016 ft., 0.5 cm
F65, M20	65.6 ft., 20 m	± 0.032 ft., 1 cm
F100, M30	98.4 ft., 30 m	± 0.064 ft., 1.5 cm
F300, M100	328.1 ft., 100 m	± 0.164 ft., 5 cm

> **! NOTE**
> To use the Barologger Gold with Software Version 4.1.2, ensure you are using version 2.007 firmware.

1.1.8 Barologger Gold

The Barologger Gold uses algorithms based on air pressure only. It measures and logs changes in atmospheric pressure, which are then used to compensate water level readings recorded by a Levelogger.

Barologger Gold Technical Specifications	
Level Sensor:	Piezoresistive Silicon in 316L Stainless Steel
Accuracy	0.05% FS
Normalization:	Automatic Temperature Compensation
Temperature Sensor:	Platinum Resistance Temperature Detector (RTD)
Temp. Sensor Accuracy:	± 0.05°C
Temp. Sensor Resolution:	0.003°C
Temp. Comp. Range:	0ºC to 40°C
Battery Life:	10 Years - based on one reading/min
Clock Accuracy:	± 1 minute/year
Operating Temperature:	-20°C to 80°C
Maximum # Readings:	40,000 of pressure and temperature
Memory:	EEPROM Slate, Continuous, and redundant backup of last 1200 readings
Communication:	Optical Infra-red: USB, RS-232, SDI-12
Communication Speed:	9600 bps
Size:	7/8" x 6" (22 mm x 154 mm)
Weight:	6.3 oz (179 grams)
Corrosion Resistance:	Zirconium Nitride (ZrN) Coating
Other Wetted Materials:	316L Stainless Steel, Delrin®, Viton®
Sampling Modes:	Linear, Event & User-Selectable with 30 separate line items, Future Start, Future Stop, Real Time View
Measurement Rates:	0.5 sec to 99 hrs

LT Models	Full Scale (FS)	Accuracy
Barologger	Air Only	± 0.003 ft., 0.1 cm

> **NOTE**
> To use the Levelogger Junior with Software Version 4.1.2, ensure you are using version 2.007 firmware.

> **NOTE**
> The Levelogger Junior looks very similar to the newer Levelogger Junior Edge. To determine the difference, look at the serial number on the body of the Levelogger. If the fourth number in the serial number is 1, it is a Levelogger Junior. If the fourth number is a 2, it is a Levelogger Junior Edge.

1.1.9 Levelogger Junior

The Levelogger Junior functions like the Levelogger Gold; provides an inexpensive alternative for measuring groundwater and surface water levels and temperature.

Levelogger Junior Technical Specifications	
Level Sensor:	Piezoresistive Silicon in 316L Stainless Steel
Ranges:	15, 30 ft. (5, 10 m)
Accuracy	± 0.1% FS
Normalization:	Automatic Temperature Compensation
Temperature Sensor:	Platinum Resistance Temperature Detector (RTD)
Accuracy:	± 0.1ºC
Resolution:	0.1ºC
Temp Compensation Range:	10ºC to 40ºC
Battery life:	5 years (based on 1 reading/minute)
Clock Accuracy:	± 1 minute / year
Operating Temperature:	-20ºC to 80ºC
Memory:	Non-volatile EEPROM, FRAM back-up, Slate mode only
Maximum # Readings	32,000 (no data compression)
Com Interface:	Optical Infra-red: USB, RS-232, SDI-12
Communication Speed:	9600 bps
Size:	7/8" x 5.5 " (22 mm x 140 mm)
Weight:	154 g (5.4 oz)
Wetted Materials:	Delrin®, Viton®, 316L Stainless Steel
Sampling Mode:	Linear, Future Start, Real Time View
Measurement Rates:	0.5 seconds to 99 hours
Altitude Input:	-980 to 16,400 ft. (-300 to 5,000 m)
Barometric Compensation:	High accuracy, air-only, Barologger Gold

LT Models	Full Scale (FS)	Accuracy
F15, M5	16.4 ft., 5 m	± 0.020 ft., 0.6 cm
F30, M10	32.8 ft., 10 m	± 0.032 ft., 1.0 cm

NOTE

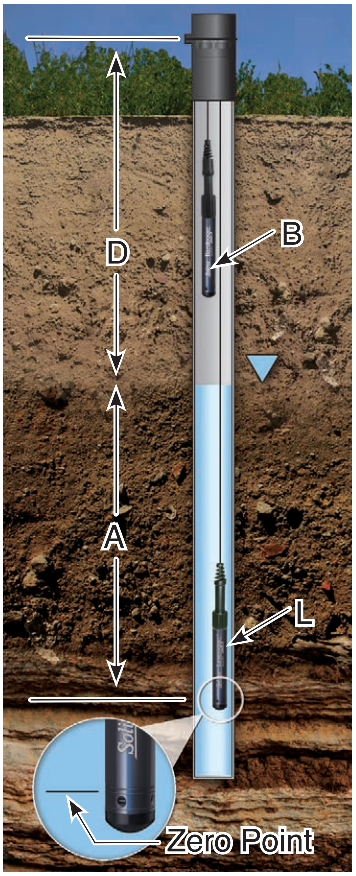
Solinst recommends using the most recent firmware, Version 2.000, when using a Rainlogger with Software Version 4.1.2.

If using a firmware version prior to version 2.000, the Rainlogger will function differently (See previous Levelogger User Guide)

1.1.10 Rainlogger

The Rainlogger is designed for use with most standard tipping-bucket rain gauges with a reed switch output. It records each tip time from the tipping-bucket, and outputs the amount of rainfall per programmed time period (based on rainfall calibration constant).

Rainlogger Technical Specifications	
Battery Life:	10 years (logging 2 parameters/10 minutes)
Clock Accuracy:	± 1 minute/year
Operating Temperature:	-20˚C to 80˚C
Maximum # Readings:	Up to 60,000 tip times
Memory:	Non-volatile EEPROM, Slate mode only
Communication:	Optical infra-red: USB, RS-232, SDI-12
Measurement:	Records each tip by the tipping-bucket rain gauge and outputs the amount of rainfall
Sampling Mode:	Event Based, Future Start, Real TIme View
Size:	7/8" x 7" (22 mm x 175 m)
Weight:	4.8 oz (135 grams)
Materials:	316L Stainless Steel, Delrin®, Viton®



A = L - B

Figure 1-1
Levelogger Measurement Fundamentals

> **NOTE**
> Leveloggers measure the pressure of air plus water column above their sensor (zero point). To adjust the level readings after data collection, for example to water level depths below top of casing (**D**), refer to the Advanced options within the software Data Wizard.

> **NOTE**
> The Levelogger Gold, Levelogger Junior and current LTC Levelogger Junior models convert pressure readings to the water level equivalent above the datalogger's pressure zero point of 950 cm (31.17 ft). The Levelogger Edge and Levelogger Junior Edge have no zero point offset. As such, water level data will appear different, although measuring the same amount of pressure. Barometric Compensation using the Data Wizard, automatically considers this zero point offset difference when compensating a mix of Models.

1.2 Measurement Parameters

1.2.1 Level

All Leveloggers measure total (absolute) pressure. When submerged, the Levelogger is recording the combination of barometric pressure and water pressure. The actual pressure of just water **(A)** above the sensor is obtained by subtracting barometric pressure **(B)** from the total pressure **(L)** (see Figure 1-1).

The best method to compensate for barometric pressure is to employ a Barologger above the water level, to obtain records of barometric pressure. The Levelogger Software includes a Data Wizard, which guides you through the automated process of barometric compensation. Manual methods can be employed to determine the absolute water level using barometric records collected on-site or available from a local weather station (i.e. airport). Water level readings from Leveloggers are automatically temperature-compensated.

A = Actual water column height

B = Barometric pressure

L = Levelogger total pressure readings

D = Depth to water level, below reference datum

Note: the Levelogger Gold, Levelogger Junior and current LTC Levelogger Junior models convert pressure readings to the water level equivalent above the datalogger's pressure zero point of 950 cm (31.17 ft). The Levelogger Edge and Levelogger Junior Edge have no zero point offset. As such, water level data will appear different, although measuring the same amount of pressure (i.e. Levelogger Edge data will appear to be reading 950 cm (31.17 ft) higher than a Levelogger Gold. Barometric Compensation using the Data Wizard, automatically considers this zero point offset difference when compensating a mix of Models.

1.2.1.1 Pressure Calibration

The Levelogger Edge is calibrated against a range of set reference points to an accuracy of 3 decimal places. During the calibration procedure, the Levelogger is fully submerged in a highly accurate water bath. The bath is set to 5°C and allowed to stabilize. The pressure is then calibrated to six separate pressure points covering the entire range of pressure for that particular Levelogger to check for any non-linearity. The process is repeated again at 35°C to check for temperature effects. Once done, the Levelogger is approved after all specifications for accuracy, precision, stability and hysteresis have been met. The Levelogger should be calibrated for the life-time of the instrument, as long as it is used within its specified range.

1.2.2 Barometric Pressure

The Barologger is designed for use in air only. It has a specific range and firmware algorithms based on air pressure rather than water pressure. This makes the Barologger less accurate if used in water, but more accurate if used as intended in air. Using a Barologger is the most accurate and convenient method of obtaining atmospheric pressure and air temperature measurements, which are then synchronized to the Levelogger. The Data Wizard in the Levelogger Software simplifies the adjustment of the level measurements for barometric pressure changes, by using the synchronized data from all Leveloggers on site and the site Barologger.

1.2.3 Temperature

Leveloggers record temperature compensated water levels. Groundwater and surface water temperature measurements are particularly important in situations where temperatures may fluctuate significantly, and when temperature is used in determining liquid level, viscosity and hydraulic conductivity. Temperature monitoring is vital in the calculation of certain temperature dependent contaminant reaction rates. A Platinum Resistance Temperature Detector is used to accurately compensate for temperature changes within the range of 0 to +50°C for the Levelogger Edge, -10°C to +50°C for the Barologger Edge, 0 to +40°C for the Levelogger Junior Edge, and +10 to +40 for the LTC Levelogger Junior. The Levelogger will record temperature in its thermal range of -20 to +80°C, but outside the range, compensation will be less accurate.

1.2.4 Conductivity

NOTE

For every degree change in temperature, there is approximately a 2% change in conductivity. To convert raw conductivity measurements to Specific Conductance measurements, you can use the following equation:

Specific Conductance = Conductivity / (1 + 0.02 * (temp(C) - 25))

You can also perform this calculation automatically using the Data Wizard.

The LTC Levelogger Junior provides the added feature of electrical conductivity measurement. It measures the actual conductivity at the current temperature. Conductivity measurement is particularly useful in monitoring saltwater intrusion, surface water infiltration and mixing, as well as the monitoring of certain pollutants and contaminant parameters. Conductivity is measured via a platinum 4-electrode sensor, which produces highly stable and consistent readings. Conductivity calibration is performed by using a liquid solution, with a known conductivity value, and the Calibration Wizard in the Levelogger Windows Software. The Data Wizard allows you to convert conductivity readings to Specific Conductance (at 25°C), or Salinity expressed in Practical Salinity Units (PSU). A Practical Salinity Unit (PSU) is a dimensionless descriptor for the Practical Salinity Scale (PSS). The PSS defines salinity as the ratio of a water sample's conductivity to that of a standard KCL solution. The Data Wizard uses the equation given in the UNESCO Technical Paper "Algorithms for computation of fundamental properties of seawater", to convert Conductivity readings to Salinity. For more information, see: Fofonoff, N. P. and R.C. Millard, Jr. Algorithms for computation of fundamental properties of seawater, UNESCO, Tech. Pap. Mar. Sci.,44.

1.2.4.1 Calibration of the Conductivity Sensor

The conductivity sensor of the LTC Levelogger Junior is a highly sensitive device requiring regular calibration by the user. The conductivity calibration frequency is dependent on the water quality of the Levelogger's monitoring environment. To determine whether an LTC Levelogger Junior should be re-calibrated, test the unit in a solution with a known electrical conductivity value at a reference temperature. In Real Time View, observe current readings by using the Read Now function. If this reading varies from the known Specific Conductance of the solution by greater than 2% of the Full Scale of Conductivity measurement, the unit should be re-calibrated using the Conductivity Calibration Wizard procedure outlined in Section 6. As a minimum, calibrate your LTC Levelogger Junior at least twice a year. Ensure that a conductivity calibration is performed when the LTC Levelogger Junior is being set up for its initial use and after long periods of dry storage.

1.2.5 Total Rainfall

Solinst Rainloggers are designed to record the number of tips of an external tipping-bucket rain gauge, and output the amount of rainfall per tip.

> **NOTE**
> For software installation instructions, see Section 3.

> **NOTE**
> Always plug in the USB device before starting the Software.
> When you plug in a USB device for the first time, you will need to install the USB Driver on the PC. (See Section 4.1.3).

1.3 Software Communication

Levelogger Software is Windows based, and is therefore used with a desktop or laptop PC. Dataloggers connect to a laptop or desktop PC with an Optical Reader cable. The Optical Reader cable uses an infrared data reader/port connected to the datalogger and a USB or RS-232 (Serial) Com Port to transfer information between the datalogger and computer.

If you are programming dataloggers in the office, or have deployed your datalogger using a wireline or cord, an Optical Reader is most commonly used for communication with a PC (see Figure 1-2).

If a datalogger is deployed in the field using a Direct Read Cable, a PC Interface Cable is used for communication with the PC, without removing it from the well (see Figure 1-3).

Figure 1-2 Levelogger Connected to a PC Using an Optical Reader

Figure 1-3
Levelogger and Direct Read Cable Connected to PC Using a PC Interface Cable

> **NOTE**
> It is always recommended to use the most recent version of software and firmware.

> **NOTE**
> For more information, visit www.solinst.com to view the 3001 Levelogger Series: Hardware Compatibility, which is located on the Downloads page.

1.3.1 Backwards Compatibility

The Levelogger Edge is not backwards compatible with previous versions of Levelogger Software. Only Levelogger Software Version 4 and up can be used to program the Levelogger Edge and Barologger Edge. The Levelogger Junior Edge is only compatible with Levelogger Software Version 4.0.2 and up. The Rainlogger Edge is only compatible with Software Version 4.1 and up.

The Levelogger Junior, LTC Levelogger Junior, Rainlogger, and Leveloader are compatible with Levelogger Software Version 4.1.2. If used with previous software versions, they will not have some of the features gained with the release of Version 4.1.2 Software. The Levelogger Gold and Barologger Gold are also compatible with Version 4.1.2. Software, and previous versions.

To use your Leveloggers with Version 4.1.2 Software, ensure your firmware is upgraded to the following versions:

Datalogger	Firmware Version
Levelogger Edge	3.003
Barologger Edge	3.003
Levelogger Junior Edge	3.003
LTC Levelogger Junior	2.005
Rainlogger Edge	3.001
Leveloader Gold	2.002
Levelogger Gold	2.007
Barologger Gold	2.007
Levelogger Junior	2.007
Rainlogger	2.000

For more information on previous software and firmware versions, visit www.solinst.com to view **3001 Levelogger Series: Hardware Compatibility**, located on the Downloads page.

2 System Requirements

The minimal hardware and software requirements for software installation and operation are:

Hardware	Software
Memory: 32 MB or more	OS: Windows XP, 7, 8 or 10
Display: VGA: 800 x 600 pixels, 256 colour	
Ports: USB or RS-232 Serial Port	

Communication Port Setting for Levelogger Communications:

Bits per second	9600
Data bits	8
Stop bits	1
Flow control	None

3 Software Installation

Web Download

Download the newest version of Levelogger Software by visiting www.solinst.com/downloads/

CD Installation

1) Insert the software CD provided.
2) If the installer does not automatically start, to activate the software install click on the 'setup.exe' file located on the software CD.
3) The Software Installation Wizard will guide you through the remaining installation process. Figure 3-1 shows the Levelogger Installation Wizard.
4) Restart the computer after installation is completed. Default Directory is C:\Program Files\Solinst\Levelogger4_1

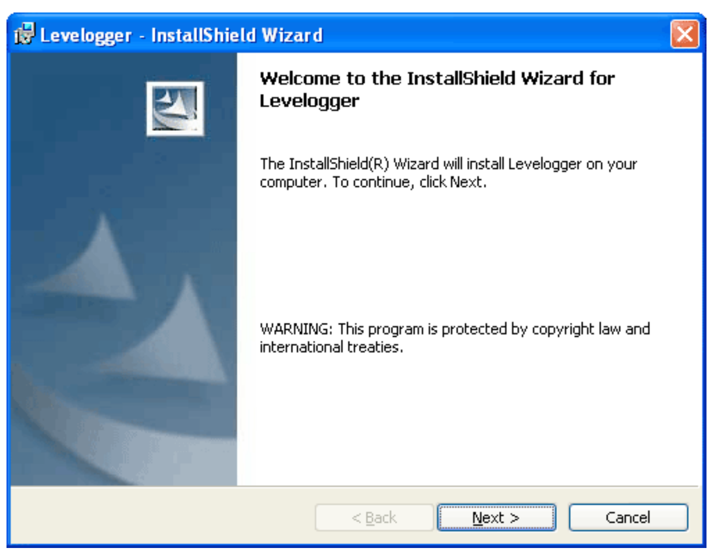


Figure 3-1 Software Installation Wizard

4 Startup, Configurations and Settings

4.1 Startup

If using a USB port, plug in the USB cable before starting the Levelogger Software. If plugging in the USB device for the first time, the driver for the device will have to be installed, see Section 4.1.3 for USB driver installation instructions.

To start the Levelogger Software, click , or click the Start button and select:

Programs > Solinst > Levelogger 4 > Levelogger 4.1.2

Once the program is started, you can set up the parameters for the Software.

4.1.1 Software/Firmware Update Checks

> **NOTE**
> Your PC must have an internet connection to check for software and firmware updates.
>
> You can also check for updates using the Help menu.

Each time the software is opened, it automatically checks for software updates. If there is an update, "Software Update Available" will appear in the top right of the menu bar. When you click the message, it will open a web page where you can download the software update.

The Software also checks for firmware updates once you have retrieved settings from a connected Levelogger (see Section 5)."Firmware Update Available" will appear in the top right menu bar. Clicking the message will open a web page where you can download the firmware update. See Section 12 for firmware update instructions.

4.1.2 Communicating with a USB Port

> **NOTES**
> To check the Com port assigned to a USB device after installation, open the Device Manager. Expand "Ports (COM & LPT)" to show the Com Port that has been assigned. To change the assigned Port, see Section 4.2.1.
>
> You may have to restart your computer after adding a new USB device, before that port will be detected by the Levelogger Software

USB port communication requires the installation of USB driver software and the setting up of a virtual com port. The user will either:

1) Connect a Levelogger Optical Reader or PC Interface Cable to the USB port
2) Use a USB to RS-232 Adapter

If 1, during the installation of Levelogger Software, the **Virtual Com Port Driver** will be installed automatically. The Levelogger Software Installation Wizard also copies a folder to the Levelogger folder containing all the Solinst USB drivers. When you plug in the Solinst USB device, check the com port designation after installing the device (see Section 4.2.1).

If 2, Solinst strongly recommends the use of either Keyspan™ or IO Gear™ USB to RS-232 Serial Adapters. These adapters have a sufficiently large buffer to accommodate the size of data bundle and bit transfer rate of the Levelogger. Follow the manufacturer's USB Driver and Com port setup installations found on the CD accompanying the adapter.

If you have installed another brand-name adapter, but cannot communicate with the Levelogger, in most cases the problem is that the adapter does not have a large enough internal memory buffer. The minimum buffer size should be 96 bytes.

> **NOTE**
> Do not install generic drivers that Windows will locate. Generic drivers are completely incompatible with Solinst USB devices.

> **NOTE**
> After plugging in the USB device, if the 'Found New Hardware Wizard' does not automatically appear, proceed to the Manual USB Installation instructions in Section 4.1.3.2

> **NOTE**
> Make sure you only select the USB Drivers folder when browsing for the driver location. Do not choose a sub file from the folder.

4.1.3 Installing USB Drivers for Levelogger 4 Software

Levelogger Software Version 4.1.2, for use with Solinst USB Optical Reader, PC Interface Cable and Leveloader, comes equipped with USB drivers for: Windows XP, 7 and 10.

Windows 8 can also be used, see Section 4.1.3.4 for instructions to enable Windows 8 USB installation.

4.1.3.1 USB Installation for Windows XP

1) Plug the USB device into the computer, and Windows will automatically detect the connected device. This will begin the 'Found New Hardware Wizard'.
2) The 'Wizard' will give the option to connect to Windows Update to search for software components, select: 'No, not at this time'.
3) Click 'Install from a list or specific location', then click the 'Next' Button. (Figure 4-1).

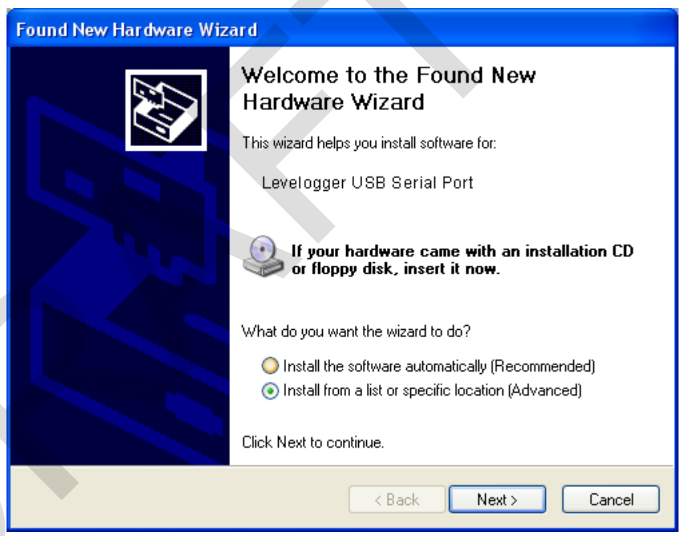
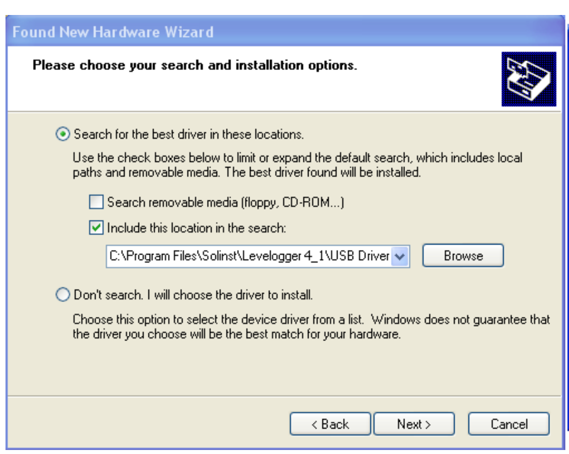


Figure 4-1 Found New Hardware Wizard Window

4) Select the installation option, 'Include this location in the search' (Figure 4-2), then click the 'Browse' button to search for the appropriate directory:

   C:\Program Files\Solinst\Levelogger4_1\USB Drivers



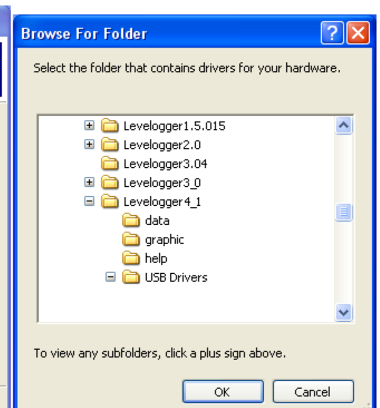


Figure 4-2 Found New Hardware Window and Figure 4-3 Browse for Folder Window

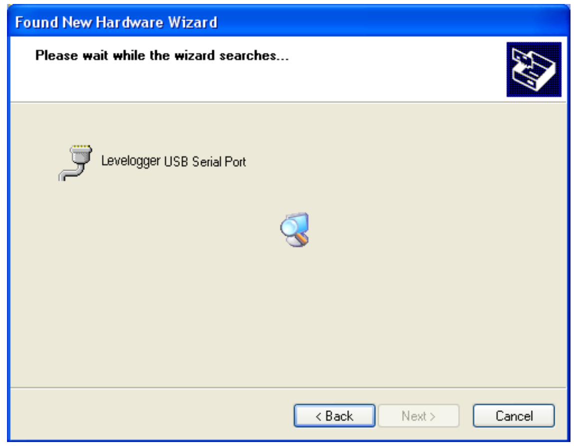


Figure 4-4 Found New Hardware Search Window

5) A warning message will then prompt that the software has not passed the Windows Logo Test. Select 'Continue Anyway' (Figure 4-5). This will complete the installation process. A system restart may be required. Repeat the steps if the installation fails the first time.

Figure 4-5 Hardware Installation Window

Figure 4-6 Found New Hardware Completed Window

4.1.3.2 Manual USB Installation

If your device is plugged in and the 'Found New Hardware Wizard' fails to start, then follow these steps:

1) Open the Device Manager. Typically this is found through the path:
   Start > Control Panel > System > Hardware > Device Manager

   Once the Device Manager is open, a version of the following list(s) will appear:

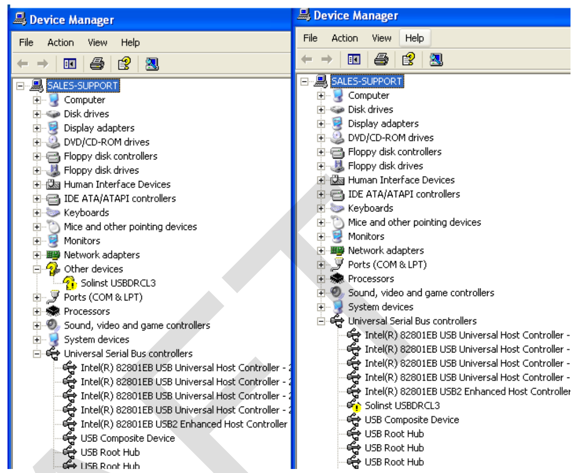


Figure 4-7 Device Manager

2) Identify the Solinst device from the list. The device will be categorized under 'Other Devices' or 'Universal Serial Bus Controllers'.

3) Highlight the device in the list and right click. You will see an option to 'Update the driver'. This will start the 'Hardware Update Wizard'. Now follow the instructions for your specific Windows version.

NOTE

If you are unsure which is the correct device in the list, with the screen visible, safely remove the device and then reconnect it. The list should automatically refresh accordingly.

NOTE

If you do not know the correct Com Port that was assigned to your device, re-open the Device Manager. Expand "Ports (COM & LPT)" to show the Com Port that has been assigned. To change the assigned Port, see Section 4.2.1.

> **NOTE**
> USB driver installation should be automatic when connecting a PC Interface Cable or Optical Reader.

> **NOTE**
> The 'Found New Hardware Wizard' may start automatically, beginning at step 3 below.

> **NOTE**
> If the USB driver does not install the first time, repeat the steps a second time. It often takes more than once to install the driver for Windows 7 systems.

> **NOTE**
> If you are unsure which is the correct device in the list, with the screen visible, safely remove the device and then reconnect it. The list should automatically refresh accordingly.

4.1.3.3 USB Installation for Windows 7

Plug the USB Device into the PC. The system will automatically detect the connected unit. Windows 7 should automatically install the driver for the device.

If no driver is automatically found, and the 'Found New Hardware Wizard' fails to start, the following steps should be taken:

1) Press the Windows start button to bring up the start menu, select 'Control Panel', then 'Hardware and Sound', then 'Device Manager'.

2) Under 'Other Devices' there will be a Solinst device shown with a yellow warning symbol. Right click on this device, and select 'Update Driver Software'.

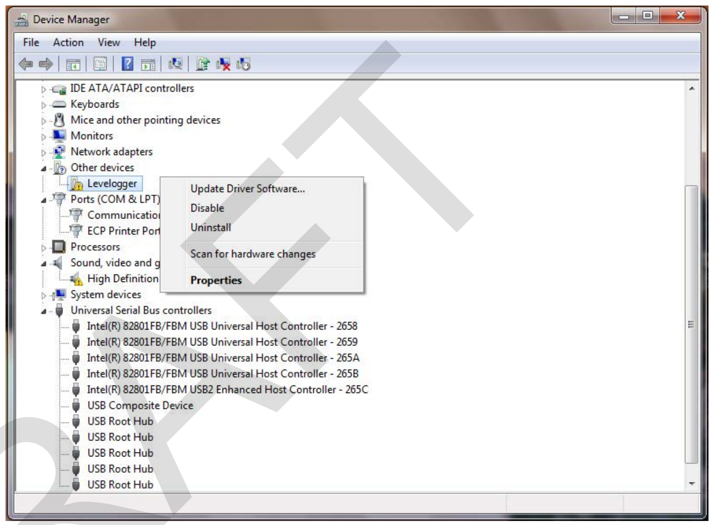


Figure 4-8 Windows 7 Device Manager

3) Select 'Browse my computer for driver software'.

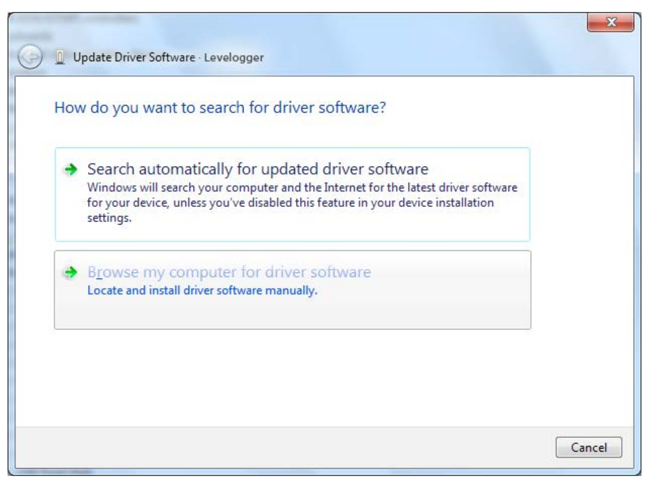


Figure 4-9 Update Driver Software

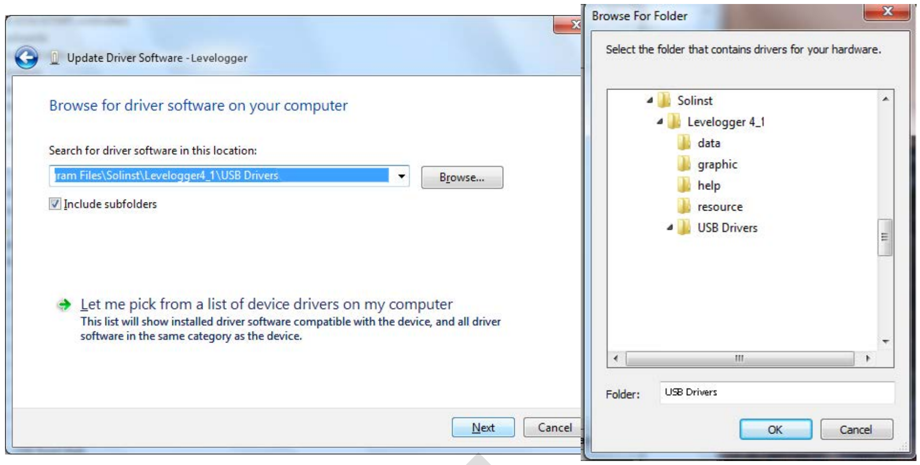


Figure 4-10 Browse for Driver Software

> **NOTE**
>
> Make sure you only select the USB Drivers folder when browsing for the driver location. Do not choose a sub file from the folder.

4) Click the Browse button and point the navigation window to the provided USB drivers located within the Levelogger4_1 folder. Default destination is:

   C:\Program Files\Solinst\Levelogger4_1\USB Drivers

   Select the actual USB Drivers folder, not a sub file from the folder.

5) Select Next. A window may appear stating 'Windows can't verify the publisher of this driver software', select 'Install this driver software anyway'.

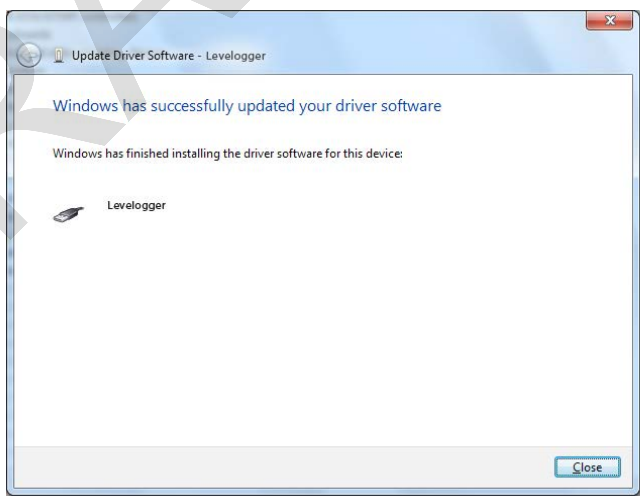


Figure 4-11 Update Complete

6) Windows will confirm when the installation is complete. Press Close to close the window, then go back to the 'Device Manager'.

NOTE

If you are unsure which is the correct device in the list, with the screen visible, safely remove the device and then reconnect it. The list should automatically refresh accordingly.

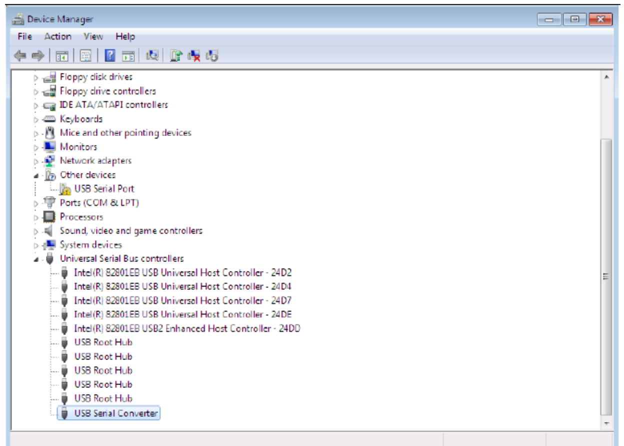


Figure 4-12 Update Serial Port

7) You may have to repeat steps 2-6 to update the USB Serial Port. This would be shown under 'Other Devices' with a yellow warning symbol.

8) Once installation is complete, a window will confirm the COM port assigned to the device.

4.1.3.4 Enabling USB Installation for Windows 8

1) Press Win + C on your keyboard to bring up the Charms Bar. Click on "Settings".
2) Click on "Change PC settings" to open the Modern Control Panel.

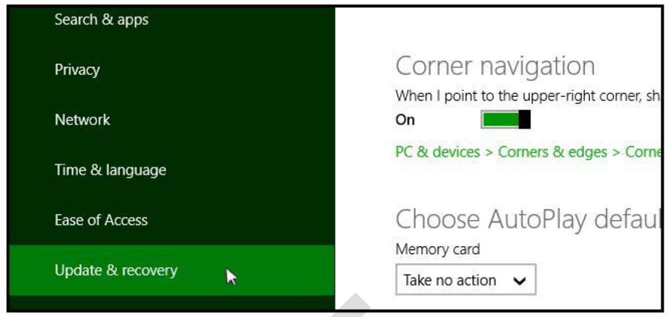


Figure 4-13 Windows 8 Control Panel

3) In the Control Panel, switch over to the "Update & recovery" section.
4) Click on the "Recovery" option.

Figure 4-14 Restart Windows 8 PC

5) In the Advanced startup section, click the "Restart now" button. This will restart your PC.

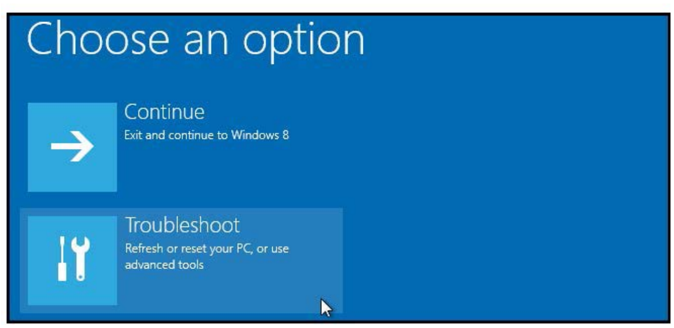


Figure 4-15 Troubleshoot Windows 8 PC

6) Once your PC has rebooted, select the "Troubleshoot" option.
7) Select "Advanced options".
8) Select "Startup Settings".
9) Select "Restart" to reboot your PC once more. This will allow modification to the boot time configuration settings.

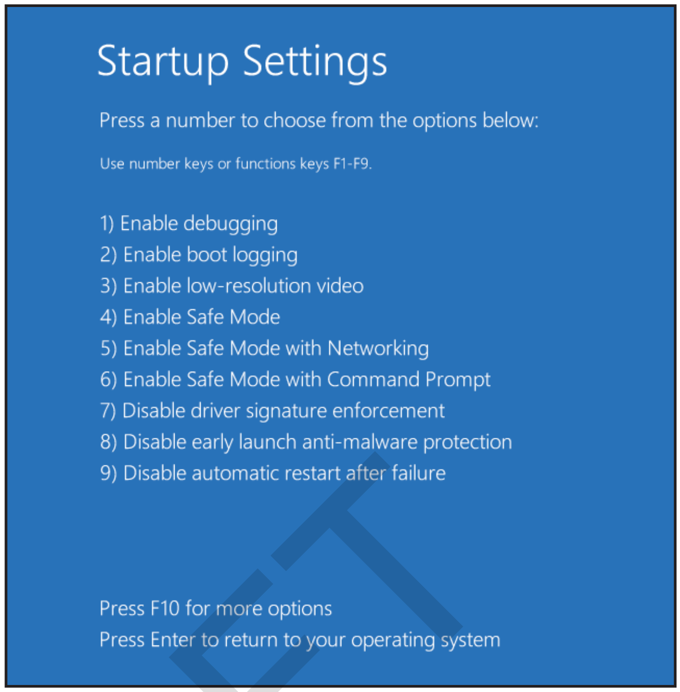


Figure 4-16 Windows 8 Startup Settings

10) A list of settings that can be changed will be shown. The setting you are looking for is "Disable driver signature enforcement". To choose this setting, press the F7 key.

11) After the PC automatically restarts, you will be able to install the USB drivers, as described in Section 4.1.3.1.

> **NOTE**
> USB driver installation should be automatic when connecting a PC Interface Cable.

> **NOTE**
> The 'Found New Hardware Wizard' may start automatically, beginning at step 5.

> **NOTE**
> If you know that you need to **Disable Driver Signature Enforcement** before installing drivers on your PC, then proceed to the instructions in section 4.1.3.6.

> **NOTE**
> If you are unsure which is the correct device in the list, with the screen visible, safely remove the device and then reconnect it. The list should automatically refresh accordingly.

4.1.3.5 USB Installation for Windows 10

Plug the USB device into the PC. The system will automatically detect the connected unit. Windows 10 should automatically install the driver for the device.

If no driver is automatically found, and the 'Found New Hardware Wizard' fails to start, the following steps should be taken:

1. Open the Windows Start Menu and click on "Settings". Click on "Devices".
2. In Devices, click on "Connected Devices". You should see your connected Solinst USB device listed under Other Devices. It should indicate that the device's setup is incomplete.

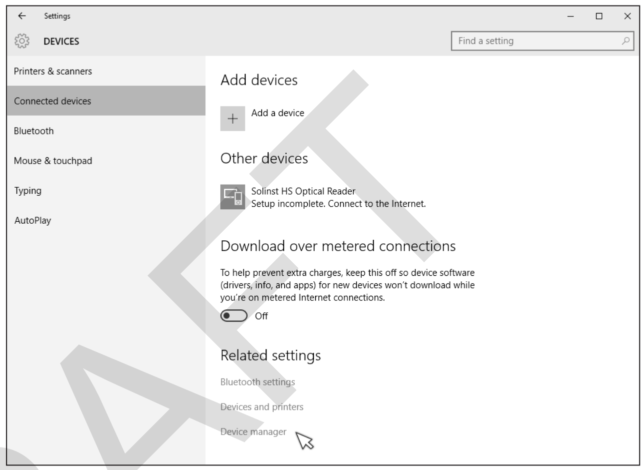


Figure 4-17 Windows 10 Connected Devices

3. Under Related settings, click on "Device Manager".

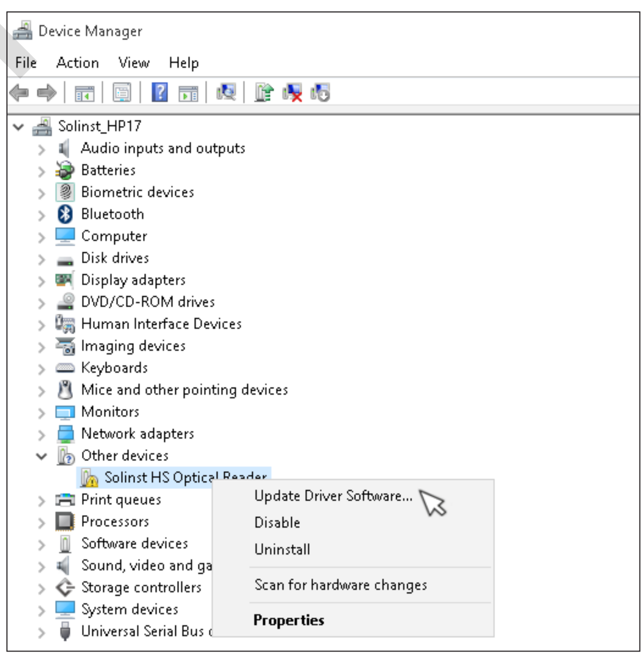


Figure 4-18 Windows 10 Device Manager

4. Under Other devices, there will be a Solinst device shown with a yellow warning symbol. Right click on this device, and select "Update Driver Software...".

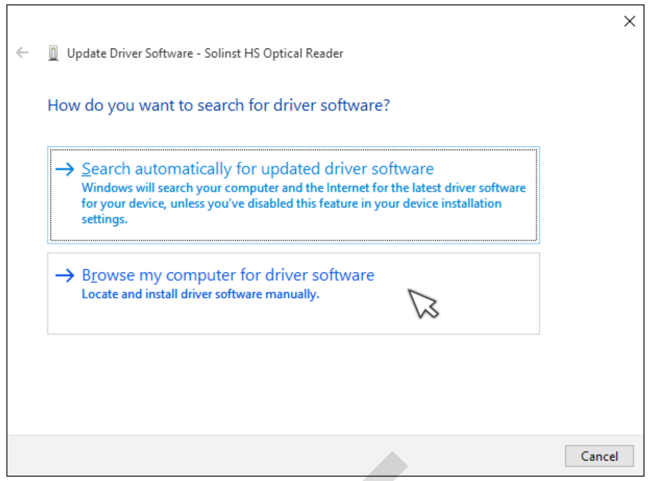


Figure 4-19 Update Driver Software

5. Select "Browse my computer for driver software".
6. Click the Browse button and point the navigation window to the provided USB drivers located within the Levelogger4_1 folder. Default destination is:

   C:\Program Files\Solinst\Levelogger4_1\USB Drivers

   Select the actual USB Drivers folder, not a sub file from the folder.

> **NOTE**
>
> Make sure you only select the USB Drivers folder when browsing for the driver location. Do not choose a sub file from the folder.

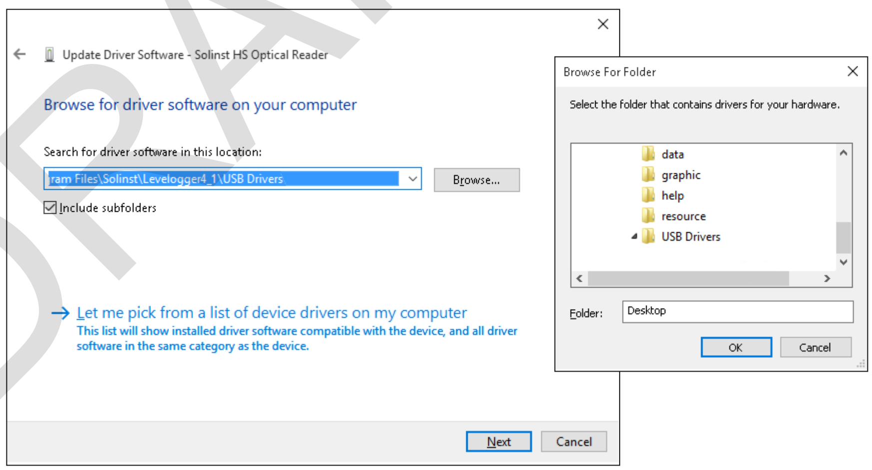


Figure 4-20 Browse for Driver Software

7. Select Next. A Window may appear stating "Windows can't verify the publisher of this driver software", select "Install this driver software anyway".

If you encounter the following error: "Windows encountered a problem installing the driver software for your device. Windows found driver software for your device but encountered an error..." Then please proceed with the instructions to **Disable Driver Signature Enforcement** in Section 4.1.3.6.

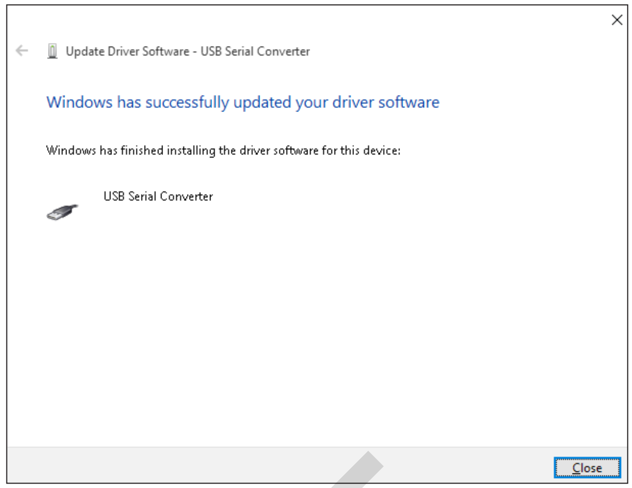


Figure 4-21 Update Complete

8. Windows will confirm when the installation is complete. Press Close, then go back to the Device Manager.

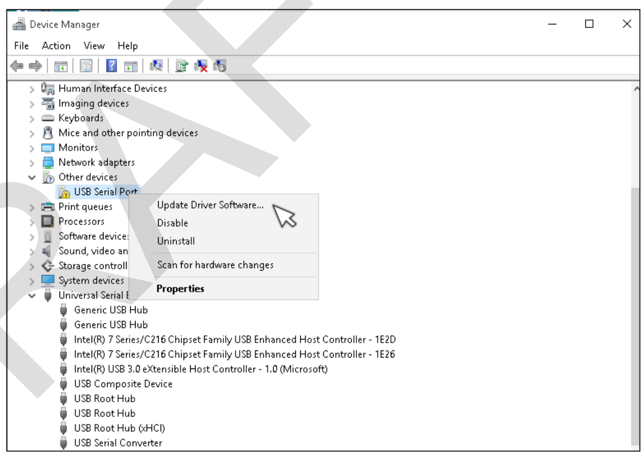


Figure 4-22 Update USB Serial Port

9. Follow Steps 4-8 to update the USB Serial Port, shown under Other devices with a yellow warning symbol.

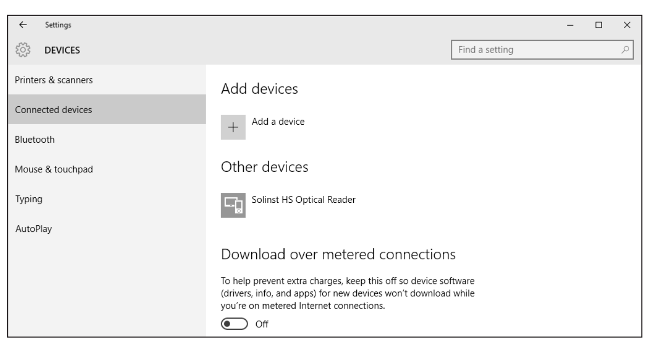


Figure 4-23 Installed Solinst USB Device

10. Once the installation is complete, this will be shown in the Devices > Connected devices Window. See Figure 4-23.

4.1.3.6 Disable Driver Signature Enforcement for Windows 10

1. Open the Windows Start Menu and click on "Settings".
2. In Settings, click on "Update & security".

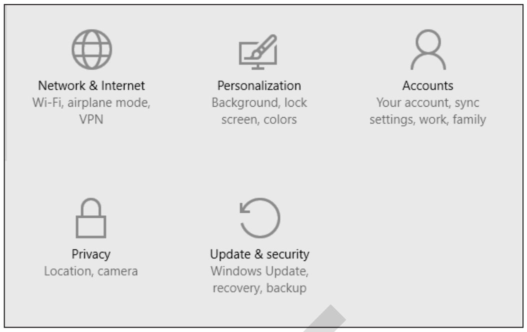


Figure 4-24 Windows 10 Settings

3. Then click on the Recovery option on the left hand side.
4. Once selected, you will see an Advanced startup section appear on the right hand side. Click on the "Restart now" button.

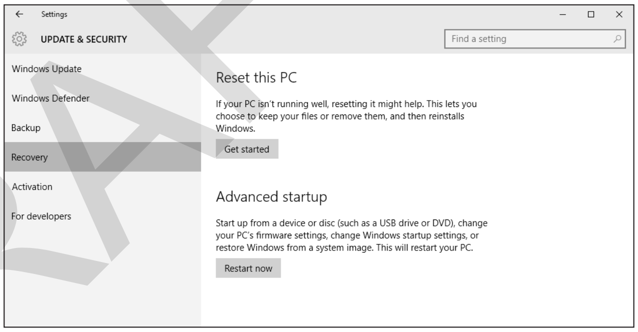


Figure 4-25 Windows 10 Advanced Startup

5. Once your Computer has rebooted, choose the "Troubleshoot" option.

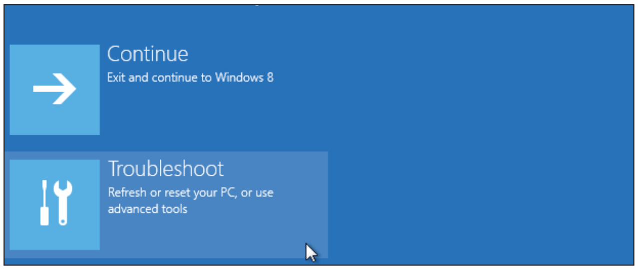


Figure 4-26 Windows 10 Troubleshoot

6. Select “Advanced options”.
7. Select “Startup Settings”.

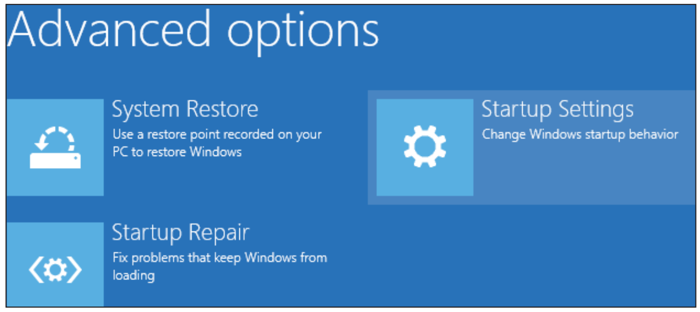


Figure 4-27 Windows 10 Advanced Options

8. Select “Restart” to reboot your PC once more. This will allow modification to the boot time configuration settings.
9. A list of settings that can be changed will be shown. The setting you are looking for is “Disable driver signature enforcement”. To choose this setting, press the F7 key.

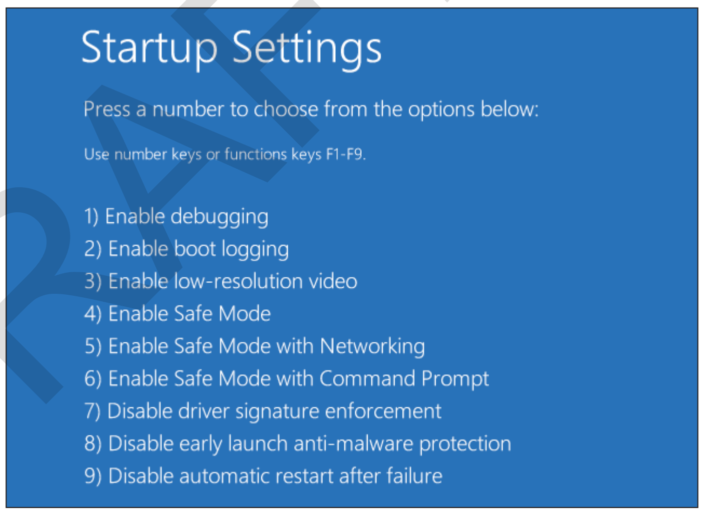


Figure 4-28 Windows 10 Startup Settings

10. After the PC automatically restarts, you will be able to install the USB drivers, as described in Section 4.1.3.5.

4.2 Configuration and Settings

4.2.1 Com Port Designation Set Up

> **NOTES**
>
> To check the Com port assigned to a USB device after installation, open the Device Manager. Expand 'Ports (COM & LPT)' to show the Com Port that has been assigned.
>
> You may have to restart your computer after adding a new USB device, before that port will be detected by the Levelogger Software

After installing a USB device, should the Com Port number assigned to the device conflict with your existing devices, it is possible to change the Com Port designation number:

1) Click Start > Settings > Control Panel
2) Click Systems to open the System Properties
3) Click the Hardware tab and click 'Device Manager'
4) Double Click the Ports Icon and select the 'USB Serial Port'
5) Right click and select Properties
6) Click the 'Port Settings' tab and click 'Advanced'
7) Select the Com Port Number and click 'OK'

Note: the path to the 'Port Settings' tab may be different for each Windows operating system. The above is just a guideline.

4.2.2 Data Directory

The program will save data downloaded to the following default directory: <C:\Program Files\Solinst\Levelogger4_1\Data> unless otherwise specified in the Default Directory field of the Application Settings window (Figure 4-29).

Click the Configuration menu at the top of the program window, select Application Settings and input or navigate to a different folder destination. After completing the Application Settings, click the OK button to confirm and save the settings.

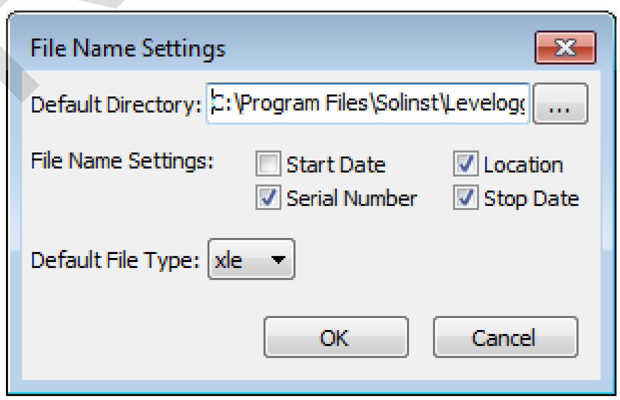


Figure 4-29 Application Setting Window

4.2.3 File Name Settings

From the Application Settings window in the Configuration menu, you can set what information will be included in your default file names of downloaded data (see Figure 4-29). You can include Start Date, Stop Date, Serial Number, and Location. Check-off the information you would like included.

After completing the Application Settings, click the OK button to confirm and save the settings.

4.2.4 Default File Type

From the Application Settings window in the Configuration menu, you can set what default file type you would like to use for downloaded, saved and exported data files. You can select between either *.xle (default) or *.lev file types (see Figure 4-29). For more information about the two file types, see Section 7.1.1.

After completing the Application Settings, click the OK button to confirm and save the settings.

> **NOTE**
>
> Depending on your Levelogger type, there will be different programming options. See Table 1-1 for the major differences. See Section 5.9 for programming the Levelogger Gold, Barologger Gold, and Levelogger Junior.

> **NOTE**
>
> Click on ? icons to get an explanation of that software feature.

> **NOTE**
>
> When first setting up a Barologger and Levelogger(s) that will be used for the same project, it is suggested to set them at the same sampling interval, and to use the Future Start and Stop options where possible. When the data sets have the same time stamps, and start and stop times, barometric compensation of the data will be most accurate. It is also useful to synchronize the clocks of the dataloggers. See Section 5.4.

> **NOTE**
>
> The Levelogger Edge, which is available in F15 (M5), F30 (M10), F65 (M20), F100 (M30), F300 (M100), and F600 (M200) ranges has actual water level ranges of 16.40 ft (5 m), 32.80 ft (10 m), 65.60 ft (20 m), 98.40 ft (30 m), 328.0 ft (100 m), and 656.2 ft (200 m), respectively.

5 Levelogger Edge Series Setup

After you start the Levelogger Software, the main Levelogger Software window will appear, with the Datalogger Settings tab open.

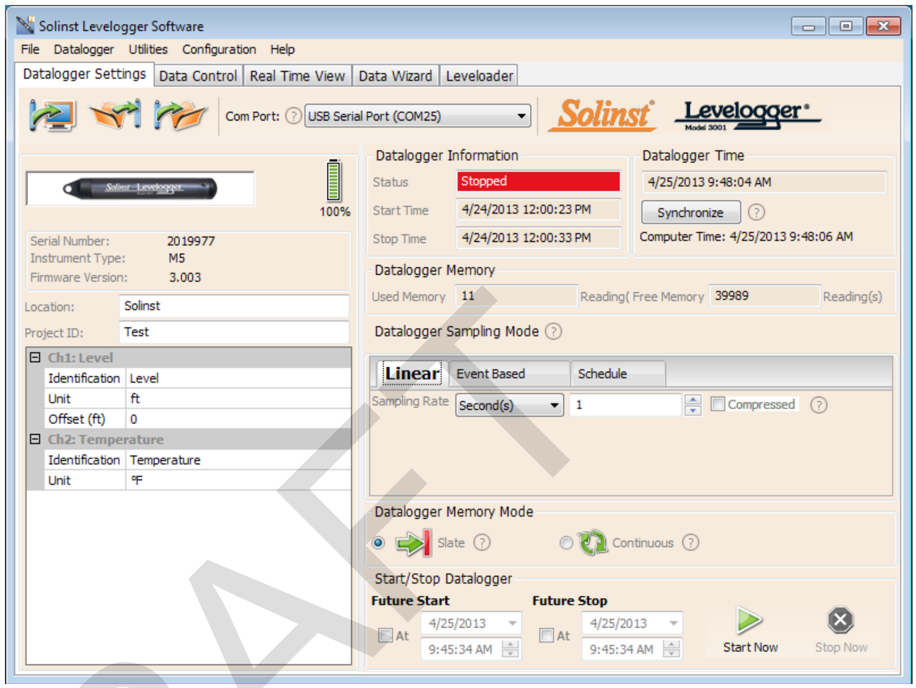


Figure 5-1 Datalogger Settings Tab

Select the appropriate COM or USB Port for the connected communications device from the centre drop-down menu.

Click [icon] to retrieve the current settings from the connected datalogger.

5.1 Datalogger Settings

After you have retrieved the settings of the connected datalogger, the Datalogger Settings tab will identify the Instrument Type, Serial Number, Firmware Version, Project ID, Location, and the Channel Settings.

- **Instrument Type**: will display the model of the attached datalogger, i.e.: F100/M30, Barologger, Rainlogger.
- **Serial Number:** the unique serial number of the attached datalogger will be displayed.
- **Firmware Version**: shows the firmware version of the attached datalogger.
- **Project ID:** input your own identification system. The Project ID is limited to 32 characters.
- **Location**: input specific site / location information. The location is limited to 32 characters.

5.1.1 Setting Up Channel Information

In the lower left portion of the Datalogger Settings tab is the area for setting channel parameters (level, temperature, conductivity, rainfall). The software will detect the available channels when the datalogger settings are retrieved.

5.1.1.1 Level Channel (Ch1)

> **NOTE**
> Readings can be converted to other units using the Data Wizard.
>
> Readings can be corrected or offset with respect to a specific reference elevation or datum for a much wider spectrum of numeric offsets as part of the Data Wizard.

- **Identification** describes the measurement parameter of the channel and has already been configured as 'LEVEL'. The channel can be re-named to suit each project. The channel monitors water column equivalent pressure. The Identification field will be the channel heading, data column heading and graph line name when viewing the data. Identification is limited to 32 characters.
- **Unit** refers to the channel's unit of measurement. There are six options when using a Levelogger Edge or Levelogger Junior Edge, m (default), cm, ft, kPa, bar, and psi. When using a Barologger Edge, the options are kPa (default), mbar, and psi.
- **Offset** refers to an adjustment, such as the distance between the tip of the Levelogger and the monitoring well cap or static water level. It is recommended that the value of 0.00 be used, as this keeps all subsequent readings relative to the tip of the Levelogger. The reference range is -1000 to 16,400 ft or -300 m to 5000 m.

> **NOTE**
> If you set your Levelogger to record in pressure units (kPa, bar, psi), you can not change the offset or enter an elevation value (in the Data Wizard). Only raw pressure readings will be provided.

> **NOTE**
> There is no Offset input option for the Barologger Edge.

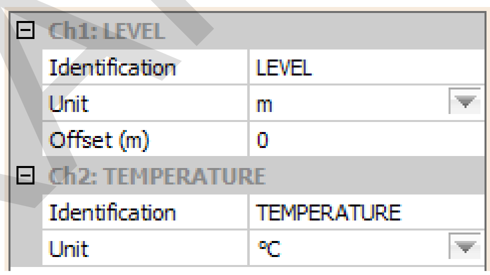


Figure 5-2 Levelogger Edge Channel Setup

The LTC Levelogger Junior also has inputs for:

> **NOTE**
> Levelogger Edge, Barologger Edge, and Levelogger Junior Edge data can be adjusted for altitude and density post data collection using the Data Wizard.

- **Altitude** in feet or meters above sea level, at which the logger is actually deployed, is input in the altitude field. You can enter an elevation between -1000 ft below sea level and 16,400 ft (or -300 m and 5000 m) above sea level. The readings will then be automatically compensated for elevation.
- **Density** is used to adjust the range of the Levelogger based on the sample fluid density. The range for the density adjustment is from 0.9 kg/L to 1.1 kg/L.

5.1.1.2 Temperature Channel (Ch2)

> **NOTE**
> The LTC Levelogger Junior only measures in °C

- **Identification** describes the measurement parameter of the channel and has already been configured as 'TEMPERATURE'. The channel can be re-named to suit each project. The Identification field will be the channel heading, data column heading and graph line name when viewing the data. Identification is limited to 32 characters.
- **Unit** refers to the channel's unit of measurement. For the Levelogger Edge, Barologger Edge, and Levelogger Junior Edge, the temperature channel can be set to °C (default) or °F.

> **NOTE**
>
> For every degree change in temperature, there is approximately a 2% change in conductivity. To convert raw conductivity measurements to Specific Conductance measurements, you can use the following equation:
>
> Specific Conductance = Conductivity / (1 + 0.02 * (temp(C) - 25))
>
> You can also perform this calculation automatically using the Data Wizard.
>
> You can also convert Conductivity readings to Salinity (expressed in Practical Salinity Units (PSU)) using the Data Wizard.

5.1.1.3 Conductivity Channel (Ch3)

- **Identification** describes the measurement parameter of the channel and has already been configured as 'CONDUCTIVITY'. The channel can be re-named to suit each project. The Identification field will be the channel heading, data column heading and graph line name when viewing the data. Identification is limited to 32 characters.
- **Unit** refers to the channel's unit of measurement. There are two units of measure available for the user to select: mS/cm or µS/cm.

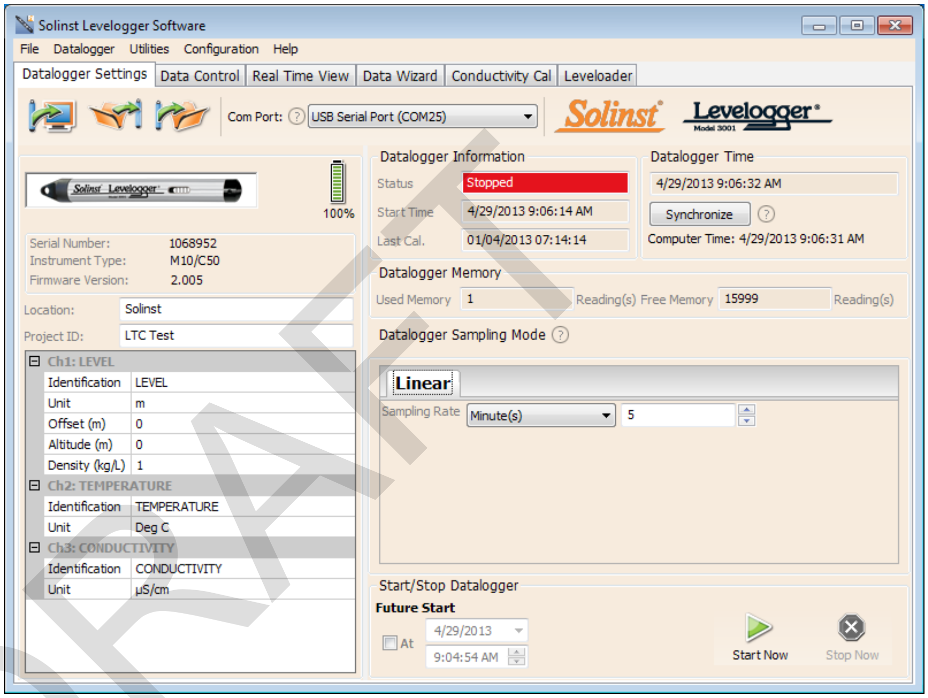


Figure 5-3 Conductivity Channel Setup

5.1.1.4 Rainloggers

There is one channel of measurement for the Rainlogger Edge and Rainlogger. The **RainFall** Channel records each tip time by the connected tipping-bucket and outputs the amount of rainfall per tip (input Rainfall Cal Constant).

- **Identification** describes the measurement parameter of the channel and has already been configured as 'RainFall'. The channel can be re-named to suit each project. The Identification field will be the channel heading, data column heading and graph line name when viewing the data. Identification is limited to 32 characters.
- **Units** refers to the channel's unit of measurement. There are two units of measure available for the user to select: mm or in.
- **The Rainfall Cal Constant** field allows you to enter the calibration factor for the tipping-bucket you will be using. The calibration factor is the amount of rainfall depth (mm, in) per tip. The calibration factor should be indicated on a label on the tipping-bucket device or in the manufacturer's documentation. Input the calibration factor in mm or inches.

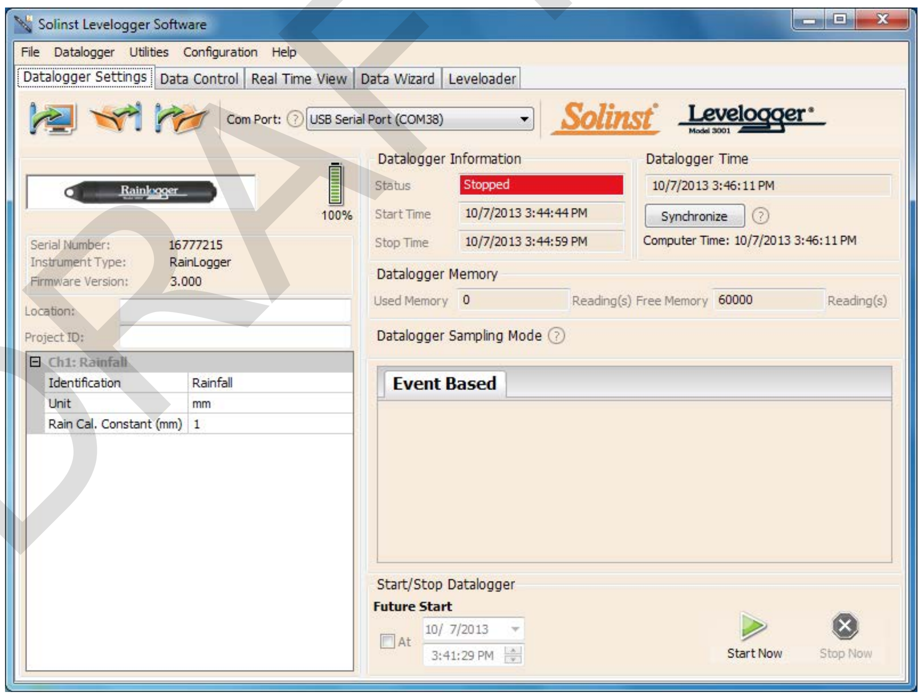


Figure 5-4 Rainlogger Channel Setup

5.2 Datalogger Information

The Datalogger Information section shows the Status of the attached datalogger (i.e.: Started, Stopped, Future Start) and the Start Time and Stop Time of the datalogger. When a Future Start and/or Stop time is set (see Section 5.8), the Start Time and Stop Time fields will fill in. The fields will update each time the datalogger is stopped and started.

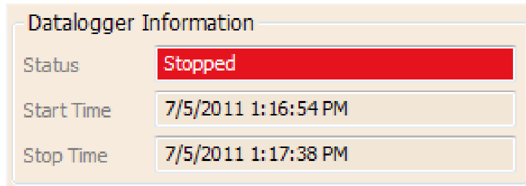


Figure 5-5 Datalogger Information

5.3 Datalogger Memory

The Datalogger Memory section shows the amount of memory used, and the amount of memory remaining (number of readings).

Figure 5-6 Datalogger Memory Remaining

If the Data Compression option is selected (see Section 5.5), the amount of free memory shown is approximated as a visual status bar.

Figure 5-7 Datalogger Compressed Memory

5.4 Datalogger Time

! NOTE

It is very useful to synchronize the clocks of all the Leveloggers and Barologgers for use on the same project.

The Datalogger Time section provides the controls for setting the datalogger clock. If you want to synchronize the datalogger's clock to the computer clock, click Synchronize to set the time in the datalogger.

If you start the datalogger without synchronizing the clock and the time difference between the datalogger and the PC is more than 3 seconds, the software will give you a message asking 'Do you want to synchronize the logger time to system time?'. Click Yes to synchronize the clock.

It can be very useful to synchronize the clocks of all the Leveloggers and Barologgers when it comes to Barometric Compensation.

! NOTE

To synchronize to a different time/ time zone you first must adjust the computer time using the Windows Operating System Date and Time Settings menu. Then re-start the Solinst Levelogger Software and synchronize your Dataloggers to the new time.

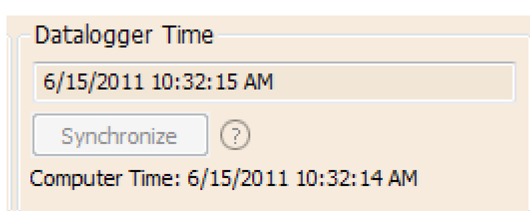


Figure 5-8 Datalogger Time

5.5 Datalogger Sampling Mode

The Datalogger Sampling Mode section allows you to choose the sampling measurement type. Options for the Levelogger Edge are Linear, Event Based and Schedule.

Linear refers to a set time interval between collection of readings. Sample Rate can be any number from 0.125 seconds to 99 hours for the Levelogger Edge. There is a data compression option available for the Levelogger Edge. This increases the memory capacity of the Levelogger Edge from 40,000 readings to up to a maximum of 120,000. Check the Data Compression box to allow data compression.

Data Compression works by only saving data changes in memory. For example, if you have linear sampling set to record each second, and your water level varies a little for 60 seconds, the memory will only record incremental values for the 60 seconds. When your data is exported, it will display all 60 intervals with the corresponding level data.

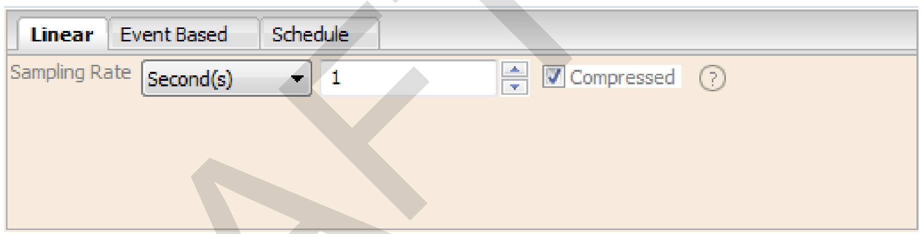


Figure 5-9 Linear Sampling Setup

Event Based sample collection is the most memory efficient means of data collection. In Event mode, the Levelogger will be activated at every defined 'Sample Rate' to check if readings have changed by the selected 'Change' from the last recorded reading.

For the Levelogger Edge, 'LEVEL' or 'TEMPERATURE' is the selected parameter where change is monitored. The Levelogger will record a new reading only if the specified change in the parameter has occurred, at the specific point in time, as defined by the 'Sample Rate'.

A default reading will also be stored in the datalogger memory, every 24 hours from the last recording, if no 'Change' occurs.

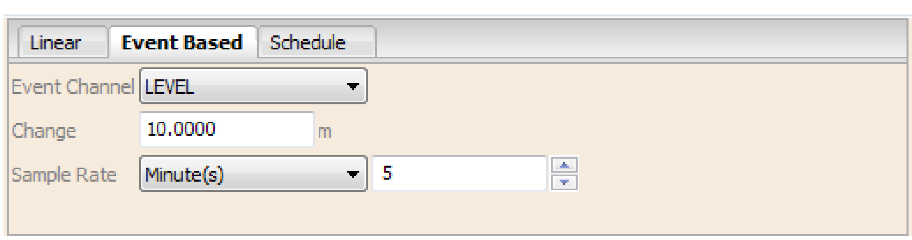


Figure 5-10 Event Based Sampling Setup

NOTES

The battery life of the Levelogger Edge is 10 Years, based on 1 reading per minute. More rapid readings will reduce the battery life. For example, if a Levelogger Edge is setup in Continuous Mode at a sampling rate of 1 second, the battery will be depleted in approximately 4 months.

If a Levelogger Junior Edge or LTC Levelogger Junior are used at a sampling rate of 5 seconds, the battery will be depleted in approximately 2.5 months.

NOTE

The LTC Levelogger Junior and Levelogger Junior Edge record using Linear sampling mode only.

The Levelogger Junior Edge has a sample rate of 0.5 seconds to 99 hours. The LTC Levelogger Junior has a sample rate of 5 seconds to 99 hours.

NOTES

In Event Based sampling mode, the Levelogger Edge has a total memory of 25,000 readings of level and temperature.

In Event Based sampling mode, battery consumption is mainly a function of sampling rate. Therefore, with a smaller sampling interval, battery power will be used up quickly whether readings are stored or not.

NOTE

Rainloggers record in Event Based mode only. They record the tip times of a connected tipping-bucket.

> **NOTE**
> A schedule can be saved and applied to other Leveloggers, or a Leveloader, by saving the Levelogger Settings file (see Section 5.7).

Schedule Sampling allows you to select a logarithmic style sampling schedule adapted to the needs of each application.

Schedule Sampling is set by using the plus and minus buttons to add or subtract line items in the Schedule window. The maximum number of line items in a schedule is 30, each with its own sampling interval of seconds, minutes or hours and duration of seconds, minutes, hours, days or weeks. A 'Pause' interval can also be selected, which stops the Levelogger from recording for the specified duration.

Running totals of the number of readings still available, from the total possible 40,000 or 120,000, and the run time to date are shown. If the number of readings selected exceeds the Leveloggers memory capacity an error message appears.

By checking Repeat, the Levelogger will continue to run through the schedule until its memory is full, or it is stopped.

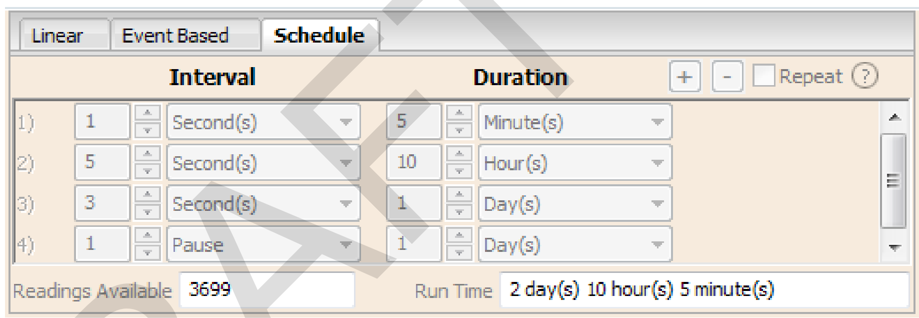


Figure 5-11 Schedule Sampling Setup

5.6 Datalogger Memory Mode

> **NOTE**
> Datalogger Memory Mode is only available for Levelogger Edge and Levelogger Gold units using Linear Sampling.
>
> Levelogger Junior Edge and LTC Levelogger Junior operate in Slate logging mode only.

Datalogger Memory Mode selection will only appear when **Linear** sampling mode is selected. When using a Levelogger Edge in Linear Mode, there is a choice of **Continuous** Logging (wrap around) or **Slate** Logging .

Compressed Linear, Event Based and Schedule sampling modes can only use the Slate Mode option.

In Continuous Logging, the new log is started at the end of any previous log and continues logging, eventually recording over the first logged data. As one of the download options is to 'Append Data', Continuous Logging can be a preferred choice when logging long-term (see Section 7.1.2).

In Slate Logging, the new log is also started at the end of any previous log, but will stop recording after 40,000 readings (or up to 120,000 readings), so that the beginning of the current log will not be written over.

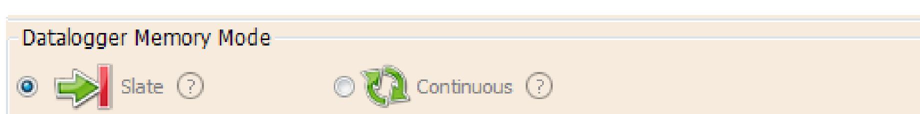


Figure 5-12 Datalogger Memory Mode

> **NOTE**
>
> Settings files created in Levelogger Software Version 3 or earlier (.lls or .sci files) can not be opened by Software Version 4. These settings files will need to be re-created and saved in Levelogger Software Version 4.

5.7 Saving and Retrieving Levelogger Settings Files

To store settings as defaults, click . It will store the settings of the Levelogger into an *.dtf file as a series of defaults. The *.dtf file will save the Project ID, Location, Sample Mode, Sample Rate, Channel ID, Unit, and Offset.

To retrieve settings from defaults, click from a selected *.dtf file. This is particularly useful if programming several Leveloggers with similar identical settings. Keep in mind that Project ID and Location identification information will be identical and should be distinguished from logger to logger or monitoring point to point.

5.8 Starting and Stopping the Datalogger

Starting the Datalogger

> **NOTES**
>
> If a setting has been changed, it will be highlighted in yellow as a reminder before the datalogger is started.
>
> If a setting has been entered incorrectly, it will be highlighted in red.
>
> Changed settings are applied to the datalogger automatically when the Start icon is selected.

There are two ways to start logging: **Start Now** or by programming a **Future Start** time.

To start logging immediately, do not fill in a Future Start time and click, . It should say Start Now below the icon to indicate an immediate start. Any changed settings will automatically be applied to the datalogger, and it will start logging. Datalogger Status will change from Stopped to Started.

After the datalogger is started, and begins collecting readings, the Start icon will be greyed out, and only the Stop icon and Future Stop settings will be active.

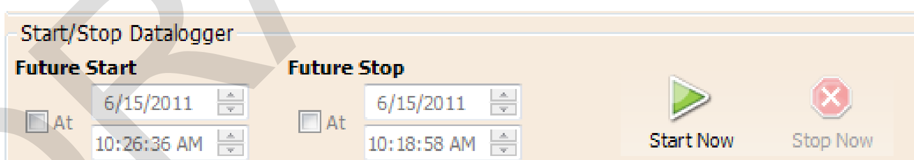


Figure 5-13 Starting the Datalogger Immediately

> **NOTE**
>
> Remember to download any data on the datalogger before starting a new session. When starting a new logging session, any data from previous recording sessions will be erased.

Check **Future Start** 'At' to set logging to start at a later date and/or time. This Start mode is referred to as Future Start in the Status field. Click to apply the Future Start time and any changes to the datalogger settings.

When the Future Start time is reached, the datalogger will start logging and the Status will change from Future Start to Started.

> **NOTE**
>
> Retrieve the Levelogger settings in order to refresh the status (i.e. when the status changes from Future Start to Started).

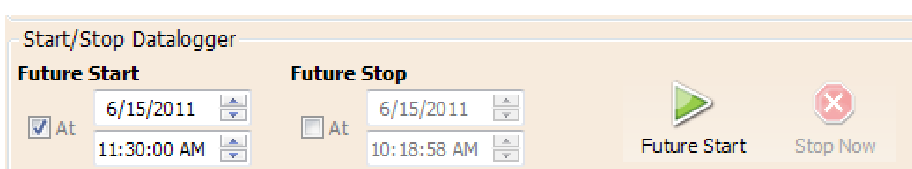


Figure 5-14 Future Start Setting

> **NOTE**
> You can not set a Future Stop time for the Levelogger Junior Edge, LTC Levelogger Junior or a Rainlogger.

> **NOTE**
> If you have set a Future Stop time, but wish to stop the datalogger immediately, uncheck the Future Stop 'At' box, and the Stop icon should say Stop Now. Click the icon to stop logging.

Stopping the Datalogger

There are two ways to stop logging: Stop Now or at a programmed Future Stop time for the Levelogger Edge and Barologger Edge.

To stop the datalogger immediately when it is logging, click , (it should say Stop Now below the icon).

The Levelogger can be stopped at any time before it reaches the maximum reading capacity. **Starting again begins a new recording session and clears previously stored data readings.**

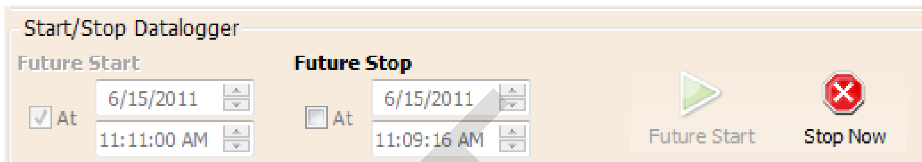


Figure 5-15 Stopping the Datalogger Immediately

To program a **Future Stop** time for your datalogger, check Future Stop 'At' and fill in the desired stop time. The Future Stop time will be applied to the datalogger once is selected for an immediate or future start.

You can also program a Future Stop time after you have started the datalogger, by checking Future Stop 'At' and filling in the desired stop time. Select to apply the Future Stop time (it should say Future Stop below the icon). The Stop Time should be shown in the Datalogger Status section.

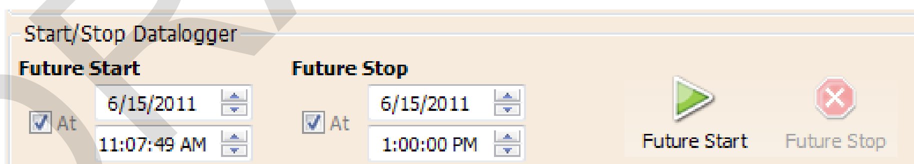


Figure 5-16 Future Stop Setting

It is critical to note that when Leveloggers log data in Slate mode, it means they will record data until stopped or their memory is full. When the memory fills, the datalogger will stop recording. For this reason, it is important to determine, based on your start time and sampling rate, the date and time at which the memory will be full and the datalogger will stop recording. Levelogger Edge units record in Slate mode if Event, Schedule, or Compressed logging, but in standard Linear mode they can be set to Slate or to Continuous logging.

5.9 Levelogger Gold Series Setup

This section briefly describes the Levelogger Gold, Barologger Gold and Levelogger Junior setup.

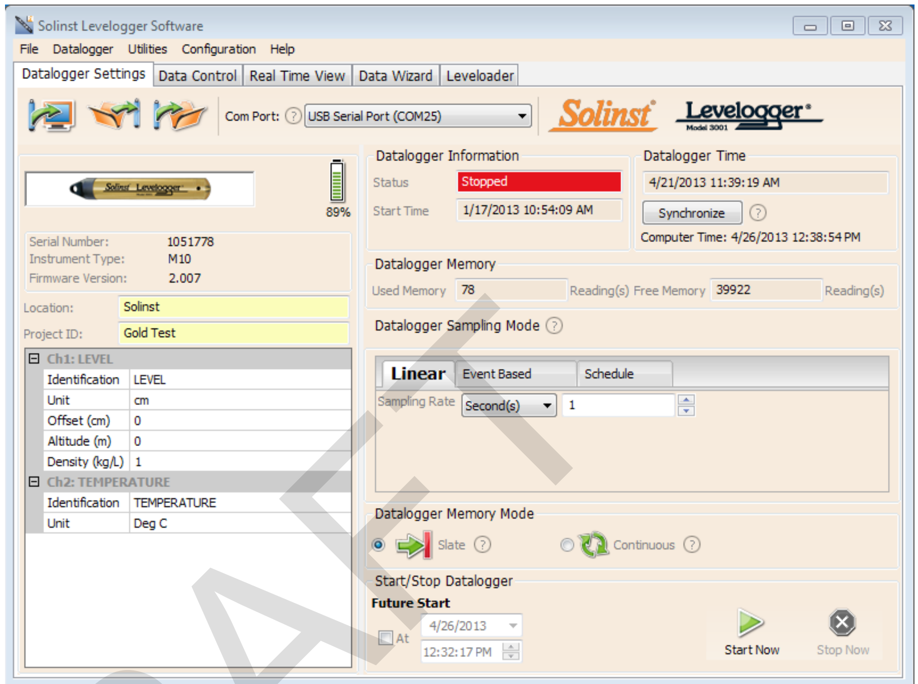


Figure 5-17 Levelogger Gold Settings

Select the appropriate COM or USB Port for the connected communications device from the centre drop-down menu.

Click to retrieve the current settings from the connected datalogger.

<u>Channel Information</u>

Level Channel (Ch1)

- **Identification** describes the measurement parameter of the channel and has already been configured as 'LEVEL'. The channel can be renamed to suit each project. The channel monitors water column equivalent pressure. The Identification field will be the channel heading, data column heading and graph line name when viewing the data. The Identification is limited to 32 characters.
- **Units** refers to the channel's units of measurement. There are three units of measure available for the user to select: cm, m or ft. When the user changes the unit, the value of the range and altitude will change according to the Unit Conversion formula. Note that when a metric unit is used, the unit of altitude is meters. When feet are the level channel units, feet are the units of altitude.

NOTE

Click on ? icons to get an explanation of that software feature.

- **Offset** refers to an offset correction, such as the distance between the tip of the Levelogger and the monitoring well cap or static water level. It is recommended that the value of 0.00 be used for offset as this keeps all subsequent readings relative to the tip of the Levelogger. The offset range for Levelogger Gold and Barologger Gold units is -1000 to 16400 ft or -300 m to 5000 m.
- **Altitude** in feet or meters above sea level, at which the logger is actually deployed, is input in the altitude field. Water column equivalent pressure decreases with altitude at a rate of approximately 1.2:1000 in the lower atmosphere below 5000 m. You can compensate for this by entering an elevation between -1000 ft below sea level and 16,400 ft (or -300 m and 5000 m) above sea level. The readings will then be automatically compensated for elevation.
- **Density Adjustment** is used to adjust the range of the Levelogger based on the sample fluid density. The range for the density adjustment is from 0.9 kg/L to 1.1 kg/L.

Temperature Channel (Ch2)

- **Identification** describes the measurement parameter of the channel and has already been configured as 'TEMPERATURE'. The channel can be re-named to suit each project. The Identification field will be the channel heading, data column heading and graph line name when viewing the data. Identification is limited to 32 characters.
- **Unit** refers to the channel's unit of measurement. The Levelogger Gold and Barologger Gold measure in °C only.

Sample and Memory Modes

Sample Mode, allows you to choose the sampling measurement type. Options are Linear, Event Based and Schedule.

- **Linear** refers to a set time interval between collection of readings. Sample Rate can be any number from 0.5 seconds to 99 hours. The Levelogger Gold and Barologger Gold can store 40,000 readings of level and temperature.
- **Event Based** sample collection is the most memory efficient means of data collection. In Event mode, the Levelogger will activate every sampling interval defined and check if readings have changed by the selected threshold (Change) from the last recorded reading. For the Levelogger Gold, 'LEVEL' or 'TEMPERATURE' is the selected parameter where change is monitored. The Levelogger will record a new reading only if the specified change in the parameter has occurred.
- **Schedule Sampling** allows you to select a logarithmic style sampling schedule adapted to the needs of each application. Schedule Sampling is set by using the plus and minus buttons to add or subtract line items in the Schedule window. The maximum number of line items in a schedule is 30, each with its own sampling interval of seconds, minutes or hours and duration of seconds, minutes, hours, days or weeks.

NOTE

The Levelogger Junior records using Linear sampling mode only.

NOTE

In Event Based sampling mode, the Levelogger Gold has a total memory of 25,000 readings of level and temperature

NOTE

An important reminder for Event Based sampling is that, although actual memory usage in stable water level conditions may be relatively small, battery power consumption is partially a function of the sample reading rate. Therefore, a small sample reading interval will consume battery power at a higher rate whether readings are stored or not.

Memory Mode selection will be grayed-out if not in Linear Mode sampling. When using a Levelogger Gold in Linear Mode, there is a choice of **Continuous** logging (wrap around) or **Slate** logging. In Continuous logging the new log is started at the end of any previous log and continues logging, eventually recording over the first logged data. As one of the download options is to 'Append Data', Continuous logging can be a preferred choice when logging long-term. In Slate logging the new log is also started at the end of any previous log, but will stop recording after 40,000 readings, so that the beginning of the current log will not be written over.

Starting and Stopping the Levelogger

There are two ways to start logging: **Start Now** or by programming a **Future Start** time.

To start logging immediately, do not fill in a Future Start time and click, . It should say Start Now below the icon to indicate an immediate start. Any changed settings will automatically be applied to the datalogger, and it will start logging. Datalogger Status will change from Stopped to Started.

After the datalogger is started, and begins collecting readings, the Start icon will be greyed out, and only the Stop icon and Future Stop settings will be active.

Check **Future Start** 'At' to set logging to start at a later date and/or time. This Start mode is referred to as Future Start in the Status field. Click to apply the Future Start time and any changes to the datalogger settings.

When the Future Start time is reached, the datalogger will start logging and the Status will change from Future Start to Started.

To stop the datalogger immediately when it is logging, click , (it should say Stop Now below the icon).

The Levelogger can be stopped at any time before it reaches the maximum reading capacity. **Starting again begins a new recording session and clears previously stored data readings.**

It is critical to note that when Leveloggers log data in Slate mode, it means they will record data until stopped or their memory is full. When the memory fills, the datalogger will stop recording. For this reason, it is important to determine, based on your start time and sampling rate, the date and time at which the memory will be full and the datalogger will stop recording. Levelogger Gold units record in Slate mode if using Event, or Schedule sampling mode, but in standard Linear mode they can be set to Slate or to Continuous logging.

Figure 6-1
LTC Levelogger Junior

NOTE

If you know the approximate conductivity range of the water that you will be measuring, best accuracy when calibrating your unit is to select two calibration points - one above, and one below that range. If you are measuring in water less than 1,413 µS/cm or above 12, 880 µS/cm, use just one calibration solution.

6 Conductivity Calibration

The LTC Levelogger Junior conductivity sensor must be calibrated for reliable conductivity measurements. Calibrate for conductivity at the start of each new monitoring project or at a minimum each new monitoring season (twice a year).

Calibrating the LTC Levelogger Junior directly after the monitoring project or season will provide information on the degree of conductivity deviation during the project or season. If necessary, readings can be corrected for any conductivity deviation in a spreadsheet program after the data has been exported.

The process of conductivity calibration is performed automatically by use of the Calibration Wizard. You place the LTC Levelogger Junior in a specified calibration solution and follow the steps provided by the wizard. Conductivity calibration solutions are available from Solinst or any laboratory supply outlet.

The LTC Levelogger Junior has an 80,000 µS/cm conductivity range and a calibrated range from 500 to 50,000 µS/cm. It can be calibrated to 3 calibration standard points:

- 1,413 µS/cm
- 5,000 µS/cm
- 12,880 µS/cm

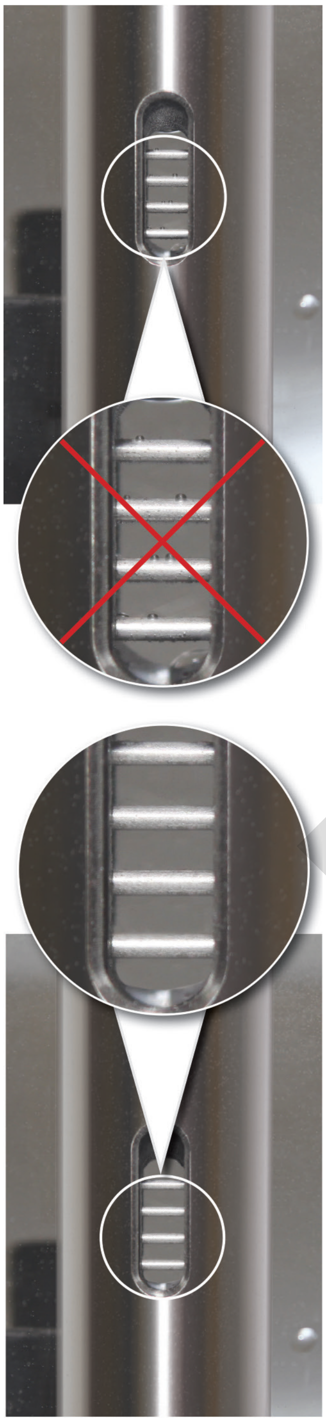
If you know the approximate conductivity range of the water that you will be measuring, best accuracy when calibrating your unit is to select two calibration points - one above, and one below that range. If you are measuring in water less than 1,413 µS/cm or above 12,880 µS/cm, use just one calibration solution.

The solution(s) must be between 10°C and 30°C during actual calibration. Temperature should remain stable during the 10 - 20 seconds it takes to perform each calibration.

For best accuracy, it is recommended you use calibration solutions that have a temperature error of ±2% or better. You should also keep the solution as close to the stated temperature on the bottle as possible (i.e. 25°C). The closer you get to the temperature extremes of 10°C and 30°C, the less accurate your calibrations may be.

NOTE

Ensure that the calibration solution covers the entire sensor cell and the logger is agitated to release entrapped air bubbles.



Retrieve the settings from the attached LTC Levelogger Junior by clicking .

Stop the LTC Levelogger Junior by clicking .

Start the Calibration Wizard by clicking the Conductivity Cal tab. The wizard will guide you through the calibration process. You can exit the wizard after any step to cancel the calibration session.

Introduction: The LTC Levelogger Junior must be connected to the computer with an Optical Reader during the entire calibration process and **must be in the stopped mode**. Ensure you use fresh calibration solution and allow thermal equilibration of the solution during the process. Also ensure no air bubbles are present on the sensor and that the pins are clean. See Section 10.2 for recommended methods to clean the sensor pins. See Section 10.1.5.3 for protection against biofouling conditions.

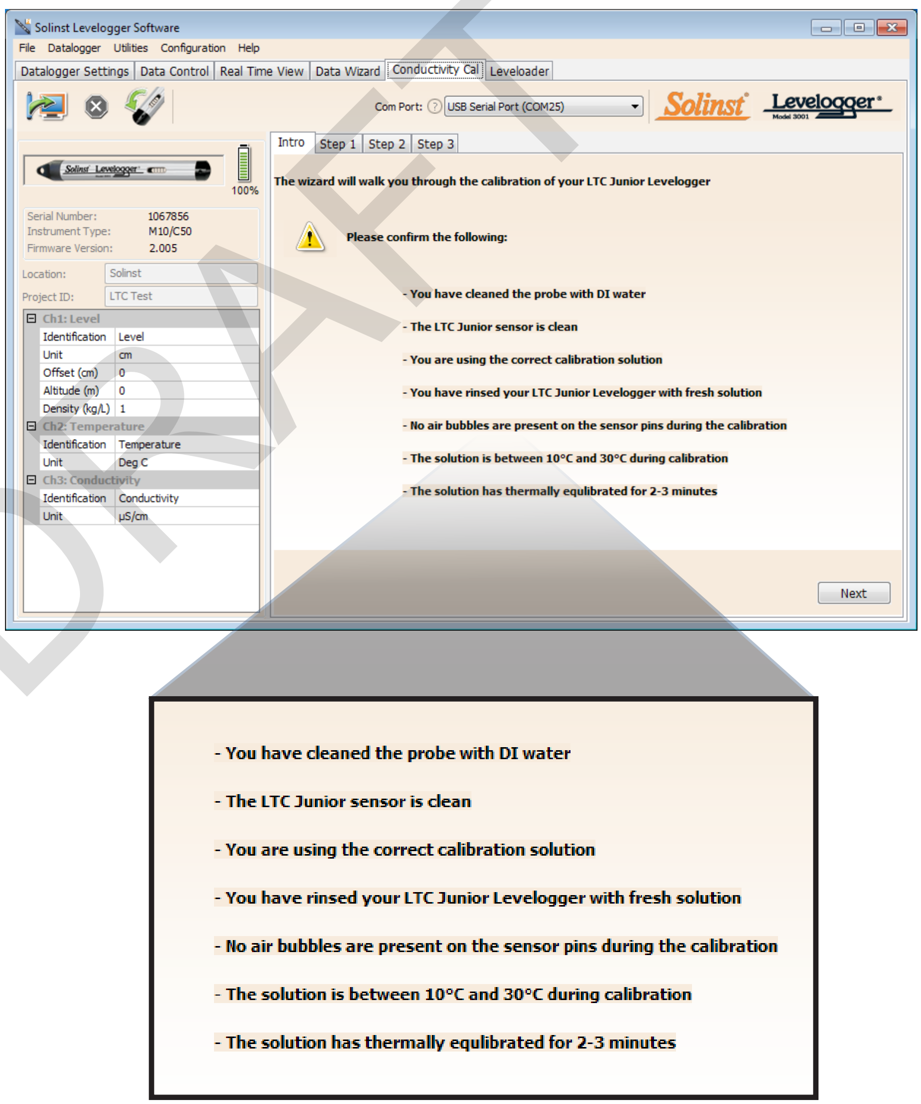


Figure 6-2 LTC Levelogger Junior Calibration Wizard Introduction

1) **Setting the Temperature Coefficient:** The default setting for the Temperature Coefficient is 2.00. If the conductivity solution you are using to calibrate the LTC Levelogger Junior states a different temperature coefficient on the label, please input that number into the Temperature Coefficient field.

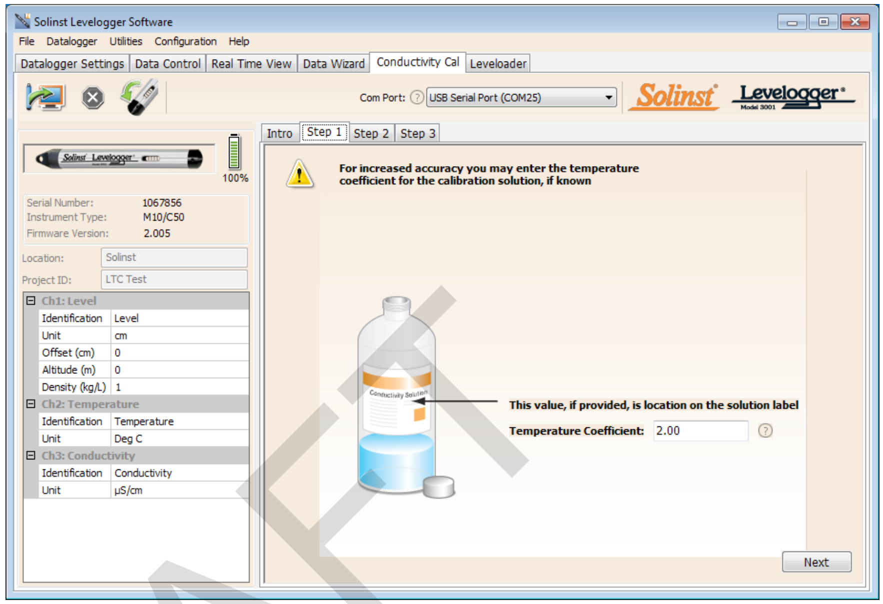


Figure 6-3 LTC Levelogger Junior Calibration Wizard Step 1

2) **Setup:** The Levelogger Software requires the user to choose the calibration solutions. You can choose up to three solutions for a multipoint calibration of the LTC Levelogger Junior. Ensure the solutions are ready in the calibration beaker or container. Start the calibration by selecting Next.

NOTE

To obtain the highest accuracy, choose the calibration solution(s) closest to your expected conductivity.

Use a two point calibration for waters between 1,413 µS/cm and 12,880 µS/cm.

Use a one point 1,413 µS/cm calibration for waters less than 1,413 µS/cm.

Use a one point 12,880 µS/cm calibration for waters greater than 12,880 µS/cm.

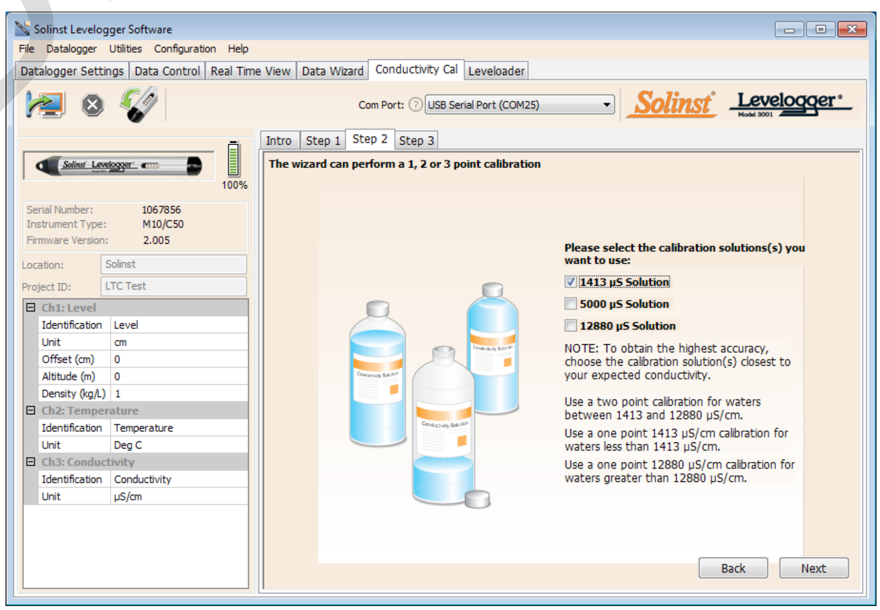


Figure 6-4 LTC Levelogger Junior Calibration Wizard Step 2

> **NOTE**
> Always remember to use fresh solution, remove all bubbles from the sensor pins, and allow for thermal equilibration of the sensor before proceeding.

3) **LTC Levelogger Junior Rinsing Process:** Use DI water to rinse the LTC Levelogger Junior first and then rinse the LTC Levelogger Junior with the displayed calibration solution. Use fresh solution for calibration, and immerse the LTC Levelogger Junior. Lightly tap the Levelogger to remove any bubbles from the sensor. Allow 2-3 minutes to stabilize, then select next to calibrate.

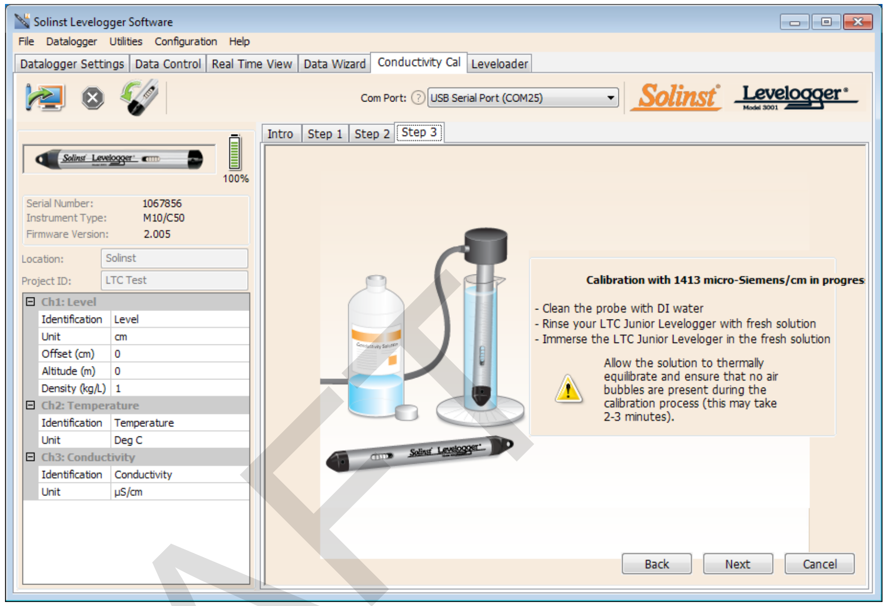


Figure 6-5 LTC Levelogger Junior Calibration Wizard Step 3
(example of window calibrating with 1413 µS/cm solution)

Calibration: Since most standard calibration solutions state conductivity at a standard temperature of 25°C, the LTC Levelogger Junior can account for temperature differences between 10 to 30°C when you calibrate the unit. The LTC Levelogger Junior will compare the current temperature and conductivity readings against the temperature corrected standard solution.

> **NOTE**
> Once the calibration is complete for the first solution of a multipoint calibration, the Calibration Wizard will then go back to the beginning of Step 3 to start the rinsing process for the next solution selected.

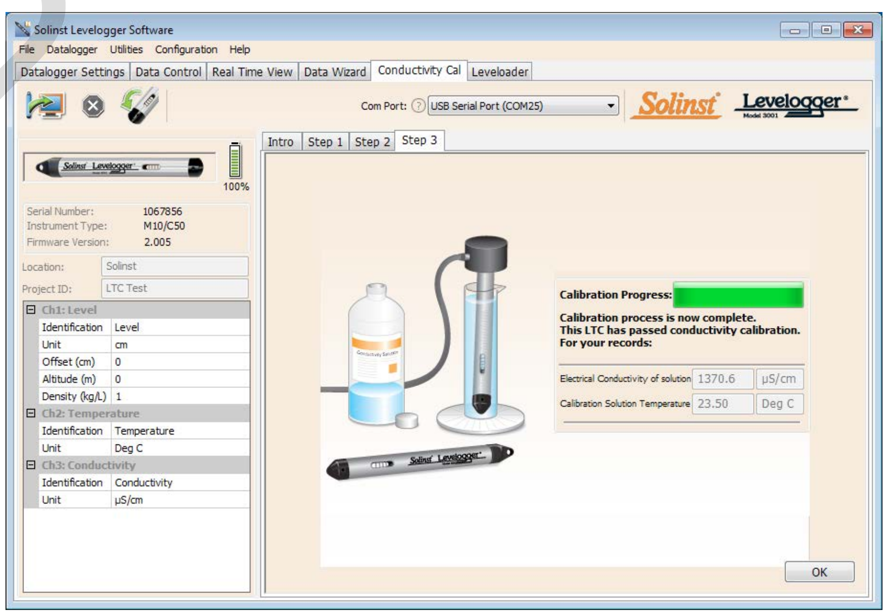


Figure 6-6 LTC Levelogger Junior Calibration Successful

When a single-point calibration is successful, the process is complete. Once the calibration is complete for the first solution of a multipoint calibration, a message will appear stating that the calibration was successful. When you select 'Okay', the Calibration Wizard will go back to the beginning of Step 3 to start the rinsing process for the next solution selected. The calibration process will proceed automatically until completed for all solutions.

If a failure occurs at any point during calibration, a message will appear asking you to clean and check your probe, then start the calibration process over for that current solution by selecting 'Yes' (Figure 6-7). If performing a multipoint calibration, any previous successful calibration points will remain.

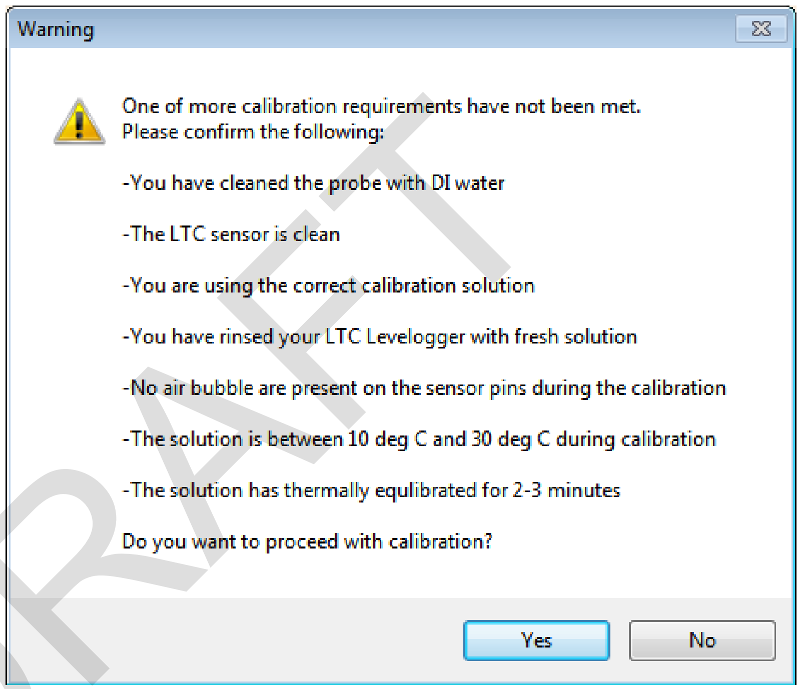


Figure 6-7 LTC Levelogger Junior Calibration Warning 1

If a second failure occurs during calibration, a warning message will appear indicating that your probe may still be dirty, or damaged. This may occur if your LTC Levelogger Junior conductivity sensor has been affected by dirt, mineral build-up, etc., so it no longer responds like it did when it was first factory calibrated. This step allows your sensor to be calibrated within a wider range of the standard solution value.

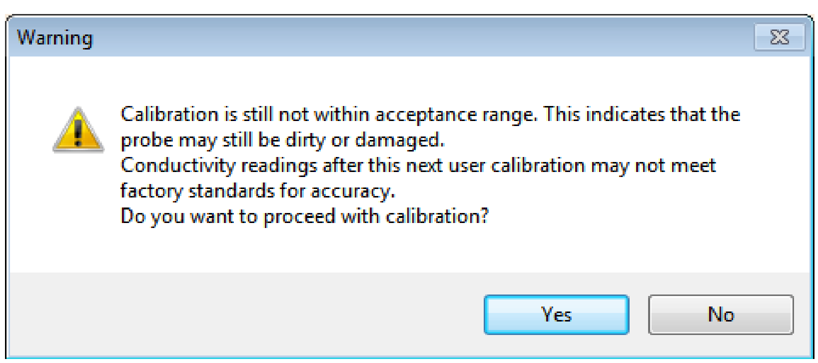


Figure 6-8 LTC Levelogger Junior Calibration Warning 2

If you select 'Yes' to accept the larger tolerance, the calibration process will start over for that current solution (Figure 6-8). If performing a multipoint calibration, any previous successful calibration points will still remain. If you select 'No', the LTC Levelogger Junior will default back to the last pre-calibrated state. You can retry the calibration using the normal tolerance range.

If a third calibration error occurs, or the results of the calibration are outside the error tolerance range, a warning message will appear asking you to contact Solinst for more options (Figure 6-9).

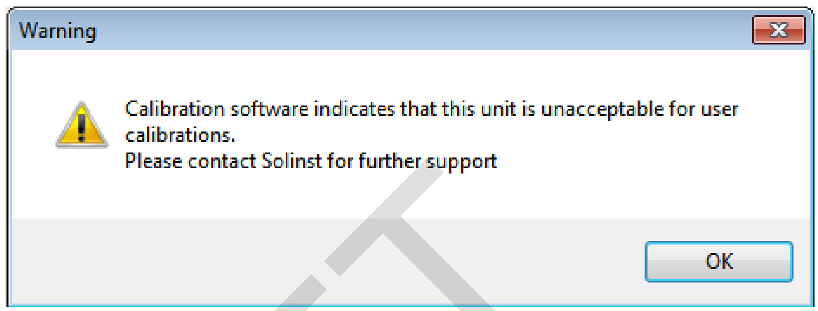


Figure 6-9 LTC Levelogger Junior Calibration Warning 3

6.1 Restore Factory LTC Levelogger Junior Calibration

An LTC Levelogger Junior can be set back to original factory calibration settings for conductivity at any time, using this function. If you suspect that user calibrations are not working properly, you can restore the LTC Levelogger Junior to its original factory settings and then perform a "first-time" conductivity user calibration to maximize accuracy.

To execute this function, simply click the Restore Factory LTC Calibration button,  with the LTC Levelogger Junior connected to the PC.

7 Data Control
(Downloading and Viewing Data)

Click the Data Control tab on the Main window. From the Data Control tab you can download data from a Levelogger, display data in tabular or graphic format, and save and export data files.

> **NOTE**
> When you click on a data point in the graph, the corresponding data point will be highlighted in the table. You can also highlight a section of data in the graph.

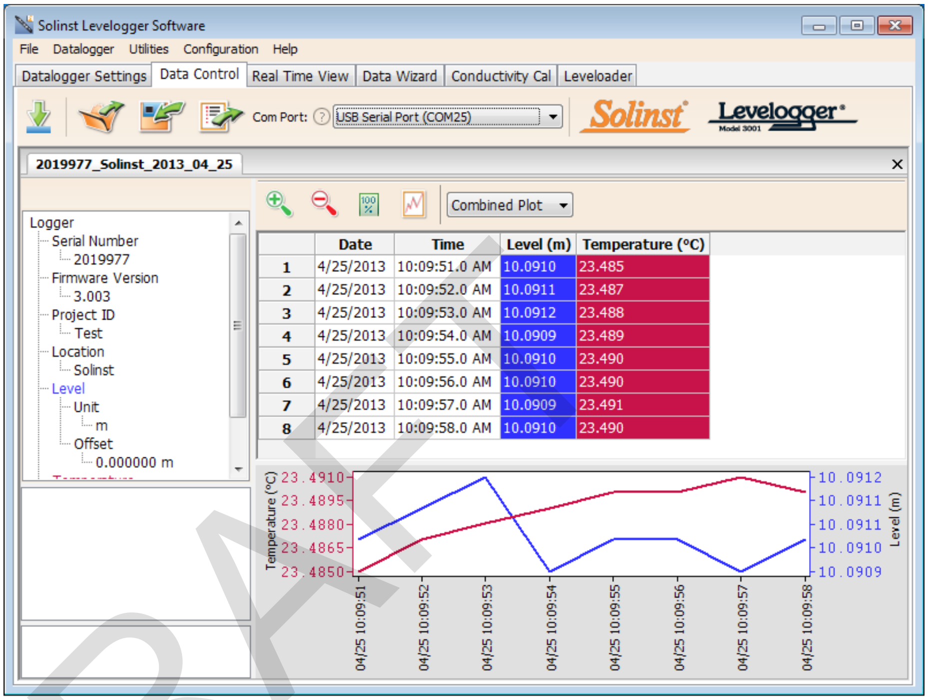


Figure 7-1 Data Control Tab

Click  to open a *.xle or *.lev file. Multiple files can be opened at the same time and are available for viewing by clicking the File Name Tab on top of the data table.

All the Levelogger settings and the channel information effective during data collection are shown on the top left of the window.

The bottom left sections of the window are used to display information after a data compensation has been performed. The middle section displays information from a Barologger, if a barometric compensation is performed, and the bottom section includes information from other conversions, such as offsets or conductivity conversions (see Section 8).

> **NOTE**
> As there is only one channel of data for Rainloggers, there are no graphing options.

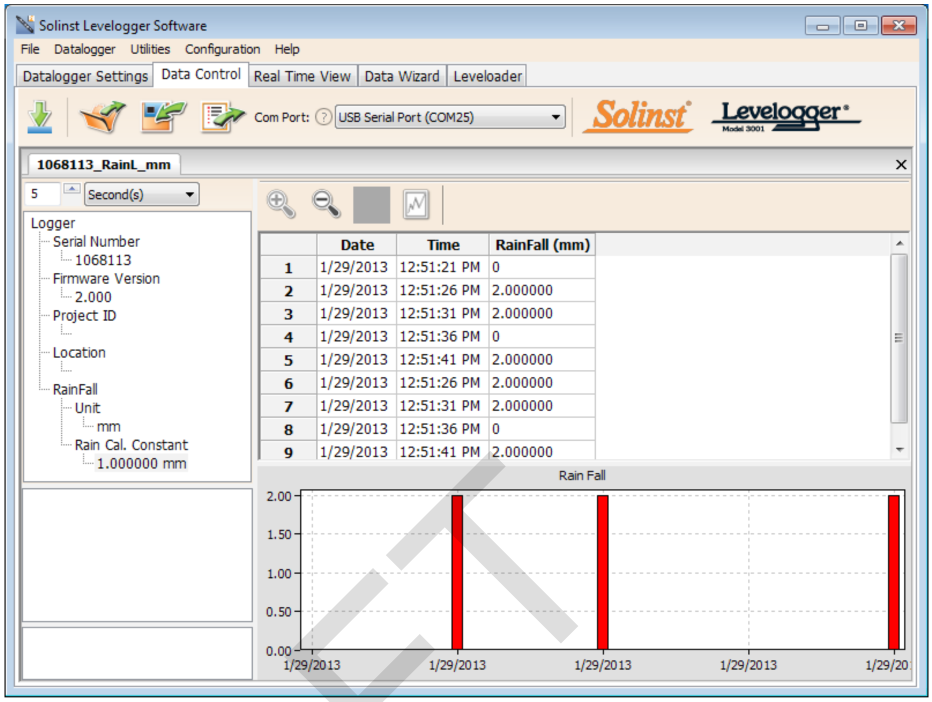


Figure 7-2 Rainlogger Data

When you view data downloaded from a Rainlogger, the RainFall data will be shown in a table and in a bar graph. A drop-down menu appears that allows you to select the time interval at which you would like the data shown, from 1 to 99 seconds, minutes, hours, days, or weeks (this acts like a zoom function). Figure 7-2 shows the data every 5 seconds from the start date and time.

7.1 Downloading Options and Saving Data Files

7.1.1 Default File Format

> **NOTE**
> The default file type is *.xle, unless changed in the Application Settings (see Section 4.2.4).

The default file type for Levelogger Software Version 4 and up is *.xle, unless changed to *.lev in the Application Settings (see Section 4.2.4). Previous Levelogger Software used *.lev files as the default. The *.xle file type is a *.xml format, which allows for enhanced functionality. The *.xle files can be exported as *.xml files, which can be integrated into external database programs.

The *.lev files of previous Levelogger downloads are compatible with Levelogger Software Version 4 and up, however, *.xle files are not compatible with previous software versions. To ensure compatibility, all Levelogger Software versions allow data to be exported as *.csv files for use in external spreadsheet programs. See Section 7.3 for Export options.

NOTE

Before downloading data you must select the COM Port that the datalogger is connected to and retrieve the settings from the attached datalogger by clicking in Datalogger Settings tab.

7.1.2 Downloading Data

Click from the Data Control tab to download data from a connected datalogger. There are four options for downloading data. They are: **All Data, Append Download, Partial Download and Recover Previous Log**.

If you select **All Data**, the program will download all the data from the current logging session of a datalogger into a *.xle file.

The default directory for saved data is in the 'Data' folder: <C:\Program\Files\Solinst\Levelogger4_1\Data>.

If you select **Append Download**, the program will append the data in an opened *.xle file from the datalogger. The opened *.xle file and the attached datalogger should have the same serial number and start time, otherwise an error will occur.

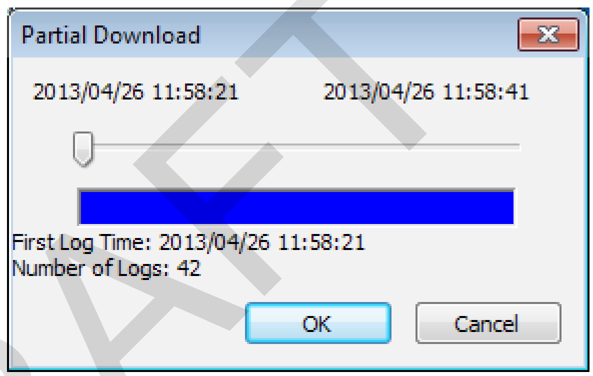


Figure 7-3 Partial Download Window

If you select **Partial Download**, a Partial Download Selection Window will open. The window shows the time stamp of the first and last reading in the logging session. Use the slider to select the time interval you would like data from. Once you click OK, all the data within that time will be downloaded to a *.xle file.

If you select **Recover Previous Log**, the software will try to recover the data from the previous log session and download the data to a *.xle file.

Once the data is downloaded from a Levelogger, it is automatically saved in a temporary file.

7.1.3 Saving Data

Click to save the data in a specific *.xle file.

The default directory for saved data is in the 'Data' folder:
<C:\Program\Files\Solinst\Levelogger4_1\Data>.

However, the default directory for saved files can be changed by clicking the Configuration menu at the top of the program window, selecting 'Application Settings' and inputting or navigating to a different folder destination. If an error is experienced in saving your first data file such as depicted in Figure 7-4, you may not have file writing privileges to the default directory. In this case, create and set as the default file save folder, a new Levelogger data folder within the My Documents folder and attempt the file save procedure again.

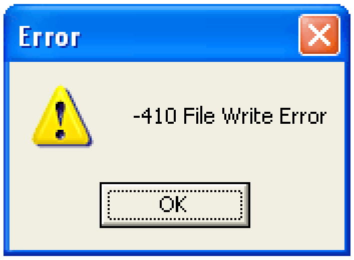


Figure 7-4 File Write Error Message

7.2 Graph Manipulation and Zoom Function

To perform the Zoom In function on the graph, click .

To perform a Zoom Out function on the graph click . Click to undo all the zoom functions.

The Zoom functions can also be used for data selections in the graph.

Click to open the Graph Option Dialog. The Graph Dialog is shown in Figure 7-5.

> **NOTE**
> As there is only one channel of data for Rainloggers, there are no graphing options.

> **NOTE**
> Right click, and drag the mouse to scan the data graph.

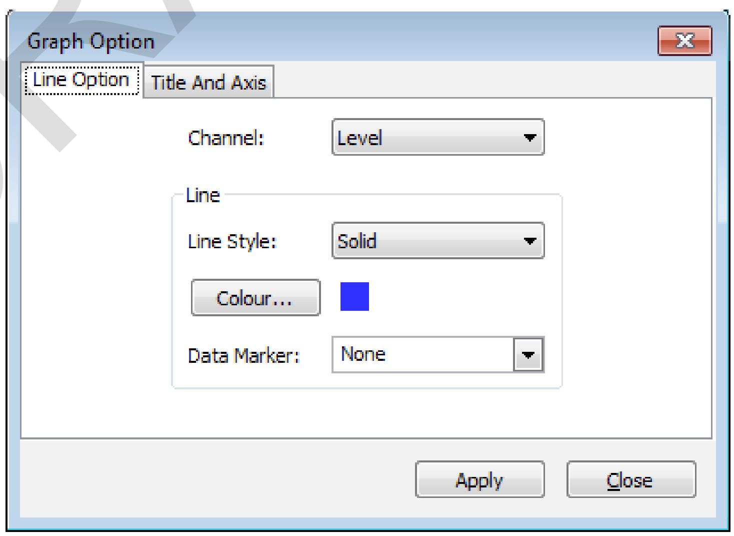


Figure 7-5 Line Option Window

The Line Option is used to adjust the style and colour of the line in the graph for each channel. The user can also select the shape of the data marker or remove the data marker.

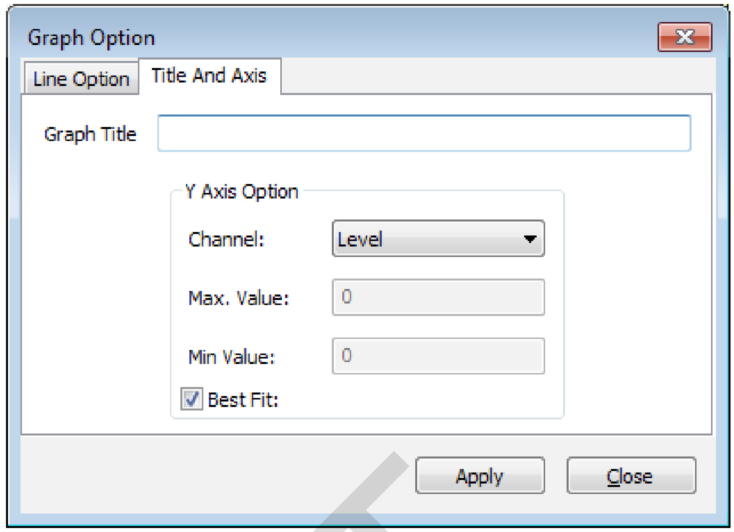


Figure 7-6 Title and Axis Option Window

The Title and Axis Option is used to enter the title of the graph and change the Y axis label or user selected scale. Check the Best Fit box to enable the software to determine the best fit scale. If the Best Fit box is not checked, the user has to enter a maximum and minimum value of the selected channel. The X axis is logging time.

There is the option to show Combined Plot graphs or Separated Plot graphs of the data. Choosing a Combined Plot will show the data from each of the channels in one graph. The Separated Plot option will show a separate graph for each data channel.

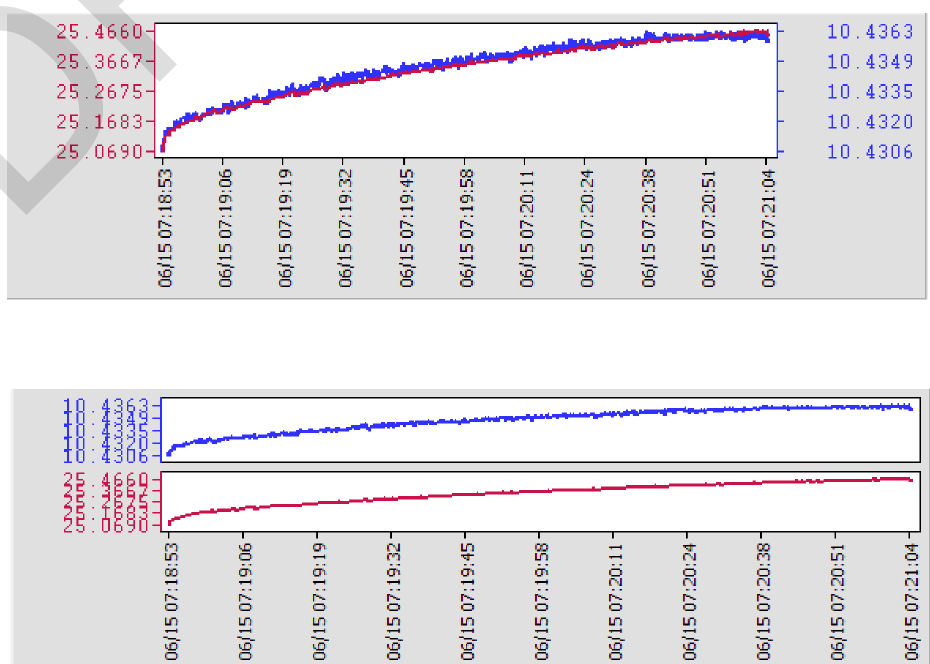


Figure 7-7 Combined and Separated Plot Graphs

There is also the option to view more than one graph at a time. Click and drag a File Name Tab and drop it when you see a shaded area on the window to open a separate graph of that data file. You can view any number of graphs at one time by re-sizing your window as required.

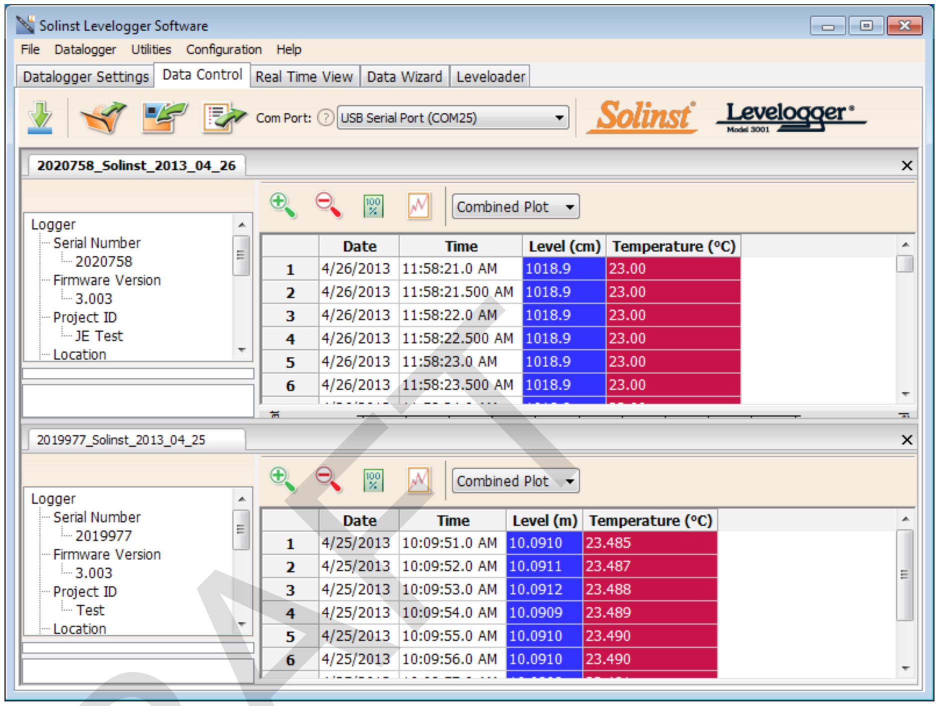


Figure 7-8 Viewing Two Graphs

7.3 File Export and Print Function

Data can be exported in *.csv (comma separated value) file format or *.xml (extensible markup language) file format by clicking File > Export > Data or 

The *.csv and *.xml file formats are supported and can be imported by most spreadsheet and database programs.

Also, the data graph can be exported to a *.bmp file or a *.png file by clicking File > Export > Graph.

The Datalogger Settings, data table and data graph can be printed. Click File > Print Preview, to open the Print Preview window. Figure 7-9 shows the print preview of the Datalogger Settings. The Datalogger Settings are always on the first page of the document. The data graph is on the second page of the document and the rest of the document is the data table.

Click Print..., to open the print dialog. You can choose to print the entire document or just a selection. You can also click File > Print, to open the print dialog.

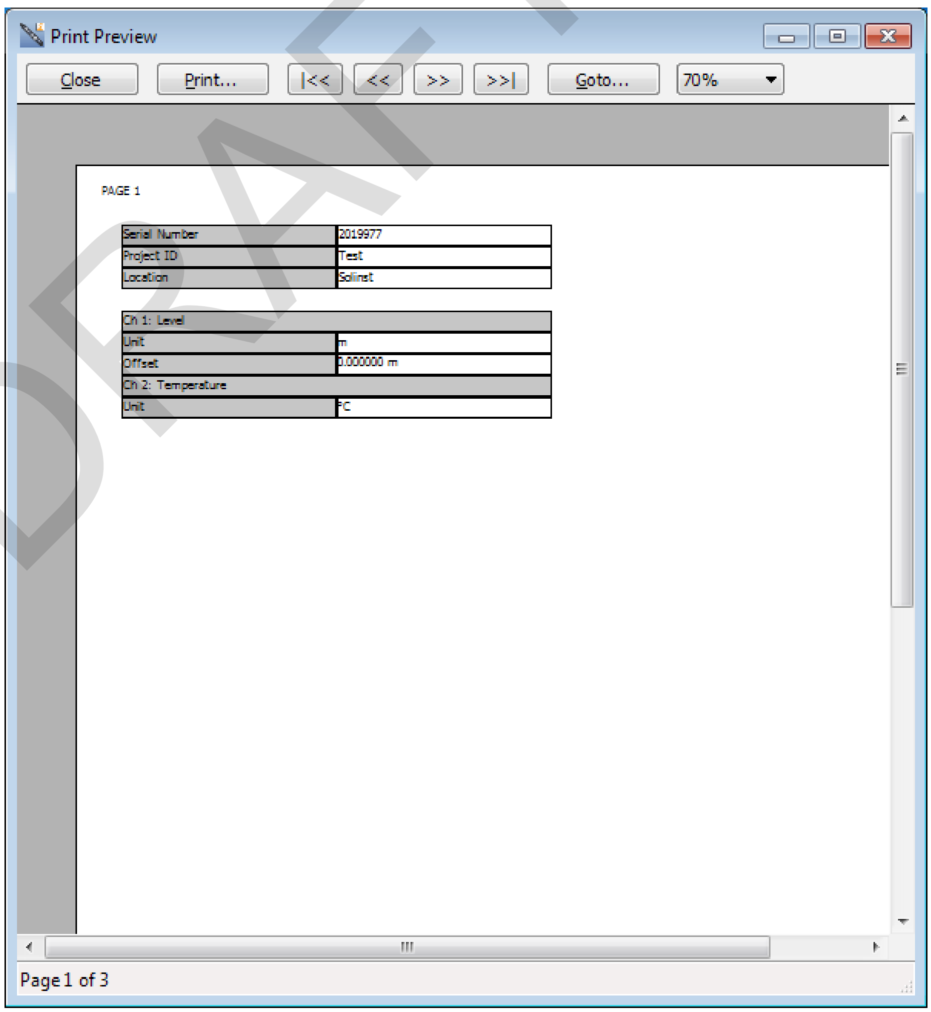


Figure 7-9 Print Preview Window

8 Data Compensation

Data Compensations, such as Barometric Compensation, Manual Data Adjustments and Parameter Adjustments can be performed automatically using the Levelogger Software Data Wizard, or manually, by exporting data to an external spreadsheet program.

8.1 Data Wizard

Open the Data Wizard tab. The first step is to select your Data Compensation Path. The choices for Leveloggers are **Basic** or **Advanced**.

Choosing **Basic** allows you to do a simple Barometric Compensation of Levelogger data only.

The **Advanced** option allows you to perform Barometric Compensation, Manual Data Adjustments and Parameter Adjustments, including adjustments to Rainlogger data.

NOTE

Multiple datalogger files can be compensated at once.

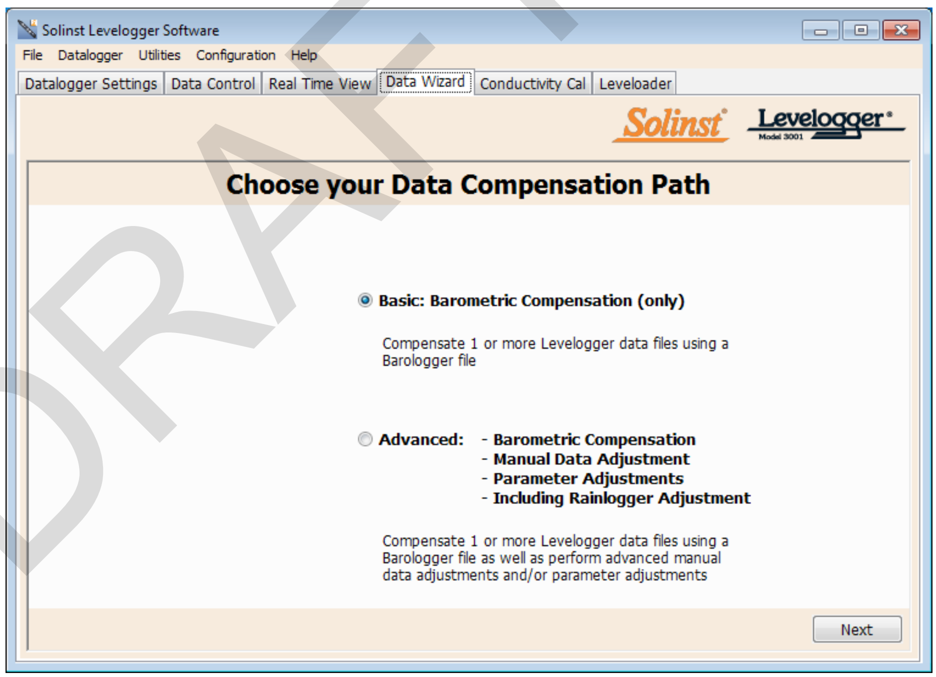


Figure 8-1 Data Wizard

NOTE

Advanced compensation provides the option of performing one, two, or all three data compensation types, in any combination.

NOTE

Manual Data Adjustment, and Parameter Adjustments are useful for correcting Levelogger data files to make data consistent across a project.

NOTE

Parameter Adjustments is the only option for compensating Rainlogger data.

NOTE

If you set your Levelogger to record in pressure units (kPa, bar, psi), you can not change the offset or enter an elevation value (in the Data Wizard). Only raw pressure readings will be provided.

NOTE

Additional Adjustments appear when ">>" is selected. These are application specific, for advanced users.

Barometric Compensation simply subtracts the barometric reading from the corresponding Levelogger reading(s), to give true water level measurements.

Manual Data Adjustment allows you to enter a manual water level measurement or reference point as a field zero, which all Levelogger water level readings can then be adjusted to. There is the option to convert readings to Depth to Water Level measurements (e.g. from the top of a well casing to water level), or Elevation of Water Level measurements (e.g. above sea level).

Parameter Adjustments allow you to change Levelogger, Barologger or Rainlogger data to different units of measurements, add an offset, correct data for elevation differences, convert conductivity to Salinity or Specific Conductance, adjust density, or adjust barometric efficiency. Only the options available for your opened datalogger file types will be active (e.g. Conductivity Conversion is only available for LTC Levelogger Junior data files).

Standard Adjustments:

- **Unit** conversion allows you to convert level readings in a Levelogger file to different units (m, cm, ft, kPa, bar or psi), a Barologger file to kPa, mbar, or psi, temperature readings to °C or °F, conductivity readings to µS/cm or mS/cm, or rainfall values to mm or inches.
- **Offset** allows you to enter any value, positive or negative, which will be added to each reading in the selected Levelogger file to be offset by that amount. It is recommended to stay with the default zero value, unless a known offset has been determined (e.g. to correct for pressure sensor drift. See Solinst Technical Bulletin: Understanding Pressure Sensor Drift).
- **Elevation** is used to correct for altitude differences between Levelogger or Barologger locations. Water column equivalent pressure decreases with altitude at a ratio of approximately 1.21/1000 in the lower atmosphere below 5000 m. You can compensate for this by entering an elevation between -1000 ft below sea level and 16,400 ft (or -300 m and 5000 m) above sea level.
- **Conductivity Conversion** allows you to convert raw Conductivity readings from an LTC Levelogger Junior, to Specific Conductivity (conductivity that is temperature compensated to the standard of 25°C). The Temperature Coefficient default for Specific Conductivity is 2.00. The Temperature Coefficient should not be adjusted, unless you know the value specific to the solution you are measuring. You can also convert Conductivity readings to Salinity expressed in Practical Salinity Units (PSU) (See Section 1.2.4).
- **Rainfall Cal. Constant** allows you to enter a different rainfall calibration constant for a Rainlogger Edge or Rainlogger data file (amount of rainfall per tip of the tipping-bucket rain gauge).

Additional Adjustments:

- **Density Adjustment** corrects the range of the level channel in the Levelogger data file based on a user input adjustment of fluid density. The range of the density adjustment is from 0.9 kg/L to 1.1 kg/L.
- **Barometric Efficiency** adjustment is used to proportionally adjust Barologger data in relation to a particular Levelogger. Barometric efficiency is often expressed as a percentage or proportion. The input field is proportional and has a default value of 1.00. For more information about Barometric Efficiency, see Section 10.1.3.1. The barometric efficiency can be set from 0.01 to 3.00.

8.1.1 Basic Compensation

> **NOTE**
> One Barologger can be used to compensate all Leveloggers in a 20 mile (30 km) radius and/or with every 1000 ft. (300 m) change in elevation.

When you choose **Basic** compensation, the next step is to select the Barologger file you want to use for compensation, then select the Levelogger file(s) you want to compensate. You can only select one Barologger file to compensate multiple Levelogger files.

For best accuracy, the Levelogger file(s) and Barologger file should have the same start time and logging interval. (The Future Start option in the Datalogger Settings tab is a convenient way to start all of your loggers at the same time.) If there is an inconsistency of the time stamp between the Barometric file and the Levelogger file(s), a linear approximation on the barometric data will be performed.

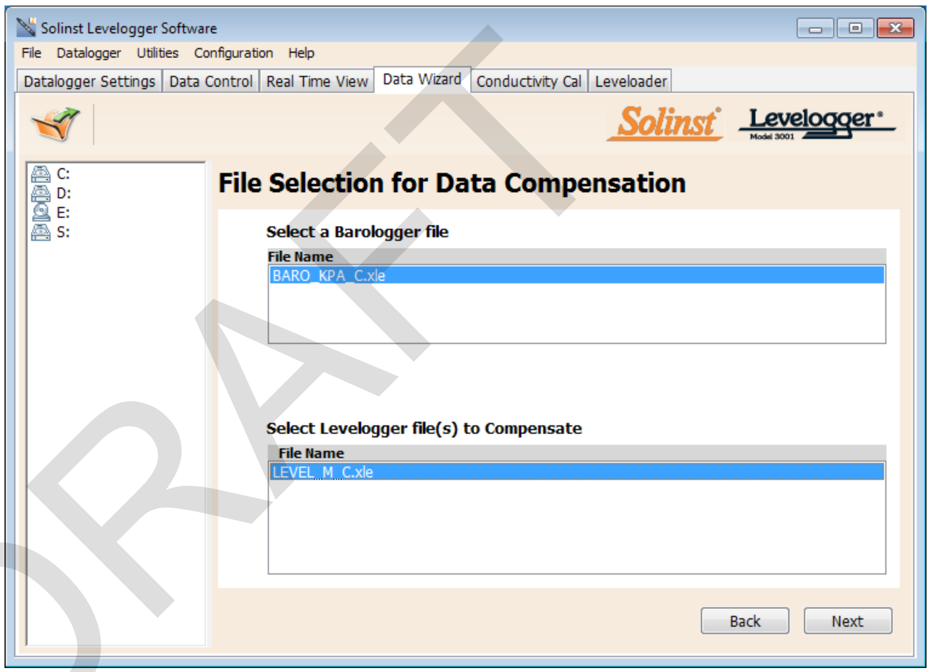


Figure 8-2 Selecting Files for Barometric Compensation

> **NOTE**
> Both a Barologger file and a Levelogger file must be selected to complete a Barometric Compensation.

Any files you have open in the Data Control tab will be listed.

Use the directory on the left of the window or click to open any other Levelogger data files you would like to compensate. Ensure the files you want to compensate are highlighted in the list. **Both the Barologger file and Levelogger file(s) must be highlighted.** Do this by clicking the file name. To de-select a file, click it again. Multiple Levelogger files can be selected at once.

> **NOTE**
> All data files are saved to the default location: <C:\Program Files\Solinst\Levelogger4_1\Data>. However, the default directory for saved files can be changed by clicking the Configuration menu at the top of the program window, selecting 'Application Settings' and inputting or navigating to a different folder destination.

Select Next to complete the compensation.

The compensated data will automatically be saved in a new *.xle file. The default file name will be the <original Levelogger file name> with the word <compensated> added to the file name prefix. Alternatively, the user can rename the compensated file by saving it in the Data Control tab. Do not change or delete the file extension. All data files are saved to the default location: <C:\Program Files\Solinst\Levelogger4_1\Data>.

The next window will show the results of the compensation. If the compensation was unsuccessful, there will be an explanation in the Reason column (e.g. time stamp of Levelogger and Barologger files were not close enough to perform an accurate compensation). You can still view the compensated file in the Data Control tab by clicking 'Open' in the Action column. If the compensation is successful, select 'Open' to view the compensated file in the Data Control tab.

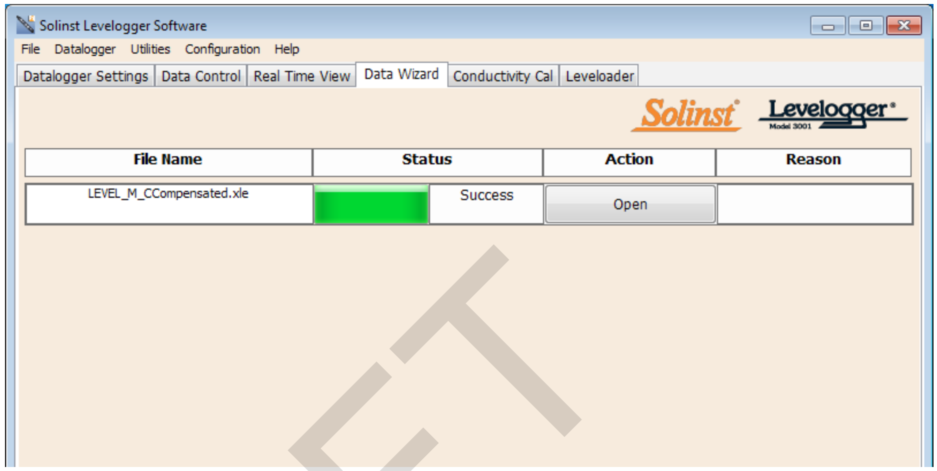


Figure 8-3 Barometric Compensation Results

From the Data Control tab, you can view the data, save the compensated file with a new filename and/or export the data (see Section 7).

All the original Levelogger settings and the channel information effective during data collection are shown on the top left of the window. The bottom left sections of the window are used to display the compensation information. The middle section displays information from the Barologger.

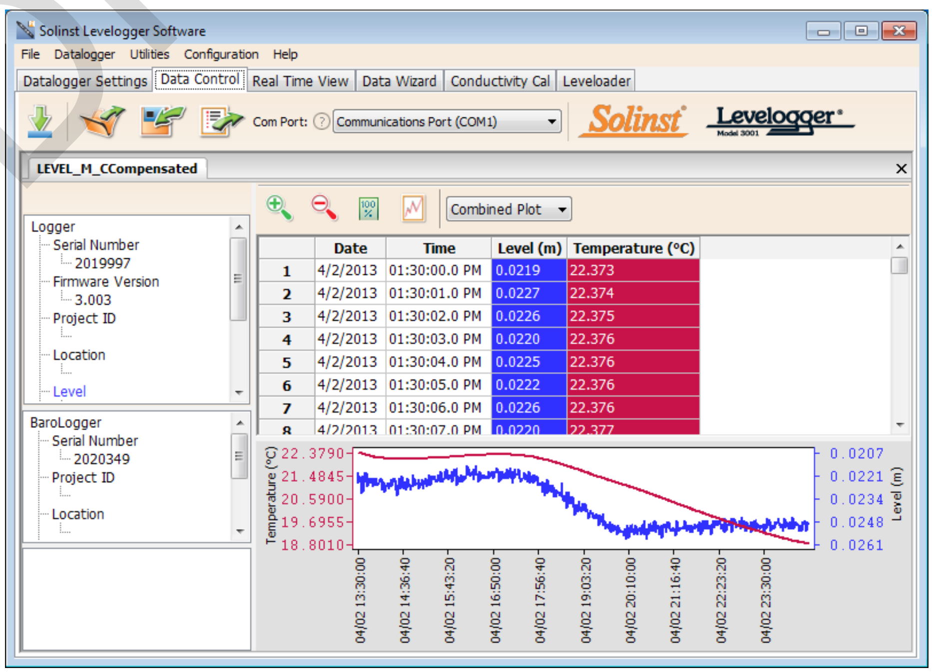


Figure 8-4 Viewing Compensated Files in the Data Control Tab

8.1.2 Advanced Compensation

When you select **Advanced** compensation, the Data Compensation Options window will open.

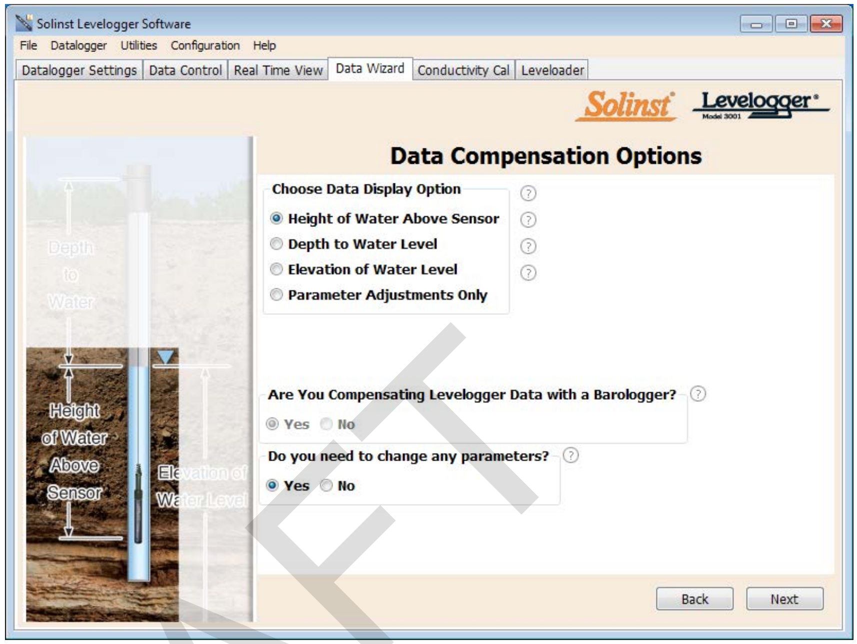


Figure 8-5 Advanced Data Compensation Options

First, you will select how you want your data displayed (Manual Data Adjustment):

- **Height of Water Above Sensor** is the default display option. Select this option to perform a Barometric Compensation and/or Parameter Adjustments to one or more data files, while keeping the sensor diaphragm (zero point) as the reference point.
- **Depth to Water Level** adjusts water level data to represent depth to water level readings (from the top of a well casing or other reference point) by entering a field zero, such as a manual depth to water level measurement. Adjustments can be made to one or more data files.
- **Elevation of Water Level** adjusts water level data to represent elevation of water level readings (above sea level or other reference point) by entering a measuring point elevation, and a field zero, such as a staff gauge measurement from that point. Adjustments can be made to one or more data files.
- **Parameter Adjustments Only** allows you to adjust one or more data files to different units, elevation, etc., while keeping the sensor diaphragm (zero point) as the reference point for Leveloggers. It also allows you to change Rainlogger data file parameters.

NOTE

Parameter Adjustments Only, is the only option for compensating Rainlogger data.

Next, you will select Yes or No to **Barometrically Compensating** the data (will not be active if you selected Parameter Adjustments Only).

Next, you will select Yes or No to performing any **Parameter Adjustments** on the data files (will not be active if you selected Parameter Adjustments Only).

Click Next, after you have selected all of your Data Compensation options.

> **NOTE**
> See Section 8.1.1 for more information on selecting files for Barometric compensation.

In the next window, you will choose the Levelogger file(s), Rainlogger file(s), and Barologger file(s) you would like to use in the compensation. Any files you have open in the Data Control tab will be listed.

Use the directory on the left of the window or click to open any other data files you would like to compensate. Ensure the files you want to compensate are highlighted in the list. **If doing a Barometric Compensation, ensure the Barologger file is highlighted.** Do this by clicking the file name. To de-select a file, click again. Select Next to continue.

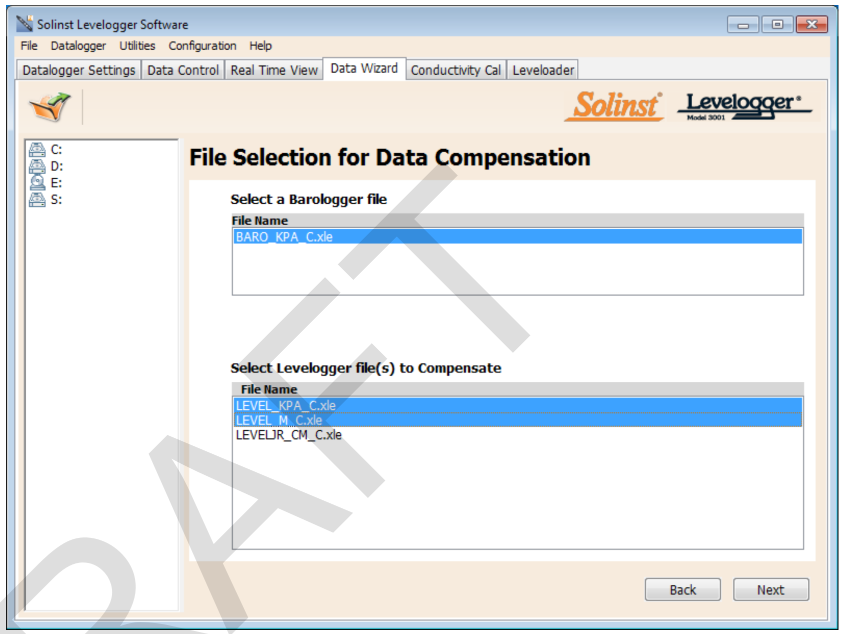


Figure 8-6 Selecting Files for Compensation

> **NOTE**
> When adjusting Units for Levelogger files or Rainlogger files, If you select apply to all, the same unit change will be applied to all of the files being compensated at that time.

If you have selected yes to **Parameter Adjustments**, or selected the **Parameter Adjustments Only** option, in the next window you will enter these. You can expand the window by clicking ">>" to show additional adjustment options. If you did not select to change any parameters, this window will not be shown.

> **NOTE**
> To show Additional Parameters that can be adjusted, click on the ">>" icon.

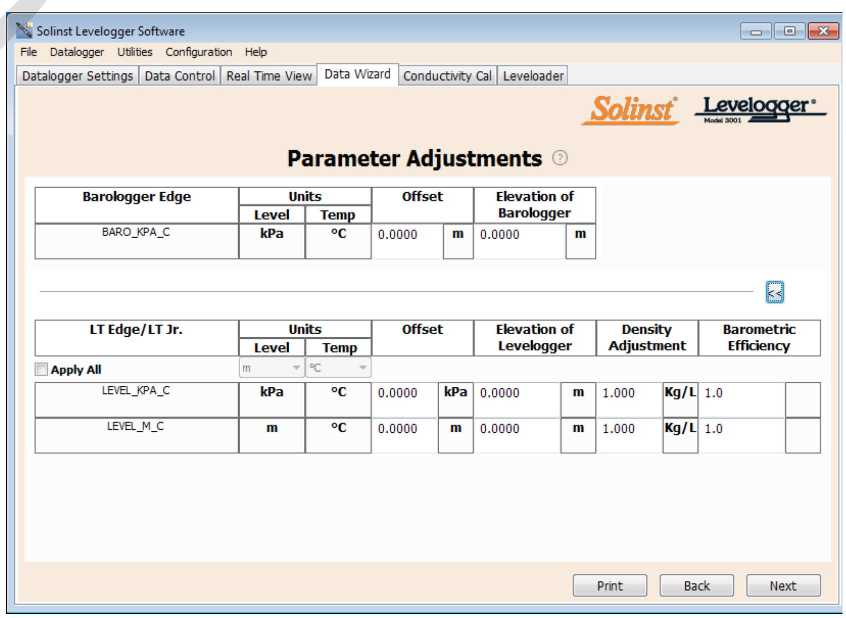


Figure 8-7 Parameter Adjustments

> **NOTE**
> The date and time of measurement of the Field Zero must be recorded to complete the adjustment. The Field Zero must replace an actual reading the Levelogger file. I.e. take a manual measurement immediately after starting the Levelogger, and note that time.

Next, for each selected Levelogger file, you will enter the Field Zero(s) you would like to use to manually adjust your Levelogger data. (If you have selected **Height of Water Above the Sensor or Parameter Adjustments Only**, this window will not be shown.)

For **Depth to Water Level** adjustments, enter a **Field Zero (A)**. If the static water level is below your Field Zero measurement, the Field Zero is input as a positive value (e.g. a manual water level meter measurement taken from the top of a well casing. See Example 8.1). If the static water level is above your Field Zero, the Field Zero is input as a negative value (such as in an artesian condition).

The Time the Field Zero measurement was taken must replace an actual reading in the Levelogger file. This is selected from the drop-down menu showing all time stamps in the Levelogger file. Click 'Add' to apply the adjustment. If you need to change a Field Zero, click 'Update' after any edits.

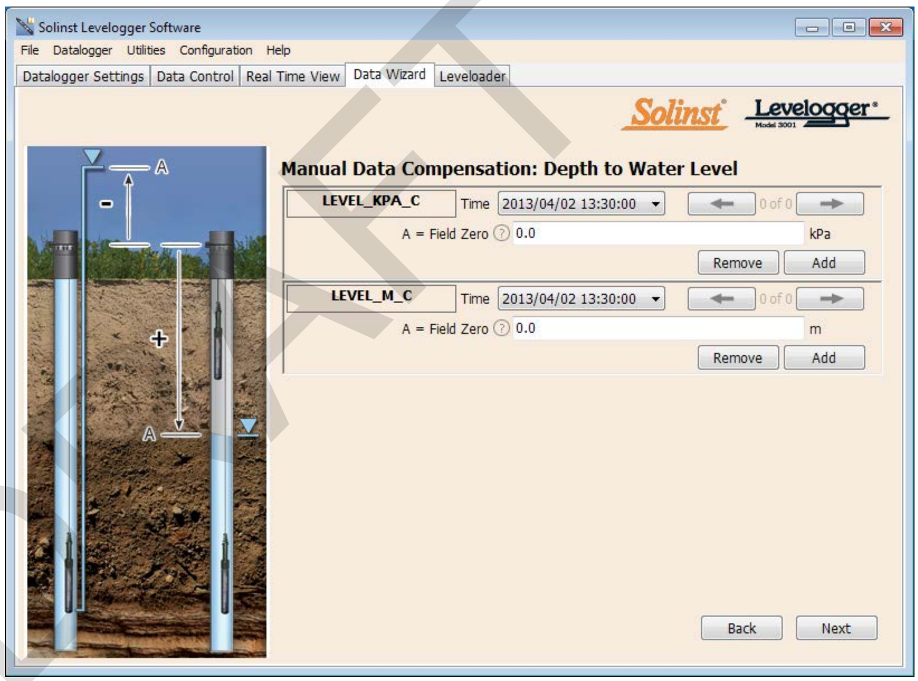
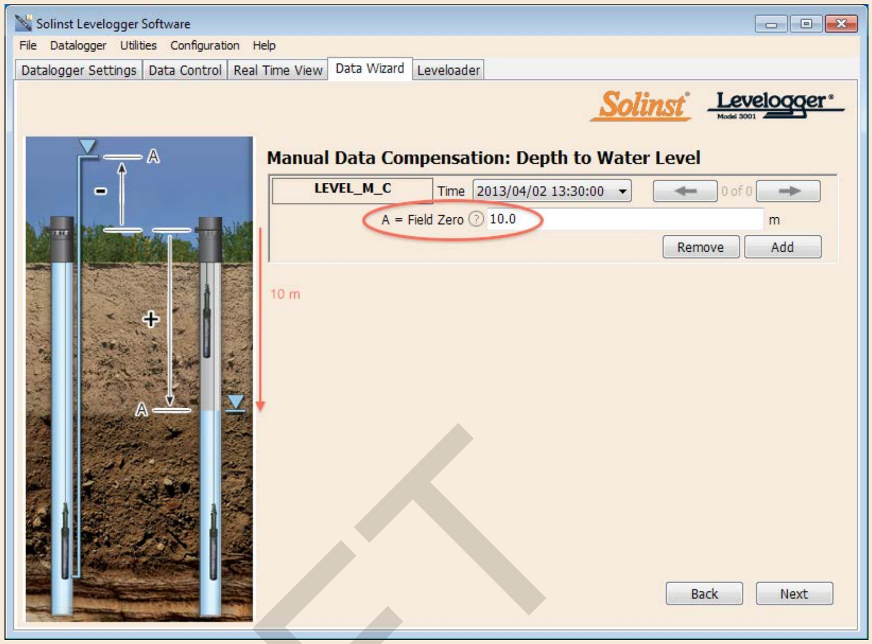


Figure 8-8 Manual Data Adjustment - Depth to Water Level



Example 8.1 Depth to Water Level Adjustment

When using a manual depth to water measurement taken from the top of a well casing as a Field Zero, enter it as a positive value (e.g. 10 m).

In your adjusted data file, your readings will increase in value as the water level decreases. This is because the depth to static water level from the top of the well casing is increasing. The adjusted readings will decrease in value as the static water level rises.

Original Levelogger Data (barometrically compensated height of water above sensor)	8.75 m	8.50 m	8.75 m	9.0 m	9.25 m
Adjusted Levelogger Data (depth to water)	(A) 10.0 m	10.25 m	10.0 m	9.25 m	9.0 m

For **Elevation of Water Level** adjustments, enter a **Measuring Point Elevation (A)** and a **Field Zero (B)** from that Measuring Point.

If the static water level is below your Measuring Point, the Field Zero is input as a positive value (e.g. if you are using a manual depth to water measurement as a Field Zero, from the top of a well casing as the Measuring Point).

If the static water level is above your Measuring Point, the Field Zero is input as a negative value (such as an artesian condition). The Measuring Point elevation may also be entered as a negative value.

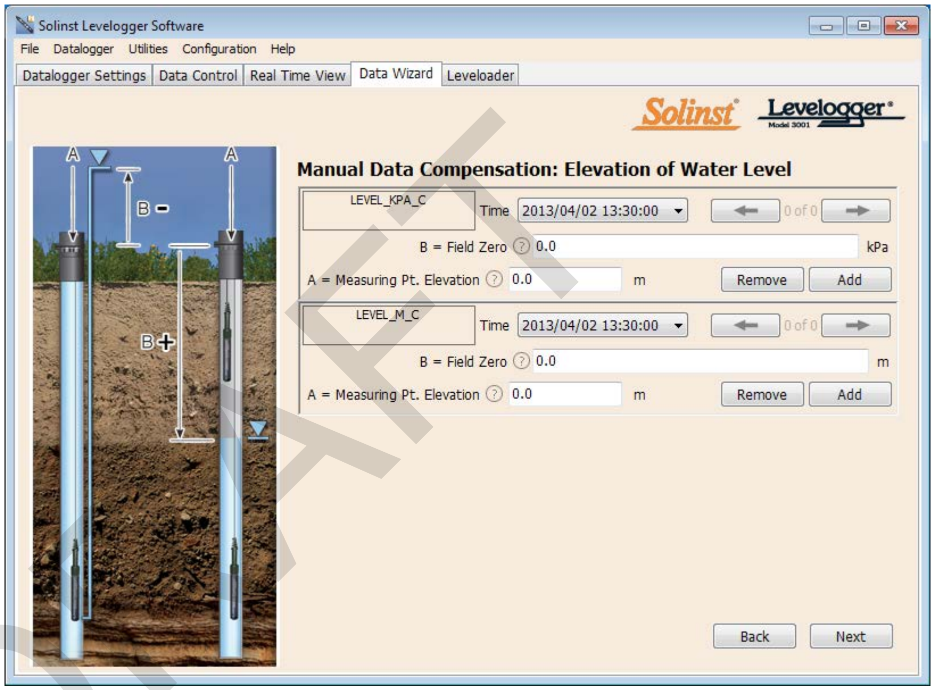


Figure 8-9 Manual Data Adjustment - Elevation of Water Level

> **NOTE**
> The date and time of measurement of the Field Zero must be recorded to complete the adjustment. The Field Zero must replace an actual reading the Levelogger file. I.e. take a manual measurement immediately after starting the Levelogger, and note that time.

The Time the Field Zero measurement was taken, must replace an actual reading in the Levelogger file, and is selected from the drop-down menu showing all time stamps in the Levelogger file. Click 'Add' to apply the adjustment. If you need to change a Field Zero, click 'Update' after any edits.

You can make multiple adjustments to one data file by selecting 'Add' again to enter another Field Zero. All readings after this Time, will be adjusted to this second measurement. You can add as many adjustments to one Levelogger data file as you would like (as long as it doesn't exceed the total number of readings in that file).

Select Next to complete the compensation.

> **NOTE**
> All data files are saved to the default location: <C:\Program Files\Solinst\Levelogger4_1\Data>. However, the default directory for saved files can be changed by clicking the Configuration menu at the top of the program window, selecting 'Application Settings' and inputting or navigating to a different folder destination.

The compensated data will automatically be saved in a new *.xle file. The default file name will be the <original Levelogger file name> with the word <compensated> added to the file name prefix. Alternatively, the user can rename the compensated file by saving it in the Data Control tab. Do not change or delete the file extension. All data files are saved to the default location: <C:\Program Files\Solinst\Levelogger4_1\Data>.

The next window will show the results of the compensation. If the compensation was unsuccessful, there will be an explanation in the Reason column (e.g. time stamp of Levelogger and Barologger files were not close enough to perform an accurate compensation). You can still view the compensated file in the Data Control tab, by clicking 'Open' in the Action column. If the compensation is successful, select 'Open', to view the compensated data file in the Data Control tab.

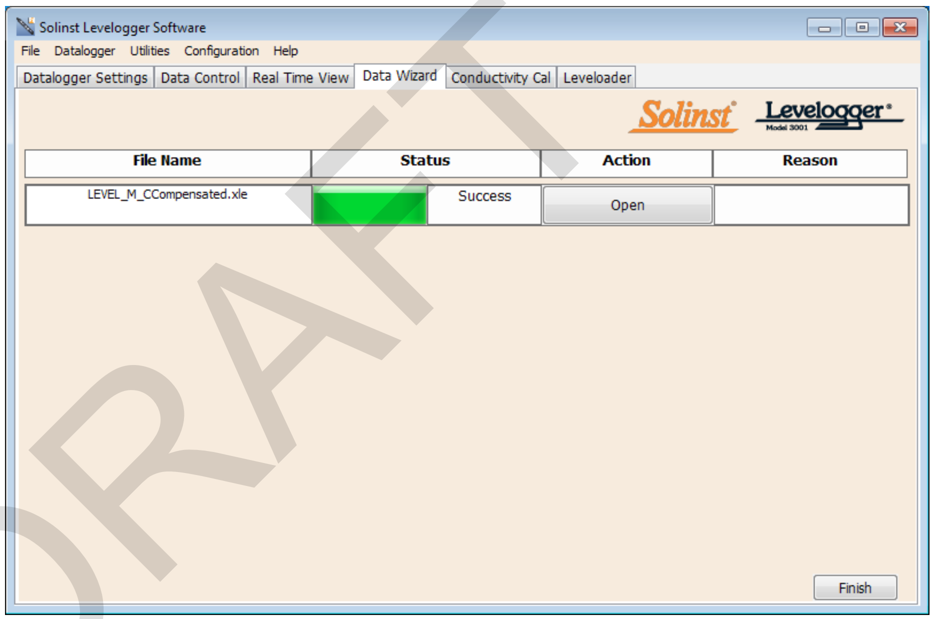


Figure 8-10 Advanced Data Compensation Results

From the Data Control tab, you can view the data, save the compensated file with a new filename and/or export the data (see Section 7).

All the original Levelogger settings and the channel information effective during data collection are shown on the top left of the window. The bottom left sections of the window are used to display the compensation information. The middle section displays information from the Barologger, and the bottom section includes information about manual data and parameter adjustments.

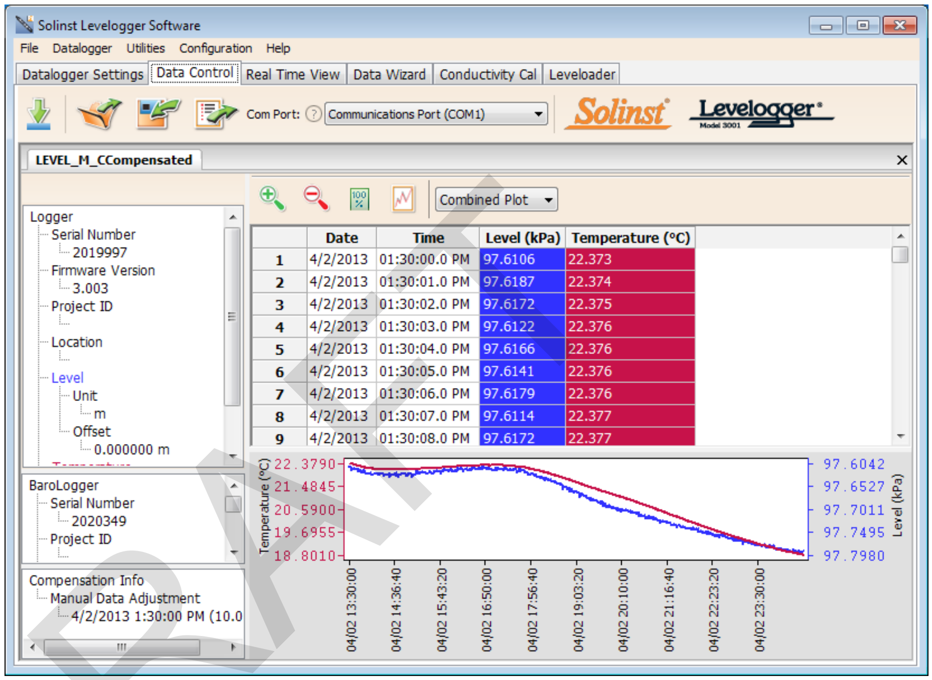


Figure 8-11 Viewing Compensated Files in the Data Control Tab

8.2 Manual Barometric Compensation

This section describes how to perform manual barometric compensation on Levelogger Edge and Levelogger Junior Edge data files when a Barologger was not dedicated as a barometric recorder.

For short term tests during which the barometric pressure varies insignificantly, the collection of continuous barometric data may be unnecessary. In this event, take a reading from an open air exposed Levelogger prior to running the short term test and record this level. This level represents the barometric pressure. Similarly, at the end of your test, take another barometric reading and record this measurement. After the submerged Levelogger data has been exported to a spreadsheet program, compensate your submerged Levelogger data files for barometric pressure. If no appreciable change in barometric reading occurred, you may write in the first cell of a new column, a simple calculation that subtracts your barometric reading from the submerged data file, then copy and paste this calculation to all the cells in that new column. The new column will represent the barometrically compensated liquid level.

Barometric data can be collected on site using a recording barometer or from a local weather station. To accomplish an accurate manual barometric compensation, the atmospheric pressure station should not be greater than 20 miles (30 km) away and within an elevation change of 1000 ft (300 m). In addition, the date and time of the barometric data should cover the range of data collected by the Levelogger. If setting up the barometer, set the recording interval to that of the Levelogger sampling interval or some multiple of the Levelogger interval. To compensate submerged Levelogger data using barometric data collected from an on site barometric datalogger or a nearby weather station, these steps must be taken:

1) Export both the Levelogger data file and the barometric file to a spreadsheet.
2) In the spreadsheet, ensure both files are using the same units. If your Levelogger data was recorded in m, cm, or ft, convert the barometric data column from its barometric measurement units (typically atm, mm Hg, psi, mbar or kPa) to feet or meters of water column equivalent using the conversion factors in Table 8-1. (There is also the option to initially set up your Levelogger Edge or Levelogger Junior Edge to record in psi, kPa, or bar. This makes compensation using other atmospheric pressure devices easier.)

Table 8-1		
Common barometric units to water column equivalent conversions		
Barometric unit	Water column equivalent (ft)	Water column equivalent (m)
1 psi	2.307	0.703
1 kPa	0.335	0.102
1 mbar	0.033	0.0102

Table 8-1 Common Barometric Units to Water column Equivalent Conversions

3) Once the units for each column are the same, subtract the barometric column from the Levelogger data to get the true net water level recorded by the Levelogger Edge.

NOTE

When analyzing barometric data it is important to keep in mind that storm events commonly reduce total atmospheric pressure by about 1.7% from pre-existing high pressure conditions. 1.7% converts to approximately 0.6 ft or 0.2 m of water level equivalent barometric fluctuation.

NOTE

For Manual Barometric Compensation instructions for the Levelogger Gold and Levelogger Junior, visit: www.solinst.com and see the Levelogger Software Version 3.4.1 User Guide in the Downloads Section.
Or view " Automatic or Manual Barometric Compensation of Your Levelogger Data" in the Technical Bulletin Section at: http://www.solinst.com/Prod/3001/Datalogger-Technical-Bulletins.html

NOTE

You can also convert the Levelogger Edge data units to match the Barometric units using the Data Wizard.

NOTE

It is important to remember that weather station barometric data will often contain an offset or normalization (i.e. normalization to sea level). Manual data conversation and barometric compensation should account for any variation of the normalization or offset used between the barometric data sourced and Solinst Leveloggers.

> **NOTE**
> Datalogger settings can not be changed in the Real Time tab. Changes must be made in the Datalogger Settings tab. The changes are applied when the Real Time readings are started.

> **NOTE**
> You can also view Real Time readings from a Rainlogger Edge or Rainlogger using firmware version 2.000 or higher.

9 Real Time View

Click the Real Time View tab from the main software window (Figure 9-1). The purpose of this tab is to provide on-screen measurement as data is being recorded by the connected datalogger. The data is displayed in tabular and graphical format. All the channel information and Levelogger settings are displayed on the left of the window.

First, select a non-logged view rate seconds 1. This rate can be set independently of the logging period of the Levelogger and does not interfere with any logging taking place in the Levelogger itself.

Checking, **Enable Manual Data Adjustment**, allows you to enter a datum/ field zero (e.g. depth to water level) to which the change in Real Time View level measurements are then adjusted against. This is only available when you are taking readings in m, cm, or ft.

Real Time View readings can be displayed as a graph or in tabular format. The same graphing options as the Data Control tab are available for Real Time View readings. Real Time View readings are being recorded within the Levelogger Software and prior to closing the window, they can be saved by exporting the data into a *.csv file, by choosing the file export option.

To start the current readings, click . Immediately the readings will be displayed.

To take a reading at any specific time, click the button and that reading will be added to the displayed data. To turn the Real Time View monitoring off, decide if you want to save the data as described above, and simply click .

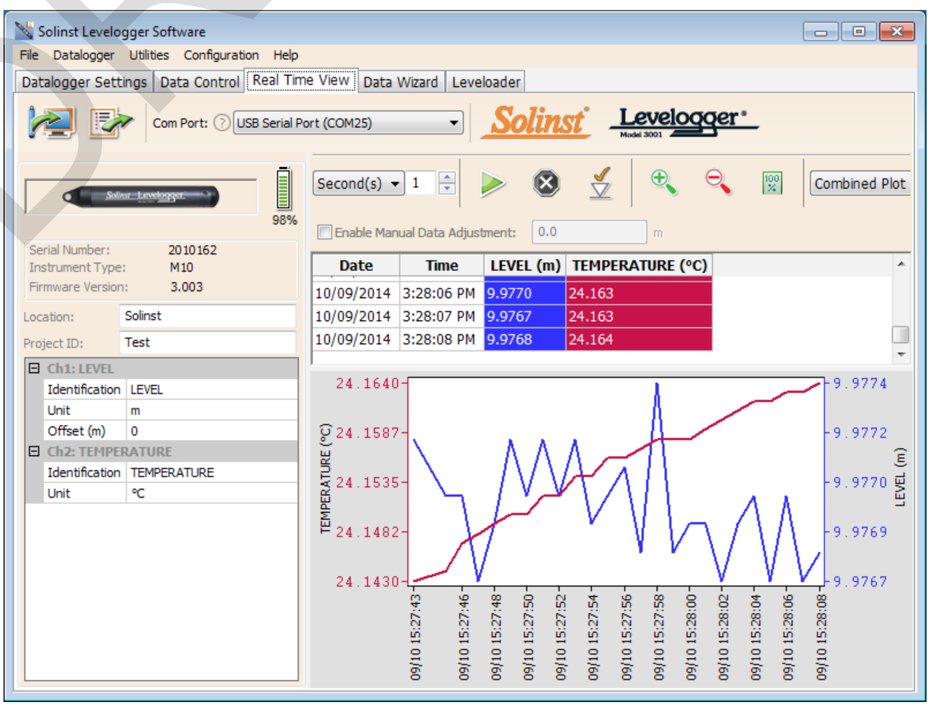


Figure 9-1 Real Time View Window

10 Installation and Maintenance of Leveloggers

10.1 Installation

Many options exist for installation of the Levelogger, but essentially these installation methods can be classified into two broad categories: free suspended or fixed installations.

1) In free suspended installations, the Levelogger is hung via suspension wire or Direct Read Cable from a well cap, or some fixed tie-off location, at the well head.
2) In fixed installations the Levelogger is fixed in place by a compression fitting, a clamping mechanism or simple metal straps.

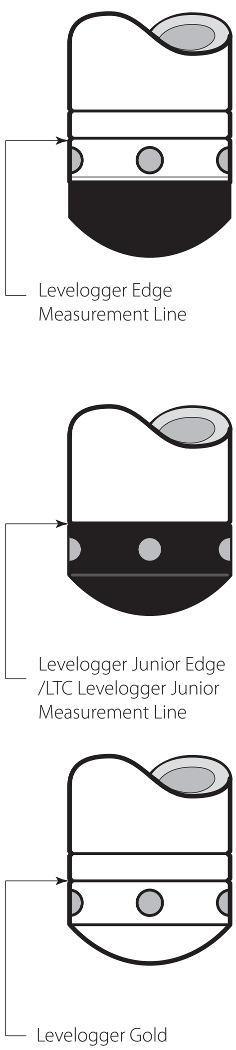


Figure 10-1

It is recommended that the Levelogger be installed in a vertical orientation. However, inclined or horizontal installation is acceptable. The level sensor in the Levelogger is indicated by the machined line about the body of the logger just above the pressure access holes. The pressure transducer is oriented in a plane normal to the long axis of the body and detects pressure directed along the plane of the long axis (Figure 10-1). In vertical orientations, the sensor detects pressure above the pressure transducer line, where as in non-vertical orientations, the pressure zero point is proportional to the angle of inclination.

Care should be taken to avoid dropping the Levelogger against a hard surface. Leveloggers should always be installed with the installation cap on (if not using a Direct Read Cable), whether it is being suspended by it or not. This prevents unnecessary battery drainage and protects the optical eyes.

Make sure you properly estimate the maximum and minimum expected water levels during the monitoring period. You need to install your Levelogger so it remains submerged at all times, and ensure that its maximum submergence depth throughout the monitoring period remains within its specified range. The pressure transducer can be damaged if the datalogger is over-pressurized by submergence greater than its level range. The Levelogger Edge and Levelogger Junior Edge are warranted to pressures up to 200% of their full scale level range (150% for the Levelogger Gold, Levelogger Junior and LTC Levelogger Junior Models), however accuracy can not be guaranteed beyond its full scale.

Other important considerations when installing the Levelogger in pressurized or intermittently pressurized locations such as pressure vessels, pressurized pipes, pulse flow conditions, drop structures or near hydraulics works, is to keep in mind the potential effect of water or steam hammer and hydraulic jump. Water hammer is caused by an abrupt alteration of flow direction resulting in pressure surges. Steam hammer occurs when steam enters a cold pipe partially filled with water. The hammer effect has the potential to significantly increase hydraulic pressure possibly exposing the pressure sensor to pressures beyond its maximum rating. Hydraulic jump is a phenomenon that occurs when water is 'lifted' or 'ramped' by velocity or flow obstructions. Hydraulic jump causes turbulence and creates non-representative head conditions in the water column. Care should be taken to avoid logger installation at points susceptible to hydraulic jump.

Figure 10-2
Solinst 2" Locking Well Cap
for Wireline or Kevlar Cord

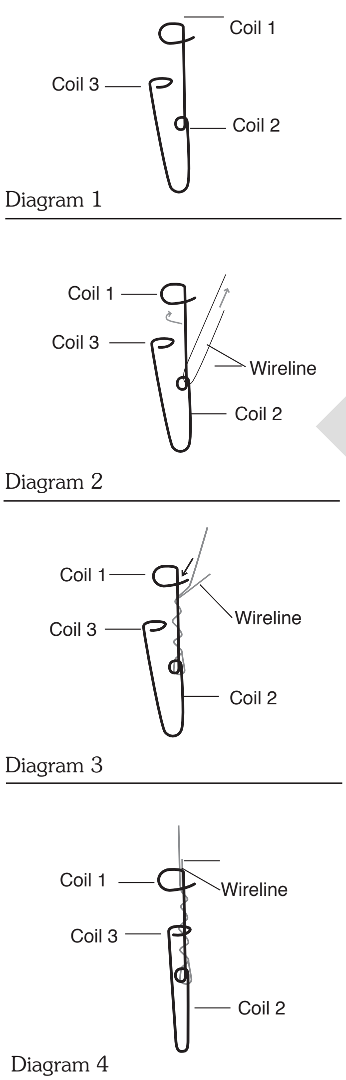


Figure 10-3 Wireline Hook Installation

10.1.1 Free Suspended Installations

10.1.1.1 Suspension Wire/Cord Installation

When installing on a suspension wire or cord, the Levelogger is pre-programmed and started using the software. It is then deployed with the suspension wire or cord connected to the installation cap of the Levelogger to the underside of a well cap. The data is retrieved manually, by withdrawing the Levelogger, removing the installation cap and attaching an Optical Reader (or Direct Read to Optical Adaptor) directly to the datalogger. Data is downloaded to a desktop or laptop PC, or by using a DataGrabber, Levelogger App & Interface, or Leveloader (see separate instructions). This type of installation is applicable to both submerged and barometric record applications.

Solinst supplies stainless steel suspension wire assemblies including SS stranded wire and hooks available in a variety of lengths from 50 ft (15 m) to 500 ft (150 m), and Kevlar cord assemblies to 500 ft (150 m). Solinst also supplies the Model 3001 2" Well Cap Assembly from which the Levelogger can be suspended. An Adaptor for 4" wells also available (see Section 10.1.1.3).

Follow these steps to install the Levelogger using **stainless steel wire and hooks**:

1) Loop the cable through the coil 2 of the hook assembly, then wind the looped strands several times around the hook shaft and pass through coil 1.
2) Pass coil 3 through the Well Cap eyelet or Levelogger/Barologger eyelet and snap coil 3 to the hook shaft.
3) If the Well Cap is not used then some secure tie-off point should be used or installed.
4) If installing a Barologger, ensure the suspension level is above the highest expected water level.
5) When retrieving data and/or reprogramming the Levelogger, extract it from the monitoring location, un-thread the installation cap, interrogate and re-suspend the unit rechecking the security of the wireline clamps each time.

Figure 10-4 Kevlar Cord

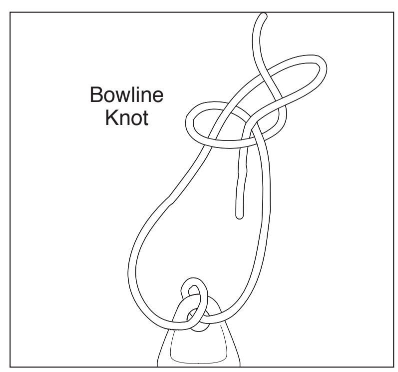


Figure 10-5 Bowline Knot Used to Connect Kevlar Cord to the Levelogger

It is recommended that the **Kevlar cord** be connected to the Levelogger and well cap using a bowline knot (see Figure 10-5). The Kevlar cord is comprised of multiple Kevlar strands braided with black polyester, and has break strength of 150 lbs. Kevlar is very suitable for underwater applications in freshwater and marine environments, as the material resists rusting.

Single Well Cap Option

Dual Well Cap Option

Figure 10-6
Solinst 2" Locking Well Caps for Direct Read Cable Installation

Figure 10-7
Solinst Direct Read Cable

10.1.1.2 Direct Read Cable Assembly Installation

When installing using a Direct Read Cable Assembly, the Levelogger can be deployed before it is programmed and started with the software. The Levelogger is installed using a Direct Read Cable to a Direct Read Wellhead, where a PC Interface Cable is connected allowing the Levelogger to communicate with a desktop or laptop PC. Alternatively, you can connect a Levelogger App Interface, DataGrabber, or Leveloader for communication (see separate instructions).

The Direct Read Cable system is composed of the ordered length of Direct Read Cable, the Model 3001 Well Cap Assembly (see Section 10.1.1.3) and the PC Interface Cable. The Direct Read cable threads to the Levelogger, while the socket at the opposite end of the Direct Read Cable fits into the specially designed Well Cap insert. The PC Interface Cable connects to the Direct Read socket at surface and to either a USB or RS-232 port on the PC. While use of the Model 3001 Well Cap is recommended and convenient, it is optional as long as a satisfactorily secure alternative tie-off point is found for the Direct Read Cable. Follow these steps to install a Direct Read Cable Assembly to the Levelogger:

1) Remove the installation cap from the Levelogger, align and connect the optical socket (two glass 'eyes' using the alignment pin) of the Direct Read cable to the Levelogger by threading the coupling onto the Levelogger tightly.
2) The Levelogger and optical socket will fit through the hole in the Well Cap insert.
3) Remove the protective cap from the non-optical socket at the wellhead end of the Direct Read Cable, seat the socket in the Well Cap Insert and align and thread it to the round socket of the PC Interface Cable.
4) Connect the USB or RS-232 socket of the PC Interface Cable to the USB or RS-232 Com Port on your PC.
5) The two plugged holes in the Well Cap can be opened to provide an access port for a Barologger, as well as a water level meter probe.

When removing a Direct Read Cable from a Levelogger, ensure you only twist the coupling. To avoid possible damage, do not twist the strain relief on the Direct Read Cable.

Figure 10-8 Proper way to remove a Direct Read Cable from a Levelogger

10.1.1.3 Model 3001 Well Cap Assembly

The Model 3001 Well Cap Assembly is designed to fit 2" wells, and provides options for installing Leveloggers with wireline, Kevlar cord, or using a Direct Read Cable.

The well cap base provides a tight friction fit onto the well casing. The cap is secured to the base with a twist lock. For further security, a 3/8" (9.5 mm) shackle diameter lock can be used. The Well Cap is vented to allow for the equalization of barometric pressure in the well. Users can choose to permanently secure the PVC Well Cap to the well casing, using three screw points on the inner shoulder of the Well Cap Base.

For wireline or Kevlar cord suspension, simply use the suspension hook on the underside of the insert to secure the Levelogger to the Well Cap (see Section 10.1.1.1). To install using a Direct Read Cable, lower the Levelogger with the Direct Read Cable through one opening in the insert (see Section 10.1.1.2).

NOTE

The insert has openings to hold two Direct Read Cables in the same well. If only one Direct Read Cable is used, the other hole (0.89" ID) provides access for Solinst Water Level Meters.

Figure 10-9 Model 3001 Well Cap Assembly (#110099)

Figure 10-10 If installing Leveloggers in a 4" well, a reducer adaptor is available. (#110235)

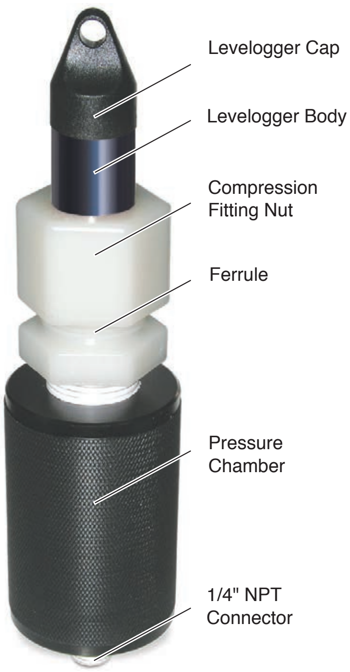


Figure 10-11
7/8" Nylon Compression Fitting with 1/4" NPT Connector

NOTE

The Levelogger NPT Adaptor is not recommended for pressures in excess of 30 psi (66 ft (20 m) of water column).

Figure 10-12
Artesian Well Fitting Assembly

10.1.2 Fixed Installations

10.1.2.1 Artesian Monitoring

Monitoring of artesian conditions in which the piezometric surface is above ground surface or more particularly above the top of well casing elevation using Leveloggers can be quite straight forward.

Continuous artesian conditions infer that the piezometric surface never drops below the level the ground surface or particularly the top of casing elevation and the casing is sealed with a sealed wellhead. In this case, where freezing is not a concern, the Levelogger need only be installed on the wellhead itself by means of a large compression fitting with a 1/4" NPT connector, as illustrated in Figure 10-11. Solinst can supply a 7/8" nylon compression fitting for this purpose. First, a 1/4" NPT hole is tapped into the wellhead. The user slides the Levelogger into the compression fitting, leaving about 1/4 of the logger body exposed above the fitting. The compression fitting nut is tightened around the Levelogger. The 1/4" NPT connector on the bottom of the pressure chamber of the fitting threads into the hole in the sealed wellhead. The user can communicate with the logger simply by removing the logger cap and attaching the optical reader. Ensure that the logger and sealed wellhead are enclosed within an outer protective well cap or enclosure. This method should only be used in low pressure conditions (less than 30 psi or 66 ft (20 m) of water column).

A second Artesian Well Fitting Assembly is available (Figure 10-12), it features a vent assembly. The assembly is installed on the top of a wellhead, and is designed to be used with a Direct Read Cable. See separate installation instructions.

When conducting artesian monitoring with Leveloggers a number of considerations must be kept in mind. First, ensure that the maximum hydraulic pressure the Levelogger will encounter within the well at its installation point will not exceed the hydraulic range of the logger. Second, artesian conditions do not preclude the necessity for barometric compensation of Levelogger data. Artesian conditions are caused by aquacludes forming confined aquifers. Confined aquifers, while not acted on by barometric pressure to the same extent as unconfined aquifers, are typically subject to barometric pressure at some barometric efficiency (See Section 10.1.3.1). Finally, bear in mind that the total pressure and subsequent water column equivalent depth measured by the Levelogger after barometric compensation may not represent the actual water level within the artesian well. Sealed intermittent artesian wells can be pressurized when artesian, but can also be de-pressurized when non artesian. The Levelogger's reading after barometric compensation represent the height of the piezometric surface.

10.1.2.2 Vacuum Monitoring

Vacuum monitoring is usually conducted by first installing pressure transducers such as the Levelogger in monitoring wells and then shutting-in or sealing those wells to the atmosphere with pressure sealed wellheads. Air is pumped out from an extraction well amongst the cluster or matrix of monitoring wells, theoretically dropping air pressure in the vicinity of the extraction well. For short-term tests in which data is not required during the extraction event, the Leveloggers can be programmed and simply suspended from hooks or eyelets on the underside of the sealed wellheads, the test run and the data collected at the end of the test by extraction and downloading of the loggers. However, if ongoing data from the Leveloggers is required during the extraction event, the loggers must be installed in a manner similar to the artesian monitoring scenarios described previously in this section. Leveloggers or Barologgers can be used to monitor the drop in pressure.

Figure 10-13 Levelogger and Barologger in Well

NOTE

The Barologger Edge should not be used to monitor water, as the internal mathematics for temperature compensation are based on air rather than water.

10.1.3 Barologger Installation

The Barologger is a Levelogger with a small range adequate to monitor the fluctuations that occur in barometric pressure. The Barologger's readings are used to barometrically compensate Levelogger readings. As a rule of thumb, a Barologger can be used to compensate all the Leveloggers in a 20 mile (30 km) radius and/or with every 1000 ft. (300 m) change in elevation.

To monitor barometric pressure correctly, the Barologger should never be submerged. In well installations, it is recommended that the Barologger be suspended in one of the monitored wells above the high water point (the well must be vented). For best reading accuracy, the Barologger should be installed in a similar thermal environment to that of the Levelogger. In groundwater wells, the Barologger should be suspended beyond the frost line and deep enough to avoid large temperature fluctuations. In surface water applications, the Barologger is best deployed in a dry well – a well embedded in the bottom of the water body, but sealed at the base from water entry and vented to the atmosphere. If a dry well cannot be installed, the Barologger can be installed on a float in the stilling well. Further information on the Barologger and barometric pressure can be found in Section 8.2.

10.1.3.1 Barometric Efficiency

The influence of barometric pressure on a groundwater surface can follow three scenarios. In confined aquifers with capillary or vadose head space, increased atmospheric pressure can tighten the pore spaces in the overlying soil and produce a capillary effect as the water level rises in response to having nowhere else to go but up. Second, some deeper aquifer systems can be quite barometrically isolated from the relatively small change in level that barometric influences can produce. The third scenario occurs in an unconfined aquifer, with high barometric efficiency, in which a barometric pressure change results in an equivalent or highly proportional drop or rise in groundwater pressure. In essence, depending on the aquifer type and depth, increased barometric pressure can result in either increased, static or decreased water levels. Barometric efficiency, the relationship of a barometric change on groundwater pressure, in confined aquifers generally ranges from 20 to 75%, whereas in unconfined aquifers the efficiency can range from 80 - 100%.

A second important element of Barometric efficiency is time lag – the time differential between a unit change in barometric at the surface to the time of transmission of that change to the aquifer. Calculating general barometric efficiency should not be done on a single barometric event, but rather on a statistically significant number of events. As a result, it may take a month or more of submerged Levelogger and Barologger data to determine barometric efficiency and time lag. As Barometric pressure fluctuates over time in excess of 60 cm water column equivalent pressure and as barometric efficiency can be such an important factor in accurately monitoring groundwater levels, it is vital that barometric compensation of the Levelogger data be performed.

The absolute pressure method used in the Levelogger and Barologger provide the user with the data necessary to determine barometric efficiency and time lag. If a barometric efficiency value has been determined from the Levelogger and Barologger data, that value can be applied to Barologger data in the Data Wizard.

Wells puncturing an aquifer have a negligible to non-existent effect on directly transmitting barometric changes to the larger aquifer. Barometric pressure is transmitted through overlying layers. To obtain the best and most accurate long term water level readings from Leveloggers, the user must first understand how the Levelogger calculates a depth of water above the transducer and second whether barometric efficiency should be considered in barometric compensation.

10.1.4 Rainlogger Installation

Figure 10-14 Solinst Rainloggers

Solinst Rainloggers (Figure 10-14) are designed to log the tip times of an external tipping-bucket rain gauge, and output the amount of rainfall per tip.

The Rainlogger Edge housing is made of ABS, while the Rainlogger housing is made of stainless steel. Direct exposure to rainfall should be avoided, and Rainloggers should not be submerged. The Rainlogger Edge ABS housing provides extra electrostatic discharge (ESD) protection.

The rain gauge connected to the Rainlogger is supplied by the customer and is a reed-switch type gauge most commonly known as a tipping-bucket rain gauge. The Rainlogger rain gauge connector (Figure 10-15) connects to the 2 m (6.5 ft.) cable supplied with the Rainlogger. The Rainlogger Edge and Rainlogger are supplied with different connector cables, which can not be interchanged. The connector cables have two wires, which are connected to the tipping-bucket by splicing to the tipping-bucket cable. As the tipping-bucket is just an electrical switch, for most models, the wires can be connected to either cable wire. Refer to the manufacturer's operating instructions. Longer, exposed cables should be protected from rodents and vandalism by cable armoring or installation within electrical conduit.

Figure 10-15
The Tipping-bucket Rain Gauge Connector of the Rainlogger Edge

> **NOTE**
> The Rainlogger Edge and Rainlogger are supplied with different connector cables, which can not be interchanged.

Figure 10-16 Rainlogger Edge Connected to Tipping-bucket

10.1.5 Installation in Extreme Environments

10.1.5.1 Freezing or High Temperature Conditions

Levelogger installation at submerged depths that may be at risk of freezing during the monitoring session is not recommended without taking adequate precautions to avoid transducer damage. When water freezes it expands approximately 9% by volume. A 9% expansion can equate to extreme pressure as demonstrated in Example 10.1. Therefore, solid freezing has the potential to damage the pressure transducer, which is rated to withstand up to 200% (150% for the Levelogger Gold and Junior Models) of its depth fluctuation range. Pressures beyond this threshold may damage the transducer. As such, care should be taken when choosing the appropriate pressure transducer range for your application.

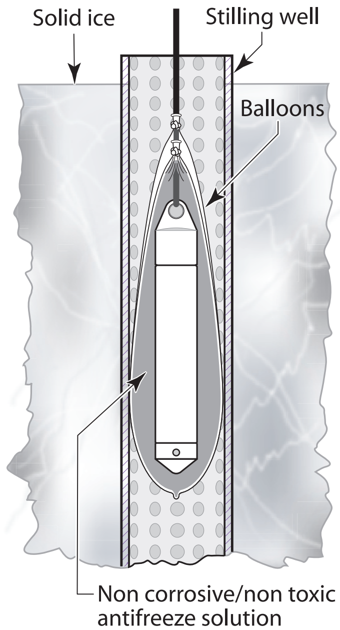


Figure 10-17
Installation in Freezing Liquid

Example 10.1 Solid Freezing Effects

The pressure exerted by the physical expansion or ice crystallization process on a retaining or enclosing contact surface is related to the temperature gradient over which the process occurs, i.e. the speed at which freezing occurs. For example, liquid freezing at -22°C, can create expansion pressures of 22 kg/cm^2 or 313 psi or the equivalent of 721 ft or 220 m water column depth.

With precautions, the Levelogger can be used in freezing liquid environments. If monitoring shallow water bodies or groundwater zones susceptible to freezing, the easiest way to avoid transducer damage is to lower the transducer to a point in the water column below the frost line or ice formation depth. In water bodies such as shallow streams, wetlands or ponds where freezing may penetrate to the bottom, install the Levelogger in a vented stilling well imbedded into the bottom of the water body beyond the frost line.

NOTE

Although precautions can be taken, placing a Levelogger in a situation where the water may freeze solid can permanently damage the sensor.

In cases where the above noted precautions cannot be taken and the Levelogger must be installed in the freezing zone, it is recommended that the logger be placed inside two elongated silicon, rubber or latex balloons, the balloons can be filled with a non-toxic, non-corrosive anti-freeze solution and sealed (Figure 10-17). Place the balloons in a section of perforated, 1.25" (30 mm) ID pipe and install the logger in the monitored water. The antifreeze solution will protect the Levelogger from ice expansion at the pressure transducer, yet transmit any pressure fluctuations that occur. However, it should be noted that even if these precautions are taken, there is still the risk that placing a Levelogger in a situation where the water may freeze solid can permanently damage the sensor (see Example 10.1).

Please note that a similar installation protection can be used when the Levelogger is monitoring liquids which are incompatible with its wetted materials.

The operating temperature range for Leveloggers is -20° to 80°C (-4° to 180°F). At the opposite end of the thermal scale, exposing the Levelogger to temperatures beyond 80°C may damage the thermistor and otherwise affect the Levelogger.

10.1.5.2 Marine or Brackish Installations

When installing the Levelogger in salt or brackish water or in a liquid having a specific gravity (density) different than fresh water, the density difference is compensated for by inputting the density of the monitored fluid in the Datalogger Settings window for the LTC Levelogger Junior and the Levelogger Gold Series (see Section 5.1). Also, see Section 8 for details in compensating the Levelogger Edge and Levelogger Junior Edge for fluid density differences.

The Levelogger Edge can be used for monitoring in salt or brackish water. However, long term use of the stainless steel body Levelogger Junior Edge, LTC Levelogger Junior, Levelogger Junior and first generation LTC and LT Leveloggers in salt or brackish water is not recommended, as the salt or other pollutants may cause pitting which can lead to perforation of the Levelogger's casing. To minimize this effect, regularly lift the Levelogger from the liquid; within seconds a thin protective layer will be formed by oxidation. Again, this precaution applies to the Levelogger Junior Edge, LTC Levelogger Junior, Levelogger Junior, and first generation LTC and LT Leveloggers.

If using these dataloggers in a continuous salt/brackish monitoring scenario, the stainless steel body of the datalogger can be protected in a manner similar to the freezing protection method described in Section 10.1.5.1. The Levelogger can be placed in balloons and the balloons filled with non-corrosive/ non-toxic fluid. As pressure changes, the fluid encasing the loggers will transmit the pressure differential to the datalogger's pressure transducer. Care must be taken in the selection of the balloon material or filling fluid such that the balloon material prevents diffusion of salts across the concentration gradient or that the filling fluid is comprised of polymeric molecules too large to diffuse out of the balloon material.

10.1.5.3 Biofouling Conditions

Figure 10-18 Biofoul Screen Dimensions

Biofouling is the unwanted buildup of microorganisms, plants, algae, or organisms such as barnacles and muscles on a wetted surface. When a Levelogger is deployed for an extended period of time, especially in a saltwater environment, there is the risk of biofouling. Biofouling on the pressure sensor and conductivity cell can compromise the accuracy of the measurements.

A Solinst Biofoul Screen can be used to protect the Levelogger from biofouling. The copper-coiled Delrin screen naturally reduces biofouling, and lengthens the time a Levelogger can be deployed before maintenance is required. The Biofoul Screen simply slips onto the sensor end of the Levelogger where it is held in place with its compression fitting. It adds about 3/4" (19 mm) to the length of the Levelogger. It allows water to freely enter the conductivity cell, as well as the pressure transducer inlets. It is replaced as required.

Figure 10-19 Solinst Biofoul Screen for the Levelogger

NOTE
It is important to ensure the installation cap or a Direct Read Cable is attached to the Levelogger during storage to prevent unnecessary battery drain and to protect the optical eyes.

NOTE
To clean the optical infrared eyes on a Levelogger, use a clean, soft cloth or cotton swab to gently wipe away any debris and dry the eyes. Avoid soap or cleaners, as it may leave a residue. Compressed air may also be used to clear away any debris.

NOTE
The Levelogger installation cap should be left on when you are soaking a Levelogger.

10.2 Levelogger Maintenance

Levelogger maintenance consists of cleaning the outside casing, the circulation holes and the optical infrared eyes. The required frequency of cleaning is dependent on several aspects of the monitored water quality. In freshwater with good to excellent water quality, the Levelogger cleaning requirements will be very minimal; amounting to a seasonal or even annual maintenance inspection.

In most cases cleaning can be accomplished by rinsing the Levelogger and using mild, non-residual, non-abrasive household cleaners using a very soft-plastic, bristled, pipe-cleaner type brush. Do not insert any object through the circulation holes at the sensor end of the Levelogger.

In some cases simple cleaners are insufficient to properly clean the Levelogger. Several commonly occurring water conditions require specific maintenance methods, these include hard water, high suspended solids loading, biological or chemical fouling and salt or brackish water conditions.

Hard water monitoring can result in the precipitation of calcium and magnesium deposits on the pressure transducer as well as other components of the Levelogger. These deposits can be safely dissolved using a diluted solution (typically ≤ 10% strength) of acetic or phosphoric acid. Commercially available products for dissolving hard water scaling are also available and can be used if designed for household use. Some industrial strength hard water scaling removers are much higher strength and are not recommended for cleaning the Levelogger.

High suspended solids load may block the circulation ports or clog the internal pressure cell of the Levelogger. The potential clogging effect of solids deposition can be minimized by placing the Levelogger in zones of flow. To remove solids build up, rinse the Levelogger under a low flow of tap water until particles have been washed away.

Bacteriological or chemical fouling can be an important consideration in many ground and surface water monitoring projects. Sessile bacteria will often utilize installed instrumentation as an attachment substrate. Chemical deposit can be the result of electrical charge differential between the instrumentation of the monitored liquid or the result of biological or algal activity. Both forms of fouling can result in difficult to remove deposits on the Levelogger transducer, the conductivity wires and the Levelogger casing. To remove fouling use a diluted (≤ 10%) solution of sulfuric acid. Persistent material may require soaking for several hours.

Cleaning LTC Levelogger Junior sensor pins is recommended before calibrating the unit prior to starting a project. The pins of the LTC Levelogger Junior sensor are platinum-coated, therefore they should not be roughly cleaned or touched with any metal. They can be cleaned with a soft bristle brush, Q-tip, or cloth. Almost any acid solution can be selected to clean the sensor, provided it is highly diluted (generally less than 10% acid). The "soaking" time should be monitored and kept to a minimum.

11 Diagnostics Utility

The Levelogger Diagnostics Utility can be used for troubleshooting Leveloggers and obtaining information about that Levelogger that can assist the Solinst Technical Support representative to identify and fix any problems you may encounter with your Levelogger. The Diagnostics Utility can be launched from the Utilities menu at the top of the software. The utility can be used to run a self-test, do a Memory Dump and create and email reports.

11.1 Run Diagnostics

The Run Diagnostics function reads the following information from the Levelogger:

1) Serial Number
2) Model Number
3) Firmware Version
4) Battery Voltage
5) Charge Level
6) Current Level Reading
7) Current Temperature Reading
8) Max/Min Pressure Reading
9) Max/Min Temperature Reading
10) Max/Min Conductivity Reading
11) Total Number of Logs

> **NOTE**
> If an LTC Levelogger Junior fails the Conductivity Sensor Test, this could mean that you have not calibrated your LTC in a while (~1 year). It is recommended that you perform a conductivity calibration, then 'Run Diagnostics' again.

This information can be used to identify firmware, battery and/or temperature/ pressure/conductivity sensor problems. This function also performs a series of self-tests on the Levelogger to check for problems with the battery, memory, pressure/temperature/conductivity sensors. If an LTC Levelogger Junior fails the Conductivity Sensor Test, this could mean that you have not calibrated your LTC in a while (~1 year). It is recommended that you perform a conductivity calibration, then 'Run Diagnostics' again. If any of these tests fail then a report should be created and emailed to Solinst Technical Support. To execute this function simply click the 'Run Diagnostics' button.

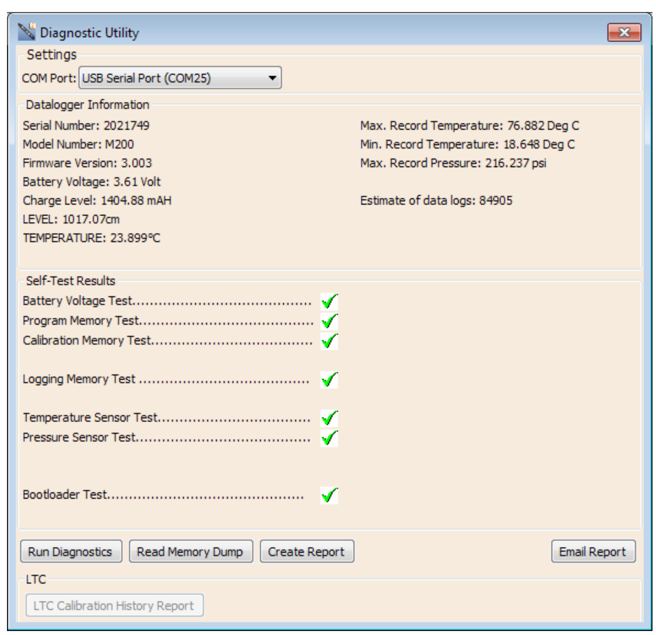


Figure 11-1 Run Diagnostics

> **NOTE**
> It is recommended that, before attempting to use this function, you use the 'Create Report' function to send a report to the Solinst Technical Support.

11.2 Read Memory Dump

This function creates a complete dump of the Levelogger's memory, which can then be sent to Solinst Technical Support for analyzing.

To execute this function simply click the Read Memory Dump button. Performing a memory dump will create a *.xle file of the data to save.

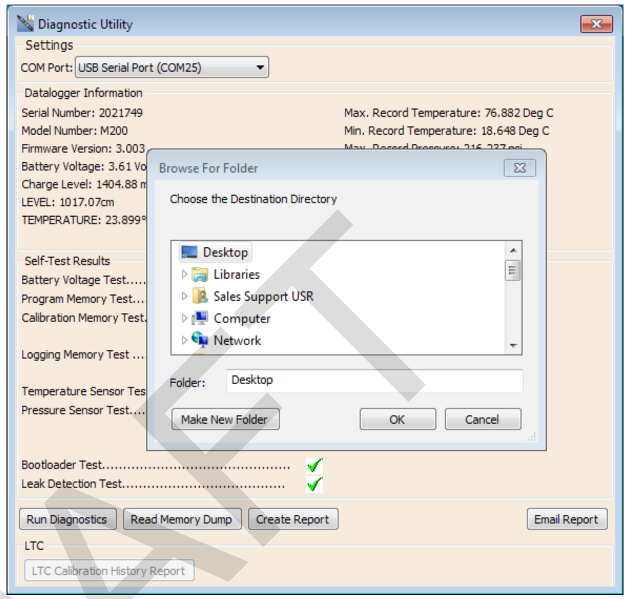


Figure 11-2 Read Memory Dump

11.3 Create Report

> **NOTE**
> The 'Email Report' option automatically creates a report and attaches it to an email to send to Solinst - all in one step.

This function simply creates a text file containing the information obtained from the Run Diagnostics function. When you click the Create Report button, a window will pop up asking you to fill out your company information. Simply fill this out and the resulting report can be saved or sent to Solinst Technical Support for troubleshooting. If creating a report for an LTC Levelogger Junior, the LTC Calibration History Report will be included.

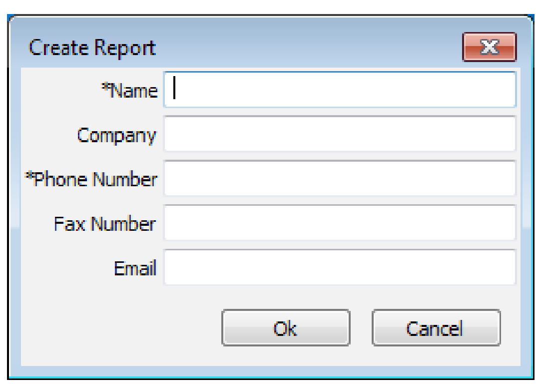
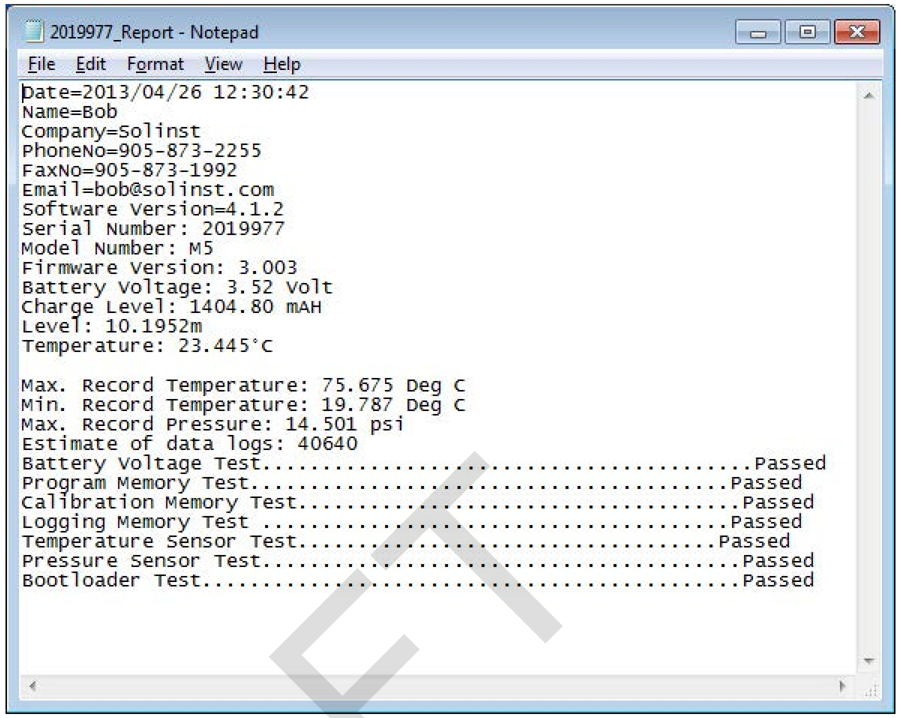


Figure 11-3 Customer Info Input Window


2019977_Report - Notepad

File Edit Format View Help

```
Date=2013/04/26 12:30:42
Name=Bob
Company=Solinst
PhoneNo=905-873-2255
FaxNo=905-873-1992
Email=bob@solinst.com
Software Version=4.1.2
Serial Number: 2019977
Model Number: M5
Firmware Version: 3.003
Battery Voltage: 3.52 Volt
Charge Level: 1404.80 mAH
Level: 10.1952m
Temperature: 23.445°C

Max. Record Temperature: 75.675 Deg C
Min. Record Temperature: 19.787 Deg C
Max. Record Pressure: 14.501 psi
Estimate of data logs: 40640
Battery Voltage Test.........................................Passed
Program Memory Test.........................................Passed
Calibration Memory Test.....................................Passed
Logging Memory Test ........................................Passed
Temperature Sensor Test....................................Passed
Pressure Sensor Test........................................Passed
Bootloader Test..............................................Passed
```

Figure 11-4 Report Example

11.4 Email Report

Clicking Email Report will guide you through the process of creating a Diagnostics Report, and it will automatically attach the report to an email to send to Solinst Technical Staff for troubleshooting. If you are emailing a report for an LTC Levelogger Junior, the LTC Calibration History Report will be included.

11.5 LTC Calibration History Report

This function creates a report of all previous user calibrations performed on the LTC Levelogger Junior. Use it to send a history report to Solinst for analysis if the LTC Levelogger Junior readings are irregular and/or the unit does not maintain its calibration. To execute this function simply click the LTC Calibration History Report button. This creates a text file that can be sent to Solinst Technical Support.

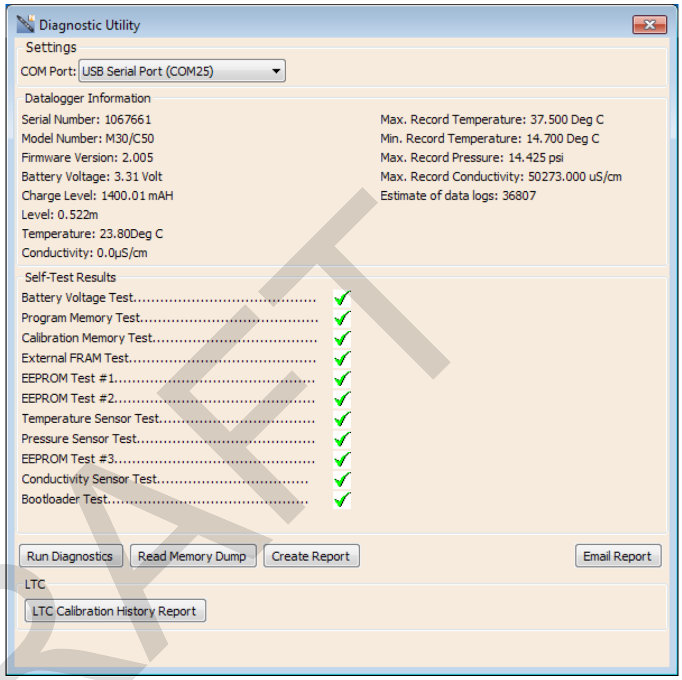


Figure 11-5 LTC Calibration History Report

11.6 Software/Firmware Updates

Each time the Diagnostic Utility is opened, it automatically checks for software updates. If there is an update, "Software Update Available" will appear in the top right of the window. When you click the message, a web page will open, allowing you to download the software update.

The Utility also checks for firmware updates. "Firmware Update Available" will appear in the top right of the window. Clicking the message will open a web page where you can download the firmware update. See Section 12 for firmware update instructions.

NOTE

Your Computer must have an Internet connection to check for software and firmware updates.

You can also check for updates using the Help menu.

> **NOTE**
> To check for firmware updates using Levelogger Software, retrieve settings from the connected datalogger (see Section 5). "Firmware Update Available" will appear in the top right menu bar if there is an update available. Clicking the message will open a web page where you can download the firmware update. You can also use the Software's Help menu.

> **NOTE**
> It is important that the communication between the PC and the Levelogger is not interrupted during a firmware/calibration upload so please make sure to close any other running programs, including screen savers, and do not disconnect the Levelogger before the upload is finished.

> **NOTE**
> Solinst recommends using an Optical Reader to connect your Levelogger to the PC during a firmware upgrade to avoid any interruptions during the extended communication period.

12 Firmware Upgrade Utility

The Firmware Upgrade Utility is used to upload new firmware files to a Levelogger. The zipped firmware file can be obtained from: http://www.solinst.com/downloads/

Make sure to unzip the firmware file after you have downloaded it, so you can access the *.ssf file.

To upload new firmware to a Levelogger, follow these steps:

1) Open the Solinst Firmware Upgrade Utility from the Utilities menu in the main Levelogger Software. Pick the Com Port to which the Levelogger is connected and make sure the Baud Rate is set to 9600.
2) Click the 'Open' button, which should open a file dialog asking for the firmware file (*.ssf) to upload. Navigate to the directory where the firmware file was saved on your PC, then click on the file and click 'Open'.
3) Check the 'Firmware File Information' box to make sure that the opened file is the right one.
4) Click the 'Upload Firmware' button, to start the firmware upload process.
5) If a communication error occurs and is indicated in the Levelogger Information Window (Figure 12-1) either before the 'Verified Program Checksum' message or after the 'Program Information Section', then restart the upgrade process.
6) If, however, a communication error occurs between the 'Verified Program Checksum' and the 'Program Information Section' messages, then please contact Solinst. You will need to give the Levelogger Serial Number and explain the exact positioning of the error message.

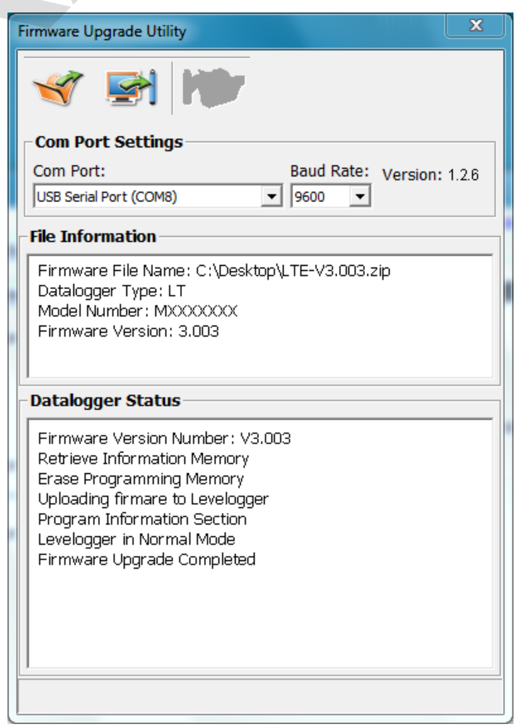


Figure 12-1
Firmware Upgrade Utility Window

13 Trouble Shooting

13.1 Problems During Installation of Levelogger Software

'Class not Registered' or 'DLL not found' or 'Access violation'

1) You may not have Administrator Rights to install the software in the Windows XP/7/8/10 environment.
   - Ask your System Administrator for assistance.
2) Some files got corrupted during installation of the Levelogger software. Use 'Add/Remove Programs' to uninstall then re-install Levelogger software.

13.2 Error During Software Uninstall Process

The 'Add/Remove Program' cannot locate the Levelogger <setup.exe> file of the software or the link between the software and the 'Add/Remove Program' is damaged.

The record in the Registry Table must be removed:

1) Ask your System Administrator to remove this.
2) Refer to the following link from Microsoft Website for instructions:
   http://support.microsoft.com/default.aspx?scid=kb;en-us;247501

13.3 Problems During Installation of RS-232 to USB Converter

NOTE

Solinst recommends Keyspan or IO Gear. For problems with converters from other manufacturers, please contact the manufacturer.

Unable to install the RS-232/USB converter from Keyspan or IO Gear

1) After plugging in the RS-232/USB Converter, a Hardware Installation Wizard will open. Follow the instruction from the Wizard and make sure to select the RS-232/USB Converter Driver from the Keyspan or IO Gear Installation CD.
2) If the Hardware Installation Wizard does not open after plugging in the RS-232/USB Converter, follow the steps below to open the Hardware Installation Wizard:
   a. Select Control Panels
   b. Double click on System
   c. Select the Device Manager Tab
   d. Double click on Other devices
   e. Right click on USB Serial Converter
   f. Select Update Driver...

13.4 Data Has Been Erased Accidentally

If Levelogger has been restarted and old data has not been saved, go to Download Options and choose Data Recovery. It downloads the immediately previous log.

13.5 Error Messages During Use of Software

'Communication Time Out' or 'Communication Error' or
'The Command that is sent to the Levelogger Edge is not defined'

1) Try communicating with another Levelogger, Optical Reader or Direct Read Cable. The communication cable, Optical Reader or Levelogger may be damaged.
2) Clean the optical 'eyes' on the Levelogger and the cable, with a soft cloth.
3) Check that the communication cable is connected to the same Com Port that is chosen in the upper middle of the Main Window of the Levelogger software.
4) Check the Com port settings. They should be as follows:
    - Bits per second: 9600
    - Data bits: 8
    - Parity: None
    - Stop bits: 1
    - Flow control: None
      (This may have been set to Xon/Xoff – change it to None, Select [OK] and back out of this pathway.)

The route to view your Com port settings is as follows:

a. Select Control Panels
b. Double click on System
c. Select the Device Manager Tab
d. Double click on Ports
e. Double click on Communications Port(s)
f. Choose the Port Settings Tab

5) Try using a different computer, to see if this is the cause of the problem.
6) If using a laptop (especially in conjunction with a Direct Read Cable) your Com Port may not be powered adequately to receive/transmit data. Try using a desktop computer to test this, or contact Solinst to obtain a PC Interface Booster Cable.
7) If problem persists, contact Solinst.

'Port Cannot Open'

1) If using a USB device, ensure you plugged it in before starting the Levelogger Software.
2) Ensure the correct Com Port is selected in the upper middle of the Main Window of the Levelogger software.
3) If the correct Com Port is not available, a USB Driver installation or update may be required.
4) Check if some other software is using the same Com Port in the background. Shut that software down or choose another Com Port if available. Such background software may be anti-virus software or PDA software.

5) Make sure your Com Port has been enabled:
    a. Select Control Panel
    b. Double click on System
    c. Select the Device Manager Tab
    d. Double click on Ports
    e. Double click on Communications Port(s)
    f. Choose General
    g. Uncheck 'Disable in this hardware profile box'
6) If you are using a virtual Com Port, like a USB optical reader or USB/RS-232 converter, refer to the 'Problems During Installation of RS-232 to USB Converter' section to make sure they are installed properly.

'File Create Error' and 'File Write Error'

1) If you do not have file-writing privileges to the Levelogger default data folder, change the folder as follows: in the Levelogger software, click 'Configuration' then 'Application Settings'. Under 'Default Directory', enter a new destination folder, to which you have file writing privileges, e.g. 'My Documents'. Follow the same procedure if you have the same problem when you export the data file in csv format.
2) Ask your System Administrator for assistance.

'File Open Error' and 'File Read Error'

1) Shut down or disable any other software that is active and using the same file.
2) In Notepad or Wordpad, open the <*.xle> or <*.lls> file to check for corruptions in the file. How are the Levelogger files ended?
3) If problems persist contact Solinst for assistance.

'Time Span Error, some data cannot be compensated'

1) Find another barometric data file that has the same time stamp as the Levelogger.
2) Perform the compensation (a simple subtraction) in a spreadsheet program for any missing time stamps.

'A different type of Levelogger is detected'

Try clicking the Retrieve Settings icon again, or replace the Levelogger currently in the Optical Reader with the one that was previously being worked on, and complete the operation.

'The selected file is not a barometer'

Select a Barologger for the compensation process.

'Data Corrupted'

Contact Solinst for assistance. Use Levelogger Diagnostic Utility to do a memory dump and sent the dump file to Solinst for further analysis.

'Internal Error'

Contact Solinst for assistance.

‘Fail to append data - A different Levelogger has been detected!’ or ‘Fail to append data - A different start time has been detected!’ or ‘Fail to append data - New data is not available in the Levelogger!’

The Levelogger software can only append data to a file that has the same serial number and start time as the connected Levelogger. Find the correct file, or use ‘All Data’ to download the complete file.

‘Only Levelogger Gold/Edge supports this function’

The ‘Append Data’, ‘Partial Download’ and ‘Data Recovery’ functions are only supported by the Levelogger Gold/Edge loggers, not previous version Leveloggers.

‘Schedule cannot be empty’

When using the ‘Schedule’ sampling option in a Levelogger Gold/Edge, the schedule must contain at least one item.

‘Readings in schedule exceed the maximum’

The number of readings in a schedule should not result in more than 40,000 (or up to 120,000) individual readings.

www.solinst.com

High Quality Groundwater and Surface Water Monitoring Instrumentation

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instruments@solinst.com

Solinst®

Water Level Meter

Model 101

For measuring the depth to water in wells, boreholes, standpipes, and tanks, Model 101 Water Level Meters are the industry standard for portable hand operated meters. They are sturdy, easy to use and read accurately to 1/100 ft. or each millimeter.

There are two versions to choose from. The Model 101 P7 Water Level Meter features a pressure-proof probe rated to 500 psi and laser marked PVDF tape. The Model 101 P2 Water Level Meter features an easy-to-repair probe and heat embossed polyethylene tape.

Also available, are the less expensive Model 102 and 102M Coaxial Cable Water Level Meters for use in small diameter tubes, and the basic Model 101B Water Level Meter (see Model 102 and 101B Data Sheets).

101 P7

Get Quote | More Info

Operating Principles

Model 101 Water Level Meters use corrosion proof stainless steel probes attached to permanently marked flat tape, fitted on a well-balanced reel. They are powered by a standard 9 volt battery.

The probes incorporate an insulating gap between electrodes. When contact is made with water, the circuit is completed, activating a loud buzzer and a light. The water level is then determined by taking a reading directly from the tape at the top of the well casing or borehole.

A sensitivity control allows the buzzer to be turned off while in cascading water, and ensures a clear signal in both high and low conductivity conditions.

Reels

With a stand-alone design, convenient carrying handle, and sturdy probe holder, the standard reels are ergonomically designed for ease of use. They are robust and smooth running. The battery is housed in a convenient drawer in the front of the reel, allowing quick replacement. The reels are equipped with an on/off sensitivity switch, light, buzzer, battery test button, brake and a tape guide stored on the frame.

P7 Probe

The P7 Probe is submersible up to 1000 ft. (300 m), therefore, you can measure total well depth in ideal conditions. The sensor at the tip of the probe provides consistent measurements with almost zero displacement. The tape seal plug design allows the probe to be quickly and easily replaced, if required.

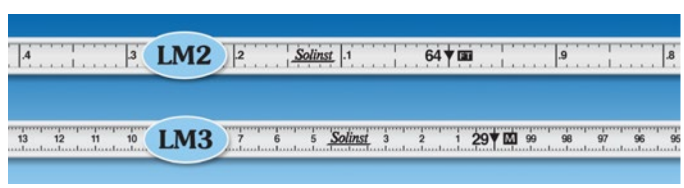
Size: 5/8" dia., 5.38" long (16 mm x 137 mm)
Weight: ~4.5 ounces (128 g)

Zero Measurement Point

PVDF Laser Marked Tape

The Model 101 P7 Water Level Meter uses extremely durable, PVDF flat tape, traceable to NIST and EU measurement standards. Each tape conductor contains 13 strands of stainless steel, and 6 strands of copper-coated steel, making the tape non-stretch and high in tensile strength and electrical efficiency. The tape has a thick dog bone design that prevents adherence to wet surfaces, and allows it to hang straight in application. It is also easy to splice. The 3/8" (10 mm) tape comes with permanent laser markings every 1/100 ft. or each millimeter, in lengths up to 5000 ft. (1500 m).

LM2: Feet and tenths: with markings every 1/100 ft.
LM3: Meters and centimeters: with markings every mm



Features

Accurate:
- Markings each 1/100 ft. or millimeter
- Traceable to national standards
- Sensitivity adjustable to conductivity
- Probes avoid false readings in cascading water

Reliable:
- Permanent laser markings
- Non-stretch PVDF tape with stainless steel conductors

Long Life:
- Rugged, corrosion proof components
- Strong, flexible tapes
- Easy to splice and repair

Flexible:
- PVDF replacement tapes are interchangeable with other meters

101 P2

P2 Probe

The P2 Probe is shielded in design to reduce or eliminate false readings in cascading water. The probe consists of a stainless steel body with a neoprene heat shrink seal. It is not suitable for submergence to any significant depth. Its simple design makes it easy to repair.

Size: 0.55" dia., 7.5" long (14 mm x 190 mm)
Weight: ~7 ounces (200 g)

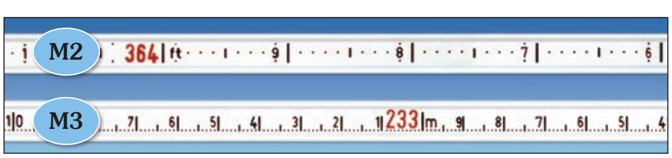
Zero Measurement Point

Polyethylene Tape

The Model 101 P2 Water Level Meter uses high quality polyethylene tape that reels smoothly, remains flexible and hangs straight in the well. Heat embossed marking each millimeter or 1/100 ft. allow accurate readings. The 3/8" (10 mm) wide tapes come in lengths up to 1000 ft. (300 m).

Seven stranded stainless steel conductors resist corrosion, provide strength and are non-stretch. They make the tape very easy to repair and splice. The dog-bone design reduces adherence to wet surfaces.

M2 Feet and tenths: with markings every 1/100 ft.
M3 Meters and centimeters: with markings every mm.



Length Options

Solinst Model 101 P7 and P2 Water Level Meters are available on reels as shown below, in the following standard lengths:

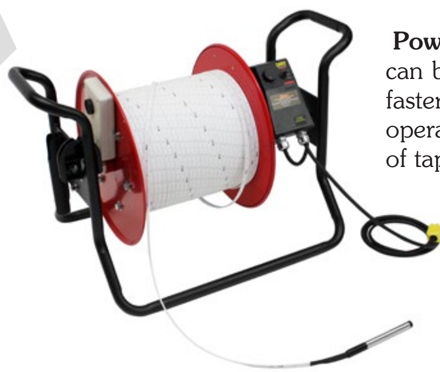
Reel	ft.	m
Small Reel	* 100 ft.	30 m
	* 200 ft.	60 m
	* 300 ft.	100 m
Medium Reel	* 500 ft.	150 m
	* 750 ft.	250 m
	* 1000 ft.	300 m
Large Reel	1250 ft.	400 m
	1650 ft.	500 m
	2000 ft.	600 m

* Polyethylene tapes are only available in these lengths

Model 101 Water Level Meter Reels

Other Options

Carrying Case: Small and medium padded nylon carrying cases are available, as an optional extra. Their design has a convenient shoulder strap, zippered front pocket, zippered top, and a grommet in the base to prevent moisture build-up.



Power Reels: Power reels can be very useful to allow faster or less strenuous operation of longer lengths of tape.

Replacement Parts: Replacement probes, tapes and other spare parts are available.

Tape Guide/Datum

A tape guide is provided with each Meter. It protects the tape from damage on rough edges of well casing and ensures easy, consistent measurements, regardless of who takes the readings. It can also provide support on the casing, for small reels.

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US Army Corps of Engineers®

Fact Sheet

Staff Gage Setup Instructions

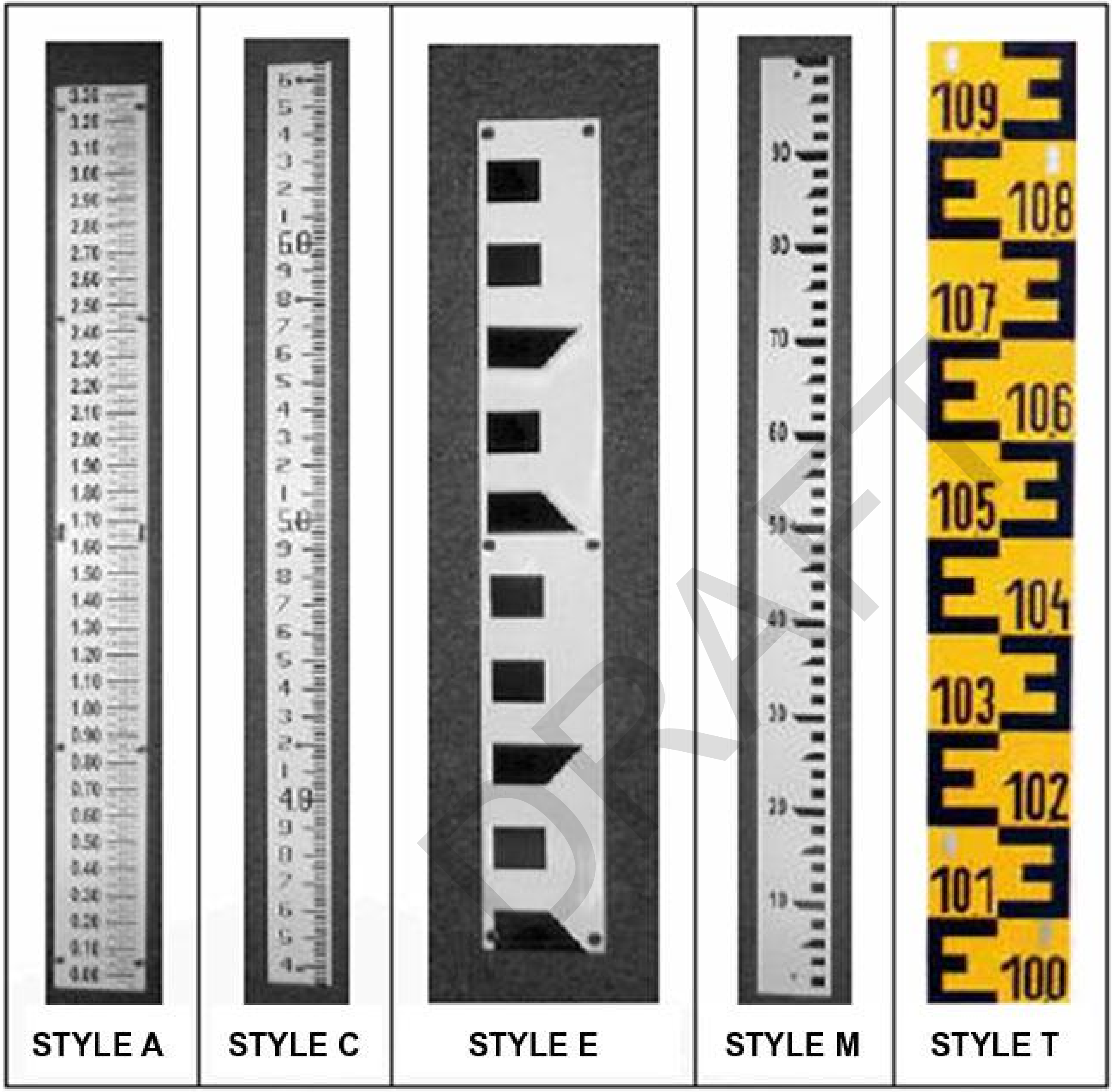
Published Sept. 10, 2012

What is a staff gage?

A staff gage is a long ruler placed in a water body that is used to measure water surface elevation or just to determine the rise/fall of the water surface over time.

Setting up a staff gage:

1. Find a sturdy fence post or pipe to use as the post of the staff gage. It needs to be able to hold up against high water or wind, but also not be too heavy to carry and set it easily. A 2x8 wooden board works well. Bolt the board to the post.
2. Obtain numbers for the gage. Porcelain or metal numbers can be bought from a number of vendors. The staff gage can start at whatever number desired. The below photo shows some types of number plates that can be used for staff gages. If no number plates are available, a simple staff gage can be made using lath and a marker. Using a tape measure, draw the scale and numbers on the lath. This type of gage will only provide temporary service, but can be useful for backwater areas during a flood. Attach the numbers to the staff gage board using screws or nails as available.



3. Choose a specific location for the staff gage. A good location is where the post will be in the water during lower water years and where it won’t be overtopped during high water years. Avoid placing the staff gage in a location where the water pools or is very slow moving, because sediments will collect around the base of the staff gage and affect readings. If there is a permanent

structure such as a dock or bridge near the desired staff gage location, the gage can be attached to that structure instead of using a fence post driven into the stream or lake bed. If it is desired to tie the staff gage into a given elevation marker, place the staff gage near the existing benchmark (place of established elevation) for ease of surveying.

4. The next step is setting the staff gage. Drive the fence post or pipe into the ground so that it will stay stable through high water or bad weather. If using a fence post driver, only fasten the board to the post using one bolt and let the board rest perpendicular to the post. This will allow the top part of the post to be used with the fence post driver. Once the post is set refasten the board onto the post.
5. If it is desired to tie the gage into an existing benchmark so it can be used to find the water surface elevation, follow the steps below.
    1. Surveying equipment like a tripod, a leveling instrument, and a rod will be needed to survey the staff gage into the benchmark. Set up the tripod and attach the leveling instrument. Level the instrument using the three knobs under it.
    2. Have a partner take the rod and place it on the benchmark, BM, location, then read the rod through the instrument. This is called your back sight reading, BS. The number read from the rod added to the known elevation of the benchmark is called the height of the instrument, HI. (HI = BM + BS).
    3. If the benchmark is far enough away from the staff gage location that it cannot be seen from the level, move the rod to an intermediate point. Place the rod on a concrete corner or somewhere that can be marked and used as a reference in the future. Take a reading through the instrument and subtract that number from the height of the instrument previously calculated. This is called the foresight reading, FS. This will give a temporary benchmark elevation, TBM. (TBM = HI – FS). Now use this TBM as a new benchmark and repeat the process as many times as needed to reach the location of the staff gage. Before each iteration of these steps, the tripod will need to be moved and the instrument re-leveled (called ‘breaking set’).
    4. Once the staff gage is reached, hold the rod against the gage with the bottom at the water surface to take a reading. The TBM calculated at this location will be the elevation of the water surface. Correlate that elevation to the number shown on the staff gage to tie your staff gage into the existing benchmark and be able to read the elevation from the staff gage.

When finished setting the staff gage, it will provide a quick and easy way to check changes in water level for anyone going past the gage.

Related Link: **Omaha District Emergency Management**
http://www.nwo.usace.army.mil/Missions/EmergencyManagement.aspx