

ARCADIS GERAGHTY & MILLER



X4
8/10/98

Mr. Richard Boice
USEPA Region V
77 West Jackson Boulevard
Chicago, IL 60604-3590

ARCADIS Geraghty & Miller, Inc.
14497 North Dale Mabry Hwy.
Suite 115
Tampa
Florida 33618
Tel 813 961 1921
Fax 813 961 2599

Subject:

July 1998 Project Progress Report for the Verona Well Field (VWF), Paint Shop, and Annex

ENVIRONMENTAL

Dear Mr. Boice:

The following narrative constitutes a monthly progress report with respect to actions and activities undertaken on RD/RA activities associated with the Verona Well Field (VWF), Annex and Paint Shop. This report is submitted voluntarily to keep United States Environmental Protection Agency (USEPA) informed of the progress of RD/RA activities and is subject to, and without waiver of, respondents' prior written objections to the scope and legality of portions of the February 18 and May 5, 1992 §106 Administrative Orders.

Date:

10 August 1998

Contact:

Greg Rorech
Bridget Morello

Extension:

813 961 1921

Description of Work Completed

- 1) CETC completed system equipment, outfall, and water quality monitoring in accordance with the NPDES permit.
- 2) From July 8-10, 1998, ARCADIS Geraghty & Miller performed the 2nd quarterly hydraulic and groundwater quality monitoring event per the 1997 Annual Monitoring Report and Addendum. In addition, ARCADIS Geraghty & Miller collected the 2nd quarter influent and effluent air samples per the air emissions SRD and 1997 Annual Monitoring Report.
- 3) ARCADIS Geraghty & Miller received a letter from USEPA dated July 7, 1998 regarding several issues including the USEPA's approval of the 1997 Annual Monitoring Report, resolution of sentinel well sampling procedures with MDEQ, additional USEPA/MDEQ comments on the Soil Cleanup Verification Sampling Plan and letter addendum (dated June 11, 1998), USEPA comments on the Construction Completion Report (CCR) and Operation and Maintenance (O&M) Plan dated June 1997, and a request for revision of the CCR and O&M Plan. In addition, ARCADIS Geraghty & Miller received a copy of a letter from USEPA to Ken Kohs of the City of Battle Creek (City) dated July 7, 1998, regarding water supply issues, the VWF Group's intention to increase the flow rate at some of the blocking wells, etc. In response to these letters from USEPA, ARCADIS Geraghty & Miller

submitted a letter to USEPA dated July 22, 1998 clarifying recent discussions between ARCADIS Geraghty & Miller and the MDEQ and indicating the VWF Group's concerns regarding revision of the CCR and O&M Plan without MDEQ comments or sign-off, increasing the flow rate at blocking wells, and the misperception that the VWF Group is responsible for protecting the VWF under conditions which exceed those required per the ROD and UAOs.

- 4) Per USEPA's request (letter dated July 7, 1998), Attachment 1 presents clarification of the groundwater sampling procedure utilized by ARCADIS Geraghty & Miller during the VWF RA monitoring events.
- 5) As indicated in our July 22, 1998 letter, in mid-July Bridget Morello and Barb Vetort (MDEQ) discussed the sentinel well sampling procedures and MDEQ's suggested revisions of those procedures. Preliminary indications are that MDEQ will require sampling the sentinel wells at agreed upon depths, using the same sampling procedure currently used. However, MDEQ is supposed to further review the sampling procedure and contact us.
- 6) On July 8 and 24, 1998, Bridget Morello and Barb Vetort discussed the MDEQ's comments on the soil cleanup verification sampling plan. Based on those discussions, it is understood that MDEQ accepts the manner in which soil sample boring locations were randomly generated for the Annex and Paint Shop, but the MDEQ suggests modification of the vertical component of the sampling plan as follows: 1) soil sampling should consist of collection of samples at each identified boring location, at 5-foot intervals to the water table, 2) the actual location of the 6-inch interval within each 5-foot section to be sampled for laboratory analysis must be determined using a random number generator, 3) no field screening (i.e., use of field GC) will be performed, 4) soil samples will be analyzed for the VWF VOCs, with the exception of several random samples (i.e., a subset of the entire sample population) which will be analyzed for the list of 48 compounds of concern on Table 21 of the ROD. With regard to the latter issue, MDEQ prefers that every sample collected be analyzed for the 48 compounds of concern, but will review and consider approving an alternate procedure involving analyses of those compounds in a subset of the entire sample population provided that plan is reasonable. ARCADIS Geraghty & Miller is currently working on a final version of the soil sampling plan, and intends to submit that plan to MDEQ/USEPA in August.
- 7) ARCADIS Geraghty & Miller reviewed bids for sandblasting/painting of the influent piping, air stripper tower, and carbon vessels. The VWF Group is currently reviewing the bid summary. The work is tentatively scheduled to be performed the week of September 21, 1998.

Summary of All Findings

None.

Sampling Results/Reports

- 1) On July 8-10, 1998, ARCADIS Geraghty & Miller performed the 2nd quarter monitoring event per the 1997 Annual Monitoring Report and Addendum. Analytical results are not yet available. Water level data are attached.
- 2) On July 15, 1998, CETC collected treatment system influent and effluent samples in accordance with the NPDES permit. No permit exceedances occurred. Analytical results and operating data, summarized on the appropriate reporting forms by ARCADIS Geraghty & Miller, were submitted to the MDEQ SWQD on August 3, 1998.
- 3) Pursuant to USEPA's requests for additional flow data, the attached table summarizes the flow data for July 1998. City production well data for July 1998 also are attached. In July 1998, the City's average daily production rate was 16.5 mgd.

Contact Made With the Public

None.

Changes in Project Personnel

None.

Problems Encountered or Anticipated and Actions Taken to Address

- 1) On July 20, 1998, wet well pump 4 failed due to moisture in the seal cavity. This pump was installed on May 5, 1998, after being retrofitted with the larger motor and impeller, and the new seal plate that was supposed to prevent such moisture failure problems. ARCADIS Geraghty & Miller contacted the pump manufacturer to discuss the problem. The manufacturer agreed to expedite shipment of the latest retrofitted pump (i.e., old #3) so it could be installed in place of pump 4, and allow pump 4 to be returned to the factory for inspection/determination of the cause of the seal failure. To keep the system on-line, however, CETC temporarily reduced the flow from the new blocking wells 30 gpm each, and the manufacturer agreed that CETC should remove pump 4 and replace the seal oil. CETC replaced the seal oil on July 21, 1998

and returned the new blocking wells to design flow rates. The system operated at the reduced flow rates for approximately 16 hours.

- 2) On July 27, 1998, CETC installed the new flow meter in the air stripper influent pipe.
- 3) On July 28, 1998, the VWF treatment system experienced a power failure due to a tree damaging the City's power substation. Power was restored on July 29, 1998, and the system was restarted. The system was down for approximately 19 hours.
- 4) Upon restarting the system on July 29, 1998, after the power failure, wet well pump 4 failed due to moisture in the seal cavity. ARCADIS Geraghty & Miller again contacted the pump manufacturer regarding the availability of the latest retrofitted pump (i.e., old #3). The pump manufacturer indicated the retrofitted pump would be at the site by August 3, 1998. CETC reduced the flow rates at the new blocking wells 30 gpm each, left the old blocking wells at design rates, and restarted the system with wet well pump 4 off-line.

CETC did not receive the retrofitted pump on August 3, 1998, but proceeded with removal of pump 4 and shipped it to the factory for inspection. Also, CETC shut down the new blocking wells and increased the flow rates at the old blocking wells to 250 gpm each, with the exception of wells V27 and V28 as noted below (problem #5). Since August 3, 1998 the VWF RA has operated with only the old blocking wells on-line, at flow rates comparable to design flow rates for the original single line blocking well system.

To compound this problem., as indicated by Bridget Morello in a telephone conversation with you on August 5, 1998, the pump manufacturer incorrectly used the new motor intended for use in retrofitting old pump #3 on someone else's pump. The factory now has two of our pumps (old #3 and the returned #4). We have informed the manufacturer that we must have either a new pump or a retrofitted pump this week. At this point, we have not received confirmation from the manufacturer of a delivery date. We will keep you posted of pump replacement activities and the pump 4 inspection findings. In the meantime, the system is operating with two new and one old pump wet well pumps on -line, with blocking wells V22, V24, V25, and V26 pumping 250 gpm, V27 pumping 237 gpm, V28 pumping 214 gpm, all new blocking wells off-line, and Annex wells pumping at approximately 52 gpm each.

- 5) As noted above, when CETC tried to increase flow rates at the old blocking wells, well V27 achieved a maximum rate of 237 gpm and well V28 achieved a maximum rate of 214 gpm. The reduced capacity at wells V27 and V28 indicates that the wells need to be inspected and chemically cleaned. The well inspections/cleaning are tentatively scheduled for the week of September 21, 1998, to coincide with the shut down for the sandblast/painting work.
- 6) During July 1998 the VWF RA operated at an average flow rate of 2698 gpm (calculation based on average of individual well flow rates from 7/6, 7/13, 7/20, and 7/27/98 shown on the attached table). The average monthly flow rate calculated on the attached table (based on flow totalizer readings from 6/29 and 7/27/98 and the total number of minutes during that period) is less than the 2698 average flow rate based on individual well rates since it does not account for the system shut downs discussed above.
- 7) As discussed in the previous progress report and our letter dated July 22, 1998, the VWF Group is concerned that the City's production this summer will exceed the estimated maximum level of protection the blocking wells can provide. The VWF Group reiterates its request for continued discussions with the USEPA and City regarding the City's options for alternate water supply sources.
- 8) As a result of the wet well pump failures, and reduced capacity at wells V27 and V28, the intended flow rate increase at blocking wells V26, V27, and V28 (i.e., 100 gpm increase at each well) was not implemented. Since the capacity of wells V27 and V28 will not be restored until September 1998, and the City's production rate begins to recede closer to the 12.4 mgd at that time, we do not anticipate implementation of the rate increase until next summer's heavy production period.

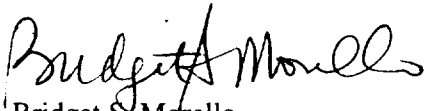
Work Anticipated in Following Month

CETC and ARCADIS Geraghty & Miller will continue monitoring the system in accordance with the GWAMP, NPDES permit, and air emissions SRD guidelines. In addition, ARCADIS Geraghty & Miller will revise and submit the soil cleanup verification sampling plan, and follow-up with MDEQ regarding sentinel well sampling issues.

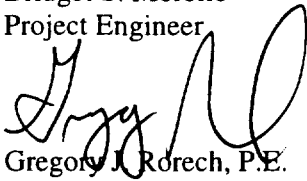
If you have questions or need additional information please do not hesitate to contact us.

Sincerely,

ARCADIS Geraghty & Miller, Inc.



Bridget S. Morello
Project Engineer



Gregory J. Rorech, P.E.
Associate

Attachments

Copies:

VWF Technical Committee
Beth O'Brien, MDEQ
Dan Plomb, CH2M Hill
David Rich, City of Battle Creek
Bruce Rasher, Consumers Power

Well Number	Elevation of T.O.C. (ft msl)	1st Qtr. '98		2nd Qtr. '98	
		D.T.W. (ft)	W.T. Elevation (ft msl)	D.T.W. (ft)	W.T. Elevation (ft msl)
		4/21/98		7/8/98	
Well Field Area					
GMBW-1	837.93	18.61	819.32	21.53	816.40
GMBW-2	837.79	18.43	819.36	21.31	816.48
GMBW-3 ^a	839.60	19.85	819.75	22.61	816.99
GMBW-4	840.14	20.10	820.04	22.75	817.39
GMBW-5	841.73	21.30	820.43	23.85	817.88
GMBW-6	841.96	21.38	820.58	23.94	818.02
GMBW-7	841.53	21.05	820.48	23.58	817.95
GMBW-8	840.41	19.56	820.85	22.02	818.39
GMP-1D	840.36	19.75	820.61	22.37	817.99
GMP-1I	840.30	19.65	820.65	22.22	818.08
GMP-2D	843.10	22.35	820.75	24.90	818.20
GMP-2I	842.75	22.05	820.70	24.58	818.17
GMP-3D	842.74	22.31	820.43	24.93	817.81
GMP-3I	842.62	22.01	820.61	24.60	818.02
GMP-4D	837.28	17.68	819.60	20.61	816.67
GMP-4I	837.53	17.70	819.83	20.51	817.02
GMP-5D	839.06	19.40	819.66	22.24	816.82
GMP-5I	839.47	19.65	819.82	22.46	817.01
GMP-6D	839.50	20.00	819.50	23.91	815.59
GMP-6I	839.54	20.02	819.52	23.91	815.63
GMP-7D	836.57	18.25	818.32	21.81	814.76
GMP-7I	836.62	18.40	818.22	21.74	814.88
GMP-8D	838.00	19.94	818.06	23.56	814.44
GMP-8I	838.02	19.74	818.28	23.04	814.98
GM-1	837.39	17.20	820.19	19.91	817.48
GM-2	836.27	17.40	818.87	20.55	815.72
GM-3	837.36	19.00	818.36	22.56	814.80
GM-4	838.80	20.38	818.42	23.71	815.09
GM-5	836.41	18.03	818.38	21.34	815.07
GM-6	835.65	17.17	818.48	20.67	814.98
CH-105D	843.47	23.00	820.47	NM	NA
W-1I	837.29	18.78	818.51	NM	NA
W-4D	843.19	22.01	821.18	24.36	818.83
W-4I	843.46	22.01	821.45	23.34	820.12
W-4S	843.74	NA	NA	NA	NA
E-16	834.97	14.35	820.62	17.15	817.82
E-17 ^g	834.88	15.87	819.01	20.05	814.83
CH-136 ^g	837.46	19.06	818.40	22.99	814.47

Footnotes on Page 2

Well Number	Elevation of T.O.C. (ft msl)	1st Qtr. '98		2nd Qtr. '98	
		D.T.W.	W.T. Elevation	D.T.W.	W.T. Elevation
		(ft)	(ft msl)	(ft)	(ft msl)
		4/21/98		7/8/98	
Annex Wells					
B-1	843.67	NM	NA	16.57	827.10
B-8S	844.23	16.53	827.70	NM	NA
B-8I	844.17	17.10	827.07	NM	NA
B-9	844.78	17.91	826.87	19.38	825.40
B-23	843.97	16.72	827.25	18.21	825.76
B-25	843.29	15.36	827.93	16.78	826.51
CH-107D	844.95	18.30	826.65	19.92	825.03
CH-107I	844.74	17.70	827.04	19.19	825.55
CH-150D	844.65	19.20	825.45	20.93	823.72
CH-150I	845.34	18.50	826.84	20.21	825.13
GMA-1D	844.32	19.32	825.00	21.08	823.24
GMA-2D	843.81	22.20	821.61	23.32	820.49
GMP-9S ^c	845.89	18.86	827.03	20.34	825.55
W-9	851.00	23.97	827.03	24.71	826.29
VE-4	845.45	17.04	828.41	19.24	826.21
VE-5	845.12	18.90	826.22	18.39	826.73
VE-9	844.63	17.20	827.43	18.62	826.01
VE-10	844.40	17.15	827.25	18.58	825.82
VE-11	844.38	17.35	827.03	18.84	825.54
VE-12	844.35	17.43	826.92	18.92	825.43
VE-16	847.67	19.41	828.26	21.75	825.92
VE-17	844.62	17.56	827.06	18.94	825.68
VE-18	844.84	17.90	826.94	19.35	825.49
Paint Shop Wells					
CH-102	851.87	NA	NA	NA	NA
CH-109	NM	NA	NA	NA	NA
CH-141	843.08	NA	NA	25.20	817.88
CH-145	842.89	NM ^b	NM ^b	25.25	817.64
W-13	843.84	NA	NA	20.67	823.17
W-14	842.92	NA	NA	20.05	822.87
CH-146	842.92	NM ^e	NM ^e	NM ^e	NM ^e

W.T. Elevation = water table elevation in feet above mean sea level (ft msl).

T.O.C. = top of casing elevation in ft msl. Note T.O.C. of W-9 is estimated.

NA Not applicable.

NM Not measured.

NI Monitoring well not installed.

^a Water level data for this well should be scrutinized per 1997 Annual Report; fixed in Jan. 98.

^b Not measured, well has been covered with asphalt and cannot be located, found in July '98.

^c Piezometer GMP-9S was installed at the Annex in November 1997.

^d Measured per Geraghty & Miller letter to USEPA dated June 21, 1997.

^e Water-level data could not be obtained due to well inaccessibility.

^f Well removed from program per 1997 Annual Report.

^g Well added to program per 1997 Annual Report/Addendum.

Summary of Remedial Action Well Flow Rates and City Production Rates, Verona Well Field Superfund Site, Battle Creek, Michigan

Well Name	Design Flow gpm	Flow 7/6/98 gpm	Flow 7/13/98 gpm	Flow 7/20/98 gpm	Flow 7/27/98 gpm	Average Flow gpm	Total Flow 6/29/98 gal	Total Flow 7/27/98 gal	Total Pumped July (gal)	Avg. Monthly Flow (gpm)**	Percent of Total Flow (%)	Percent of Design Flow (%)
V22	120	120	120	119	122	120	56768100	61039900	4271800	106	4.4	88.3
V24	120	110	120	120	120	118	44495200	48917900	4422700	110	4.5	91.4
V25	150	143	150	148	148	147	75726700	81147000	5420300	134	5.5	89.6
V26	165	150	165	165	165	161	81606600	87689700	6083100	151	6.2	91.4
V27	190	174	189	189	189	185	9336100	16325200	6989100	173	7.1	91.2
V28	190	173	190	191	189	186	93931800	100844500	6912700	171	7.0	90.2
GMBW-1	225	223	220	221	220	221	96844000	104833100	7989100	198	8.1	88.1
GMBW-2	220	215	222	219	218	219	94869300	102588400	7719100	191	7.9	87.0
GMBW-3	170	170	168	177	177	173	73799100	80110600	6311500	157	6.4	92.1
GMBW-4	160	159	160	158	157	159	68909200	74588500	5679300	141	5.8	88.0
GMBW-5	230	229	230	231	229	230	68409300	76663200	8253900	205	8.4	89.0
GMBW-6	230	233	229	231	230	231	98074200	106417800	8343600	207	8.5	90.0
GMBW-7	220	220	221	221	220	221	94150500	102158000	8007500	199	8.2	90.3
GMBW-8	220	221	221	220	220	221	20180300	28166300	7986000	198	8.1	90.0
GMA-1D	45	56	55	55	55	55	22378800	24309500	1930700	48	2.0	106.4
GMA-2D	45	55	52	52	52	53	23988800	25830300	1841500	46	1.9	101.5
TOTAL	2700	2651	2712	2717	2711	2698	1023468000	1121629900	98161900	2435	2.2%	
Original BW Avg. Rate (gpm):						917	Original BW Monthly Avg. Rate (gpm):			846	34.7	90.5
New BW Avg. Rate (gpm):						1673	New BW Monthly Avg. Rate (gpm):			1495	61.4	89.3
Annex Wells Avg. Rate (gpm):						108	Annex Wells Monthly Avg. Rate (gpm):			94	3.8	104.0
Avg. City Production Rate (mgd):						16.5						

Notes:

The two types of average flow rates listed above were calculated as follows:

- 1) The average of individual weekly well flow rates = Avg. Flow (gpm); and
- 2) The monthly average flow rate calculated by dividing the total flow pumped by the total number of minutes between flow readings = Avg. Monthly Flow (gpm).

City production rates calculated from data provided by City.

BW Blocking Well

NA not available

gal gallons

gpm gallons per minute

** Flow averaged over number of minutes between readings, does not account for system downtime.



July '98

FAX:

From :

Number of Pages 5
(including this cover sheet)

David L. Rich
City of Battle Creek
Verona Pumping Station
TX: 616-966-3494

FAX: 616-966-3614

To: Bridget MorelloFAX: 813-961-2599Company: Geraghty + Miller**MESSAGE:**Requested informationA Copy of last Months Operation SummaryA Copy of last months Well OperationA Copy of the Filter Backwash Dates and
Estimated figure for discharge to lagoonsA Copy of the current months Well ProgramIf you have any questions on this information,
Please contact meDavid L. Rich

CITY OF BATTLE CREEK

PUBLIC WORKS DEPARTMENT

WATER PRODUCTION DIVISION

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Record of Pumpage

Through Last Day of July, 1998

MONTH	MONTHLY DEMAND			MAXIMUM DAILY DEMAND		MINIMUM DAILY DEMAND	
	Verona	Lakeview	Total	Verona	Lakeview	Verona	Lakeview
JANUARY	336.94	0.00	336.94	12.60	0.00	8.48	0.00
FEBRUARY	322.31	0.00	322.31	13.12	0.00	8.99	0.00
MARCH	355.89	0.00	355.89	12.79	0.00	9.60	0.00
APRIL	353.04	0.00	353.04	15.01	0.00	8.56	0.00
MAY	479.69	0.00	479.69	19.86	0.00	11.41	0.00
JUNE	509.50	0.00	509.50	20.89	0.00	11.62	0.00
JULY	511.50	0.00	511.50	19.09	0.00	11.75	0.00
AUGUST			0.00				
SEPTEMBER			0.00				
OCTOBER			0.00				
NOVEMBER			0.00				
DECEMBER			0.00				
TOTALS	2868.87	0.00	2868.87	21.84 MG-Record Day 7/31/97			
YEARLY	1998	2868.87		MAXIMUM	1998	Verona 22.90	Lakeview 0.00
TOTALS	1997	2687.52		DAILY	1997	24.40	0.00
TO DATE	1996	2637.93		RATE	1996	24.80	0.00
				On Record:	Verona June 1959	26.70	
					Lakeview July 7, 1988	6.34	
AVERAGE	1998	409.84		MAXIMUM	1998	Verona 511.50	Lakeview 0.00
MONTHLY	1997	383.93		MONTHLY	1997	539.43	0.00
DEMAND	1996	376.85		DEMAND	1996	498.93	0.00
TO DATE				On Record:	July-97	539.43	June-88 136.13

All Values E All Values Expressed in Million Gallons

42 Hrs	Total Hrs.
0	12
0	54
0	0
0	0
0	0
0	6
0	0
0	0
0	0
0	0
0	6
0	27
0	90
0	82
0	86
0	72
0	30
0	34
0	12
0	15
0	0
0	12
0	0
0	21
0	0
0	15
0	90
0	46
0	60
0	40
=====	
0	810
0.00	48.96

CITY OF BATTLE CREEK

MONTHLY WELL PUMPAGE WSSN 0450

7/98

Pg.6

Date	13 Hrs O/S	14 Hrs	15 Hrs	17 Hrs	30 Hrs O/S	36 Hrs	37 Hrs	38 Hrs	39 Hrs	40 Hrs	41 Hrs	42 Hrs	Total Hrs.
1		4	4	4		0	0	0	0	0	0	0	12
2		18	18	18		0	0	0	0	0	0	0	54
3		0	0	0		0	0	0	0	0	0	0	0
4		0	0	0		0	0	0	0	0	0	0	0
5		0	0	0		0	0	0	0	0	0	0	0
6		2	2	2		0	0	0	0	0	0	0	6
7		0	0	0		0	0	0	0	0	0	0	0
8		0	0	0		0	0	0	0	0	0	0	0
9		0	0	0		0	0	0	0	0	0	0	0
10		0	0	0		0	0	0	0	0	0	0	0
11		0	0	0		0	0	0	0	0	0	0	0
12		2	2	2		0	0	0	0	0	0	0	6
13		7	7	7		0	0	0	0	3	3	0	27
14		24	24	24		0	0	0	0	9	9	0	90
15		24	24	24		0	0	0	0	5	5	0	82
16		24	24	24		0	0	0	0	7	7	0	86
17		24	24	24		0	0	0	0	0	0	0	72
18		10	10	10		0	0	0	0	0	0	0	30
19		10	10	10		0	0	0	0	2	2	0	34
20		4	4	4		0	0	0	0	0	0	0	12
21		5	5	5		0	0	0	0	0	0	0	15
22		0	0	0		0	0	0	0	0	0	0	0
23		4	4	4		0	0	0	0	0	0	0	12
24		0	0	0		0	0	0	0	0	0	0	0
25		7	7	7		0	0	0	0	0	0	0	21
26		0	0	0		0	0	0	0	0	0	0	0
27		5	5	5		0	0	0	0	0	0	0	15
28		24	24	24		0	0	0	2	8	8	0	90
29		12	12	12		0	0	0	0	5	5	0	46
30		16	16	16		0	0	0	0	6	6	0	60
31		9	9	9		0	0	0	13	0	0	0	40
Total Hrs	0	235	235	235	0	0	0	0	15	45	45	0	810
M. Gals.	0.00	14.10	14.10	14.10	0.00	0.00	0.00	0.00	1.26	2.70	2.70	0.00	48.96

CITY OF BATTLE CREEK

MONTHLY WELL PUMPAGE WSSN 0450 7/98

Pg.7

Date	43 Hrs.	44 Hrs.	45 Hrs.	46 Hrs.	47 Hrs.	48 Hrs.	49 Hrs.	50 Hrs.	51 Hrs.	52 Hrs.	53 Hrs.	54 Hrs.	Total Hrs.
1	0	24	24	24	24	24	24	24	24	24	24	24	264
2	0	24	24	24	24	24	24	24	24	24	24	24	264
3	0	24	24	24	24	24	24	24	24	24	24	24	264
4	0	24	24	24	24	24	22	22	18	17	7	7	213
5	0	24	24	24	24	18	15	13	13	10	20	2	187
6	0	24	24	24	24	24	24	24	24	24	24	24	264
7	0	24	24	24	24	24	24	24	24	24	24	24	264
8	0	16	24	24	24	24	24	24	24	24	24	24	256
9	0	20	24	24	24	24	24	24	24	24	24	24	260
10	0	24	24	24	24	24	24	24	24	24	24	24	264
11	0	13	24	24	24	24	19	19	24	24	24	24	243
12	0	8	24	24	24	24	9	9	24	24	24	24	218
13	0	18	24	24	24	24	24	24	24	24	24	24	258
14	0	24	24	24	24	24	24	24	24	24	24	24	264
15	0	24	24	24	24	24	24	24	24	24	24	24	264
16	0	24	24	24	24	24	24	24	24	24	24	24	264
17	0	24	24	24	24	24	24	24	24	24	24	24	264
18	0	24	24	24	24	24	24	24	24	24	24	24	264
19	0	24	24	24	24	24	24	24	24	24	24	24	264
20	0	24	24	24	24	24	24	24	24	24	24	24	264
21	0	24	24	24	24	24	24	24	24	24	24	24	264
22	0	17	24	24	24	24	18	18	24	24	24	24	245
23	0	18	24	24	24	24	18	18	24	24	24	24	246
24	0	12	24	24	24	24	8	8	24	24	24	24	220
25	0	16	24	24	24	24	24	24	24	24	24	24	256
26	0	24	24	24	24	24	24	24	24	24	24	24	264
27	0	24	24	24	24	24	24	24	24	24	24	24	264
28	0	24	7	24	24	24	24	24	24	24	24	7	230
29	0	24	24	24	24	24	24	24	24	24	24	24	264
30	0	24	24	24	24	24	24	24	24	24	24	24	264
31	0	24	24	24	24	24	24	24	24	24	24	24	264
Total	0	666	727	744	738	685	683	727	723	723	705	727	7848
M. Gals	0.00	55.94	61.07	62.50	53.14	49.32	49.18	52.34	52.06	52.06	50.76	61.07	599.42

CITY OF BATTLE CREEK
VERONA WATER TREATMNT PLANT
FILTER RUN TIMES JULY 1998

Date	Filter No.	Backwash Time	Run Time Hours
07/01/98	F-5	09:19	184
07/02/98	F-8	09:44	180
07/03/98	F-2	09:35	214
07/04/98	F-6	09:02	216
07/05/98	F-1	10:29	134
07/06/98	F-4	11:22	156
07/07/98	F-7	10:31	201
07/08/98	F-3	12:00	205
07/09/98	F-5	08:07	191
07/10/98	F-8	08:06	191
07/11/98	F-1	08:06	142
07/12/98	F-2	10:28	215
07/13/98	F-6	09:31	216
07/14/98	F-4	08:11	188
07/15/98	F-7	08:15	190
07/16/98	F-3	08:18	188
07/17/98	F-5	08:25	192
07/18/98	F-1	10:11	170
07/19/98	F-8	09:44	218
07/20/98	F-4	08:34	144
07/21/98	F-6	09:00	215
07/22/98	F-2	08:15	238
07/23/98	F-7	09:26	193
07/24/98	F-1	08:56	143
07/25/98	F-5	09:00	192
07/26/98	F-3	09:22	217
07/27/98	F-8	09:15	192
07/28/98	F-4	08:17	192
07/29/98	F-6	07:35	190
07/30/98	F-1	08:16	143
07/31/98	F-7	08:27	191

There were 31 filter backwashes for the month of July. At an estimated 175,000 gals. each for a total of 5,425,000 gals. discharged to the lagoons. None of this water was discharged to the river.

Influent Total 489.55 million gals.

Well Program 7-6-98

Step 1: 51-54

Step 2: 45, 50-54

Step 3: 45-47, 50-54

Step 4: 45-54

Step 5: 39, 44-54

Step 6: 14-17, 39, 44-54

Step 7: 14-17, 39-41, 44-54

Step 8: 14-17, 39-54

Step 9: 14-17, 37-54

Step 10: 14-17, 36-54

No Change for August!



ATTACHMENTS



ATTACHMENT 1
for Project Progress Report dated August 10, 1998

Groundwater Sampling Procedure
Verona Well Field Superfund Site
Battle Creek, Michigan

In response to USEPA's request for clarification of the groundwater sampling procedures (letter dated July 7, 1998), ARCADIS Geraghty & Miller reviewed previous reports/correspondences including the Quality Assurance Project Plan (QAPP), Field Sampling Plan (FSP) appended to the QAPP, Groundwater and Air Monitoring Plan (GWAMP), Monitoring Report for the First Quarter of Operation of the VWF RA and addendum, and 1997 Annual Monitoring Report and addendum. In addition, ARCADIS Geraghty & Miller reviewed USEPA protocol/guidance documents regarding groundwater sampling procedures. Based on our review, we conclude the following:

I) All groundwater sampling performed prior to 1996 was conducted in accordance with procedures listed in the QAPP and FSP.

II) All groundwater sampling performed from the 1996 pre-startup (baseline) event to date was conducted in accordance with improved low stress (low flow) sampling techniques per USEPA protocol. However, due to the slow rate of groundwater recovery/recharge in four monitoring wells located in the Paint Shop area (W-13, W-14, CH-141, and CH-145), groundwater samples from those wells were collected utilizing polyvinyl chloride (PVC) bailers. The sampling procedure utilized from the 1996 pre-startup event to date is as follows:

1. Check the condition of the well and look for any damage or evidence of tampering and record.
2. Remove the well cap.
3. Measure the depth to water with an electronic water-level device from the top of casing and record the measurement in the logbook. Do not measure the depth to the bottom of the well at this time (in order to avoid disturbing any accumulated sediment). Obtain depth to bottom information from well installation log. Calculate standing water volume as: depth of water column times cross-sectional area of the well. Record information on the water sampling log.
4. Lay out polyethylene sheeting and place all equipment on the sheeting. To avoid cross contamination, do not let any downhole equipment touch the ground surface.
5. Measure the depth to water in the well again. If the measurement has changed more than 1/100th of a foot, check and record the measurement again.
6. Attach and secure the dedicated polyethylene tubing to the low-flow pump. As the pump is slowly lowered into the well, secure the safety drop cable, tubing, and electrical lines.
7. The pump should be set at approximately the middle of the screen, or the predefined depth in open borehole wells. Avoid placing the pump intake less than 2 feet above the bottom of the well as this may cause mobilization of any sediment present in the bottom of the well. When necessary, cover the discharge line between the flow-through cell and the well cap with foam insulation to minimize temperature change. Start purging the well with pump set at low flow

rate. Avoid surging. Observe air bubbles displaced from discharge tube to assess progress of steady pumping until water arrives at the surface. Record the start time on the water sampling log.

8. The water level in the well should be monitored during purging, and ideally, the purge rate should equal the well recharge rate so that there is little or no drawdown in the well. (The water level should stabilize for the specific purge rate.) There should be at least 1 foot of water over the pump intake so there is no risk of the pump suction being broken, or entrainment of air in the sample. Record adjustments in the purge rate and changes in depth to water in the logbook. Purge rates should, if needed, be decreased to the minimum capabilities of the pump to avoid affecting well drawdown. The well should not be purged dry. If the recharge rate of the well is so low that the well is purged dry, then wait until the well has recharged to a sufficient level and collect the appropriate volume of water for the sample with the pump. In the event the recharge rate and/or standing water height is insufficient to allow use of the low flow sampling pump, use a disposable bailer to purge the well dry then collect the sample upon recharge.
9. During well purging, use the flow-through cell to monitor the pH, temperature, specific conductivity, dissolved oxygen, and oxidation-reduction potential field parameters every 3 to 5 minutes. If the field parameters fail to stabilize within two hours and three well volumes have not been purged, move the meter to the next well to be sampled and continue to purge the first well. Field parameters will be monitored every one to two hours until they stabilize or three well volumes are removed, whichever occurs first.
10. A sample will be collected when the field parameters stabilize to within 10 percent of the mean of three consecutive meter readings taken at least three minutes apart.
11. Once the field parameters have stabilized, collect the samples directly from the end of the discharge tube. Volatile organic compounds (VOCs) and analytes that degrade by aeration should be collected first. All sample bottles should be filled by allowing the water from the discharge tube to flow gently down the inside of the bottle with minimal turbulence. Cap each bottle as it is filled and place in iced cooler. Record sample completion time on the sampling log.
12. The pump assembly should be carefully removed from the well. The tubing should be dedicated to each well and should be placed in a large plastic garbage bag, sealed, and labeled with the appropriate well identification number.
13. Decontaminate the pump head by placing the unit in a clean 5-gallon bucket or other container so that the pump head can be entirely submerged within a laboratory-grade solution. Run pump for 5 to 10 minutes to thoroughly clean the unit. Rinse pump by placing the pump head in a bucket of distilled water and running the pump. Add additional distilled water to the rinsing bucket as necessary to complete the pump decontamination.
14. Close and lock the well.

III) Comparison of the procedure outlined above with those specified in the QAPP/FSP (Sections 7.3 and 8.2, and Tables 11.1 and 11.2) indicates the following:

1. The above procedure varies from the QAPP/FSP in the following manner:
 - a) The old procedure specified purging 3 to 5 well volumes of water from each well prior to sample collection. The new procedure is based upon the USEPA's low flow purging and

sampling protocol, which allows for the collection of groundwater samples after stabilization of field parameters has occurred. In the event that field parameters fail to stabilize within two hours and three well volumes of water have not been purged, purging will continue for that well. Field parameters will be monitored once every one to two hours until they stabilize or three well volumes of water have been removed from that well. In addition, the new procedure generates less purge water to dispose of and requires less field time for the collection of groundwater samples.

- b) The old sampling procedure relied upon the use of individual units for the measurement of field parameters (pH, temperature, specific conductivity, dissolved oxygen, oxidation-reduction potential, and turbidity) after purging each well volume. The new procedure utilizes updated, higher technological equipment, specifically a multi-parameter probe and flow-through cell manufactured by YSI, to simultaneously measure the field parameters referenced above. Field personnel record the field parameter readings displayed on the YSI once every 5 minutes. Purging is considered complete and sampling may begin when all the indicator field parameters (listed below) have stabilized. Stabilization is considered to be achieved when three consecutive readings, taken at five minute intervals, are within the following limits: pH - ± 0.1 unit, temperature - $\pm 3\%$, specific conductivity - $\pm 3\%$, dissolved oxygen - $\pm 10\%$, and oxidation reduction potential - ± 10 millivolts. The new procedure does not include field measurement of turbidity.
- c) The old procedure specified calibration checks for field equipment once every 4 hours. Per manufacturer's instructions for calibration of the YSI multi-parameter probe, the new procedure includes calibration checks once per day, prior to use.
- d) The old procedure specified the use of a photoionization detector (PID) at each well head prior to purging/sampling to identify any potential chemical hazards to field personnel. Based upon observations/instrument readings recorded during all previous groundwater gauging/sampling activities, continued vapor monitoring at each well head is not required. Conditions of concern for field personnel have not been observed in any site monitoring wells. Thus, the new procedure does not include the use of a PID prior to purging/sampling each well.
- e) The preventative maintenance and calibration procedures specified for the old field equipment no longer apply. The appropriate maintenance and calibration procedures (per the manufacturer) for the new multi-parameter probe and flow-through cell are attached in Appendix A.

These variances from the QAPP/FSP in our opinion are insignificant, and do not affect the quality or defensability of the data generated. Based upon this information, ARCADIS Geraghty & Miller believes the current groundwater sampling procedure is appropriate and consistent with USEPA protocol.

We trust this information addresses the agency's concerns. Please contact Bridget Morello at (813)264-3423 if there are any remaining or additional concerns.

APPENDIX A



600XL

Multi-Parameter Water Quality Monitor

Instruction Manual

**YSI Incorporated
1725 Brannum Lane
Yellow Springs, OH 45387
(800) 765-4974 (513) 767-7241
Fax (513) 767-9353**



®

3. BASIC OPERATION

In the previous Section, you learned how to **install** probes and set up the PC6000, EcoWatch for Windows, and 600XL sonde software. In this Section, you will learn how to **calibrate** and **run** the Model 600XL and how to **view** your **data** on a computer display. If you choose to use your 600XL with a 610-series display/logger, refer to the **operations** manual for the 610 to obtain similar instructions to those provided below.

3.1 CALIBRATION TIPS

WARNING: Reagents used to **calibrate** and **check** this instrument may be hazardous to your health. Refer to Appendix A for **health** and **safety** information.

Before you begin the calibration procedures outlined below, you may find it helpful to follow some or all of these calibration tips.

1. Remove the sonde stainless steel weight on the bottom of the sonde guard by turning it counterclockwise. This allows the **calibration** solutions access to the probes with minimal displacement of fluid within the **calibration cup**. Additionally, carry-over from one solution to the next is reduced.
2. Fill a large bucket with ambient temperature water for rinsing the sonde between calibration solutions.
3. Have several clean, absorbent paper towels or cotton cloths available to dry the sonde between rinses and calibration solutions. It is **important** to remove as much residual liquid as possible from the sonde after each rinse. Shake the sonde to remove excess rinse water from the inside of the guard. Then dry the outside of the sonde and guard. Drying the sonde and probes in this way reduces carry-over contamination of **calibrator** solutions and increases the accuracy of the calibration, particularly lower conductivity calibration standards.
4. It is not necessary to remove the **probe guard** to rinse and dry the probes between calibration solutions. The inaccuracy resulting from simply rinsing the probe compartment and drying the outside of the sonde is minimal.

3.2 CALIBRATION PROCEDURES

WARNING: Calibration reagents may be **hazardous** to your health. Refer to Appendix A for **health** and **safety** information.

A calibration cup is supplied with the Model 600XL. Because the calibration cup fits over the outside of the sonde sensor guard, it is **not recommended** or necessary to remove the guard to calibrate the sensors. Follow the **procedures** below to calibrate the sensors. Only *basic* DO

percent saturation, Conductivity, pH, and Depth calibration procedures are discussed in this section. Temperature does not require calibration and is, therefore, not included in the Calibrate menu. ORP calibration is required only infrequently and is discussed in Section 4.2. For more detailed calibration procedures, which can be used to enhance the accuracy of some measurements, see Section 4.2.

From the sonde Main menu select **2. Calibrate**. The Calibrate menu will be displayed.

Calibrate	
1. Conductivity	4. ISE1-pH
2. Dissolved Oxy	5. ISE2-Orp
3. Pressure-Abs	
Select option (0 for previous menu):	

Pressure only appears if a sensor has been installed at the factory. The selection will read Pressure-Abs for depth sensors and Pressure-Gau for level sensors.

Selection of any of the parameters from the Calibrate menu listing will require the user to input a numerical value and then press Enter. For example, for calibration of specific conductance, the following display will be shown during the calibration sequence.

Enter SpCond in mS/cm (10):

The number in parentheses is the default value of this parameter and will be used in the calibration if *only* Enter is pressed without typing in another value. Similar prompts will be displayed calibration of all parameters, but for some sensors, such as pH, no default values are provided. In these cases, the user must input a numerical value and then press Enter.

After the calibration value is input and Enter is pressed, a real-time display similar to the following will then appear on the screen. Note that all parameters which have been enabled will appear - not just the one being calibrated at the moment. The user should carefully observe the stabilization of the readings of the parameter which is being calibrated and, when the readings are stable for approximately 30 seconds, press Enter to implement the calibration.

Temp	SpCond	Cond	Sal
C	mS/cm	mS/cm	ppt
To calibrate, press <Enter> when the readings are stable.			
23.00	10.0	10.0	15.7
Select option (0 for previous menu)			

NOTE: If an ERROR message appears, **begin** the calibration procedure again. Be certain that the value you enter for the calibration standard is correct. Also see Section 8, Troubleshooting for more information on error messages.

CAUTION: Be certain to **immerse the entire sonde** in solution standards for calibration of all parameters. Most calibrations require **readings** not only from the sensor being calibrated but also from the temperature sensor.

Specific start-up calibration procedures for **all sensors** which commonly require calibration are provided in the following paragraphs of **this section**. Remember that these are basic protocols designed to get the user up and running with regard to the 600XL. The more-detailed discussion of sensor calibration found in Section 4.2 should be examined prior to use of the instrument in the field.

NOTE: If the particular sensor listed is **not installed** in your sonde, proceed to the next sensor until the calibration protocol is complete.

CONDUCTIVITY

NOTE: This procedure calibrates not only **conductivity**, but also specific conductance, salinity, and total dissolved solids.

Place approximately 300 mL of conductivity standard in a clean and dry calibration cup. The conductivity standard you choose should be within the same conductivity range as the water you are preparing to sample. However, we do not recommend using standard less than 1 mS/cm. For example:

- For fresh water choose a 1 mS/cm conductivity standard.
- For brackish water choose a 10 mS/cm conductivity standard.
- For sea water choose a 50 mS/cm conductivity standard.

Caution: Before proceeding insure that **the sensor** is as dry as possible. Ideally, rinse the conductivity sensor with a small amount of **standard** that can be discarded. Be certain that you avoid cross contamination of standard solutions with other solutions. Make certain that there are no salt deposits around the oxygen and pH/ORP probes, particularly if you are employing standards of low conductivity.

Without removing the sonde guard, *carefully* immerse the probe end of the sonde into the solution. Gently rotate and/or move the sonde up and down to remove any bubbles from the conductivity cell. The probe must be completely **immersed past** its vent hole.

Allow at least one minute for temperature equilibration before proceeding.

From the **Calibrate** menu, select **1. Conductivity** to access the Conductivity calibration procedure and then **1. SpCond.** to access the specific conductance calibration procedure. Enter the calibration value of the standard you are using (mS/cm at 25 C) and press **Enter**. The current values of all enabled sensors will appear on the screen and will change with time as they stabilize.

Observe the readings under Specific Conductance or Conductivity and when they show no significant change for approximately 30 seconds, press **Enter**. The screen will indicate that the calibration has been accepted and prompt you to press **Enter** again to return to the Calibrate menu.

Rinse the sonde in tap or purified water and dry the sonde.

pH 2-POINT

Place approximately 200 mL of pH 7 buffer in a clean calibration cup. *Carefully* immerse the probe end of the sonde into the solution.

Allow at least 1 minute for temperature equilibration before proceeding.

From the **Calibrate** menu, select **4. ISE1 pH** to access the pH calibration choices and then **2. 2-Point**. Press **Enter** and input the value of the buffer (7 in this case) at the prompt. Press **Enter** and the current values of all enabled sensors will appear on the screen and will change with time as they stabilize in the solution. Observe the readings under pH and when they show no significant change for approximately 30 seconds, press **Enter**. The display will indicate that the calibration is accepted.

After the pH 7 calibration is complete, press **Enter** again, as instructed on the screen, to continue.

Rinse the sonde in water and dry the sonde before proceeding to next step.

Place approximately 200 mL of a second pH buffer solution in a clean calibration cup. The second buffer might be pH 4 if the sample is expected to be acidic or pH 10 if the sample is expected to be basic. *Carefully* immerse the probe end of the sonde into the solution.

Allow at least 1 minute for temperature equilibration before proceeding.

Press **Enter** and input the value of the second buffer at the prompt. Press **Enter** and the current values of all enabled sensors will appear on the screen and will change with time as they stabilize in the solution. Observe the readings under pH and when they show no significant change for approximately 30 seconds, press **Enter**. After the second value calibration is complete, press **Enter** again, as instructed on the screen, to return to the Calibrate menu.

Rinse the sonde in water and dry the sonde.

Thoroughly rinse and dry the calibration cups for future use.

DISSOLVED OXYGEN

Place approximately 1/8 inch of water or a wet sponge in the bottom of the calibration cup. Place the probe end of the sonde into the calibration cup. Make certain that the DO and the temperature probes are not immersed in the water. Wait approximately 10 minutes for the air in the calibration cup to become water saturated and for the temperatures of the thermistor and the oxygen probe to equilibrate. Make certain that the calibration cup is vented to the atmosphere.

From the **Calibrate** menu, select **2. Dissolved Oxy** to access the DO % calibration procedure.

Enter the current barometric pressure in mm of Hg . *Remember that barometer readings which appear in meteorological reports are generally corrected to sea level and are not useful for you calibration procedure unless they are uncorrected.*

NOTE: Inches of Hg x 25.4 mm/inch = mm Hg

Press Enter and the current values of all **enabled** sensors will appear on the screen and will change with time as they stabilize. Observe the **readings** under DO % and when they show no significant change for approximately 30 seconds, press **Enter**. The screen will indicate that the calibration has been accepted and prompt you to press **Enter** again to return to the Calibrate menu.

Rinse the sonde in water and dry the sonde.

NOTE: Calibration of dissolved oxygen in the DO % procedure also results in calibration of the DO mg/L mode and vice versa.

NOTE: The above procedure is designed to calibrate your dissolved oxygen sensor for use in sampling applications where the sensor is being pulsed continuously in the Run mode because both "Auto sleep" and "Wait for DO" functions have been disabled as described in Section 2. If your 600XL is to be used in a monitoring application in which data is being captured to a computer or data collection platform, "Auto sleep" and "Wait for DO" will be activated and the calibration displays will be somewhat different. See Section 4 for details.

DEPTH AND LEVEL

Following the DO calibration, leave the sonde in air. Make certain that the sonde is not submerged in water for this calibration.

From the Calibrate menu, select **Pressure**. Input 0.00 or some known sensor offset in feet. Press **Enter** and monitor the stabilization of the **readings** with time. When no significant change occurs for approximately 30 seconds, press **Enter** to confirm the calibration and zero the sensor.

After depth is zeroed, press Enter again, as instructed on the screen, to return to the Calibrate menu.

The sensors are now calibrated. Press ESC until the sonde Main menu is displayed.

3.3 TAKING READINGS

When you have calibrated the sensors, enabled the sensors as you prefer, and have set up the report to show the parameters you want to see, you are then ready to take readings.

Select 1. **Run** from the sonde Main menu. The following menu will be displayed:

-----Run setup-----	
1-Start sampling	2-Sample interval=4
Select option (0 for previous menu):	

Select 2. Sample interval. The following prompt will be displayed:

Enter sample interval:

Input a number which represents the number of **SECONDS** between samples. For this example, input 4 seconds, the minimum sample interval for most applications.

Next, Select 1. **Start sampling** from the Run setup menu. A screen similar to the following will be displayed:

=====					
Temp	SpCondCond	Sal	DOsat	pH	
C	mS/cm	mS/cm	ppt	%	
23.00	10.0	10.0	15.0	98.6	7

Measurements will begin to appear on the screen at the sampling interval you have defined. This data will not be stored to a file unless you instruct PC 6000 to capture this data. To create a file of

Next, Select 1. Start sampling from the Run setup menu.

Sequential lines of data will begin to appear on the screen at the sampling interval you have defined. This data will not be stored to a file unless you have correctly configured PC6000 or EcoWatch for Windows to capture this data.

4.2 CALIBRATE

All of the Model 600XL sensors (except temperature) require periodic calibration to assure high performance. However, the calibration protocols and user-interface with sonde software for all parameters are significantly different depending on whether the sonde is being set up for spot sampling or longer term monitoring studies. This difference is user-selectable and is required primarily because the optimal performance of the Rapid Pulse dissolved oxygen sensor cannot be attained unless the control of this sensor varies from short term to long term applications. For example, for spot sampling it is best to pulse the sensor continuously during the Run mode to attain the most accurate results and optimize the response time. However, this continuous pulsing is not ideal for longer term logging studies in which the sonde data is captured to a computer or data collection platform at much less frequent intervals (e.g. 15 minutes). Under these latter conditions, continuous pulsing not only shortens the time between required probe maintenance, but also consumes much more power. By proper selection of the "Auto sleep" and "Wait for DO" options (discussed in detail in Section 4.6), the user can configure the sonde software to either run continuously or "go to sleep" between samples to minimize DO probe wear and conserve power. The effect of this choice on the user interface relative to calibration is significant, as described below:

- If "Auto sleep" and "Wait for DO" are deactivated, the sonde runs continuously no matter what sample interval has been selected. Under these conditions, the user retains manual control of the calibration routines, viewing the stabilization of the readings in real time and confirming the calibration with keyboard entries.
- If "Auto sleep" and "Wait for DO" are activated, the sonde will 'warm up' the sensors for the period of time selected for the DO sensor (DO warm up time; see Section 4.6 for details). Under these conditions, the user will lose manual control of the calibration routine; each parameter will automatically calibrate after the time selected for warm up of the DO sensor has expired. In this mode of calibration, the user will not observe stabilization of the readings in real time, but instead will observe a countdown of the warm up period followed by a message indicating that the calibration is complete.

For longer term monitoring studies, it may be most convenient for the user to mix the calibration modes, calibrating all sensors except DO under manual control with "Auto sleep" and "Wait for DO" deactivated, reactivating these options, and then calibrating DO automatically at the end of the designated warm up time (usually 60 seconds). The user should then leave "Auto sleep" and "Wait for DO" activated during the study. In addition, once warm up time has been utilized in DO calibration, the length of that time should not be changed during a study. A new calibration should be performed whenever the value of the warm up time is altered.

The following sections detail the calibration routines for all parameters under manual user control ("Auto sleep" and "Wait for DO" deactivated). Remember that the sequence of events is very similar in the automatic calibration mode except the calibration will occur with no user input to the keyboard.

Select 2. **Calibrate** from the sonde Main menu, the Calibrate menu will be displayed. Note that only the enabled parameters will be available for calibration.

Calibrate	
1-Conductivity	4-ISE1-pH
2-Dissolved Oxy	5-ISE2-Orp
3-Pressure-Abs	
Select Option (0 for previous menu):	

1. Conductivity

Select this option to calibrate the conductivity probe and a second menu will offer you the options of calibrating in specific conductance, conductivity, or salinity. Calibrating any one option automatically calibrates the other two. After selecting the option of choice (specific conductance is normally recommended), you will be asked to enter the value of the standard used during calibration. Be certain that the units are correct. After pressing Enter, you will be able to follow the stabilization of the readings and confirm the calibration when the readings are stable by pressing Enter as instructed on the screen. Then, as instructed, press Enter again to return to the Calibrate menu.

2. Dissolved Oxy.

Select this option to calibrate the oxygen probe, the submenu will offer you the option of calibrating in percent saturation or mg/L. After selecting the option of choice (water-saturated air is normally recommended), you will be prompted for the next step. Calibrating either of the choices will automatically calibrate the other.

For the percent saturation mode, be certain that the sensor has been thermally equilibrated in water-saturated air and that the sensor has stabilized (about 10-15 minutes) prior to beginning the calibration routine, particularly after a membrane change. Relieve pressure in the cup if necessary. See Section 3.2 for more details. Then follow the screen prompt and enter the local barometric pressure in mm Hg, (in Hg x 25.4), press Enter, and monitor the stabilization of the DO readings. After no changes occur for approximately 30 seconds, press Enter to confirm the calibration. Then, as instructed, press Enter again to return to the Calibrate menu.

For the mg/l mode, calibration is carried out in a water sample which has a known concentration of dissolved oxygen, usually determined by a Winkler titration. For this calibration procedure, the sensor should be immersed in the water. After thermal equilibration, enter known mg/l value, press Enter, and the calibration procedure will begin with similar viewing of stabilization and confirmation of calibration as for the percent saturation mode above.

NOTE: Usually the stability of your DO sensor will allow calibration in 2-3 minutes of pulsing during the calibration protocol. However, after a membrane change, a somewhat longer period may be required (approximately 5 minutes). If you have resurfaced your DO sensor, we recommend running the probe (either in the Run or Calibrate modes) for 15-30 minutes or until good stability is realized.

3. Pressure -Abs

Select this option to zero the pressure sensor used for depth and level measurements (If it is a level sensor, the menu item will appear as Pressure-Gau.). The pressure sensor is factory calibrated, but it is necessary to zero the sensor. The zeroing procedure should be carried out with the sonde in air. Do not attempt to zero the depth probe when the sonde is immersed. After the pressure option is selected, enter 0.00 at the prompt, press Enter and monitor the stabilization of the readings. After no changes occur for approximately 30 seconds, press Enter to confirm the calibration. As instructed, press Enter again to return to the Calibrate menu.

In some unusual applications, an offset other than 0.00 may be desired and can be entered when prompted for a calibration value

4. ISE1-pH

On selecting this option, you will be given the choice of 1-point, 2-point, or 3-point calibrations.

Select the 1-point option only if you are adjusting a previous calibration. If a 2-point or 3-point calibration has been performed previously, you can adjust the calibration by carrying out a one point calibration. Immerse the sonde in a buffer of known pH value and press Enter. You will be prompted to type in the pH value of the solution. Press Enter again, and the screen will display real-time readings which will allow you to determine when the pH and temperature readings have stabilized. Pressing Enter will confirm the calibration. Then, as instructed, press Enter again to return to the Calibrate menu. This calibration procedure adjusts only the pH offset and leaves the slope unaltered.

Select the 2-point option to calibrate the pH probe using only two calibration standards. In this procedure, the pH sensor is calibrated using a pH 7 buffer and *one additional* buffer. A two point calibration procedure (as opposed to a 3-point procedure) can save time if the pH of the media being monitored is known to be either basic or acidic. For example, if the pH of a pond is known to vary between 5.5 and 7, a two point calibration with pH 7 and pH 4 buffers is appropriate. Three point calibration with an additional pH 10 buffer will not increase the accuracy of this measurement since the pH is not within this higher range.

To begin the calibration, immerse the sonde in one of the buffers, as instructed, and enter the actual pH value. Press Enter, and the screen will display real-time readings which will allow you to determine when the pH sensor has stabilized. Pressing Enter will confirm the calibration. Following the instructions on the screen, place the sonde in the second pH buffer, input the pH value, press Enter, and view the stabilization of the values on the screen in real time. After the readings have stabilized, press Enter to confirm the calibration. Then, as instructed, press Enter again to return to the Calibrate menu.

Select the **3-point** option to calibrate the pH probe using three calibration solutions. In this procedure, the pH sensor is calibrated with a pH 7 buffer and two additional buffers. The 3 point calibration method assures maximum accuracy when the pH of the media to be monitored cannot be anticipated. The procedure for this calibration is the same as for a 2 point calibration, but the software will prompt you to select a third pH buffer to complete the 3 point procedure.

5. ISE2-Orp

Select this option to calibrate the ORP sensor. Immerse the sonde in a solution with a known oxidation reduction potential value (we recommend Zobell solution) and press Enter. You will be prompted to enter the ORP value of the solution. Press Enter, and monitor the stabilization of the ORP and temperature readings. After no changes occur for approximately 30 seconds, press Enter to confirm the calibration. Then, as instructed, press Enter again to return to the Calibrate menu.

4.3 SYSTEM

With this menu, the user can customize the 600XL communication protocol and display style, and enter an instrument identification number.

Select **3. System** from the sonde Main menu. The System setup menu will be displayed:

```
-----System-setup-----
1. Comm setup
2. Page length=25
3. Instrument ID
4. SDI-12 address=0

Select option (0 for previous menu):
```

6. PRINCIPLES OF OPERATION

6.1 CONDUCTIVITY

The 600XL utilizes a cell with four pure nickel electrodes for the measurement of solution conductance. Two of the electrodes are current driven, and two are used to measure the voltage drop. The measured voltage drop is then converted into a conductance value in milli-Siemens (millimhos). To convert this value to a conductivity value in milliSiemens per cm (mS/cm), the conductance is multiplied by the cell constant which has units of reciprocal cm (cm^{-1}). The cell constant for the 600XL conductivity cell is $5.0/\text{cm} \pm 4\%$. For most applications, the cell constant is automatically determined (or confirmed) with each deployment of the system when the calibration procedure is followed; see Section 3.2. Solutions with conductivities of 1.00, 10.0, 50.0, and 100.0 mS/cm, which have been prepared in accordance with recommendation 56-1981 of the Organization International De Metrologie Legale (OIML) are available from Endeco/YSI. The instrument output is in mS/cm for both conductivity and specific conductance. The multiplication of cell constant times conductance is carried out automatically by the software.

CALIBRATION AND EFFECT OF TEMPERATURE

The conductivity of solutions of ionic species is highly dependent on temperature, varying as much as 3% for each change of one degree Celsius (temperature coefficient = 3%/C). In addition, the temperature coefficient itself varies with the nature of the ionic species present.

Because the exact composition of a natural media is usually not known, it is best to report a conductivity at a particular temperature, e.g. 20.2 mS/cm at 14 C. However, in many cases, it is also useful to compensate for the temperature dependence in order to determine at a glance if gross changes are occurring in the ionic content of the medium over time. For this reason, the 600XL software also allows the user to output conductivity data in either raw or temperature compensated form. If Conductivity is selected, values of conductivity which are *NOT* compensated for temperature are output to the report. If Specific Conductance is selected, the 600XL uses the temperature and raw conductivity values associated with each determination to generate a specific conductance value compensated to 25 C. The calculation is carried out as in equation (1) below, using a temperature coefficient of 1.91%/C ($\text{TC} = 0.0191$):

$$\text{Specific Conductance (25 C)} = \frac{\text{Conductivity}}{1 + \text{TC} * (\text{T} - 25)}$$

As noted above, unless the solution being measured consists of pure KCl in water, this temperature compensated value will be somewhat inaccurate, but the equation with a value of $\text{TC} = 0.0191$ will provide a close approximation for seawater and for solutions of many common salts such as NaCl and NH_4Cl .

MEASUREMENT AND CALIBRATION PRECAUTIONS

- (1) When filling the calibration cups prior to performing the calibration procedures, make certain that the level of calibrant buffers is high enough in the calibration/storage cup to cover the entire conductivity cell (approximately 300 mL). Gently agitate the sonde to remove any bubbles in the conductivity cell.
- (2) Rinse the sensors with deionized water between changes of calibration solutions.
- (3) During calibration, allow the sensors time to stabilize with regard to temperature (approximately 60 seconds) before proceeding with the calibration protocol. The readings after calibration are only as good as the calibration itself.
- (4) Perform sensor calibration at a temperature as close to 25°C as possible. This will minimize any temperature compensation error.

6.2 SALINITY

Salinity is determined automatically from the 600XL conductivity readings according to algorithms found in *Standard Methods for the Examination of Water and Wastewater* (ed. 1989). The use of the Practical Salinity Scale results in values which are unitless, since the measurements are carried out in reference to the conductivity of standard seawater at 15 C. However, the unitless salinity values are very close to those determined by the previously used method where the mass of dissolved salts in a given mass of water (parts per thousand) was reported. Hence, the designation "ppt" is reported by the instrument to provide a more conventional output.

6.3 OXIDATION REDUCTION POTENTIAL (ORP)

The 600XL determines the Oxidation Reduction Potential (ORP) of the media by measuring the difference in potential between an electrode which is relatively chemically inert and a reference electrode. To measure ORP with the 600XL, a combination pH/ORP probe must be in place in the sonde bulkhead and ORP must be accessed via the ISE2 channel of the sonde. The ORP sensor consists of a platinum ring found on the tip of the probe. The potential associated with this metal is read versus the Ag/AgCl reference electrode of the combination sensor which utilizes gelled electrolyte. ORP values are presented in millivolts and are not compensated for temperature

CALIBRATION AND EFFECT OF TEMPERATURE

Calibration is usually not required for the ORP sensor of the 600XL. However, older probes which have been deployed extensively may show some deviation from the theoretical ORP value. This deviation is usually due to a change in the concentration of the KCl in the reference electrode gel. To determine whether the sensor is functioning correctly, place the ORP probe in 3682 Zobell

solution and monitor the millivolt reading. If the probe is functioning within specifications, the ORP reading should be within the range of 221-241 at normal ambient temperature. If the reading is outside of this range, the probe can be calibrated to the correct value (231 mV at 25°C) using the calibration procedure outlined in Section 4.2.

ORP readings for the same solution can vary up to 100 mv depending on the temperature. However, no standard compensation algorithms exist for this parameter. Be sure to take this factor into account when reporting ORP values. For Zobell solution, consult the following chart:

TEMPERATURE, CELSIUS	ZOBELL SOLUTION VALUE, MV
-5	270
0	263.5
5	257
10	250.5
15	244
20	237.5
25	231
30	224.5
35	218
40	211.5
45	205
50	198.5

6.4 pH

The 600XL employs a field replaceable pH electrode for the determination of hydrogen ion concentration. The probe is a combination electrode consisting of a proton selective glass reservoir filled with buffer at approximately pH 7 and a Ag/AgCl reference electrode which utilizes gelled electrolyte. A silver wire coated with AgCl is immersed in the buffer reservoir. Protons (H⁺ ions) on both sides of the glass (media and buffer reservoir) selectively interact with the glass, setting up a potential gradient across the glass membrane. Since the hydrogen ion concentration in the internal buffer solution is invariant, this potential difference, determined relative to the Ag/AgCl reference electrode, is proportional to the pH of the media.

The 6561 pH sensor available for the 600XL should provide long life, good response time, and accurate readings in most environmental waters. For waters of very low conductivity, however, the 6564 low ionic strength pH probe may provide better results. The 6564 features a low impedance glass membrane and a lower impedance junction reference junction than the 6561. While the 6564 will produce good data in freshwater of higher conductivity, it is likely to have a shorter lifetime than the 6561 due to the loss of gel through the reference junction over time.

CALIBRATION AND EFFECT OF TEMPERATURE

The software of the 600XL calculates pH from the established linear relationship between pH and the millivolt output as defined by a variation of the Nernst equation:

$$E = E_o + \frac{2.3RT}{nF} \cdot \text{pH}$$

where E = millivolts output

E_o = a constant associated with the reference electrode

T = temperature of measurement in degrees Kelvin

R, n, and F are invariant constants

Thus, in simplified $y = mx + b$ form, it is (mv output) = (slope)x(pH) + (intercept). In order to quantify this simple relationship, the instrument must be calibrated properly using commercially available buffers of known pH values. In this procedure, the millivolt values for two standard buffer solutions are experimentally established and used by the 600XL software to calculate the slope and intercept of the plot of millivolts vs. pH. Once this calibration procedure has been carried out, the millivolt output of the probe in any media can readily be converted by the 600XL software into a pH value, *as long as the calibration and the reading are carried out at the same temperature*. This last qualifier is almost never met in actual environmental measurements since temperatures can vary several degrees during a deployment simply from a diurnal cycle. Thus, a mechanism must be in place to compensate for temperature or, in other words, to accurately convert the slope and intercept of the plot of pH vs. millivolts established at T_c (temperature of calibration) into a slope and intercept at T_m (temperature of measurement). Fortunately, the Nernst equation provides a basis for this conversion.

According to the Nernst equation as shown above, the slope of the plot of pH vs. millivolts is *directly proportional* to the absolute temperature in degrees Kelvin. Thus, if the slope of the plot is experimentally determined to be 59 mv/pH unit at 298 K (25 C), then the slope of the plot at 313 K (40 C) must be $(313/298) \cdot 59 = 62$ mv/pH unit. At 283 K (10 C), the slope is calculated to be 56 mv/pH unit $((283/298) \cdot 59)$. Determination of the slope of pH vs. mv plots at temperatures different from T_c is thus relatively simple. In order to establish the intercept of the new plot, the point where plots of pH vs. mv at different temperatures intersect (the isopotential point) must be known. Using standard pH determination protocol, the 600XL software assigns the isopotential point as the mv reading at pH 7 and then calculates the intercept using this assumption. Once the slope and intercept to the plot of pH vs. mv are assigned at the new temperature, the calculation of pH under the new temperature conditions is straightforward, and is automatically carried out by the sonde software.

MEASUREMENT AND CALIBRATION PRECAUTIONS

- (1) When filling the calibration cup prior to performing the calibration procedure, make certain that the level of calibrant buffers is high enough in the calibration/storage cup to cover the pH probe and temperature sensor of the 6561 probe (approximately 200 mL).
- (2) Rinse the sensors with deionized water between changes of calibration buffer solutions.

(3) During pH calibration, allow the sensors time to stabilize with regard to temperature (approximately 60 seconds) before **proceeding with the calibration protocol**. The pH readings after calibration are only as good as the calibration itself.

(4) Clean and store the probe according to **the manufacturer's instructions**.

6.5 DEPTH AND LEVEL

The 600XL can be equipped with either **depth** or level sensors. In fact, both sensors measure depth, but by convention, level refers to **vented measurements** and depth refers to non-vented measurements. Both measurements use a **differential strain gauge transducer** to measure pressure with one side of the transducer exposed to **the water**.

For depth measurements, the other side of **the transducer** is exposed to a vacuum. The transducer measures the pressure of the water column **plus the atmospheric pressure** above the water. Depth must be calculated from the pressure **exerted by the water column alone**; therefore, when depth is calibrated in air, the software records the **atmospheric pressure** and subtracts it from all subsequent measurements. This method of **compensating for atmospheric pressure** introduces a small error. Because the software uses the **atmospheric pressure** at the time of calibration, changes in atmospheric pressure between calibrations **appear as changes in depth**. The error is equal to 0.045 feet for every 1 mm Hg change in atmospheric pressure. In sampling applications, frequent calibrations eliminate the error. Considering **typical changes in barometer** during long term monitoring, errors of ± 0.6 feet (0.2m) **would be common**. In applications where this error is significant, we recommend using a **level sensor in place of the depth sensor**.

As with depth measurements, level uses a **differential transducer** with one side exposed to the water. However, the other side of the **transducer** is vented to atmosphere. In this case, the transducer measures only the pressure **exerted by the water column**. Atmospheric pressure is ignored and changes in atmospheric pressure **do not affect the reading at all**.

The voltage output of the transducer is **directly proportional** to the pressure. The 600XL software converts this voltage to a depth reading **in feet or meters** via calibration parameters which are factory installed. Readings are **automatically compensated** for the density of the environmental medium which is estimated from the **measured salinity**.

CALIBRATION AND EFFECT OF TEMPERATURE

The depth sensor must be zeroed prior to **deployment** to account for atmospheric pressure. This procedure is carried out by following **the calibration menu instructions** with the sonde in air only (do not submerge). The **temperature dependence** of the sensor is automatically taken into account by the sonde software based on input from **factory calibration**.

MEASUREMENT AND CALIBRATION PRECAUTIONS

- (1) Be certain that the sonde is not immersed in water during the calibration procedure.
- (2) Remember that the depth sensors for the 600XL are not vented. In practical terms, this means that changes in barometric pressure after the sensor is calibrated will appear as changes in depth. This effect is significant, particularly for the 0-30 ft option of the depth probe. For example, a change of 1 mm of Hg in barometric pressure will change the apparent depth by approximately 0.04 ft (0.012 m). For the level sensor which is vented, this error is eliminated.

6.6 TEMPERATURE

The 600XL utilizes a thermistor of sintered metallic oxide which changes predictably in resistance with temperature variation. The algorithm for conversion of resistance to temperature is built in to the 600XL software, and accurate temperature readings in degrees Celsius, Kelvin, or Fahrenheit are provided automatically. No calibration or maintenance of the temperature sensor is required.

6.7 DISSOLVED OXYGEN

The 600XL employs the patented YSI Rapid Pulse system for the measurement of dissolved oxygen (DO). Use of this technology provides major advantages for the *monitoring* of DO without significantly compromising the accuracy of *sampling* applications. Standard electrochemical detectors of DO are highly flow dependent and therefore require external stirring of the medium being evaluated. The operation of this mechanical stirrer consumes most of the power associated with the DO determination and severely limits the length of remote deployment unless an external battery source is utilized. The Rapid Pulse system needs no external stirring, allowing the 600XL to accurately monitor DO for up to 90 days. In addition, because of the nature of the technology, some effects of fouling of the sensor are minimized.

The Rapid Pulse system utilizes a Clark-type sensor which is not radically different from other membrane-covered, steady-state dissolved oxygen probes. The system still measures the current associated with the reduction of oxygen which diffuses through a teflon membrane, and this current is still proportional to the partial pressure (not the concentration) of oxygen in the solution being evaluated. The membrane isolates the electrodes necessary for this reduction from the external media, encloses the thin layer of electrolyte required for current flow, and prevents other non-gaseous, electrochemically active species from interfering with the measurement. However, as the user will note from examination of the 6561 probe, the sensor consists of three electrodes (a cathode, anode, and reference electrode) while steady state Clark probes usually have only two electrodes (a cathode and a combined anode-reference electrode). In addition, the geometry of the sensor is novel, consisting of a thin linear gold cathode placed between two silver rectangles which

serve as anode and reference electrodes. These sensor changes were required to implement the new Rapid Pulse method for DO measurement as described in the following section.

METHOD OF OPERATION

Standard Clark dissolved oxygen sensors which are marketed by YSI and other manufacturers are continuously polarized at a voltage sufficiently negative to cause oxygen (which diffuses through the teflon membrane) to be reduced to hydroxide ion at the cathode and silver metal to be oxidized to silver chloride at the anode. The current associated with this process is proportional to the oxygen present in the solution outside the membrane. However, as this electrochemical reaction proceeds, oxygen is consumed (or depleted) in the medium, resulting in a decrease in measured current (and apparent oxygen content) if the external solution is not stirred rapidly. To minimize this oxygen depletion, the probe electrodes in the YSI Rapid Pulse system are rapidly and reproducibly polarized (on) and depolarized (off) during a measurement sequence. The Rapid Pulse system thus measures the charge or coulombs (current summed over a specific time period) associated with the reduction of oxygen during a carefully controlled time interval. The coulombs due to charging of the cathode (capacitance), but not to reduction of oxygen, are subtracted during integration after the cathode has been turned off. The net charge, like the steady state current in a standard system, is proportional to the oxygen partial pressure in the medium. Because oxygen is only being reduced 1/100th of the total measurement time, even if the probe is pulsed in this manner continuously, oxygen consumption outside the membrane is kept to a minimum, and the stirring dependence of the system is greatly reduced.

One key to the practicality of Rapid Pulse oxygen system is the fact that the on time is very short. This allows the off time to also be relatively short and still maintain the off to on ratio of 100 which is necessary to obtain relatively flow independent measurements. The second important aspect of the Rapid Pulse technology is the integration (summing of the current) over the total pulse (on and off). Because the charging current of the electrodes is subtracted in this process, the net signal is due only to the reduction of oxygen. From a practical point of view, this means that when there is zero oxygen partial pressure outside the membrane, the Rapid Pulse signal will also be zero; this in turn allows the system to be calibrated with a single medium (air or water) of known oxygen pressure.

CALIBRATION AND EFFECT OF TEMPERATURE

The 600XL Rapid Pulse system is calibrated using the same basic methods employed for steady state oxygen sensors. However, the software which controls the calibration protocol is somewhat different depending on whether the unit will be used in sampling or deployment studies. For sampling studies using either a 610 display unit or a laptop computer, the Rapid Pulse system is allowed to run continuously when the Run mode is activated by turning off "Wait for DO" and "Autosleep" as detailed in Section 4. Under these software conditions, the user views the DO readings in real time and confirms the calibration manually after the readings have stabilized.

For studies in which the 600XL is deployed and readings are saved to a computer or data collection platform less frequently (5-60 minutes), it is best to activate "Wait for DO" and input an appropriate warm up time for the system. Usually 60 seconds is adequate for this parameter, but,

in some cases, larger values may result in more accurate results. In addition, for deployment studies, “Autosleep” should be activated. With these software entries in place, the user will input the calibration value (concentration or barometric pressure), and the unit will automatically calibrate after the selected warm up time.

The description below is designed around sampling applications with “Wait for DO” and “Autosleep” deactivated.

The two general calibration methods possible with the 600XL are “DO mg/l” and “DO %”. The former method is designed for calibration in solution while the latter utilizes water-saturated air as the medium. Since the percent saturation (DO %) and concentration (DO mg/l) values are related by well-known algorithms, calibration by either method results in correct outputs in both units.

If the mg/L method is selected from the 600XL **Calibrate** menu, the oxygen concentration of an aqueous solution is determined either by:

- 1.) Winkler titration
- 2.) Aerating the solution and assuming that it is saturated, or
- 3.) Measurement with another instrument.

If this calibration method is employed, place the sonde into this known-value solution, input the value (in mg/l) into the 600XL software, and then, after the reading has stabilized (2-15 minutes, depending on whether the probe has been serviced recently), confirm the calibration according to the instructions.

If the Percent Saturation method is selected, the sonde is simply placed in a calibration cup which contains a small quantity of water or a damp sponge. *The probe sensor should not be in the water for this calibration procedure.* The barometric pressure is entered into the 600XL software and then, after the readings have stabilized (5-15 minutes, depending on whether the probe has been serviced recently), the calibration is confirmed according to the instructions.

NOTE: Remember that calibration will occur automatically if the unit is set up properly for deployment (“Wait for DO” and “Autosleep” activated).

The DO readings of steady state oxygen systems are greatly affected by temperature (approximately 3% per degree Celsius) due to the effect of temperature on the diffusion of oxygen through the membrane. The Rapid Pulse system exhibits a greatly reduced effect of temperature (approximately 1% per degree Celsius), but this factor still must be accounted for if DO readings acquired at temperatures different from that at calibration are to be accurate. This compensation is automatically carried out by the sonde software.

In addition, the relationship between the measured partial pressure of oxygen (percent saturation) and the solubility of oxygen in mg/L is very temperature dependent. For example, air saturated water (100 percent saturated) at 20 C contains 9.09 mg/L, but only 7.65 mg/L at 30 C. Both of these temperature related factors are compensated for by the 600XL software after instrument calibration. The temperature compensation for the percent saturation reading is empirically

derived, while the conversion from percent saturation and temperature to a solubility in mg/L is carried out using formulae available in *Standard Methods for the Examination of Water and Wastewater* (ed. 1989). See Appendix F for dissolved oxygen solubility tables as a function of salinity and temperature.

FLOW DEPENDENCE

As noted above, oxygen readings acquired using the Rapid Pulse technology are much less affected by sample flow than steady state probes. However, there is a finite stirring dependence exhibited by the Rapid Pulse system if measurements are taken when the probe is being pulsed continuously. Our tests indicate that, under these sampling conditions, observed dissolved oxygen readings can be 2-3 percent lower than the true readings in very still water. Minimal agitation of the water removes this effect.

This small flow dependence of the sensor is greatly reduced in longer term monitoring deployments where the sampling interval is longer, e.g. 15 minutes. Under these conditions, the sensor is pulsed for only approximately 60 seconds every 15 minutes, and normal diffusion of oxygen in the medium re-establishes the oxygen which has been depleted in the previous warm-up/read sequence.

MEASUREMENT AND CALIBRATION PRECAUTIONS

- (1) If water-saturated air is used as the calibrating medium, make certain that *both the DO reading and the temperature* have stabilized (10-15 minutes) before starting the calibration sequence. A wet thermistor can indicate artificially low temperature readings due to evaporation and this situation will result in poor temperature compensation and inaccurate readings.
- (2) Insure that the calibration cup being used is vented or pressure released.
- (3) Keep the probe moist when not in use, either by immersing in water or by placing a damp sponge in the calibration vessel. If the membrane appears to be damaged or has dried out, be sure to replace it prior to calibration and deployment.
- (4) Always calibrate the Rapid Pulse system at a temperature as close as possible to that of the sample being measured. If possible, immerse the calibration chamber (which contains either a small amount of water or a wet sponge) into the body of water which is later to be measured. *Do not allow the sample water to seep into the calibration chamber.* Monitor the readings; after thermal equilibrium has been established, proceed with the calibration.
- (5) Before you install a new membrane, make sure that the O-ring groove and the probe tip are clean and smooth. If the KCl electrolyte solution leaks from the probe surface during monitoring studies, the readings are likely to be less accurate in a shorter period of time.

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6. PRINCIPLES OF OPERATION

6.1 CONDUCTIVITY

The 600XLM utilizes a cell with four pure nickel electrodes for the measurement of solution conductance. Two of the electrodes are current driven, and two are used to measure the voltage drop. The measured voltage drop is then converted into a conductance value in milli-Siemens (millimhos). To convert this value to a conductivity value in milliSiemens per cm (mS/cm), the conductance is multiplied by the cell constant which has units of reciprocal cm (cm⁻¹). The cell constant for the 600XLM conductivity cell is approximately 5.0/cm. For most applications, the cell constant is automatically determined (or confirmed) with each deployment of the system when the calibration procedure is followed; see Section 3.2. Solutions with conductivities of 1.00, 10.0, 50.0, and 100.0 mS/cm, which have been prepared in accordance with recommendation 56-1981 of the Organization International De Metrologie Legale (OIML) are available from YSI. The instrument output is in mS/cm or uS/cm for both conductivity and specific conductance. The multiplication of cell constant times conductance is carried out automatically by the software.

CALIBRATION AND EFFECT OF TEMPERATURE

The conductivity of solutions of ionic species is highly dependent on temperature, varying as much as 3% for each change of one degree Celsius (temperature coefficient = 3%/deg C). In addition, the temperature coefficient itself varies with the nature of the ionic species present.

Because the exact composition of a natural media is usually not known, it is best to report a conductivity at a particular temperature, e.g. 20.2 mS/cm at 14 °C. However, in many cases, it is also useful to compensate for the temperature dependence in order to determine at a glance if gross changes are occurring in the ionic content of the medium over time. For this reason, the 600XLM software also allows the user to output conductivity data in either raw or temperature compensated form. If Conductivity is selected, values of conductivity which are *NOT* compensated for temperature are output to the report. If Specific Conductance is selected, the 600XLM uses the temperature and raw conductivity values associated with each determination to generate a specific conductance value compensated to 25 C. The calculation is carried out as in equation (1) below, using a temperature coefficient of 1.91%/deg C (TC = 0.0191):

$$\text{Specific Conductance (25°C)} = \frac{\text{Conductivity}}{1 + \text{TC} * (\text{T} - 25)}$$

As noted above, unless the solution being measured consists of pure KCl in water, this temperature compensated value will be somewhat inaccurate, but the equation with a value of TC = 0.0191 will provide a close approximation for seawater and for solutions of many common salts such as NaCl and NH₄Cl.

MEASUREMENT AND CALIBRATION PRECAUTIONS

- (1) When filling the calibration vessel prior to performing the calibration procedure, make certain that the level of calibrant standard is high enough in the calibration cup or beaker to cover the entire conductivity cell (approximately 300 mL).
- (2) After placing the sonde in the calibration solution, agitate the sonde to remove any bubbles in the conductivity cell.
- (3) During calibration, allow the sensors time to stabilize with regard to temperature (approximately 60 seconds) before proceeding with the calibration protocol. The readings after calibration are only as good as the calibration itself.
- (4) Perform sensor calibration at a temperature as close to 25°C as possible. This will minimize any temperature compensation error.

6.2 SALINITY

Salinity is determined automatically from the 600XLM conductivity and temperature readings according to algorithms found in *Standard Methods for the Examination of Water and Wastewater* (ed. 1989). The use of the Practical Salinity Scale results in values which are unitless, since the measurements are carried out in reference to the conductivity of standard seawater at 15 °C. However, the unitless salinity values are very close to those determined by the previously used method where the mass of dissolved salts in a given mass of water (parts per thousand) was reported. Hence, the designation "ppt" is reported by the instrument to provide a more conventional output.

6.3 OXIDATION REDUCTION POTENTIAL (ORP)

The 600XLM determines the Oxidation Reduction Potential (ORP) of the media by measuring the difference in potential between an electrode which is relatively chemically inert and a reference electrode. To measure ORP with the 600XLM, a combination pH/ORP probe must be in place in the sonde bulkhead and ORP must be accessed via the ISE2 channel of the sonde. The ORP sensor consists of a platinum button found on the tip of the probe. The potential associated with this metal is read versus the Ag/AgCl reference electrode of the combination sensor which utilizes gelled electrolyte. ORP values are presented in millivolts and are not compensated for temperature.

CALIBRATION AND EFFECT OF TEMPERATURE

Calibration is usually not required for the ORP sensor of the 600XLM. However, older probes which have been deployed extensively may show some deviation from the theoretical ORP value. This deviation is usually due to a change in the concentration of the KCl in the reference electrode gel. To determine whether the sensor is functioning correctly, place the ORP probe in 3682 Zobell solution and monitor the millivolt reading. If the probe is functioning within specifications, the ORP reading should be within the range of 221-241 at normal ambient temperature. If the reading

is outside of this range, the probe can be calibrated to the correct value (231 mV at 25°C) using the calibration procedure outlined in Section 4.2.

ORP readings for the same solution can vary up to 100 mv depending on the temperature. However, no standard compensation algorithms exist for this parameter. Be sure to take this factor into account when reporting ORP values and checking sensor calibration. For Zobell solution, consult the following chart:

TEMPERATURE, CELSIUS	ZOBELL SOLUTION VALUE, MV
-5	270.0
0	263.5
5	257.0
10	250.5
15	244.0
20	237.5
25	231.0
30	224.5
35	218.0
40	211.5
45	205.0
50	198.5

MEASUREMENT AND CALIBRATION PRECAUTIONS

(1) Instructions for preparation of ORP calibrator solutions (including Zobell reagent) can be found in Section 2580 A. of *Standard Methods for the Examination of Water and Wastewater*. Alternatively, the Zobell solution is available from YSI.

(2) ORP readings usually stabilize much more rapidly in standards (e.g., Zobell solution) than in most environmental water. Be certain to consider this factor when determining ORP in field studies.

(3) Clean and store the pH/ORP sensor following the instructions in Section 7 and Appendix G of this manual.

6.4 pH

The 600XLM employs a field replaceable pH electrode for the determination of hydrogen ion concentration. The probe is a combination electrode consisting of a proton selective glass reservoir filled with buffer at approximately pH 7 and a Ag/AgCl reference electrode which utilizes gelled electrolyte. A silver wire coated with AgCl is immersed in the buffer reservoir. Protons (H^+ ions) on both sides of the glass (media and buffer reservoir) selectively interact with the glass, setting up a potential gradient across the glass membrane. Since the hydrogen ion concentration in the

internal buffer solution is invariant, this potential difference, determined relative to the Ag/AgCl reference electrode, is proportional to the pH of the media.

Our testing of the 6561 pH and 6565 pH/ORP sensors available for the 600XLM indicates that they should provide long life, good response time, and accurate readings in most environmental waters, including freshwater of low ionic strength. Thus, no special sensor is required (nor offered) for water of low conductivity.

CALIBRATION AND EFFECT OF TEMPERATURE

The software of the 600XLM calculates pH from the established linear relationship between pH and the millivolt output as defined by a variation of the Nernst equation:

$$E = E_0 + \frac{2.3RT}{nF} \cdot \text{pH} \quad \text{where } E = \text{millivolts output}$$

E_0 = a constant associated with the reference electrode

T = temperature of measurement in degrees Kelvin

R , n , and F are invariant constants

Thus, in simplified $y = mx + b$ form, it is (mv output) = (slope)x(pH) + (intercept). In order to quantify this simple relationship, the instrument must be calibrated properly using commercially available buffers of known pH values. In this procedure, the millivolt values for two standard buffer solutions are experimentally established and used by the 600XLM software to calculate the slope and intercept of the plot of millivolts vs. pH. Once this calibration procedure has been carried out, the millivolt output of the probe in any media can readily be converted by the 600XLM software into a pH value, *as long as the calibration and the reading are carried out at the same temperature*. This last qualifier is almost never met in actual environmental measurements since temperatures can vary several degrees during a deployment simply from a diurnal cycle. Thus, a mechanism must be in place to compensate for temperature or, in other words, to accurately convert the slope and intercept of the plot of pH vs. millivolts established at T_c (temperature of calibration) into a slope and intercept at T_m (temperature of measurement). Fortunately, the Nernst equation provides a basis for this conversion.

According to the Nernst equation as shown above, the slope of the plot of pH vs. millivolts is *directly proportional* to the absolute temperature in degrees Kelvin. Thus, if the slope of the plot is experimentally determined to be 59 mv/pH unit at 298 K (25 C), then the slope of the plot at 313 K (40 C) must be $(313/298) \cdot 59 = 62$ mv/pH unit. At 283 K (10 C), the slope is calculated to be 56 mv/pH unit $((283/298) \cdot 59)$. Determination of the slope of pH vs. mv plots at temperatures different from T_c is thus relatively simple. In order to establish the intercept of the new plot, the point where plots of pH vs. mv at different temperatures intersect (the isopotential point) must be known. Using standard pH determination protocol, the 600XLM software assigns the isopotential point as the mv reading at pH 7 and then calculates the intercept using this assumption. Once the slope and intercept to the plot of pH vs. mv are assigned at the new temperature, the calculation of pH under the new temperature conditions is straightforward, and is automatically carried out by the sonde software.

MEASUREMENT AND CALIBRATION PRECAUTIONS

- (1) When filling the calibration cup prior to performing the calibration procedure, make certain that the level of calibrant buffers is high enough in the calibration/storage cup to cover the 6561 or 6565 pH probe and the temperature sensor of the 6560 probe.
- (2) Rinse the sensors with deionized water between changes of calibration buffer solutions.
- (3) During pH calibration, allow the sensors time to stabilize with regard to temperature (approximately 60 seconds) before proceeding with the calibration protocol. The pH readings after calibration are only as good as the calibration itself.
- (4) Clean and store the probe according to the instructions found in Section 7 and Appendix G of this manual.

6.5 DEPTH AND LEVEL

The 600XLM can be equipped with either depth or level sensors. In fact, both sensors measure depth, but by convention, level refers to vented measurements and depth refers to non-vented measurements. Both measurements use a differential strain gauge transducer to measure pressure with one side of the transducer exposed to the water.

For depth measurements, the other side of the transducer is exposed to a vacuum. The transducer measures the pressure of the water column plus the atmospheric pressure above the water. Depth must be calculated from the pressure exerted by the water column alone; therefore, when depth is calibrated in air, the software records the atmospheric pressure and subtracts it from all subsequent measurements. This method of compensating for atmospheric pressure introduces a small error. Because the software uses the atmospheric pressure at the time of calibration, changes in atmospheric pressure between calibrations appear as changes in depth. The error is equal to 0.045 feet for every 1 mm Hg change in atmospheric pressure. In sampling applications, frequent calibrations eliminate the error. Considering typical changes in barometer during long term monitoring, errors of ± 0.6 feet (0.2m) would be common. In applications where this error is significant, we recommend using a level sensor in place of the depth sensor.

As with depth measurements, level uses a differential transducer with one side exposed to the water. However, the other side of the transducer is vented to the atmosphere. In this case, the transducer measures only the pressure exerted by the water column. Atmospheric pressure is ignored and changes in atmospheric pressure do not affect the reading at all.

The voltage output of the transducer is directly proportional to the pressure. The 600XLM software converts this voltage to a depth reading in feet or meters via calibration parameters which are factory installed. Readings are automatically compensated for the temperature and for the density of the environmental medium which is estimated from the measured salinity.

NOTE: For more additional information on measuring level, see APPENDIX H in this manual.

CALIBRATION AND EFFECT OF TEMPERATURE

The depth sensor must be zeroed prior to deployment to account for atmospheric pressure. This procedure is carried out by following the calibration menu instructions with the sonde in air only (do not submerge). The temperature dependence of the sensor is automatically taken into account by the sonde software based on input from factory calibration.

MEASUREMENT AND CALIBRATION PRECAUTIONS

- (1) Be certain that the sonde is not immersed in water during the calibration procedure unless you know the exact distance between the sensor and the water surface. Calibration (zeroing) in air is usually the recommended method.
- (2) Remember that the depth sensors for the 600XLM are not vented. In practical terms, this means that changes in barometric pressure after the sensor is calibrated will appear as changes in depth. This effect is significant, particularly for the 0-30 ft option of the depth probe. For example, a change of 1 mm of Hg in barometric pressure will change the apparent depth by approximately 0.045 ft (0.012 m). As noted above, this error is eliminated for level sensors because they are vented to the atmosphere.

6.6 TEMPERATURE

The 600XLM utilizes a thermistor of sintered metallic oxide which changes predictably in resistance with temperature variation. The algorithm for conversion of resistance to temperature is built in to the 600XLM software, and accurate temperature readings in degrees Celsius, Kelvin, or Fahrenheit are provided automatically. No calibration or maintenance of the temperature sensor is required.

6.7 DISSOLVED OXYGEN

The 600XLM employs the patented YSI Rapid Pulse system for the measurement of dissolved oxygen (DO). Use of this technology provides major advantages for the *monitoring* of DO without significantly compromising the accuracy of *sampling* applications. Standard electrochemical detectors of DO are highly flow dependent and therefore require external stirring of the medium being evaluated. This stirring must be supplied either by an auxiliary stirrer (which can consume much of the battery reserve in a portable system) or by manually agitating the sonde when carrying out spot sampling applications (which can be inconvenient). These disadvantages are overcome by the Rapid Pulse dissolved oxygen technology associated with the 600XLM since it needs no stirring to yield accurate readings. In addition, because of the nature of the technology, some effects of fouling of the sensor are minimized.

The Rapid Pulse system utilizes a Clark-type sensor which is not radically different from other membrane-covered, steady-state dissolved oxygen probes. The system still measures the current associated with the reduction of oxygen which diffuses through a Teflon membrane, and this current is still proportional to the partial pressure (not the concentration) of oxygen in the solution being evaluated. The membrane isolates the electrodes necessary for this reduction from the external media, encloses the thin layer of electrolyte required for current flow, and prevents other non-gaseous, electrochemically active species from interfering with the measurement. However, as the user will note from examination of the 6562 probe, the sensor consists of three electrodes (a cathode, anode, and reference electrode) while steady state Clark probes usually have only two electrodes (a cathode and a combined anode-reference electrode). In addition, the geometry of the sensor is novel, consisting of a thin linear gold cathode placed between two silver rectangles which serve as anode and reference electrodes. These sensor changes were required to implement the new Rapid Pulse method for DO measurement as described in the following section.

METHOD OF OPERATION

Standard Clark dissolved oxygen sensors which are marketed by YSI and other manufacturers are continuously polarized at a voltage sufficiently negative to cause oxygen (which diffuses through the Teflon membrane) to be reduced to hydroxide ion at the cathode and silver metal to be oxidized to silver chloride at the anode. The current associated with this process is proportional to the oxygen present in the solution outside the membrane. However, as this electrochemical reaction proceeds, oxygen is consumed (or depleted) in the medium, resulting in a decrease in measured current (and apparent oxygen content) if the external solution is not stirred rapidly. To minimize this oxygen depletion, the probe electrodes in the YSI Rapid Pulse system are rapidly and reproducibly polarized (on) and depolarized (off) during a measurement sequence. The Rapid Pulse system thus measures the charge or coulombs (current summed over a specific time period) associated with the reduction of oxygen during a carefully controlled time interval. The coulombs due to charging of the cathode (capacitance), but not to reduction of oxygen, are subtracted during integration after the cathode has been turned off. The net charge, like the steady state current in a standard system, is proportional to the oxygen partial pressure in the medium. Because oxygen is only being reduced 1/100th of the total measurement time, even if the probe is pulsed in this manner continuously, oxygen consumption outside the membrane is kept to a minimum, and the stirring dependence of the system is greatly reduced.

One key to the practicality of Rapid Pulse oxygen system is the fact that the "on time" is very short. This allows the "off time" to also be relatively short and still maintain the off to on ratio of 100 which is necessary to obtain relatively flow independent measurements. The second important aspect of the Rapid Pulse technology is the integration (summing of the current) over the total pulse (on and off). Because the charging current of the electrodes is subtracted in this process, the net signal is due only to the reduction of oxygen. From a practical point of view, this means that when there is zero oxygen partial pressure outside the membrane, the Rapid Pulse signal will also be zero; this in turn allows the system to be calibrated with a single medium (air or water) of known oxygen pressure.

CALIBRATION AND EFFECT OF TEMPERATURE

The 600XLM Rapid Pulse system is calibrated using the same basic methods employed for steady state oxygen sensors. However, the software which controls the calibration protocol is somewhat different depending on whether the unit will be used in sampling or deployment studies. For sampling studies using either a 610 display unit or a laptop computer, the Rapid Pulse system is allowed to run continuously when the Run mode is activated if “Autosleep” is turned off as detailed in Section 4. Under these software conditions, the user views the DO readings in real time and confirms the calibration manually after the readings have stabilized.

For studies in which the 600XLM is deployed and readings are saved to sonde memory, a computer or data collection platform less frequently (5-60 minutes), an appropriate warm up time is selected for the system during Sensor setup. Usually 40 seconds is adequate for this parameter, but, in some cases, larger values may result in more accurate results. Most importantly for deployment studies, “Autosleep” should be activated. With these software entries in place, the user will input the calibration value (concentration or barometric pressure), and the unit will automatically calibrate after the selected warm up time.

The description below is designed around deployment applications with “Autosleep” activated.

The two general calibration methods possible with the 600XLM are “DO mg/L” and “DO %”. The former method is designed for calibration in solution while the latter utilizes water-saturated air as the medium. Since the percent saturation (DO %) and concentration (DO mg/L) values are related by well-known algorithms, calibration by either method results in correct outputs in both units.

If the mg/L method is selected from the 600XLM Calibrate menu, the oxygen concentration of an aqueous solution may be determined by several methods:

- ☐ Winkler titration
- ☐ Aerating the solution and assuming that it is saturated, or
- ☐ Measurement with another instrument.

If this calibration method is employed, place the sonde into this known-value solution and wait 5-10 minutes for equilibration to occur. Then input the value (in mg/L) into the 600XLM software and begin the calibration protocol according to the instructions. The calibration will occur automatically at the end of the specified warm-up time.

If the Percent Saturation method is selected, the sonde is simply placed in a calibration cup which contains a small quantity of water or a damp sponge. ***The probe sensor should not be in the water for this calibration procedure.*** The sonde should be left under these conditions for 10-15 minutes to allow temperature and humidity equilibration to occur. Then input the true barometric pressure into the 600XLM software and begin the calibration protocol according to the instructions. The calibration will occur automatically at the end of the specified warm-up time.

NOTE: Remember that control of the calibration will be manual rather than automatic if the unit is set up properly for spot sampling applications (“Autosleep” deactivated).

The DO readings of steady state oxygen systems are greatly affected by temperature (approximately 3% per degree Celsius) due to the effect of temperature on the diffusion of oxygen through the

7. MAINTENANCE

A Model 6570 Maintenance Kit is available for use with the 600XL. The kit includes several items which will be helpful or necessary in performing the proper routine maintenance on the 600XL. The kit includes two types of O-rings (for probes and cable connector), a probe installation and replacement tool, 2 cleaning brushes for the conductivity sensor, O-ring lubricant, and a syringe for cleaning the depth port.

The Model 6570 Maintenance Kit can be ordered from any authorized YSI dealer, or directly from YSI. See Appendix D for details.

7.1 SONDE MAINTENANCE

When caring for the 600XL sonde, it is important to remember that the sonde is sealed at the factory, and there is never a need to gain access to the interior circuitry of the sonde; in fact, to do so would void the manufacturer's warranty.

SONDE STORAGE

Since the introduction of the YSI Environmental Monitoring Systems (EMS) product line several years ago, YSI has learned a great deal about storage protocols which will maximize the lifetime of our sensors. This knowledge has come from our own extensive in-house testing programs as well as from feedback from a large number of customers and sales representatives. Just prior to the release of the 6820 in May 1996, we have summarized these storage recommendations in a separate document which is included in this manual as Appendix G.

These current storage guidelines are, in some cases, slightly different from those provided in our previous manuals on the YSI Models 6000UPG, 600, and 600XL. We believe that the previous storage recommendations were good, but that the procedures described in the current version are better. No doubt these recommendations will continue to be refined slightly as we introduce new sensors and gain additional information from testing. Please refer to Appendix G for detailed instructions for sensor storage. Note that the appendix deals with instruments other than the 600XL -- be sure to refer specifically to the instructions for the instrument which you have purchased.

Proper storage of the 600XL sonde between periods of usage will not only extend the life of the sensors, but will also ensure that the unit will be ready to use as quickly as possible in your next application.

Sondes with level sensors have a tube that vents the pressure transducer to atmosphere. It is imperative that the air in the tube remain dry at all times. Sondes with integral cables should be stored with the desiccant in place and the vented end of the desiccant sealed. Sondes with connectors should be stored with the connector cap firmly in place. Do not disconnect the cable without putting the cap on immediately. Vented cables should be stored with their caps on, in a bag with desiccant.

SONDE PROBE PORTS

Whenever a probe is installed, removed, or replaced, it is extremely important that the entire sonde and all probes be thoroughly dried prior to the removal of the probe or the probe port plug. This will prevent water from entering the port. Once the probe or plug has been removed, examine the connector inside the sonde probe port. If any moisture is present, use compressed air to completely dry the connector. If the connector is corroded, return the sonde to your dealer or directly to YSI's Product Service Department (see Appendix C for details). When reinstalling a probe or port plug, lightly grease the O-ring with lubricant supplied in the 6570 Maintenance Kit.

CABLE CONNECTOR PORT

The cable connector port at the top of the sonde should be covered at all times. While communicating with the sonde, a cable should be installed and tightened in place. This will assure that a proper connection is being made and prevent moisture and contaminants from entering.

When a communications cable is not connected to the cable connector port, the pressure cap supplied with the instrument should be securely tightened in place.

If moisture has entered the connector, dry the connector completely with compressed air, a clean cloth, or paper towel. Apply a very thin coat of lubricant from the 6570 Maintenance Kit to the O-ring inside the connector cap before each installation.

7.2 PROBE MAINTENANCE

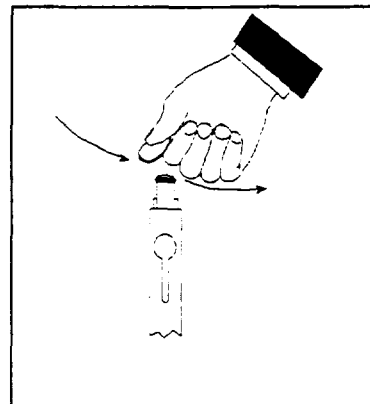
Once the probes have been properly installed, regular cleaning and oxygen probe membrane changes are required.

6562 DO PROBES

For best results, it is recommended that the KCl solution and the teflon membrane at the tip of the 6562 probe be changed prior to each sonde deployment and at least once every 30 days during the use of the 600XL in sampling studies. In addition, the KCl solution and membrane should be changed if (a) bubbles are visible under the membrane; (b) significant deposits of dried electrolyte are visible on the membrane or the O-ring; and (c) if the probe shows unstable readings or other malfunction. See Section 2.2 for instructions on changing the membrane.

After removing the used membrane from the tip of the 6562 probe, examine the electrodes at the tip of the probe.

If either or both of the silver electrodes are black in color, the probe should be resurfaced using the sanding disks which are provided in the 6035 reconditioning kit. Following the instructions supplied with the kit, first dry the probe tip completely with lens cleaning tissue. Next, hold the probe in a vertical position, place one of the sanding disks under your thumb, and stroke the probe face in a direction parallel to the gold electrode. The motion is similar to that used in striking a match. Usually 10-15 strokes of the sanding disk is sufficient to remove black deposits on the silver electrodes, but, in extreme cases, more sanding may be required to regenerate the original silver surface.



After the sanding procedure is complete, repeatedly rinse the probe face with clean water and wipe with lens cleaning tissue to remove any grit left by the sanding disk. After cleaning, thoroughly rinse the entire tip of the probe with distilled or deionized water and install a new membrane. See Section 2.2.

NOTE: Be sure to: (1) Use *only* the sanding disks provided in the 6035 maintenance kit in the resurfacing operation and (2) Sand in a direction parallel to the gold electrode. *Not adhering to either of these instructions can seriously damage the electrodes.*

NOTE: If this procedure is unsuccessful, as indicated by improper probe performance, it may be necessary to return the probe to an authorized dealer service center. See Appendix C for contact information.

6560 CONDUCTIVITY/TEMPERATURE PROBES

The openings which allow fluid access to the conductivity electrodes must also be cleaned regularly. The small cleaning brush included in the 6570 Maintenance Kit is ideal for this purpose. Dip the brush in clean water and insert it into **each** hole 15-20 times. In the event that deposits have formed on the electrodes, it may be necessary to use a mild detergent with the brush. After cleaning, check the response and accuracy of the conductivity cell with a calibration standard.

NOTE: If this procedure is unsuccessful, or if probe performance is impaired, it may be necessary to return the probe to an authorized dealer service center. See Appendix C for contact information.

The temperature portion of the probe requires no maintenance.

6561 pH, 6564 LOW IONIC STRENGTH, 6563 ORP PROBES, AND 6565/6567 COMBINATION pH-ORP PROBES

Cleaning is required whenever deposits or contaminants appear on these glass probes. Remove the probe from the sonde. Use clean water and a clean cloth to remove all foreign material from the glass probe. Carefully remove any material which may be blocking the circular reference electrode junction of the sensor.

Dry the sonde port and probe connector with compressed air and apply a very thin coat of O-ring lubricant to all O-rings before re-installation.

DEPTH SENSORS

The depth sensors are factory installed options which are located between the bulkhead and the sonde tube. On the side of the sonde, there is a circular cap with two small holes that protects the depth sensor. The cap cannot be removed, but a syringe is supplied in the maintenance kit to aid cleaning the pressure port. Fill the syringe with clean water, press the syringe against one of the holes and gently force water into the pressure port. Ensure that the water comes out of the other hole. Continue flushing the pressure port until the water comes out clean.

CAUTION: Never try to remove the circular pressure port cap.

LEVEL SENSORS

For level sensors follow all the maintenance procedures given for depth sensors. In addition, ensure that the desiccant always remains active. Active desiccant is a distinctive blue color. When it can absorb no more moisture it is a rose red or pink color. For either the cartridge or the canister, the end that is vented to atmosphere will begin to change color first. As long as the desiccant closest to the sonde is blue, no maintenance is required. Local conditions will dictate how long the desiccant will last. In humid environments, the desiccant may need to be changed or regenerated well before it is completely exhausted to ensure that it lasts the entire deployment.

You may regenerate the desiccant, replace the desiccant in the cartridge or canister, or replace the entire cartridge or canister.

To regenerate the desiccant remove it from the unit and spread it evenly, one granule deep, on a suitable tray. Heat for about one hour at about 200 degrees C (about 400 degrees F). The desiccant should then be cooled in a suitable, tight container before refilling the unit. The felt filters should also be dried at about 100 degrees C (about 200 degrees F) for about 30 minutes before assembly.

Desiccant granules are sold separately. Both the cartridge and canister can easily be opened, emptied and refilled.

To replace a cartridge or canister, see Section 2.

CAUTION: It is important to keep the tube in vented sondes and cables dry. They are supplied with caps for closing the volume when not in use. Keep the caps on until just before calibration and deployment. For storage, replace the caps.

7.3 GENERAL MAINTENANCE NOTE

In the event that the 600XL continues to exhibit some problem that you can not correct by following the Maintenance procedures outlined within this section, call your authorized service center. See Appendix C for contact information.

REMEMBER: DO NOT ATTEMPT TO GAIN ACCESS TO THE INTERNAL CIRCUITRY OF THE SONDE.

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SENSOR PERFORMANCE PROBLEMS

SYMPTOMS	POSSIBLE CAUSE	ACTION	REF
Dissolved Oxygen reading unstable or inaccurate	Probe not properly calibrated	Follow DO cal procedures	3.1
	Membrane not properly installed or may be punctured	Follow 6562 setup procedure	2.2
	DO probe electrodes require cleaning	Follow DO cleaning procedure use 6035 maint. kit	7.2
	Water in probe connector	Dry connector; reinstall probe	2.2
	Algae or other contaminant clinging to DO probe	Rinse DO probe with clean water	
	Barometric pressure entry is incorrect	Repeat DO cal procedure	3.1
	Cal at extreme temperature	Recal at (or near) sample temperature	
	DO Charge too high >75 1. Anodes polarized (tarnished) 2. Probe left on continuously	Enable DO charge parameter in the Sonde report menu. Run 600, if charge is over 75, recondition probe with 6035 maint. kit Follow DO cleaning procedure	4.1 7.2
	DO Charge too low <25 Insufficient electrolyte.	Replace electrolyte and membrane.	
	DO probe has been damaged	Replace 6562 probe	2.2
pH, ORP, unstable or inaccurate. Error messages appear during calibration.	Internal failure	Return sonde for service	C
	Probe requires cleaning, Temperature thermistor not in pH solution at time of cal.	Follow probe cleaning procedure	7.2
	Probe requires calibration	Follow cal procedures	3.1
	Probe has been damaged. Check for gel at base of probe	Replace pH or ORP probe..	E
	Water in probe connector	Dry connector; reinstall probe	E
	Calibration solutions out of spec or contaminated with other solution	Use new calibration solutions	
	ORP fails Zobell check	Repeat test. Check possible causes above.	6.3
	Internal failure	Return sonde for service	C
Depth unstable or inaccurate	Depth sensor has not been zeroed	Follow depth zero procedure	3.1
	Depth sensor access hole is obstructed	Follow depth cleaning procedure	7.2
	Depth sensor has been damaged	Return sonde for service	C
	Internal failure	Return sonde for service	C

Conductivity unstable or inaccurate. Error messages appear during calibration.	Conductivity improperly calibrated.	Follow cal procedure	3.1
	Conductivity probe requires cleaning	Follow cleaning procedure	7.2
	Water drop attached to temperature sensor	Dry temperature sensor	
	Conductivity probe damaged	Replace probe	2.2
	Calibration solution out of spec or contaminated	Use new calibration solution	3.2
	Calibration value too far from sample value	Cal at or near expected value	3.2
	Internal failure	Return sonde for service	C
	Calibration solution or sample does not cover entire sensor .	Immerse sensor fully.	3.1
Installed probe has no reading	The sensor has been disabled	Enable sensor	4.7
	Water in probe connector	Dry connector; reinstall probe	2.2
	Probe has been damaged	Replace the 6560 probe	2.2
	Report output improperly set up	Set up report output	4.6
	Internal failure	Return sonde for service.	C
Temperature, unstable or inaccurate	Check thermistor sheath for damage.	Dry connector; reinstall probe	
	Probe has been damaged	Replace the 6560 probe	2.2

Table 2: Calibration Values for Various Atmospheric Pressures and Altitudes

PRESSURE			ALTITUDE		CALIBRATION VALUE
Inches Hg	mm Hg	Millibars	Feet	Meters	Percent Saturation
30.23	768	1023	-276	-84	101
29.92	760	1013	0	0	100
29.61	752	1003	278	85	99
29.33	745	993	558	170	98
29.02	737	983	841	256	97
28.74	730	973	1126	343	96
28.43	722	963	1413	431	95
28.11	714	952	1703	519	94
27.83	707	942	1995	608	93
27.52	699	932	2290	698	92
27.24	692	922	2587	789	91
26.93	684	912	2887	880	90
26.61	676	902	3190	972	89
26.34	669	892	3496	1066	88
26.02	661	882	3804	1160	87
25.75	654	871	4115	1254	86
25.43	646	861	4430	1350	85
25.12	638	851	4747	1447	84
24.84	631	841	5067	1544	83
24.53	623	831	5391	1643	82
24.25	616	821	5717	1743	81
23.94	608	811	6047	1843	80
23.62	600	800	6381	1945	79
23.35	593	790	6717	2047	78
23.03	585	780	7058	2151	77
22.76	578	770	7401	2256	76
22.44	570	760	7749	2362	75
22.13	562	750	8100	2469	74
21.85	555	740	8455	2577	73
21.54	547	730	8815	2687	72
21.26	540	719	9178	2797	71
20.94	532	709	9545	2909	70
20.63	524	699	9917	3023	69
20.35	517	689	10293	3137	68
20.04	509	679	10673	3253	67
19.76	502	669	11058	3371	66

Table 3. Conversion Factors for Feet/Meters, Celsius/Fahrenheit, mg/L/ppm

TO CONVERT FROM	TO	EQUATION
Feet	Meters	Multiply by 0.305
Meters	Feet	Multiply by 3.28
Degrees Celsius	Degrees Fahrenheit	$5/9 \times (^\circ\text{F} - 32)$
Degrees Fahrenheit	Degrees Celsius	$9/5 \times (^\circ\text{C}) + 32$
Milligrams per liter (mg/L)	Parts per million (ppm)	Multiply by 1

Table 4. Conversion Factors for Common Units of Pressure

	kilo Pascals	mm Hg	millibars	inches H ₂ O	PSI	inches Hg
1 atm	101.325	760.000	1013.25	406.795	14.6960	29.921
1 kiloPascal	1.00000	7.50062	10.0000	4.01475	0.145038	0.2953
1 mmHg	0.133322	1.00000	1.33322	0.535257	0.0193368	0.03937
1 millibar	0.100000	0.750062	1.00000	0.401475	0.0145038	0.02953
1 inch H ₂ O	0.249081	1.86826	2.49081	1.00000	.0361	0.07355
1 PSI	6.89473	51.7148	68.9473	27.6807	1.00000	2.0360
1 inch Hg	3.38642	25.4002	33.8642	13.5956	0.49116	1.00000
1 hectoPascal	0.100000	0.75006	1.00000	0.401475	0.0145038	0.02953
1 cm H ₂ O	0.09806	0.7355	9.8×10^{-7}	0.3937	0.014223	0.02896



Thank you for choosing C. C. Lynch and Associates, Inc. for your equipment needs. Please call 1-800-333-2252 if you have any questions or if any item is missing from your shipment. The following procedure is designed to assist you with the calibration of the instrument you have ordered. However, we recommend that you read the instruction manual.

Also, please remember that you are responsible for cleaning the equipment before returning it to C.C.L.A. The equipment should be returned via any overnight service.

CALIBRATION

Order of calibration:

- (1) conductivity
- (2) PH
- (3) ORP(Redox)-if applicable
- (4) Turbidity -if applicable
- (5) Dissolved Oxygen

Note: It is necessary to allow the instrument to stabilize in the solutions for all parameters before calibration. Allow a minimum of 30-60 seconds for stabilization for all parameters except Dissolved Oxygen which requires a minimum of 15 minutes.

Conductivity - When calibrating conductivity, you must use Specific Conductance which compensates for temperature. It is recommended that you use a standard within the same range as the water you will be sampling. For example:

- sea water 50ms/cm
- fresh water 1ms/cm
- brackish water 10ms/cm

PH - 3 point calibration is recommended, 4, 7, and 10. It is necessary to calibrate using the 7 buffer first followed by 4 & 10 in any order.

ORP (Redox) - calibration is done in millivolts and is dependant on temperature. See attached form for YSI 3682 Zobell Solution. Use the column marked Ag/AgCl in millivolts.

Turbidity - A 2 point calibration is recommended, one of which must be 0 NTU. It is necessary to calibrate the 0 NTU first. 100 NTU is recommended for the second standard. It is also necessary to use the grey calibration cup(supplied with instrument) when calibrating turbidity. Otherwise, the presence of ambient light can adversely affect the calibration. In addition, if wiping turbidity is being used, test the wiper and wipe before calibration.

Dissolved Oxygen - calibration will be done to local barometric pressure. Place the sonde in the calibration cup containing a damp sponge or napkin making sure to break the seal slightly to allow for air to enter the cup. After stabilization occurs(minimum of 15 minutes), select Dissolved Oxygen calibration mode, then select % saturation. You must enter barometric pressure in millimeters of mercury.

Note: Inches of Hg x 25.4 mm/inch = mm Hg.



DISSOLVED OXYGEN CALIBRATION

From the Main Menu, select the following in sequence:

- (1) Calibration Mode
- (2) Dissolved Oxygen
- (3) D O %
- (4) Input Barometric Pressure in mm Hg*
- (5) Press ENTER when stable

*NOTE: BP in Inches Hg x 25.4 = BP in mm Hg

*NOTE: Weather channel or Airport reports BP corrected to sea level

To obtain uncorrected Barometric Pressure, use the following formula:

$$UBP = CBP - 0.5(A/100) \quad \text{where} \quad \begin{array}{l} UBP = \text{Uncorrected Barometric Pressure} \\ CBP = \text{Corrected Barometric Pressure} \\ A = \text{Altitude in feet} \end{array}$$

Find Altitude on chart to determine what your calibration value should be after calibration.

YSI 3682 ZOBELL SOLUTION INSTRUCTIONS

DESCRIPTION

The YSI 3682 Zobell Solution is a reference solution that is used to verify the performance characteristics of redox potential cells such as the YSI 3540 ORP Electrode Assembly. This product is packaged in dry form and must be reconstituted before use. Each amber bottle contains 75% Potassium Chloride, 14% Potassium Ferrocyanide Trihydrate and 11% Potassium Ferricyanide by weight.

The reconstituted solution has a maximum shelf life of 6 months. The shelf life of an unopened bottle is 24 months; it should be stored below 40°C.

To reconstitute the solution, add 125 ± 5 mL of deionized or distilled water. (125 mL typically fills the bottle to the bottom of the neck.) The label should be marked to indicate the correct expiration date.

CALIBRATION

Pour Zobell Solution into a sample cup. (Suitable cups are provided in the YSI 3565 Sample Cup Pack.) Clean and rinse the ORP electrode with deionized or distilled water followed by a rinse of 3682 solution before immersing it in the sample cup. Most pH meters that read in millivolts can be used to take redox potential readings.

Use this product with Ag/AgCl or saturated calomel electrode systems. According to the U.S.G.S., the expected redox potential values for the Ag/AgCl and saturated calomel electrode systems in Zobell reference solutions at 25°C are 231 ± 10 mV and 185 ± 10 mV respectively.

At 25°C, the reference voltage of the Ag/AgCl and saturated calomel electrode systems in Zobell Solution varies inversely with temperature according to the following equations. T is in °C.

$$E(\text{Ag/AgCl}) = 0.231 + 0.0013 (25-T) \text{ Volts}$$

$$E(\text{calomel}) = 0.185 + 0.00164 (25-T) \text{ Volts}$$

The effects of temperature on oxidation-reduction reactions, which form the basis for redox potential measurements, are small but should be considered for temperatures higher or lower than 25°C. Redox potentials for Ag/AgCl and saturated calomel electrode systems in Zobell reference solution are shown in the following table:

TEMP. in °C	Ag/AgCl (4M KCl) in millivolts	CALOMEL in millivolts
5	270.0	234.2
0	263.5	226.0
5	257.0	217.8
10	250.5	209.6
15	244.0	201.4
20	237.5	193.2
25	231.0	185.0
30	224.5	176.8
35	218.0	168.6
40	211.5	160.4
45	205.0	152.2
50	198.5	144.0

The YSI 3682 Zobell Solution is not for food or drug use and can be harmful if swallowed. *It will react with acids to form harmful by-products, including hydrocyanide gas.* Dispose of this product in accordance with all Federal, State and Local Environmental Regulations and Laws concerning health and pollution.

REFERENCES

National Handbook of Recommended Methods for Water Data Acquisition, United States Geological Survey, Chapter 2.

"Studies on Redox Potential of Marine Sediments," *Bulletin of the American Association of Petroleum Geologists*, 30, 4, pp. 477-513, Tulsa, Okla.

Midgeley, Derek, *Potentiometric Water Analysis*, 1978.

National Handbook of Recommended Methods for Water Data Acquisition, United States Federal Interagency Work Group on Designation of Standards for Water Data Acquisition, 1972.

Yellow Springs Instrument Company, Engineering, Water Quality Group, *Design and Computation Book 1*, Zobell Calibrator Solution Weekly Chart.

Field Applications in Hydrogeology, Hydrogeology Group, Department of Earth Sciences University of Waterloo, Ontario, Canada, 1981.

