FINAL REPORT

U.S. Environmental Protection Agency
and
Montana Department of Environmental Quality

2008 to 2013 Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site
Butte, Montana

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List of Acronyms and Abreviations

<	Less than
AAS	Atomic Absorption Spectroscopy
amsl	Above mean sea level
ANOVA	Analysis of variance
AR	Atlantic Richfield Company
ARAR	Applicable or relevant and appropriate requirements
BMP	Best management practices
BPSOU	Butte Priority Soils Operable Unit
BRW	Butte Reduction Works
BSB	Butte-Silver Bow County
BTC	Blacktail Creek
BTL	Butte Treatment Lagoons
CAS	Chemical addition system
CCR	Construction completion report
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFRSSI	Clark Fork River Superfund Site Investigations
cfs	Cubic feet per second
CMP	Corrugated metal pipe
CN	Curve number
COC	Contaminants of concern
CSM	Conceptual site model
DEQ	Montana Department of Environmental Quality
DM/DVP	Data management/data validation plan
DOC	Dissolved organic carbon
DQO	Data quality objectives
DSWMP	Diagnostic surface water monitoring plan
EPA	U.S. Environmental Protection Agency
ERA	Expedited response action
ESD	Explanation of significant differences
ESL	Emergency surface line
FS	Feasibility study
GFAA	Graphite furnace atomic absorption
GIS	Geographic information system
gpm	Gallons per minute
HCC	Hydraulic control channel
HDD	Hydrodynamic device
HDPE	High density polyethylene
ICP-AES	Inductively coupled plasma atomic emission spectroscopy
ICP-MS	Inductively coupled plasma mass spectrometry
IMP	Interim monitoring plan
LAO	Lower Area One
LAP	Laboratory analytical protocol
lb/day	Pounds per day

MCL	Maximum contaminant level
MDEQ	Montana Department of Environmental Quality
mg/L	Milligrams per liter
mm	Millimeter
MSD	Metro Storm Drain
NCP	National Contingency Plan
NPL	National Priorities List
NRCS	Natural Resource Conservation Service
O&M	Operations & maintenance
OU	Operable unit
Pioneer	Pioneer Technical Services
PVC	Polyvinyl chloride
PRP	Potentially responsible party
QA/QC	Quality assurance/quality control
QAPP	Quality assurance project plan
RA	Remedial action
RAO	Remedial action objective
RCP	Reinforced concrete pipe
RD	Remedial design
RG	Remedial goal
RI	Remedial investigation
ROD	Record of decision
SBC	Silver Bow Creek
SCADA	Supervisory control and data acquisition
SCS	Soil Conservation Service
SNOTEL	Snow telemetry
SOP	Standard operating procedures
su	Standard units
UAO	Unilateral administrative order
USGS	United States Geological Survey
µg/L	Micrograms per liter
yd^3	Cubic yards

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Section 1
Introduction

This document presents a summary and interpretation of surface water quality data collected at the Butte Priority Soils Operable Unit (BPSOU) of the Silver Bow Creek/Butte Area National Priorities List (NPL) Site from 2008 through 2013 and supplements the prior surface water characterization report (EPA 2008). The Silver Bow Creek/Butte Area National Priorities List NPL Site represents one of four contiguous Superfund Sites in the upper Clark Fork River Basin that extend 140 miles from the headwaters of Silver Bow Creek north of Butte to the Milltown Reservoir near Missoula, Montana (Figure 1-1). The BPSOU lies within the Butte portion of the Silver Bow Creek/Butte Area site, encompassing the town of Walkerville, the part of Butte north of Silver Bow Creek and west of the Berkeley Pit, and a section of land that extends south from Silver Bow Creek to Timber Butte (Figure 1-2). The record of decision (ROD) for the Butte Site (U.S. Environmental Protection Agency [EPA], with partial concurrence by Montana Department of Environmental Quality [DEQ] 2006) required ongoing monitoring of surface water and production of data summary and interpretation reports. This is the second data interpretation report to be completed since issuance of the Butte Site ROD in 2006.

1.1 Remedial Action Objectives for Surface Water

The selected remedy described in the ROD is intended to be the comprehensive remedial action for the BPSOU, designed to meet remedial action objectives (RAOs) and remedial goals (RGs) as well as performance standards. In the ROD, EPA identified site-specific human health and environmental RAOs and RGs for ground water, surface water, storm water, soils, indoor dust, and mining-related wastes in the BPSOU. RAOs are the final media-specific (e.g., solid media, ground water, and surface water) statements regarding the objectives to be achieved by the remedial action. They address the various contaminants of concern (COCs), media of concern, exposure pathways and receptors, and current and likely future land use in the operable unit (OU). RGs are numerical cleanup goals for environmental media. The RGs are based on applicable or relevant and appropriate requirements (ARARs) or are the results of baseline risk assessments for the BPSOU. Remedial actions implemented for the purpose of meeting RGs are intended to result in attainment of RAOs. The RAOs for contaminated surface water specified in the ROD for BPSOU were as follows:

- *Prevent ingestion or direct contact with contaminated surface water that would result in an unacceptable risk to human health.*
- *Return surface water to a quality that supports its beneficial uses.*
- *Prevent source areas from releasing contaminants to surface water that would cause the receiving water to violate surface water ARARs and RGs for the OU and prevent degradation of downstream surface water sources, including during storm (*wet weather*) events.*
- *Ensure that point source discharges from any water treatment facility (e.g., water treatment plant and wetland) meet ARARs.*
- *Prevent further degradation of surface water.*

- *Meet the more restrictive of chronic aquatic life or human health standards for surface water identified in Circular DEQ-7 (Table 8-2) through the application of B-1 class standards.* [Applies to base and normal high flow conditions. Acute aquatic life standards apply to wet weather conditions.]

1.2 Selected Remedy

The Selected Remedy for surface water is directed at achieving the primary objectives of returning Silver Bow Creek to its beneficial uses and protecting downstream receptors from releases of contamination from BPSOU. In accordance with the ROD, the Selected Remedy will protect human health and the environment, achieve water quality standards for COCs in Grove Gulch, Blacktail Creek, and Silver Bow Creek, and meet all ARARs that are not waived. The Selected Remedy for surface water consists of the following components:

- Surface Water Management Program. This program uses best management practices (BMPs) and engineered controls to address runoff of contaminated storm water and snow melt as well as specific capping and other measures described in the ROD. This component has been partially implemented by construction of additional capped source areas, concrete storm water channels, storm water diversion channels to the Berkeley Pit, curb and gutter programs, storm water sediment cleanout, and retention/detention ponds (catch basins) in select areas, and hydrodynamic devices. Additional BMPs and engineered controls are required to meet RAOs – the ROD calls for a multi-year iterative BMP program.

- Source control along streams. Removal of wastes, contaminated soil, and sediments along the surface water bodies in the OU is required as described in the ROD. In addition to the removals previously conducted at Lower Area One (LAO), removal actions are required from above the confluence with Blacktail Creek and upper Silver Bow Creek (formerly known as Metro Storm Drain [MSD]) to the beginning of the reconstructed Silver Bow Creek channel. This action began in October 2010 with removals in the Golden Triangle area including along the banks of Blacktail Creek from Montana Street to George Street.

- Capture and treatment of contaminated ground water. Capture systems have been implemented at upper Silver Bow Creek (formerly known as the "MSD subdrain" and now referred to as the "BPSOU Subdrain") and at LAO with the captured water treated at the Butte Treatment Lagoons (BTL). Since initial design and construction, these capture and treatment systems have undergone evaluation, re-design, and upgrades as part of the remedial action to ensure effectiveness, permanence, and ARAR compliance (see Section 3.1). Further upgrades may be required after additional characterization of the ground water and BPSOU subdrain system. This evaluation is ongoing.

- Monitoring of surface water. Monitoring includes in-stream and storm water system outfall locations. Contingency actions may be required if monitoring indicates the remedy is not meeting RAOs.

Contingency elements include:

- Additional ground water capture and treatment. If the surface water is still impacted or ARARs are not met following the additional streamside removal action or other ground water control actions described in the ROD, then additional ground water capture and treatment will be required. This contingency has not yet been required and is awaiting determination of whether surface water ARARs are being met.

- Capture and treatment of storm water. If the surface water management system described in the ROD, including BMPs/engineering controls, does not achieve the RAOs such as returning Silver Bow Creek to its beneficial uses and meeting ARARs, further efforts at capture and engineered treatment of storm water or snow melt will be required. This contingency has not yet been implemented.

- Flow augmentation. Following implementation of the remedial actions and contingency measures required by the ROD, the addition of clean water flow may be considered to meet the RAOs and ARARs.

1.3 Previous Surface Water Interpretation Reports

Previous data interpretation has been included in broad documents, including:

- CH2M Hill and Chen Northern 1990. Silver Bow Creek Phase II RI Data Summary, Area One Operable Unit. CH2M Hill, Inc. and Chen Northern, Inc. August 29, 1990.

- PRP Group 2002. Phase II Remedial Investigation Report, Butte Priority Soils Operable Unit of the Silver Bow Creek/Butte Area Superfund Site. Prepared for the PRP Group by McCulley, Frick & Gilman Inc. April.

- MFG, Inc. 2003. Addendum - Final Phase II Remedial Investigation Report, Butte Priority Soils Operable Unit (BPSOU). Prepared for the PRP Group by MFG, Inc. May.

- PRP Group 2004. Feasibility Study Report, Phase II Remedial Investigation/Feasibility Study, Butte Priority Soils Operable Unit, Silver Bow Creek/Butte Area Superfund Site. Prepared for the PRP Group by McCulley, Frick & Gilman Inc. April.

All of the previous surface water data and interpretations were summarized in the ROD. On behalf of the BPSOU potentially responsible parties (PRPs), Atlantic Richfield (AR) continues to collect surface water data as part of the evolving Surface Water Interim Monitoring Plan (IMP) and subsequent revisions (see Section 4.1 of this report) (AR 2007; AR 2013a). Data collected under the IMP have been determined to be usable in accordance with the draft *Quality Assurance Project Plan for the Use of Existing Data* (CDM Smith 2014).

The most recent surface water interpretation report is the *Final Surface Water Characterization Report Butte Priority Soils Operable Unit* (EPA 2008) and was primarily based on IMP data from 2007 and 2008.

1.4 Remedial Activities since the Last Surface Water Characterization Report

From 2008 through 2013, the following remedial activities were completed and are discussed further in Section 3 of this report:

- Continued operation and upgrades of the BPSOU subdrain system;

- Continued operation and upgrades of the LAO ground water capture and treatment system;

- Remedial activities at the Butte Reduction Works (BRW).
- Partial removal of contaminated material and rehabilitation of the Silver Bow Creek stream banks.
- Completion of first, second, and third cycle BMPs, including the installation of storm drain cleanouts and sediment basins, slip lining, curb and gutter, hydrodynamic devices, and source area controls.

1.5 ROD/UAO Requirements for Surface Water Monitoring

The ROD outlined specific elements of the Surface Water Management Program to be conducted as a part of the selected remedy. The Surface Water Management Program employs a diverse range of BMPs to control loading of heavy metals and arsenic to Silver Bow Creek, Blacktail Creek, and Grove Gulch during wet weather water flow conditions. Elements of this program include:

1. Monitoring. Surface water monitoring will be performed to measure progress in achieving surface water quality standards during wet weather water flow and to measure the performance of the BMPs implemented in the preceding cycle to provide data for analysis of compliance with action levels and performance standards and to evaluate the degree and location of continued contaminant loading to receiving surface waters.
2. Compliance Analysis. Analysis of data to evaluate compliance with performance standards.
3. Loading Analysis. Assessment of contaminant loading to receiving surface waters to help identify potential loading sources and assist in determining where new BMPs may be needed.

BMP development and implementation requirements for the Surface Water Management Program are as follows:

1. BMP Selection. Specific new BMPs (type and location) will be identified and prioritized based on the previous steps and other indicators.
2. BMP Implementation. BMPs will be implemented to address compliance with RGs.

The surface water monitoring program has been conducted under the 2007 Draft Surface Water IMP (AR 2007), the 2013 Draft IMP revision (AR 2013a), and the revised draft IMP and addendums (AR 2014a). The revised draft IMP and addendums had not received final approval from the Agencies for the 2013 and 2014 seasons at the time of sampling. In addition, the long-term program has not yet been written.

1.6 Performance Standards

The ROD defined performance standards for surface water as narrative and numeric water quality standards, which were described in Section 8 and Appendix A of the ROD. The most pertinent numeric standards for the BPSOU surface water COCs are shown in Table 1-1. These standards apply to point sources and as in-stream standards.

For normal flow, chronic aquatic life and human health standards promulgated under Circular DEQ-7 (February 2006) are the required standards. The arsenic standard is based on the maximum contaminant level (MCL), which was adopted by the state. The standard for aluminum is based on dissolved concentrations; all other standards are based on the total recoverable amount of the identified chemical, which is intended to protect organisms from other exposure pathways beyond water (e.g., contaminated sediment). For storm water run-off conditions or "wet weather flows," acute aquatic life standards promulgated under Circular DEQ-7 (February 2006) are the required performance standards. The BPSOU ROD does not identify human health standards for wet weather flows.

Table 1-1 Numeric Surface Water Quality Standards

Contaminant	Human Health Standard (µg/L)	Chronic Aquatic Standard (µg/L)	Acute Aquatic Standard (µg/L)	Notes
Aluminum	--	87	750	Dissolved fraction
Arsenic	10	150	340	
Cadmium	5	0.097	0.52	Hardness-dependent
Copper	1,300	2.85	3.79	Hardness-dependent
Iron	--	1,000	--	
Lead	15	0.545	13.98	Hardness-dependent
Mercury	0.05	0.91	1.7	
Silver	100	--	0.374	Hardness-dependent
Zinc	2,000	37	37	Hardness-dependent

Note: All standards are based on total recoverable analysis except for aluminum. Standards for cadmium, copper, lead, silver, and zinc are hardness-dependent. Values shown are calculated based on a total hardness (as $CaCO_3$) of 25 milligrams per liter (mg/L) (Montana Numerical Water Quality Standards, Circular DEQ-7, February 2006).
µg/L – micrograms per liter

Hardness-dependent standards are variable based on formulae contained in Circular DEQ-7, February 2006 edition. Values in this table are calculated based on a total hardness (as $CaCO_3$) of 25 mg/L.

Results indicated as normal flow are assumed in this report to be equivalent to a 4-day average. A 4-day average of concentrations greater than the chronic standard is determined to be an exceedance. Results indicated as wet weather flow in this report are assumed to be equivalent to a 1-hour average. A 1-hour average of concentrations greater than the acute standard is determined to be an exceedance.

In addition, the dissolved oxygen concentrations must not fall below 3.0 mg/L; the pH must be maintained within a range of 6.5 to 9.5; the physical properties (e.g., temperature, turbidity, solids [floating or suspended], and color) that will or are likely to create a nuisance or render the water harmful, detrimental, or injurious to public health, recreation, safety, welfare, livestock, wild animals, birds, fish, or wildlife must not be increased; and discharges of toxic, carcinogenic, or harmful parameters must not be allowed that may commence or continue that lower or are likely to lower the overall quality of these waters.

All substantive requirements of the Montana Pollutant Discharge Elimination System must be adhered to for point sources addressed or created in the remedial process. For B-1 classification waters (Blacktail Creek and Grove Gulch Creek), non-degradation rules require that any surface water below any of the above standards must be maintained and protected unless degradation is allowed under the non-degradation rules.

In-stream sediments are not specifically addressed in the RGs. However, one goal of the previous response actions and future remedial actions for the BPSOU is to eliminate or minimize sources of contamination to Silver Bow Creek sediment (i.e., surface water transport of contaminated soils or waste) such that excessively contaminated sediments are not present. Sediments in LAO were substantially addressed during the LAO Expedited Response Action (ERA). The LAO portion of Silver Bow Creek channel and floodplain were reconstructed. Additional sediment removal upstream of the reconstructed reach was required in the ROD and is discussed further in Section 3.2.

1.7 Surface Water Flow Regime

Surface water at BPSOU is categorized into three basic flow regimes: normal flow conditions (which is broken down further into base flow and normal high flow) and wet weather events. Water quality in the stream is affected by different sources of contamination for each regime. The flow regimes are described in greater detail below:

- Base Flow –Base flow is defined as times when ground water inflow comprises the greatest percentage of flow within surface water. Both surface water and ground water vary seasonally, but base flow generally occurs in late summer and winter when surface water conditions are fairly stable (i.e., not rising or falling and storm water or snowmelt runoff is not occurring). Discharge below the rolling 50th percentile of the daily discharge for a 1-year period represents base flow conditions. The purpose of analyzing base flow surface water conditions is to evaluate the effects of ground water inflow on surface water. Ground water input is best observed at lower flows. For compliance, metals concentrations at base flow are compared to chronic and human health standards. The evaluation of base flow data is described further in Sections 6 and 7.

- Normal High Flow –Normal high flow is defined as normal flow that increases above base flow when the winter mountain snowpack melts, and there is no wet weather event. To distinguish normal high flow conditions from base flow conditions, the 50th percentile of the daily discharge for a rolling 1-year period was developed to illustrate the obvious seasonal normal high flow periods, as well as other short duration peaks that probably correlate with wet weather events. The rolling 50th percentile discharge for 2008 to 2013 is shown on Figure 1-3. Discharge below the line represents base flow conditions and discharge above the line represents normal high flow and wet weather event flow. In general, the highest concentrations of contaminants are associated with normal high flows and wet weather event flows and are a focus of compliance analysis in this report. For compliance, metals concentrations at normal high flow are compared to chronic aquatic and human health standards. The evaluation of normal high flow data is described further in Sections 8 and 9.

- Wet Weather Flow – Wet weather flow is defined as short duration periods when runoff is occurring from the Butte Hill as measured at storm drain outfalls and/or when samples are collected at any of the wet weather discharge points. In general, wet weather flow conditions are highly variable and typically occur during rainfall and snowmelt events from spring through late summer and early fall. For compliance purposes, metals concentrations in samples collected during wet weather flow conditions are compared to acute aquatic standards. The evaluation of wet weather flow data is described further in Sections 10 and 11.

1.8 Points of Compliance

Water quality standards are applicable to all surface water at all times. The ROD specified minimum sampling locations to evaluate compliance as follows:

"In-stream surface water quality must meet surface water ARARs during normal flow conditions. Surface water flow and chemistry will be collected at least monthly from compliance monitoring stations GG-01 (Grove Gulch); SS-04 (Blacktail Creek); and stations SS-05, SS-05A, SS-06A, SS-06G, and SS-07 in Silver Bow Creek."

"Compliance during wet weather conditions means consistently measuring concentrations of COCs at in-stream compliance monitoring locations that are below the Montana [Circular] *DEQ-7 acute aquatic life standards (Table 8-1). This ROD establishes points of compliance for wet weather conditions at monitoring stations GG-01 (Grove Gulch), SS-04 (Blacktail Creek), and stations SS-05, SS- 05A, SS-06A, SS-06G, and SS-07 in Silver Bow Creek."*

It should be noted that station GG-01 (Grove Gulch) is no longer sampled due to very low flow, though it is noted it could still be a loading source to Silver Bow Creek via ground water contributions. Storm water outfalls and surface water in upper Silver Bow Creek are not included as points of compliance under the ROD. Therefore, contaminant loads contributed by these discharges that increase concentrations do not count as exceedances of water quality standards in surface water. Regulations governing Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) cleanups, known as the National Contingency Plan (NCP), allow for the refinement of compliance points during remedial design/remedial action (RD/RA) activities.

1.9 Report Organization

This surface water quality interpretation report is intended to meet the specified reporting requirements in the Butte Site ROD. The remaining chapters include:

Section 2 - Conceptual Site Model for Surface Water
Section 2 provides a review of the conceptual site model for surface water and discusses the sources and pathways that impact surface water quality. In addition, this section discusses ground water and surface water interaction and the potential effects of ground water control systems operation on surface water quality.

Section 3 – Remedial Activities and System Operations Affecting Surface Water
Section 3 discusses the remedial activities and/or operations that have been ongoing since 2007 that have potential impacts on surface water quality.

Section 4 – Surface Water Quality Data
Section 4 summarizes the available surface water quality data collected in accordance with the existing interim surface water monitoring plan.

Section 5 – Other Relevant Data, Reports, and Studies
Section 5 summarizes other pertinent data from normal flow related reports, Butte-Silver Bow (BSB) municipal storm water system improvement plan, storm water hydraulic modeling work, and the west camp data summary report. This section also presents supplemental data collection from outside sources, including the United States Geological Survey (USGS) surface water stream data, Snow Telemetry (SNOTEL) snow pack data, and meteorological data. Evaluation of the data presented in this section is provided in Section 12.

Section 6 – Base Flow Compliance Analysis
Section 6 compares recent base flow data to numeric water quality standards presented in the ROD. A significant RAO is to meet water quality standards, and this section evaluates progress toward that objective.

Section 7 – Base Flow Loading Analysis
Section 7 evaluates mass loading of metals in surface water in BPSOU during base flow conditions with emphasis on determining sources of metals loading.

Section 8 - Normal High Flow Compliance Analysis
Similar to Section 6, Section 8 evaluates normal high flow compliance.

Section 9 - Normal High Flow Loading Analysis
Similar to Section 7, Section 9 evaluates normal high flow loading.

Section 10 - Wet Weather Flow Compliance Analysis
Section 10 compares COC concentrations in surface water during wet weather events to acute aquatic life standards.

Section 11 - Wet Weather Flow Loading Analysis
Similar to Sections 7 and 9, Section 11 evaluates loading during wet weather conditions.

Section 12 –Other Relevant Data Interpretation
This section provides an interpretation of the other relevant data presented in Section 5.

Section 13 - Summary
Section 13 summarizes the findings of the analysis sections.

Section 14 - References
Section 14 contains a list of the documents referenced in this report.

Section 2

Conceptual Site Model for Surface Water

This section presents a review of the conceptual site models (CSMs) for the source and transport of COCs in Silver Bow Creek during normal flow and wet weather flow conditions. The basis of the CSMs was described in detail in the surface water characterization report (EPA 2008). A CSM flow chart is included for base and normal high flow as Figure 2-1 and wet weather flow as Figure 2-2.

2.1 Base and Normal High Flow Conceptual Site Model

2.1.1 Sources

During base and normal high flow conditions, the following three main categories of contaminant sources exist that impact Silver Bow Creek (see Figure 2-1).

- Mine Waste (Waste Rock and Tailings). The waste rock, tailing deposits, and other contaminated materials influencing surface water at the BPSOU are the result of 140 years of hard rock mining, smelting, milling, and other processing activities. Mining wastes were also utilized in the construction of railroad grades and embankments. Historically, significant quantities of mine waste were intentionally released into Silver Bow Creek to be carried off site; thus, a sizeable amount of mine waste was deposited within the historic stream channel and in large impoundments constructed within the floodplain and low-lying wetlands. Tailings and mine waste leach metals to ground water and cause ground water contamination. Impacts to surface water have historically occurred via discharge of contaminated ground water into Silver Bow Creek.

  Over 1 million cubic yards (yd^3) of tailings and waste were removed during the LAO removal action; however, significant quantities of mine waste remain in areas in the BPSOU that still contribute to ground water contamination. Silver Bow Creek was reconstructed to be elevated above ground water in LAO so that the contaminated ground water would not discharge into the creek, as long as ground water interception systems are implemented and maintained. Subsurface mine waste still remains beneath the Metro Sewer Treatment Plant and under the slag walls at the former BRW facility. These areas could contribute to the ground water contamination and may contribute to surface water contamination if the contaminated ground water is not successfully captured and treated or hydraulically prevented from entering surface water.

  Additionally, there are substantial deposits of tailings along the historic upper Silver Bow Creek corridor. Some of these include the Parrot Tailings, Diggings East, and the Northside Tailings which are sources of ground water contamination. EPA's position is that most contaminated ground water, which formerly discharged directly into Silver Bow Creek is now captured and pumped to the LAO for treatment.

- Mine Waste in Bank Deposits and Bed Sediments. Another source of metals contamination is mine waste in bank deposits and bed sediments upstream of previously reclaimed reaches of Silver Bow Creek. Because Silver Bow Creek was the closest water source to the mines on the Butte Hill, numerous milling and smelting plants were constructed along the creek for easy disposal of mine waste. Most of these contaminated sediments located in LAO were removed during the LAO reclamation phase. Bank sediments and floodplain deposits near the confluence of the upper Silver Bow Creek channel and Blacktail Creek were removed during the BPSOU Silver Bow Creek Stream Bank Reclamation Project in 2010 to 2011. The streambed sediments in the confluence area remain in place.

However, the reach between upper Silver Bow Creek and SS-05A (also known as the "slag canyon"), and the berm area located just upstream of the confluence area remain unreclaimed. During seasonal normal high flows, bed sediments in portions of this reach are likely entrained and transported downstream.

In addition to the primary sources discussed above, sediments that have been in contact with low quality water in the past may contain metals adsorbed onto the surfaces of the grains. A recent sediment sampling event (TREC 2010) has shown that metals concentrations are consistently higher in the fine-grained fractions, which strongly suggests that the metals are adsorbed.

- Other Upstream Sources. The primary source of flow in Silver Bow Creek is inflow from Blacktail Creek. Elevated copper concentrations in Blacktail Creek during normal high flow conditions indicate that there may be contaminant sources or urban runoff effects upstream of the BPSOU. Base flow water quality entering the BPSOU from upstream rarely exceeds chronic water quality standards.

2.1.2 Pathways

During normal flow conditions, the following pathways for contaminant sources exist (see Figure 2-1):

- Mine Waste to Ground Water to Surface Water. The unremediated area between the upper Silver Bow Creek and LAO includes the former BRW and the slag canyon. Subsurface waste materials in the area remain in contact with and are a source of contamination to the alluvial ground water system. Since the alluvial ground water is contaminated, the responsible parties are required to collect and convey ground water to the BTL via an interceptor trench. However, sampling demonstrated that some of this contaminated ground water was entering Silver Bow Creek upstream of LAO. Investigation of this source in 2008 and 2009 identified seepage of highly contaminated ground water to surface water in the BRW area. Remedial action to address this pathway included extension of the Hydraulic Control Channel (HCC) and construction of ground water collection features in the BRW area from 2011 to 2012. Ongoing monitoring will evaluate if additional sources remain in this area.

  The unreclaimed slag canyon reach of Silver Bow Creek (immediately upstream of BRW) has been classified as a transitional reach of Silver Bow Creek. This means the reach can be gaining ground water or losing ground water, or doing neither. These conditions can change seasonally. Mine waste deposits are present underneath the slag walls, which parallel and contain Silver Bow Creek and, as ground water passes through the mine waste deposits, it becomes contaminated. The BRW ponds and the extended BRW control channel are intended to capture this groundwater and limit groundwater gain to surface water in the slag canyon area. Ongoing monitoring will evaluate if the BRW ponds and channel extension are effective.

  Contaminated groundwater may pass through bed sediments and metals may attenuate resulting in contaminated sediments. This pathway has not been confirmed.

- Contaminated Sediments to Surface Water. Stream reaches from the mouth of Grove Gulch Creek to Station SS-05A contain contaminated sediments within the banks and stream bed. During base flow, deposits of metals-impacted sediment can act as a continuing source of metals, especially in areas where the stream is gaining ground water through the banks and bottom of the stream channel. The water passes through the impacted sediments, leaches metals and enters the water column (surface water flow in the stream). During normal high flow, contaminated bank deposits and stream bed sediments are resuspended increasing total recoverable metals concentrations. Resuspension also exposes sediment grains allowing adsorbed metals to desorb into the water increasing dissolved metals concentrations.

  A remedial action which removed contaminated materials was completed in 2010 to 2011 to address contaminated soil along the streambank at the confluence of Blacktail Creek and upper Silver Bow Creek. This is expected to address a potential source of metals loading to surface water in this area, however bed and bank material remain in the Blacktail Berm area. Ongoing monitoring will evaluate if additional sources remain.

2.2 Wet Weather Flow Conceptual Site Model

2.2.1 Sources

The CSM for mine waste contamination of wet weather flow is similar to that discussed above for normal flows; however, different sources of mine waste become pertinent during a wet weather flow event (See Figure 2-2).

Mine waste prevails in two major types: dumps and impoundments; and historic pipe bedding and backfill material used throughout Butte. All of the known sample locations of source areas where lead or arsenic exceeded solid media action levels for human health have been reclaimed or otherwise addressed by previous response actions. Additionally, most of the areas that contained elevated levels of copper and zinc were also reclaimed. Run-off from ubiquitous mine waste contamination continues to cause elevated metal and arsenic contamination in storm water or snowmelt events. However, soil and/or sediments containing concentrations of COCs below the human health action level may still be a loading source to surface runoff and can be mobilized during wet weather events.

The storm water infrastructure in Butte was historically constructed using conveniently available materials which tended to be waste rock. While some infrastructure has been addressed along trunk lines, an extensive network of laterals remains as a possible source of metals due to waste rock in pipe bedding or deposition of salts containing metals as a result of inflow of contaminated ground water. There are continued contributions from drainages in the BPSOU during runoff events that indicate further action is warranted under the BMP program.

Another metals source to Silver Bow Creek during wet weather events is from surface water entering the BPSOU from upstream as described above. Upstream sources of contamination, if determined to be mining-related, would be addressed in the West Side Soils OU. The West Side Soils OU has not yet undergone a remedial investigation (RI), feasibility study (FS), or had a ROD completed to evaluate and control sources of contamination.

2.2.2 Pathways

During wet weather flow conditions, the following pathways for contaminant sources exist (see Figure 2-2):

- Surface Runoff to Storm Sewer System to Silver Bow Creek. During wet weather flow events, surface water runoff may erode barren areas in the BPSOU, and mobilize sediments with potentially elevated metals concentrations. Sediment-laden surface water then enters the municipal storm sewer system through a variety of catchment mechanisms, eventually discharging to Silver Bow Creek. Initial BMP actions, such as source area capping, the curb and gutter program, catch basin improvements, hydrodynamic devices (HDDs), and the initiation of sediment removal in the storm sewer system on a periodic base, have begun to address this pathway.

- Storm Sewer System to Silver Bow Creek. Historically, mine waste and contaminated soils were readily available for use as pipe bedding, backfill for roads, foundations, and subsurface components of the storm water system. The deterioration of the storm water infrastructure allows for contaminated mine waste to enter into the tunnels and pipes. Additionally, water seepage through contaminated mine waste causes accumulation of evaporative metals salts within the storm drain infrastructure. During wet weather flow events, the accumulated sediments and salts are mobilized and transported to Silver Bow Creek. BSB has developed and begun implementing an important storm water system assessment and improvement plan. EPA and Montana DEQ (MDEQ) will work with BSB to ensure continued analysis and implementation of the plan. Also, as noted above, maintaining the storm water system sediment cleanouts on a periodic basis and the addition of hydraulic control devices on storm water outlets were identified and implemented as BMPs under the CERCLA BMP development program. Other BMP actions for the storm water conveyance system may be identified in the future.

- Upstream Sources to Storm Water to Silver Bow Creek. During wet weather flow events, storm water contained in Blacktail Creek above SS-01 shows elevated levels of total and dissolved metals. This potential contamination is occurring before entering the BPSOU. The causes of elevated metals in surface water upstream of the BPSOU await further investigation.

Section 3

Remedial Activities and System Operations Affecting Surface Water

This section discusses operations and remedial actions that have potential to affect surface water quality and quantity. As shown in Figure 3-1, a timeline was developed to illustrate operational changes and remedial activities, as well as to support evaluation of data. As shown in Figure 3-2, copper, cadmium, and zinc compliance ratios are presented to illustrate changes in concentration versus remedial activities.

3.1 Ground Water Capture System

Ground water capture was ongoing during the 2008 to 2013 period at both the LAO and MSD systems. Upgrades to both systems were implemented that improved water handling, and had minor effects on water collection and treatment. The extension of ground water collection to the east boundary of the BRW area was a significant change in ground water collection that led to an immediate and significant improvement to surface water quality. Actions that potentially affected surface water quality, temporarily or permanently, are discussed below.

The components of the ground water capture system include the following:

- HCC
- BPSOU Subdrain
- BRW Ponds

A map showing the locations of the ground water control systems is provided in Figure 3-3.

3.1.1 Hydraulic Control Channel

The HCC was constructed between 1996 and 1998 as part of the Colorado Tailings ERA which included waste removal and floodplain reconstruction within LAO. Approximately 1.2 million yd^3 of tailings and contaminated soils were removed from LAO, replaced with clean borrow, and revegetated (EPA 2006). Waste was left in place beneath the BSB water treatment plant along the northern border of LAO, adjacent to the slag walls, and beneath the excavation limits, which necessitated the use of hydraulic and engineering controls to address flow of contaminated ground water into Silver Bow Creek.

The channel of Silver Bow Creek was reconstructed at a higher elevation, and the HCC was installed to minimize or prevent contaminated ground water from flowing into Silver Bow Creek. The HCC consists of a 4,900-foot long unlined trench, which parallels Silver Bow Creek, extending from the downgradient end of Slag Canyon to the Interstate 15/90 overpass at the western end of the BPSOU boundary. The HCC and the reconstruction of Silver Bow Creek at a higher elevation were designed to provide a gradient that results in ground water flow into the HCC trench and away from Silver Bow Creek. The water from the HCC is treated at the BTL using a lime addition process and discharged to

Silver Bow Creek. The BTL consists of an operations building, a lime addition system, concrete distribution channels, and a series of ponds or cells separated by dikes. Two of the cells adjacent to Silver Bow Creek (D2 and D3) and one at the end of the HCC (D4) function as additional ground water collection points to supplement the HCC.

3.1.2 BPSOU Subdrain Operations

The BPSOU subdrain was constructed between 2004 and 2005 directly beneath the upper Silver Bow Creek channel to capture contaminated ground water that was previously entering the upper Silver Bow Creek channel and discharging into Silver Bow Creek below the confluence of Blacktail Creek (BTC) and upper Silver Bow Creek. The subdrain extends from the eastern portion of the Civic Center parking lot to just past Kaw Avenue near the Butte Visitor's Center. The system was installed during reconstruction of the upper Silver Bow Creek channel and consists of a buried perforated 8-inch polyvinyl chloride (PVC) pipe set in a bed of gravel. The gravel is overlain by a geosynthetic filter fabric, bedding material and a geosynthetic clay liner, and additional gravel. The system was designed to separate the ground water from the surface water within the channel using both barriers and hydraulic control. Several cleanouts and five manholes were installed within the subdrain. The manholes are used as locations to measure flow, collect samples, and perform maintenance on the system. The water collected within the subdrain reports to a pump vault where the water is conveyed to the HCC via a pipeline and treated at the BTL. The BTL was expanded during the winter of 2004 and 2005 to accommodate the additional flow.

The ROD required that the COC loads entering the subdrain be measured once per year during the fall to assess the effectiveness of the capture (EPA 2006). Flows were measured in March 2005 and September 2009 using a Marsh-McBirney flow meter and a fluorescent dye tracer study, respectively. The quality of the flow measurements using the fluorescent dye test were found to be inadequate, and an Explanation of Significant Differences (ESD) was prepared that changed the flow measurement method from dye tracers to dedicated flumes within a series of manholes (EPA 2011). Four manholes were installed between 2009 and 2010 (for a total of five) to replace the cleanouts. Flow was measured in November 2011 using a combination of dedicated flumes and flow meters. The loads collected by the subdrain are summarized in Table 3-1 for arsenic, cadmium, copper, iron, lead, and zinc. This data was reported in the 2013 BTL Operations & Maintenance (O&M) report pertaining to discharge into the HCC.

Table 3-1 BPSOU Subdrain Average Annual Load - 2013

Total Recoverable Arsenic	0.029	lb/day
Total Recoverable Cadmium	0.22	lb/day
Total Recoverable Copper	13	lb/day
Total Recoverable Iron	84	lb/day
Total Recoverable Lead	0.012	lb/day
Total Recoverable Zinc	51	lb/day

lb/day = pound per day
Source: Atlantic Richfield 2015. Final 2013 Metro Storm Drain Subdrain Loading Study Data Summary Report. August 4, 2015.

The effects of installation of the BPSOU subdrain on the quality of Silver Bow Creek were discussed on the 2008 Surface Water Characterization report (EPA 2008). Arsenic, cadmium, copper, lead, and zinc concentrations decreased in Silver Bow Creek following installation of the BPSOU subdrain.

3.1.3 BPSOU Subdrain Pump Station Construction

The original BPSOU subdrain system was completed in 2005 to prevent contaminated ground water from entering the Upper Silver Bow Creek surface water channel and to collect contaminated ground water. Water collected in the BPSOU subdrain flows into a concrete wet well.

The original system relied on submersible pumps located in the wet well to pump the collected water to the HCC via an 8-inch diameter high density polyethylene (HDPE) pipeline. Ongoing problems with the submersible pumps, due largely to the corrosive nature of the captured ground water, led to the design and construction of a dry pit vault to house new pumps.

The 2010 *Ground Water Data Analysis Report* (EPA 2012) demonstrated that if water levels were allowed to rise above the pump vault inlet pipe invert, an increased amount of contaminated ground water would be released downgradient into the upper Silver Bow Creek channel and then into Silver Bow Creek at the confluence of upper Silver Bow Creek and BTC (see Figure 3-4 as reproduced from 2010 Ground Water Data Analysis Report).

In 2008, a new dry well pump vault was constructed. The pumps were designed to maintain the water level in the wet well below the inlet pipe invert elevation. Operational problems with the new pumps began almost immediately and required the use of an auxiliary pump in addition to the new pumps to maintain the water level in the wet well below the invert. The 2010 Ground Water Characterization Report (EPA 2012) indicated that this operational change resulted in significant decreases in cadmium and zinc concentrations in surface water exiting the upper Silver Bow Creek channel at monitoring station Silver Bow Creek-OUT. This, in turn, resulted in reducing cadmium and zinc loading to Silver Bow Creek to a point of not being detectable in samples collected in Silver Bow Creek upstream and downstream of the confluence with BTC (EPA 2012).

As a result of continued operating inefficiencies, it was determined that the discharge line was partially restricted and needed to be cleaned. On November 29, 2011, 3,400 feet of 8-inch HDPE BPSOU subdrain discharge pipeline was cleaned between the BPSOU subdrain and BTL. Prior to cleaning, an emergency surface line (ESL) was constructed in case the primary discharge line became totally plugged during the cleaning process. Cleaning involved using water pressure to force a soft swab and a small plug, or "pig," through the pipe repeatedly. The pig and swab were designed to remove buildup off the interior pipe wall. The pig size was increased incrementally with each successive pass until the line is determined to be clean.

After the pipeline was cleaned, the dry well pumps performed as designed, and the auxiliary pump was taken offline. It was clear that buildup on the interior pipe walls created enough flow resistance to prevent the dry well pumps from performing properly. In 2013, provisions for regular scheduled cleaning were made by installing a permanent pig launcher and a dedicated flushing system immediately downstream of the upper Silver Bow Creek. Current protocol requires the line to be cleaned two times each year (April-May and October-November) based on the most reliable indicator of flow rate measured at the BPSOU subdrain vault. In 2014, proposals for jetting the BPSOU subdrain were approved by EPA and DEQ, and are now required. In addition, a second discharge line was installed in 2014 to 2015. This second line adds redundancy and reliability to the system.

Maintaining the water level below the invert elevation of the wet well influent pipe is considered critical by the EPA to prevent contaminated ground water from bypassing the BPSOU subdrain capture system. Water in the wet vault must be maintained below the invert of the inlet pipe. Safeguards are in place to assure that the water level is maintained below the invert elevation.

3.1.4 Lower Area One Operations

Originally constructed in 1997 as a 100 gallons per minute (gpm) pilot test, and expanded multiple times for additional pilot testing, the BTL are designed to remove metals from ground water using a lime precipitation process. Adding lime raises the pH, and at higher pH, metals in the water form insoluble precipitates that settle as the water flows through a series of ponds. Originally, the BTL system was designed to treat ground water flowing into the HCC. The BTL system capacity was expanded to 450 gpm in 2001 to treat water from the abandoned West Camp mine workings. In 2005, the treatment system capacity was increased again to accept water from the newly constructed BPSOU subdrain ground water capture system. This expansion was designed to treat 1,000 gpm routine flow and a peak flow of 1,500 gpm.

Ground water from the HCC and BRW Pond extension and the rest of LAO, BPSOU subdrain, West Camp, and Missoula Gulch normal flow are routed to the D4 cell and pumped to the chemical addition system (CAS) building where the lime is added. As additional sources were added to the BTL system, the influent pumping system at D4 was no longer able to keep up, so two small auxiliary pumps (HCC-02A and HCC-02B) were installed to pump directly from the HCC into the distribution tank at the CAS.

Additional BTL upgrades were made in 2012 and 2013. Phase I work was completed between the fall of 2012 and the spring of 2013 and included construction of a new influent pump station, two new pipelines between the pump station and the CAS building, and a new effluent sampling building. The new pump station was placed online April 24, 2013, and HCC-02A and HCC-02B were taken offline.

Phase II work included construction of a new operations building, a new dredge storage building, expansion of the CAS building, pond embankment modifications, pond outlet structure repairs, and a major supervisory control and data acquisition (SCADA) upgrade.

During influent pump station construction, pond D4 was dewatered from the fall of 2012 through the spring of 2013. To work on pond A1, B1, and C1 embankment modifications, and other pond outlet structures, dewatering of individual treatment ponds was required. The dewatering reduced treatment capacity and affected BTL performance. The agencies issued a temporary construction waiver of certain discharge standards during the construction period so this work could be accomplished.

Impacts from BTL effluent on water quality in Silver Bow Creek during construction included exceedances of water quality standards, which was not unexpected. According to the *Draft Annual Operations and Maintenance Report Butte Treatment Lagoon System – 2013 Butte Priority Soils Operable Units (BPSOU)* (AR 2014b), exceedances of DEQ-7 water quality standards were observed in the BTL effluent samples for arsenic, cadmium, and copper. In 2013, exceedance of the arsenic standard occurred 22 times, all in the 6-month period of May through November. Cadmium concentration exceeded the chronic standard three times, on January 21, May 23, and June 27. Copper exceeded the standard four times in 2013, on January 17, September 19, 23, and 26. Copper exceedances followed increased influent copper concentrations and increased flows. By contrast, no exceedances were reported in 2012, and only one copper exceedance was reported in 2011. In 2010, five copper exceedances and one mercury exceedance were reported.

In 2012, the annual volume treated in the BTL was 644 million gallons. In 2013, the annual volume treated in the BTL was 606 million gallons, approximately 6% less than the previous year. The decrease was likely due to the West Camp Critical Water Level study (MBMG 2014a), which shut down the WCP-1 pumps between July 7, 2013 and September 17, 2013. WCP-1 typically pumps between 100 and 200 gpm.

The reduction in WCP-1 flow was partially offset by additional flow to the BTL from dewatering at the Butte Silver Bow Wastewater Treatment Plant (see Section 3.1.6).

3.1.5 Butte Reduction Works Remediation

The BRW ponds were created during tailings removal activities, which occurred in the late 1990s. There are three ponds: BRW-01 West, BRW-01 East, and BRW-00. The ponds were deepened in 2010-2011 and are used for ground water collection which is discharged into the HCC. BRW-00 pond was extended to the east to capture local contaminated ground water that was entering Silver Bow Creek and causing exceedances of copper. The BRW-00 upgrade represents an extension of the HCC system and is an important hydraulic control on the west end of the slag canyon.

Monitoring of surface water within Silver Bow Creek in 2007 and 2008 revealed a significant increase in normal flow copper loading within the relatively short distance between monitoring stations SS-05.7 and SS-05.9, in the eastern portion of the BRW area. In August 2008, AR prepared a work plan (AR 2008) to investigate how manipulating local ground water levels and stream stage affects copper concentrations within Silver Bow Creek. Previous water level data within wells north of the stream (BPS-07-09A, GS-13A, and GS-13B) suggested that the ground water level was potentially higher than the level of Silver Bow Creek, which would result in the creek gaining ground water at this location. During the investigation several potential sources of copper were identified, including tailings and other mine wastes at the eastern edge of the BRW and beneath the slag walls and slag tunnel.

A ground water seep in the bed of Silver Bow Creek, referred to as the Slag Tunnel Seep, was located just west of the BSB asphalt plant access road and a few feet upstream of sampling station SS-05.7. Copper concentrations in the seep for samples taken in August 2008 ranged from 437 to 169,000 µg/L, depending on where along the path of the seep the sample was collected (Pioneer 2010a).

The study showed a relationship between the relative stage of the stream and the adjacent water table elevation, and total recoverable copper concentrations in Silver Bow Creek. When the stream stage was significantly higher than the ground water (due to plugging of the culverts and/or pumping from the dewatering wells) the copper concentrations in Silver Bow Creek were lower compared to the times where the ground water level was higher than the elevation of the stream. The study also concluded that there is a significant source of impacted ground water/mining waste near the BPS07-09A monitoring well.

A ground water interception pond was constructed on the east end of the site adjacent to the slag tunnel. Well BPS07-9A was located within the excavation footprint and had to be replaced by well BPS97-25. Approximately 1,270 yd^3 of mine waste was also removed during excavation activities. The interception pond conducts ground water to the BRW-00 pond via an 18-inch pipe. The regrading of the BRW-00 pond took place from November 4, 2010 through January 6, 2011. The BRW-00 pond and the adjacent BRW-01 East pond were graded to promote drainage into an outlet structure, which conducts water to the HCC (Pioneer 2012). A follow-up study (Pioneer 2012) using a replacement well (BPS07-25) showed that the interception pond effectively reversed the ground water gradient away from Silver Bow Creek, which eliminated the slag tunnel seep and any subsurface ground water flows into the creek.

3.1.6 Butte Silver Bow Waste Water Treatment Plant Dewatering

Dewatering has periodically occurred at the Butte Metro Sewer Treatment Plant from 2010 through 2016 Dewatering activities are related to construction of upgrades at the plant. Known dewatering periods (Morrison Maierle 2013) pertinent to this report are as follows:

- March through April 2010 (approximate)
- July 25 through October 24, 2010
- May 24 through June 5, 2013

It is not anticipated that the dewatering operation directly affected water quality or significantly affected flows.

3.2 Silver Bow Creek Stream Channel Remediation Project

As described in the *Final BPSOU Silver Bow Creek Stream Bank Reclamation Project Construction Completion Report* (AR 2012a), the Silver Bow Creek stream channel remediation project site is located within the city limits of Butte along Silver Bow and Blacktail Creeks. The site is bound to the south by George Street, to the west by Montana Street, and generally to the east by a pedestrian path. The north boundary of the project site is generally the north top of bank of Silver Bow Creek at its confluence with BTC. A portion of the Selected Remedy, as described in the BPSOU ROD (EPA 2006), Section 12.1.3 requires:

> *Excavation and removal to a repository of contaminated sediments from the stream bed, banks, and adjacent floodplain along Blacktail Creek and Silver Bow Creek, from just above the confluence of Blacktail Creek and* [upper Silver Bow Creek] *to the beginning of the reconstructed Silver Bow Creek floodplain at Lower Area One.*

The Silver Bow Creek Bank Reclamation RA consisted of the following components:

- Stream Bank Reclamation:
  - Areas of existing infrastructure, including structural improvements (bridges) and underground utility improvements: 12-inch maximum removal and riprap stabilization.
  - Other areas required entire stream embankment removal and reconstruction with clean fill.
- Floodplain Reclamation:
  - Areas of higher contamination required removal to a depth of approximately 2 feet, graded to drain, covered with clean soil, and seeded.
  - Areas of lower contamination required the area be graded to drain, covered with clean soil, and seeded.

Construction began October 2010 and was completed by May 2011. Approximately 3.3 acres of floodplain along with approximately 1,935 linear feet of stream bank were addressed as part of this project. In addition, 7,200 yd^3 of impacted soil were removed from the site.

This reclamation action addressed a portion of the ROD requirements by removing bank sediments between George Street and Montana Avenue. It did not address any bed sediments nor did it address bank sediments within the slag canyon or upstream of George Street. This partial action may have had an incremental effect on improving water quality during high flow conditions.

3.3 First, Second, and Third Cycle BMPs

As described in the BPSOU ROD (EPA 2006), the Surface Water Management Program employs an iterative process to achieve the ultimate goal of meeting surface water standards during storm events. Each cycle consists of installing BMPs, monitoring the drainages and BMP components, and then using the data to optimize the BMP components and/or evaluate the need for additional BMPs through loading analyses. After a cycle is completed, the results are evaluated to determine the progress made in achieving surface water standards during wet weather flows.

The selected remedy for surface water specified in the ROD included a surface water management program, which utilizes iterative BMPs to address contaminated storm water runoff and improve storm water quality. BMPs identified in the ROD included:

- Source controls
- Engineered sediment controls
- Curb and gutter
- Detention/retention basins
- Routing of storm water away from surface water bodies
- Removing source materials

3.3.1 Storm Sewer Cleanout

The 2009 Butte-Silver Bow Municipal Stormwater Improvements Plan (Morrison-Maierle 2009) recommended a number of maintenance and improvement projects intended to improve water quality in storm sewer effluent. This report led to development of a Sediment Removal Plan (WWC 2010a). Continuation of the cleanouts was required under the PRI Work Plan (EPA 2011). BSB will continue to clean out the storm drains in accordance with the 2014 O&M plan on an ongoing basis.

3.3.2 Storm Sewer Slip Lining

Buffalo Gulch slip lining was conducted in two phases. Phase I consisted of 3,800 feet of spiral wound PVC pipe being installed and grouted from Woolman Street to Porphyry Street. Construction of Phase I was completed in May 2012.

Phase II of Buffalo Gulch slip lining was initiated in October 2012 and was completed May 2013. Phase II included 3,166 feet of spiral wound PVC pipe grouted in place from Porphyry Street south to the new hydrodynamic device at Webster Garfield School.

The upper portion of the Anaconda Road/Butte Brewery trunk line, which reports to the Berkley Pit, was slip lined in 2011.

3.3.3 Curb and Gutter

The curb and gutter program was implemented to mitigate sediment loading to the existing BSB stormwater infrastructure and subsequently to Silver Bow Creek. The lack of curb and gutter and/or valley gutters, allows storm water runoff to erode both vegetated and barren areas throughout Butte. The sediment transported during this erosion can reduce the capacity of the municipal storm sewer system and can negatively impact water quality in Blacktail Creek and Silver Bow Creek.

Participants from the Agencies and PRPs traveled through the BPSOU block by block and determined where there was a need for curbs and gutters. The first phase of curb and gutter installation included 12 curb and gutter sites and 11 valley gutter sites. In general, the work performed under the Curb and Gutter Design Report (WWC 2010b) included saw cutting existing asphalt, preparing subgrade, construction of curb and gutter and valley gutters, adjusting existing storm water inlets, pouring concrete collars around existing storm water inlets, and placing asphalt patches to provide a transition from the newly constructed curb and gutter or valley gutter to the existing roadway. Lay downs for approaches, driveways, and future Americans with Disabilities Act ramps were placed as designed, or field fit where necessary, to accommodate traffic to and from the roadway. Work began in the fall of 2010 and was completed by the summer of 2012. The construction completion report (CCR) for the Phase 1 curb and gutter and valley gutter improvements provides additional details about this work (AR 2012b). A small curb and gutter project on Edison Street was completed in November 2012.

The second phase of curb and gutter installation included eight curb and gutter sites and 10 valley gutter sites. Additional storm water features, such as riprap channels and storm water inlet improvements, were also completed. Road base and asphalt was placed at all locations to tie the new features into the existing street. Work began April 29, 2013 and was completed by September 24, 2013. The CCR for the Phase 2 curb and gutter and valley gutter improvements provides additional details about this work (AR 2014c).

3.3.4 Hydrodynamic Device Installation

Storm water HDDs are storm water control systems designed to remove course grained sediment. A total of five HDDs were installed in 2012 and 2013 as described in the HDD work plans at the following locations: Warren Avenue (AR 2011b), Buffalo Gulch (AR 2012c), Anaconda Road (AR 2012d), Texas Avenue (AR 2012e), and Montana Street (AR 2012f).

All HDDs were installed and functionally completed in 2012 to 2013. Some minor landscaping or paving may remain, but does not affect water quality. The construction schedule for these HDDs was as follows:

- The Warren Avenue HDD was installed in January to February 2012.
- The Buffalo Gulch-Webster Garfield HDD was largely complete on June 14, 2012.
- The Anaconda Road HDD was completed on August 23, 2012.
- The Texas Avenue HDD construction started the week of July 30, 2012. Dewatering was required, but the effluent was directed into the BPSOU subdrain and did not affect surface water. Construction was essentially complete on December 14, 2012.
- The Montana Street HDD began construction January 28, 2013 and was functionally complete in April 2013.

- The location of the Front Street HDD is currently being redesigned and negotiated.

3.3.5 Source Area Controls

As described in the BPSOU ROD (EPA 2006), contaminated solid media located in non-residential areas at the BPSOU are defined as source areas and include waste rock piles, milling waste, smelter waste, and contaminated soils. The following sections describe source area controls completed from 2008 through 2013 in the BPSOU.

3.3.5.1 Third Cycle Best Management Practices for Source Areas

Sediment Basins

As described in the *Draft Final Third Cycle Best Management Practices Source Areas Sediment Basins Construction Completion Report* (AR 2012g), the Sediment Basins project consisted of installing concrete sediment structures immediately upstream of existing storm water inlet structures and storm channel reconstruction at the following locations:

- Site 3S Montana Street and Virginia Bridge
- Site 2S Intersection of Boardman and Sutter Streets
- Site 5S West of Virginia Street
- Site 14S South of Warren Avenue

The Montana Street and Virginia Street Bridge (3S) is located immediately north of the Virginia Street Bridge on the east side of Montana Street. The intersection of Boardman and Sutter Streets (2S) is located at the head of the Buffalo Gulch drainage immediately north of the walking trail. The West of Virginia Street (5S) is located in the Missoula Gulch drainage northeast of the Anselmo Yard. The South of Warren Avenue (14S) is located northeast of the Civic Center parking lot on an existing storm drainage that flows into the upper Silver Bow Creek.

The objectives of the Sediment Basin work were as follows:

- Mitigate sediment loading into existing storm water infrastructure
- Mitigate soil erosion
- Provide a sediment storage device that is easily maintained
- Comply with unilateral administrative order (UAO) directives

The work was intended to catch sediments in a sediment structure prior to their discharge into the existing storm water inlets and subsequent release into Silver Bow Creek. This work involved excavating and pouring the concrete structures in place, grading the area to direct flows into the structure, and constructing rock-lined storm channels to reduce velocities and prevent soil erosion. No concrete structure was installed at site 3S.

Construction activities associated with the Sediment Basins started on November 16, 2011, and major construction activities were substantially completed by February 9, 2012 as shown on Figure 3-1.

1S Agate Street
As described in *Final Third Cycle Best Management Practices Source Areas 1S Agate Street Construction Completion Report* (AR 2012h*)*, the project area is located on the north side of the City of Butte, Montana. The Agate Street section allows storm water runoff, and the associated sediments, to flow down a revegetated area to the south of the existing roadway. The runoff was cause for concern due to the possibility of erosion and sediment loading to the existing storm water infrastructure. This work was performed in tandem with a curb and gutter project. The curb and gutter work directed the storm water runoff down the roadway (Agate Street). The 1S Agate Street project captured the storm water in a newly installed drop inlet at the end of the curb and gutter section in order to direct the runoff north to the new sediment trap and through a new storm sewer main under Agate Street. Area grading also directed existing surface flows to the new sediment trap for sediment removal prior to discharge to the existing storm water infrastructure. The installed storm main crosses a recently installed city water main. This work involved removing and installing pavement, installing storm pipe and pre-cast concrete structures, constructing a storm channel, and site grading.

Construction activities associated with the 1S Agate Street construction work started on October 26, 2011 and major construction activities were substantially complete by May 7, 2012 as shown on Figure 3-1. As part of source area controls, the Agate Street project performed the work necessary to mitigate sediment loading at the head of the Buffalo Gulch drainage. The work was performed to catch sediments in a sediment trap prior to their discharge into the existing storm water infrastructure and subsequent release into Silver Bow Creek.

Shields Avenue Overpass
As described in the *Final Third Cycle Best Management Practices Source Areas Shields Avenue Overpass Construction Completion Report* (AR 2012i), the Shields Avenue Overpass Project is located in the north-central side of the City of Butte, Montana. The overpass, which crosses a railroad line, is located approximately ¼ mile north of the transition of Farrell Street into Shields Avenue. The areas to the east and west of the project location had been previously reclaimed. The existing base topography, at the transition from the flats to the uptown areas, consisted of fairly level terrain with the overpass built up above existing ground. The north facing slope was steep, eroding, and terminated along the railroad right-of-way. The work included debris removal, soil excavation and backfill, cover soil installation, geotechnical fabric installation, riprap installation, fertilizing and seeding operations, hydro-mulching, liming operations, and storm water control construction. Construction activities began on May 3, 2012 and were completed by June 1, 2012 as shown on Figure 3-1.

8S Idaho Drainage
As described in *Final Third Cycle Best Management Practices Phase II Source Controls Site 8S Idaho Construction Completion Report* (AR 2014d), the Source Controls Site 8S Idaho Drainage is located west of Montana Street and approximately 380 feet northwest from the Montana and 2nd Street intersection. The previous drainage system consisted of a 36-inch reinforced concrete pipe (RCP) culvert outfall into an unimproved channel flowing to the south before turning sharply to the west. Immediately after the western turn, the channel flowed on the north side of an existing building before flattening out prior to discharging into Catch Basin-9 (CB-9). The back of the existing building was one wall of the channel. The existing 36-inch RCP outflow pipe was blocked by sediment to approximately ½ of the pipe's diameter. There was no clear flow path for approximately 600 feet of the existing channel west of the existing building due to the level terrain. Access to the area was denied by the property owner so a viable survey was not conducted to determine the exact grades and the amount of sediment deposition in the previous channel. In order to move the wet weather flows

away from the building and to prevent sediment deposition, a dual 30-inch HDPE storm main was installed at a minimum 1% slope along the south boundary of the RARUS/Patriot right-of-way. The installed pipes and manholes divert wet weather flows via a new inlet structure placed on the existing 36-inch RCP and routed approximately 1,900 feet west to a constructed riprap outfall immediately above CB-9. Dual 36-inch HDPE culverts were placed immediately above CB-9 to cross a previously constructed maintenance access road. The original channel at the 36-inch outfall remains in place to provide a spillway channel should wet weather flows exceed the estimated 90.6 cubic feet per second (cfs) 25-year design event. The 36-inch RCP was cleaned out as part of the construction activities. All excess material generated from storm pipe trench excavation was placed along the south slope of the alignment and reclaimed with cap and cover. Construction began at the constructed outfall and proceeded toward the installed inlet to prevent wet weather flows from entering the infrastructure during construction.

Construction activities associated with the Source Controls Site 8S Idaho Drainage started on July 31, 2012 and major construction activities were substantially completed by January 2, 2013 as shown on Figure 3-1. Seeding/revegetating was completed on May 6, 2013.

Phase II Source Controls
As described in the *Final Third Cycle Best Management Practices Phase II Source Controls Construction Completion Report* (AR 2014e), the Phase II Source Controls project consisted of six separate source area control sites within the Butte, Montana area. Site remediation was completed by using various measures such as installing storm water drop inlets, storm pipe, manholes, removing and installing pavement, site grading, cap and cover operations, fertilizing and seeding, riprap structures, and constructing storm water channels. The site locations include the following:

- 4S Alley near Copper and Alaska Streets
- 6S Franklin Street
- 9S Nevada Avenue
- 12S upper Silver Bow Creek (originally MSD) north of Shields
- 15S Civic Center Parking Lot
- New and Mahoney
- Main and Bufallo-2013-2014
- South Parrot 2014
- Upper Missoula Gulch 2013-2014
- Ophir Mine Yard 2013-2014
- Colorado Smelter 2014

Construction activities associated with the Phase II Source Controls started on September 17, 2012, and major construction activities were substantially completed by June 3, 2013 as shown (by individual site) on Figure 3-1.

3.3.5.2 LAO East End Culvert Removal and Low Flow Channel Crossing Removal

As described in the *Final Lower Area One East End Culvert Removal and Low Flow Channel Crossing Removal Construction Completion Report* (AR 2012j), the East End Culvert Removal began on March 5, 2012 (see Figure 3-1) with the construction of the upstream and downstream diversion structures and installation of the dewatering system. The East End Culvert Removal work included removing in-stream sediment, excavating the crossing material and removing the culverts, and planting vegetation in the disturbed areas. Riprap and overburden were removed from the sides and top of the two southern culverts and stockpiled in the BRW area. The two exposed corrugated metal pipe (CMP) culverts were removed and hauled to the BRW area prior to disposal. The excavated floodplain and streambank were shaped to match the existing upstream and downstream contours.

The Low Flow Channel Culvert Removal began on March 21, 2012 (see Figure 3-1) with the construction of the new crossing for the BPSOU subdrain discharge ESL. Work for the Low Flow Channel Crossing Removal included constructing a temporary crossing structure across Silver Bow Creek for the ESL, relocating the ESL to utilize the new crossing, removing the crossing materials and culverts, and planting vegetation in the disturbed areas. Similar to the East End Culvert Removal, riprap and overburden were removed from the sides and top of the two northern and southern culverts and stockpiled in the BRW area. The exposed CMP and concrete culverts were removed and hauled to the BRW area for decontamination prior to disposal. The excavated floodplain and streambank were shaped to match the existing upstream and downstream contours. The ESL crossing was constructed using two 40-foot W 14X22 I-beams, spaced 18 inches apart, and connected laterally by welding 3-inch steel angle iron placed every 5 feet along the beams. This structure was placed on the concrete jersey barrier on each bank of Silver Bow Creek and bolted in place. The ESL was disassembled and reconstructed along the new alignment. A trench was excavated through the Flood Control Dike to allow the ESL to reach the HCC.

Section 4
Surface Water Quality Data

This section summarizes the available surface water data and reports that were generated since 2008 that reflect surface water quality and surface water quality influences in Silver Bow and Blacktail Creeks in or near the BPSOU.

Surface water quality data have been collected and analyzed in accordance with the 2007 Surface Water IMP (AR 2007). In addition, other surface water quality data have been collected and analyzed under the USGS Clark Fork Lang-Term Monitoring Project (USGS 2009), and under the Streamside Tailings Operable Unit sampling plan (Naughton *et al*., 2014). Surface water data are currently being collected and analyzed in accordance with the 2013 version of the IMP (AR 2013a). To the extent newly collected data are available and can be considered, they may be included in this report. The following sections summarize the objectives of the 2007 interim surface water monitoring plan and provide a description of the water quality data set used in this report. Section 12 describes comparisons to the USGS and Streamside Tailings Operable Unit data.

4.1 Interim Surface Water Monitoring Plan

The 2007 IMP (AR 2007) was prepared to identify and describe post-RI and ROD surface water monitoring at BPSOU for wet weather and normal flow conditions. Among other reasons, monitoring is performed in order to collect data that are usable to determine if additional BMPs, remedial actions, or other alternatives (normal flow or wet weather flow-related) are necessary to protect water quality in Silver Bow Creek. The data collected through the 2007 IMP as modified in 2013 will continue to be used to identify COC source locations where BMPs, remedial actions, or other alternatives can be implemented as well as establish a basis for future monitoring.

The 2007 IMP identifies the data collection locations and establishes data quality objectives (DQOs) to ensure that collected data will be comparable to and compatible with historical data and useable for the BMP approach to wet weather water management. The IMP is intended to present the main concepts and details of the monitoring events (schedule, station locations, types of samplers, and analytical parameters).

The 2007 IMP has been an evolving document that will eventually become a finalized long-term surface water monitoring plan for the Butte Site. A revision to the 2007 IMP was developed for 2013 (draft 2013 IMP) (AR 2013a) and was used for sampling in that year.

4.2 Interim Surface Water Monitoring Plan Data

The surface water quality data are currently managed and maintained by AR on behalf of the PRPs. A dataset distributed to EPA on April 9, 2014 from AR includes water quality results and discharge data collected by AR between January 1, 2008 and December 31, 2013. Historic data have been obtained previously and were presented in the preceding 2008 Surface Water Characterization Report (EPA 2008).

The surface water quality data for the COCs are presented in Sections 6 through 11 of this report. Note, mercury was not discussed in the compliance analysis and loading analysis sections due to data quality concerns; there is low confidence in any conclusions based on the mercury data. Sulfate and DOC were also reported as part of the surface water quality data set. As requested by MDEQ, these analytes have been presented for base flow and normal high flow conditions in this report and are further interpreted as part of the other relevant data discussion in Section 12.

To ensure data collected are of the quality required to support decisions regarding identification of source areas and implementation of BMPs, it is required that all sample analysis, quality assurance/quality control (QA/QC), data management/validation, reporting, and other related activities be performed in accordance with the 2007 IMP and pertinent sections of the following Clark Fork River Superfund Site Investigations (CFRSSI) regional control documents:

- CFRSSI Laboratory Analytical Protocol (LAP) (AR 1992a)
- CFRSSI Quality Assurance Project Plan (QAPP) (AR 1992b)
- CFRSSI Data Management/Data Validation Plan (DM/DVP) (AR 1992c)
- CFRSSI DM/DVP Addendum (AR 2000a)
- CFRSSI Standard Operating Procedures (SOPs)(AR 1992c)
- CFRSSI Pilot Data Summary Report for Organic and Inorganic Data (AR April 1993)
- CFRSSI Pilot Data Summary Report Addendum (AR 2000b)

For the purposes of this report, all surface water quality data collected under the 2007 IMP by AR are considered to have met the data quality objectives described above and are considered suitable for evaluation. Most of the data collected under the IMP meet the requirements for enforcement quality data and may be used for any Superfund purpose. Some of the data collected under the IMP only meet the requirements for screening quality data for a number of possible reasons, including spike recoveries out of control limits or detection of COCs in blanks. These data are flagged appropriately and are used for general characterization, but not for comparison to standards or when the data may form the basis of a remedial decision. Other surface water quality data collected for purposes other than those in the IMP may or may not meet all of the QA requirements included above and are used within the context of the investigations under which they were collected.

Section 5

Other Relevant Data, Reports, and Studies

The following section describes other relevant water quality, sediment, and meteorological data, reports, and studies from other sources that are used in this report to supplement the surface water quality and flow data collected by AR on behalf of the PRPs as part of the 2007 IMP (AR 2007) and draft 2013 IMP (AR 2013a). Data collected under the IMP form the main body of data used in this characterization report, but data collected under various investigations for specific purposes can also be useful. The following sections list and describe these potentially useful investigations that have been conducted during the period of 2008 to 2013. Interpretation of the data is provided in Section 13.

There are several other reports were generated since 2008 (i.e., 2012 upper Silver Bow Creek (formerly MSD) loading studies, evaluation of ground water and surface water area between Silver Bow Creek, upper Silver Bow Creek and LAO, etc.) that are not related to surface water quality or have not been finalized , and therefore are not discussed.

5.1 Ground Water Reports and Studies

Three different ground water-related studies were conducted in 2011 to locate potential areas of ground water discharge to Blacktail and Silver Bow Creeks. These include:

- Radon Tracing – *2011 Radon Tracing Evaluation to Detect Upwelling Ground Water in Blacktail Creek and Silver Bow Creek During Base Flow Conditions* (AR 2012). This report details the use of radon tracing methodology to quantify and identify the location of ground water upwelling along Blacktail Creek and Silver Bow Creek. The study reach was between Harrison Avenue and SS-07.

- Thermal Imaging – *2011 Blacktail Creek and Silver Bow Creek Aerial Thermal Imaging Survey Technical Memorandum* (AR 2011c). This report details the use of aerial thermal imaging to compare temperature gradients within the surface water to identify ground water upwelling to Blacktail and Silver Bow Creeks.

- Bromide Tracing - *A continuous Tracer Injection Investigation Conducted during Baseflow Conditions* (MBMG 2014b). This report presents the data and analysis of a tracer dilution test conducted in Blacktail Creek for 1.5 miles upstream of George Street. The main purpose of the report was to identify sources of inflow to the stream at base flow and determine if COC loading sources exist in a specific reach.

5.2 Wet Weather Flow Data, Reports, and Studies

The following sections summarize wet weather flow-related data and reports.

5.2.1 Outfall and In-System Data

The Butte Hill Diagnostic Surface Water Monitoring Plan (DSWMP) (AR 2013b), a revision to the 2008 IMP, was prepared to identify and describe diagnostic surface water monitoring of wet weather conditions within the Butte Hill drainage basins that discharge to Blacktail Creek and Silver Bow

Creek. Water quality data collection began in 2013 (with some samples collected in 2012) to determine the concentrations, significance, and impact on the receiving waters, of COCs from individual Butte Hill drainage basins. As described in the DSWMP, the purpose of the plan was to establish a scientific and resource-effective data collection program that would support the evaluation of existing BMPs effectiveness, and to evaluate the need for additional BMPs. As required on CFRSSI projects, the DSWMP developed DQOs to ensure that collected data will be comparable to historic data, will be useable for wet weather management, and will be useful for evaluating of BMPs.

Similar to the DSWMP, storm water data were also collected in 2009, which included site-wide sampling and targeted sampling. The work was conducted in accordance with *Buffalo Gulch Stormwater Study Sampling and Analysis Plan, Butte Priority Soils Operable Unit, Silver Bow Creek/Butte Area Site, Butte, Montana* dated March 2009 (EPA 2009a) and Addendum #1 to the sampling and analysis plan (EPA 2009b). Site-wide sampling included collection of storm water samples at several outfalls not recently or previously sampled. Because previous data identified Buffalo Gulch as a major source of metals loading to surface water, the original SAP (EPA 2009a) targeted locations throughout Buffalo Gulch, including within the underground pipes. Subsequently, Addendum #1 (EPA 2009b) extended the scope of the storm water sampling to include all of the major urban subdrainages on the Butte Hill, including Warren Avenue, Anaconda Road/Butte Brewery, Upper Silver Bow Creek, Idaho Street, Montana Street, Missoula Gulch, and West Side. The purpose of the investigation was to:

- Better characterize the nature and magnitide of contaminant contributions from subdrainages throughout the Butte Hill
- Identify surface water sources of COCs within the storm water sewer system
- Determine if the rising limb is contributing most of the contamination or if contaminant loading is distributed over the entire storm hydrograph

5.2.2 Butte-Silver Bow Municipal Storm Water System Improvement Plan

In 2008, BSB developed a storm water improvement plan (BSB 2008) to provide infrastructure solutions to the municipal storm water collection system and to improve water quality in Silver Bow Creek by reducing pollutants contained in storm water discharges. Prior to this plan, BSB had not established design standards for its municipal storm water collection system. The report provides BSB a summary of the existing conditions of its storm water infrastructure, provides an updated geographic information system (GIS) mapping and field survey of the majority of storm water infrastructure within the BPSOU, and provides recommendations and cost estimates for redevelopment and reconstruction of the BPSOU storm water infrastructure.

5.2.3 Wet Weather Flow Hydraulic Modeling

The *Butte Stormwater Modeling Report* (CDM Smith 2010) summarizes the hydrologic and hydraulic analyses of wet weather flow within the BPSOU for several single event design storms. The analysis included performance of hydrologic and hydraulic analyses to predict hydrographs, peak flow rates, and maximum runoff volumes for the 2-, 5-, 10-, 25-, 50-, and 100-year 24-hour wet weather events for the 15 drainages basins study area. These predictions are used to determine the hydraulic capacity of the existing storm water system, identify potential BMPs, and prioritize storm water infrastructure improvements within the study area. The analyses presented in the storm water modeling report are based on the Natural Resource Conservation Service (NRCS), formerly the Soil Conservation Service (SCS), Unit Hydrograph Method and the NRCS Curve Number (CN) Method.

5.2.4 Drainage Basin and Underground Storm Sewer Maps

The original BPSOU watershed boundary, which includes 16 drainage basins, was established by EPA, MDEQ, and BSB. The Lower Railroad Yard drainage basin was excluded from the current 15 drainage basins because its runoff is contained within the drainage basin (see Figure 5-1).

As part of the *Butte Stormwater Modeling Report* (CDM Smith 2010), the original exterior drainage boundaries were slightly adjusted using 2-foot topographical contours, existing infrastructure, and aerial photography provided by the Butte-Silver Bow County GIS Department: with exception, Grove Gulch was adjusted/delineated using 30-foot contour interval maps. The aerial photography was used to establish the flow paths within the streets (curb and gutter) and storm water distribution system. Figure 5-2 through Figure 5-12 present the location of the subbasin boundaries, areas, and outlets of the 15 drainage areas. After the adjusted drainage basin boundaries were established, they were divided into subbasins. These subbasins were delineated by selecting an outlet point for each subbasin. The outlets were selected based on the flow paths and the connection points with other subbasins. In addition, these figures show the underground network of storm sewer piping that exists within each drainage basin. In general, surface water flow is conveyed into the underground storm water sewer system, sometimes passing through BMPs or other storm water control mechanisms. This system then conveys the flow towards a central outlet point(s) that ultimately discharges storm water to either Blacktail Creek or Silver Bow Creek.

Storm water sub-basins on the east side of upper Silver Bow Creek (e.g., the Texas Avenue drainage) are much more significant contributors to storm water contamination than has been previously realized. Sampling in these areas began after 2013 and is not included in this report.

5.2.5 Timing of Wet Weather Flow

The timing of flows from the east Butte Hill drainages (Buffalo Gulch and the MSD drainages) is important to understand in characterizing storm water in Silver Bow Creek. A diagnostic sampling component was added to the wet weather monitoring in 2013 (AR 2013a). The additional sampling will aid in understanding the timing of flows.

5.3 Streambed Sediment Sampling

The quality of the streambed sediment has potential impacts on both aquatic organisms and on surface water quality. The ROD states:

> *"Elevated arsenic and metals occur in stream-bed and bank sediments in Silver Bow Creek at concentrations that present significant risks to aquatic biota. These sediments are most notable within the slag canyon west of Montana Street and within the upper reaches of the Silver Bow Creek channel in Lower Area One and the lower reach of Blacktail Creek. The Selected Remedy will remove contaminated sediments from the stream channel bottom and stream banks, and adjacent floodplain from above the confluence through the slag canyon to the reconstructed floodplain in Lower Area One." (ROD Section 7.3)*

The excavations required in the ROD were specified in order to protect aquatic biota, but could also be beneficial to surface water quality. This was partially completed in 2010 to 2011 during the Silver Bow Creek Stream Bank Reclamation Project (AR 2012a) when contaminated bank sediments were removed between George Street and Montana Avenue. In 2010, prior to stream bank construction, TREC and AECOM collected sediment within the reaches of Silver Bow Creek and Blacktail creeks as specified in the ROD (TREC 2012a, TREC 2012b). The data were collected "to aid in evaluating the feasibility and effectiveness of removing sediment within the ROD-specified reach."

Sampling for the March 2010 event was conducted at 13 locations (B-1 through B-13) from the 0- to 6-inch interval. Two locations (B-5A and B-7A) were added, and the sample interval increased from 0 to 6 inches to 0 to 12 inches (where possible) during follow-up sampling by TREC in August 2010. Samples were sieved into three grain-size fractions; less than (<) 0.063 millimeters (mm), 0.063 to 1 mm, and 1 to 2 mm and analyzed for arsenic, cadmium, copper, lead, and zinc. Bulk concentrations were then calculated from the concentrations of metals in each fraction and the proportion of each size fraction in the samples.

5.4 USGS Discharge and Water Quality Data

As detailed below, there are three USGS monitoring stations along Silver Bow Creek/Blacktail Creek that are part of the Clark Fork Superfund data collection program. A summary of these data collected since 2008, is presented in Section 12. The annual water data report generated by USGS for each station is included as Appendix A.

5.4.1 Station 12323250 (SS-07)

USGS Station 12323250 is co-located with the most downstream point-of-compliance sampling location SS-07 in Silver Bow Creek, and is at the downstream boundary of the Operable Unit. Stage, discharge, and water quality data have been recorded at this location since October 1983. The USGS measures instantaneous discharge when collecting water quality samples, and at various times to keep the station stage-discharge curve current. Real time stage and discharge measurements are collected, of which the data are available on the USGS website.

5.4.2 Station 12323240 (SS-04)

USGS Station 12323240 is co-located with compliance sampling location SS-04 at the mouth of Blacktail Creek just upstream of the confluence with upper Silver Bow Creek. The station is approximately ½ mile downstream of the eastern Operable Unit boundary. Stage and discharge data have been recorded at this location since October 1988. This is not a current USGS water quality station. The USGS measures instantaneous discharge at various flow rates and times of the year to keep the station-discharge curve current. Real time stage and discharge measurements are collected, of which the data are available at the USGS website.

5.4.3 Station 12323230 (SS-01)

USGS Station 12323230 is co-located with sampling station SS-01 approximately one mile upstream of the Operable Unit boundary on Blacktail Creek. The USGS has been collecting water quality samples since April 1990, with a few interrupted periods. The USGS measures instantaneous discharge when collecting water quality samples. Real time stage and dischare measurments are not collected at this station.

5.5 Meteorological Data

The following sections provide an overview of the meteorological data (snow pack, precipitation) collected. A summary of this data is presented in Section 12.

5.5.1 SNOTEL Data

The NRCS installs, operates, and maintains an extensive, automated system to collect snowpack and related climatic data in the Western United States called SNOTEL. The Basin Creek SNOTEL station (station No. 315) is located approximately 14 miles south of Butte, Montana and 5 miles northwest of Table Mountain (Latitude 45 deg.; 48 min. N; Longitude 112 deg.; 31 min. W) in Silver Bow County. The station is west of the Continental Divide at approximately 7,180 feet above mean sea level (amsl). The Basin Creek Station has been recording snow depth data since June 9, 2003.

5.5.2 Precipitation Data

Meteorological data are currently collected from multiple sources and from multiple locations throughout the Butte valley. For the purposes of this report, precipitation data were compiled from weather stations on the Butte Hill to better represent wet weather events that would impact the BPSOU drainage basin, Blacktail Creek, and Silver Bow Creek. The following stations provide precipitation data:

- Montana Pole Treatment Plant (MTPOLE): Located at the Montana Pole Treatment Plant from October 2002 through December 16, 2012. This weather station is no longer in operation. During its operation, hourly precipitation data were collected using a Campbell Scientific with CR10X unheated data logger. Data were downloaded monthly from the equipment.

- Butte Silver Bow Shop (BSB Shop): Located at the Butte Silver Bow maintenance shop at 1700 Civic Center Road. Hourly precipitation and temperature data have been collected using a Davis Instruments Vantage Pro 2 since April 14, 2010 and have been downloaded monthly from the equipment.

- Catchbasin-1 (CB-1): Located at the Syndicate Pit/CB-1 Empire Street. Hourly precipitation and temperature data have been collected using a Davis Instruments Vantage Pro 2 since April 14, 2010 and have been downloaded monthly from the equipment.

- HKMR2: Located along Montana Street from September 5, 2003 to August 13, 2012. This station is no longer in operation. During its operation, hourly precipitation data were collected using a Met-1 type tipping bucket, unheated, 8-inch diameter, interfaced to Campbell Scientific 21X data logger. Data were downloaded towards the beginning of each quarter.

- HKMR3: Located near the Kelley Mine. Hourly precipitation data are collected using a Met-1 type tipping bucket, unheated, 8-inch diameter, interfaced to Campbell Scientific 21X data logger from August 17, 2012 to present. Data are downloaded towards the beginning of each quarter.

- BTL (BTL): Located at the BTL shop on Centennial Avenue. Six-minute precipitation, wind, barometric pressure, and temperature data have been collected using a Davis Instruments Vantage Pro 2 since January 18, 2013 and have been downloaded monthly from the equipment.

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Section 6

Base Flow Compliance Analysis

This section compares base flow data to numeric water quality standards at points of compliance along Silver Bow Creek and Blacktail Creek as required in the ROD; interpretation of this data is the focus of Section 12. As discussed in Section 1.6, the BPSOU RAOs require that surface water meet the more restrictive of chronic aquatic life or human health standards for surface water identified in Circular DEQ-7 through the application of B-1 class standards, and this section evaluates progress towards that requirement (ROD Section 8.3.1).

As described in Section 1.7, base flow conditions are defined as times when ground water inflow comprises the greatest percentage of flow within surface water. Surface water conditions vary seasonally, with base flow generally occurring in late summer and winter. Base flow also requires that surface water conditions are fairly stable - not rising or falling and no storm -water or snowmelt runoff is occurring. The main purpose of analyzing base flow surface water conditions is to evaluate the effects of ground water inflow on surface water. For compliance, metals concentrations at base flow are compared to the more restrictive of chronic aquatic and human health standards.

The BPSOU data set for mercury has data quality issues including, in some cases, too high of a reporting limit, lack of qualifiers, and/or similar or identical results for all samples in a sample delivery group. These issues need to be resolved before these data can be presented and analyzed and therefore are not presented in this report. Mercury data from an outside source (SSTOU) are presented and evaluated in Chapter 12.

As part of the review of the surface water data, non-COCs including sulfate and dissolved organic content data are presented and evaluated in Chapter 12.

6.1 In-Stream Compliance Stations

For base flow conditions, the following in-stream compliance stations were sampled and are presented in this section:

- SS-01 (Blacktail Creek at Harrison Avenue, USGS 123231230)
- SS-04 (Blacktail Creek above its confluence with Silver Bow Creek, USGS 12323240)
- SS-05 (Silver Bow Creek below its confluence with Blacktail Creek and Buffalo Gulch)
- SS-05A (Silver Bow Creek below “slag canyon”)
- SS-06A (Silver Bow Creek below new channel below Catch Basin 9)
- SS-06G (Silver Bow Creek below treatment lagoon effluent)
- SS-07 (Silver Bow Creek below wastewater treatment plant, USGS 12323250)
- GG-01 and GG-04 (Grove Gulch downstream of Lexington Avenue)

6.2 Compliance Analysis of Individual COCs

The ROD uses Circular DEQ-7 February 2006 for acute and chronic aquatic life standards as well as human health standards. The numeric standards of interest are presented in Table 1-1. Since the aquatic standards for most metals are variable based on hardness, presentation of the standards on charts and in statistics are not simple. Therefore, the comparison to the standards is presented as follows:

- Time-Based Comparisons. For time-based comparisons where a single point in time has a single COC concentration and a single calculated or static water quality standard adjusted for hardness, was presented.

- Statistical Comparisons. For statistical comparisons where multiple numeric standards are used in a calculation, a "compliance ratio" has been computed (COC concentration/compliance standard). When the COC concentration is equal to the calculated standard, the compliance ratio is 1. If the COC concentration is less than the standard, the compliance ratio will be less than 1. An exceedance of the standard results in a compliance ratio greater than 1.

Base flow results are compared to chronic standards (representative of a 4-day average of COC concentrations) and human health standards. Non-detected values were assumed to be equal to the detection limit in the statistical summaries. This has no effect on maximums, but, in some cases, the minimums reflect the detection limit rather than the minimum detected value. The remaining values, including quartiles and medians, are affected by this substitution. The degree to which these are affected depends on the number of non-detects in the sample set. For most sample sets, the number of non-detects is small and does not significantly affect the statistics. For mercury, in a few cases, the detection limit is greater than the standard used for comparison. This is clearly identified in the discussions.

A map showing the surface water sampling stations in the BPSOU is shown in Figure 6-1. Surface water standards are applicable only to those stations within Blacktail Creek, Silver Bow Creek and Grove Gulch.

6.2.1 Review of Compliance for Copper

Surface water station SS-07 is the farthest downstream point of compliance before Silver Bow Creek exits the OU and, historically, has had the worst water quality of any station on the perennial streams in the OU. Historic copper concentrations at SS-07 under all flow conditions from 1996 to December 2013 are shown in Figure 6-2. Since 2004, base and normal high flow copper concentrations have decreased. From 2006 through 2008, copper concentrations were fairly stable. Concentrations noticeably dropped at the beginning of 2011, especially for base and normal high flow dissolved copper. This decrease in copper concentrations correlates with the completion of remedial activities at the BRW Seep (as discussed in Section 3). From 2010 through 2013, total recoverable copper concentrations consistently have been lower on average than any other period since 1996. The lowest total recoverable copper concentration during base flow conditions at SS-07 was 8.8 µg/L on September 6, 2012.

Copper results, limited to base flow at SS-07, are shown in Figure 6-3. There is a considerable difference (often 50 percent or more) between dissolved and total recoverable copper concentrations, indicating that colloids or fine sediments containing copper are suspended in the surface water during base flow. From 2008 through January 2011 (construction completion to remediate the BRW Seep [see Section 3.1.5]), recoverable copper exceeded the chronic standard (55 percent exceedances);

whereas, from July 2011 through 2013, there were fewer total recoverable copper exceedances (45 percent).

The discharge of the sewage treatment plant (SS-STP) just upstream of SS-07 has a significant impact on water quality in Silver Bow Creek as observed with increased concentrations of copper at SS-07 compared to SS-06G. Copper concentrations at station SS-06G from 2008 to 2013 as shown in Figure 6-4. From 2008 through July 2011, total recoverable copper concentrations had an exceedance rate of 33 percent for the chronic standard. From July 2011 through 2013, total recoverable copper had no (0 percent) exceedances.

Base flow copper concentrations from 2008 to 2013 at SS-06A are shown in Figure 6-5. Similar to SS-06G, total recoverable copper is somewhat higher than dissolved. From 2008 through July 2011, total recoverable copper exceeded the chronic standard in 54 percent of the samples results; however, from July 2011 through 2013, total recoverable copper exceeded the chronic standard only once (9 percent).

Base flow copper concentrations from 2008 to 2013 at SS-05A are seen in Figure 6-6. Similar to SS-06G and SS-06A, total recoverable copper had several exceedances from 2008 through July 2011 (31 percent) but no exceedances since July 2011 (0 percent).

Base flow copper concentrations from 2008 to 2013 at SS-05 are seen in Figure 6-7. Total recoverable copper exceeded the chronic standard only twice, once on February 29, 2008 and once on December 16, 2010 (all before July 2011) for a rate of 15 percent. There have been no exceedances since July 2011. The primary sources upstream of SS-05 are Buffalo Gulch and upper Silver Bow Creek.

Base flow copper concentrations from 2008 to 2013 at SS-04 are shown in Figure 6-8. Total recoverable copper concentrations were typically below the chronic standard, with the exception of two sample result s. On December 16, 2010 and February 7, 2013, total recoverable concentrations exceeded the chronic standard. These exceedances occurred during winter months. Dissolved copper concentrations have been very stable since January 2008.

Station SS-01 is upstream of Grove Gulch and represents water quality entering the OU. Other than one exceedance of the criteria in 2008, all copper concentrations are well below the chronic standard. There is less separation between total recoverable and dissolved values, and the seasonal increase seen at other stations is less apparent at this station (see Figure 6-9).

A summary of exceedances of the chronic standard for copper in Blacktail and Silver Bow creeks prior to the BRW seep remediation (July 2011) are shown in Table 6-1. These data include only total recoverable copper as specified by DEQ-7. During this period, exceedances of the chronic standard are common downstream of SS-05 and less frequent upstream of SS-05.

Table 6-1 Base Flow Total Recoverable Copper Comparison to Chronic Standard in Surface Water (Pre-July 2011)

Station	n	Minimum (µg/L)	Maximum (µg/L)	Number of Exceedances	Percent Exceedances
SS-07	11	11.00	23.5	6	55%
SS-06G	12	5.70	25	4	33%
SS-06A	13	6.70	34	7	54%
SS-05A	13	5.90	24.1	4	31%
SS-05	13	3.50	23.7	2	15%
SS-04	13	3.00	14	1	8%
SS-01	10	1.70	31.2	1	10%

Note: Date range evaluated from January 10, 2008 to December 17, 2013.

Table 6-2 presents a comparison to the chronic standard following construction complete at the BRW extension in July 2011. Total recoverable copper exceedances downstream of SS-05 have been reduced significantly (e.g., less than 10 percent). Only station SS-07 has greater than 10 percent exceedance (45 percent); however, this likely is attributed to the SS-STP discharge (see section 7.2.4).

Table 6-2 Base Flow Total Recoverable Copper Comparison to Chronic Standard in Surface Water (Post-July 2011)

Station	n	Minimum (µg/L)	Maximum (µg/L)	Number of Exceedances	Percent Exceedances
SS-07	11	8.80	17	5	45%
SS-06G	11	4.30	12	0	0%
SS-06A	11	2.80	18	1	9%
SS-05A	11	3.00	9.6	0	0%
SS-05	11	2.50	5.1	0	0%
SS-04	11	2.50	12	1	9%
SS-01	11	1.50	5.7	0	0%

Note: Date range evaluated from January 10, 2008 to December 17, 2013.

Figure 6-10 presents summary statistics for the compliance ratios based on total recoverable copper results pre-July 2011. At all stations, the maximum detected value exceeded the compliance ratio of 1. Median total recoverable copper concentrations are equal to the compliance ratio of 1 at SS-06A and SS-07. There is an increase in the compliance ratio from SS-01 to SS-06A, a decrease at SS-06G to results similar to SS-05 and SS-05A, and a subsequent increase at SS-07 to results similar to SS-06A.

Figure 6-11 presents summary of statistics for the compliance ratios based on total recoverable copper results following July 2011. The maximum concentrations of total recoverable copper only exceeded the compliance ratio of 1 at SS-04, SS-06A, and SS-07. Median compliance ratios are below the compliance ratio of 1 at all locations; however, SS-07 is very near the compliance ratio of 1 (0.913). Total recoverable copper compliance ratios for post-July 2011 sample results from stations SS-05 through SS-06G are approximately half compared with pre-July 2011 sample results.

Grove Gulch monitoring at base and normal high flow ended after 2009, so only two years of data are within the period evaluated in this report. Station GG-01, located just downstream of the culvert under Lexington Avenue was monitored from 2002 to 2008. Station GG-04, located upstream of the

Interstate culvert, was monitored only in 2008. Station GG-BTC is located within Blacktail Creek at the confluence with Grove Gulch and is a wet weather monitoring station.

Measured discharge for the 2008-2009 sampling events in Grove Gulch are sown in Table 6-3. Based on the definitions in Section 1.7, the flow conditions in Blacktail Creek are also included. Based on these flow conditions and the discharge values, it appears that some of the data collected likely represent normal high flow conditions and some (at least one) may be base flow. Because separation of base flow from normal high flow may not be accurate, all non-wet weather data are presented.

Table 6-3 Total Recoverable Copper Comparison to Chronic Standard in Surface Water in Grove Gulch

Station	Date	Discharge (cfs)	Flow Condition in Blacktail Creek	Total Recoverable Copper (µg/L)	Chronic Standard (µg/L)	Exceedance?
GG-01	4/18/2008	0.06	Normal High	10	16.4	No
GG-01	5/2/2008	0.7	Normal High	7.39	13	No
GG-01	6/19/2008	0.4	Normal High	7.67	14.5	No
GG-04	4/21/2009	0.9	Normal High	6.5	11.2	No
GG-04	5/21/2009	0.3	Normal High	6.7	14.8	No
GG-04	6/29/2009	0.1	Normal High	5.6	21.7	No
GG-04	7/21/2009	0.1	Base	6.3	15.8	No
GG-04	10/22/2009	0.1	Normal High	7.8	20.3	No

Total recoverable copper concentrations in Grove Gulch are also shown in Table 6-3 along with the calculated chronic standard. No exceedances were recorded.

6.2.2 Review of Compliance for Aluminum

According to Circular DEQ-7, the chronic standard for aluminum only applies to the dissolved fraction; therefore, total recoverable aluminum is not discussed. For some stations, many of the results are not detected and for some dates all results are not detected. Results from January 10 and February 29, 2008 had high detection limits and most results were not detected, therefore, these data are excluded from the aluminum analysis. For the remaining data, U flagged (undetected) and J flagged (estimated) results were accepted at these limits and included in the statistics.

Base flow aluminum concentrations in surface water at SS-07 from 2008 to 2013 are shown in Figure 6-12. Table 6-4 provides a statistical summary of dissolved aluminum concentrations compared to the chronic standard.

Table 6-4 Base Flow Dissolved Aluminum Comparison to Chronic Standard in Surface Water (2008-2013)

Station	n	Number of Detects	Minimum (µg/L)	Maximum (µg/L)	Number of Exceedances	Percent Exceedances
SS-07	20	20	4.8	13	0	0%
SS-06G	21	14	1.5U	30	0	0%
SS-06A	22	19	1.5U	12	0	0%
SS-05A	22	18	1.5U	4.8	0	0%
SS-05	22	17	1.5U	5.3	0	0%
SS-04	22	20	1.5U	8.3	0	0%
SS-01	19	15	1.5U	7.3	0	0%
GG-01 and GG-04	8	8	6.7	47	0	0%

Note: Date range evaluated from January 10, 2008 to December 17, 2013.
Grove Gulch samples include all data regardless of flow condition.
U – Not detected at the value shown.

Figure 6-13 presents summary statistics for the compliance ratios based on dissolved aluminum results from 2008 to 2013 is shown in Figure 6-13. The chronic standard was not exceeded at any station.

6.2.3 Review of Compliance for Arsenic

Arsenic concentrations in surface water at SS-07 from 2008 to 2013 are shown in Figure 6-14. The human health standard of 10 µg/L is far below the chronic standard (150 µg/L), so, per the ROD, the human health standard is the ARAR used for compliance evaluation. All sample results for total recoverable arsenic, from 2008 to 2013, are below the human health standard. Summary statistics for arsenic total recoverable concentrations from 2008 to 2013 are shown in Table 6-5. Statistic for total recoverable arsenic in Grove Gulch are shown in Table 6-6.

Table 6-5 Base Flow Total Arsenic Comparison to Human Health Standard in Surface Water (2008-2013)

Station	n	Minimum (µg/L)	Maximum (µg/L)	Number of Exceedances	Percent Exceedances
SS-07	22	2.6	5.7	0	0%
SS-06G	23	2.9	8.8	0	0%
SS-06A	24	2.9	7.6	0	0%
SS-05A	24	2.4	7.3	0	0%
SS-05	24	2.2	7.5	0	0%
SS-04	24	2.1	7.5	0	0%
SS-01	21	1.3	7.1	0	0%

Note: Date range evaluated from January 10, 2008 to December 17, 2013.

Table 6-6 Total Recoverable Arsenic Comparison to Human Health Standard in Surface Water in Grove Gulch

Station	Date	Discharge (cfs)	Flow Condition in Blacktail Creek	Total Recoverable Arsenic (µg/L)	Human Health Standard (µg/L)	Exceedance?
GG-01	4/18/2008	0.06	Normal High	9.3	10	No
GG-01	5/2/2008	0.7	Normal High	7.62	10	No
GG-01	6/19/2008	0.4	Normal High	11.3	10	Yes
GG-04	4/21/2009	0.9	Normal High	8.1	10	No
GG-04	5/21/2009	0.3	Normal High	9.8	10	No
GG-04	6/29/2009	0.1	Normal High	40	10	Yes
GG-04	7/21/2009	0.1	Base	130	10	Yes
GG-04	10/22/2009	0.1	Normal High	51	10	Yes

Figure 6-15 presents summary statistics for the compliance ratios based on total recoverable arsenic from 2008 to 2013. No exceedances of the human health standard (or the chronic standard) for total recoverable arsenic were recorded in Blacktail and Silver Bow Creeks during this period. Half of the non-wet weather samples collected in Grove Gulch exceeded the human health standard; however, none exceeded the chronic standard.

6.2.4 Review of Compliance for Cadmium

Cadmium concentrations in surface water at SS-07 from 2008 to 2013 are shown in Figure 6-16. Only station SS-06A had a total recoverable cadmium exceedance of the chronic standard (see Figure 6-17); however, that sample was collected during the BRW work. A statistical summary of total recoverable cadmium concentrations in surface water at base flow is shown in Table 6-7.

Table 6-7 Base Flow Total Recoverable Cadmium Comparison to Chronic Standard in Surface Water (2008-2013)

Station	n	Number of Detects	Minimum (µg/L)	Maximum (µg/L)	Number of Exceedances	Percent Exceedances
SS-07	22	22	0.041	0.20	0	0%
SS-06G	23	23	0.076	0.32	0	0%
SS-06A	24	23	0.032U	0.4	1	4%
SS-05A	24	24	0.060	0.28	0	0%
SS-05	24	21	0.03U	0.26	0	0%
SS-04	24	15	0.03U	0.13	0	0%
SS-01	21	2	0.02U	0.15	0	0%
GG-01 and GG-04	8	6	0.026U	0.169	0	0%

Note: Date range evaluated from January 10, 2008 to December 17, 2013.
Grove Gulch samples include all data regardless of flow condition.
U – Not detected at the value shown.

Figure 6-17 presents summary statistics for the compliance ratios based on total recoverable cadmium from 2008 to 2013. There is an increase in the total recoverable cadmium compliance ratio beginning at station SS-05A with the remaining downstream locations (SS-06A, SS-06G, and SS-07) being similar.

6.2.5 Review of Compliance for Lead

Lead concentrations in surface water at SS-07 from 2008 to 2013 are shown in Figure 6-18. Total recoverable lead at SS-07 has not exceeded the chronic standard. The maximum total recoverable concentration occurred on December 6, 2010 at 4.1 µg/L. The corresponding chronic standard was 5.6 µg/L.

At SS-06G, total recoverable lead concentrations ranged from 0.48 µg/L to 7.1 µg/L. Only one total recoverable concentration exceeded the chronic standard (7.1 µg/L versus a standard of 6.5 µg/L on December 6, 2010, as shown in Figure 6-19). All other total recoverable concentrations of lead were below the chronic standard at this station.

Lead concentrations at SS-06A from 2008 to 2013 are shown in Figure 6-20. Two exceedances of the chronic standard occurred: once during the BRW remedial action and; once in 2013.

Figure 6-21 shows lead concentrations at SS-05A from 2008 to 2013. Total recoverable lead exceeded the chronic standard once on February 29, 2008 at a concentration of 5.3 µg/L (5.2 µg/L chronic standard). All other total recoverable lead concentrations were below the chronic standard.

Lead concentrations from 2008 to 2013 in surface water at SS-05 are shown in Figure 6-22. Two total recoverable lead exceedances occurred on February 29, 2008 and December 16, 2010.

Figure 6-23 shows lead concentrations at SS-04 from 2008 to 2013. Only one total recoverable lead exceedance occurred on December 16, 2010.

The total recoverable lead concentrations at SS-01 are shown in Figure 6-24. Only one exceedance occurred in February 2008. All other total recoverable lead concentrations were below 1 µg/L with the exception of February 7, 2013 with a concentration of 1.4 µg/L (the chronic standard was generally near 4 µg/L).

A statistical summary of total recoverable lead concentrations in surface water at base flow is shown in Table 6-8. Generally, with the exception of SS-07, all stations had low numbers of exceedances of the lead chronic standard.

Table 6-8 Base Flow Total Recoverable Lead Comparison to Chronic Standard in Surface Water (2008-2013)

Station	n	Minimum (µg/L)	Maximum (µg/L)	Number of Exceedances	Percent Exceedances
SS-07	22	0.63	4.1	0	0%
SS-06G	23	0.48	7.1	1	4%
SS-06A	24	0.55	12	2	8%
SS-05A	24	0.48	5.31	1	4%
SS-05	24	0.44	8.75	2	8%
SS-04	24	0.53	4.3	1	4%
SS-01	21	0.06	8.02	1	5%
GG-01 and GG-04	8	0.456	3.8	0	0%

Note: Date range evaluated from January 10, 2008 to December 17, 2013.
Grove Gulch samples include all data regardless of flow condition.

Figure 6-25 presents summary statistics for the compliance ratios based on total recoverable lead from 2008 to 2013. The median and third quartile compliance ratios for lead are below unity for all stations. A notable increase in the compliance ratio occurs between SS-01 and SS-04. The remaining stations are similar to SS-04.

6.2.6 Review of Compliance for Zinc

Zinc concentrations in surface water at SS-07 from 2008 to 2013 are shown in Figure 6-26. Zinc concentrations have been relatively stable with no distinct difference between total recoverable and dissolved fractions. Samples collected from 2008 to 2013 are well below the chronic standard for zinc.

A statistical summary of total recoverable zinc concentrations in surface water at base flow is shown in Table 6-9. Exceedance of the chronic standard has not occurred for zinc at base flow conditions.

Table 6-9 Base Flow Total Recoverable Zinc Comparison to Chronic Standard in Surface Water (2008-2013)

Station	n	Minimum (µg/L)	Maximum (µg/L)	Number of Exceedances	Percent Exceedances
SS-07	22	42	80.4	0	0%
SS-06G	23	16	220	0	0%
SS-06A	24	12	80	0	0%
SS-05A	24	10	62.6	0	0%
SS-05	24	5.5	57.1	0	0%
SS-04	24	4.8	28	0	0%
SS-01	21	1.8	42.8	0	0%
GG-01 and GG-04	8	14	140	0	0%

Note: Date range evaluated from January 10, 2008 to December 17, 2013.

Grove Gulch samples include all data regardless of flow condition.

Figure 6-27 presents summary statistics for the compliance ratios based on total recoverable zinc from 2008 to 2013. Total recoverable zinc is well below unity for all statistics.

6.2.7 Review of Compliance for Silver

Silver concentrations in surface water at SS-07, from 2008 to 2013, are shown in Figure 6-28. Note that most results are undetected values. A statistical summary of total recoverable silver is shown in Table 6-10 and on Figure 6-29. There is no chronic standard for silver in DEQ-7; however, no exceedances of the acute standard for silver occurred from 2008 through 2013 (the period of analysis).

Table 6-10 Base Flow Total Recoverable Silver Comparison to Acute Standard in Surface Water (2008-2013)

Station	n	Number of Detects	Minimum (µg/L)	Maximum (µg/L)	Number of Exceedances	Percent Exceedances
SS-07	24	7	0.04 U	0.37	0	0%
SS-06G	25	2	0.04 U	0.33	0	0%
SS-06A	26	1	0.04 U	0.26 U	0	0%
SS-05A	26	0	0.04 U	0.26 U	0	0%
SS-05	26	2	0.04 U	0.26 U	0	0%
SS-04	26	3	0.04 U	0.26 U	0	0%
SS-01	23	2	0.04 U	0.28	0	0%
GG-01 and GG-04	8	0	0.25 U	0.368 U	0	0%

Note: Date range evaluated from January 10, 2008 to December 17, 2013.
Grove Gulch samples include all data regardless of flow condition.
U – Not detected at the value shown.

6.2.8 Review of Compliance for Iron

Iron concentrations in surface water at SS-07, from 2008 to 2013, are shown in Figure 6-30. No exceedances occurred at this station. A statistical summary of total recoverable iron is shown in Table 6-11 and on Figure 6-31. There are one or fewer exceedances of the iron standard at each station (except Grove Gulch) and the concentrations are all less than two times the chronic standard of 1,000 µg/L. The Grove Gulch data include samples collected during normal high flow conditions.

Table 6-11 Base Flow Total Recoverable Iron Comparison to Chronic Standard in Surface Water (2008-2013)

Station	n	Minimum (µg/L)	Maximum (µg/L)	Number of Exceedances	Percent Exceedances
SS-07	22	97	700	0	0%
SS-06G	23	110	1200	1	4%
SS-06A	24	190	1700	1	4%
SS-05A	24	200	891	0	0%
SS-05	24	180	1200	1	4%
SS-04	21	190	1300	1	4%
SS-01	23	160	1640	1	5%
GG-01 and GG-04	8	33	4400	3	38%

Note: Date range evaluated from January 10, 2008 to December 17, 2013.
Grove Gulch samples include all data regardless of flow condition.
U – Not detected at the value shown.

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Section 7

Base Flow Loading Analysis

This section evaluates mass loading of metals in surface water in the BPSOU during base flow conditions, with an emphasis on determining sources of metals loading.

7.1 Methodology

This metals loading analysis was used to determine where contaminated ground water is entering the streams during base flow conditions. The main stem stations on Blacktail Creek and Silver Bow Creek (below its confluence with Blacktail Creek) consist of SS-01, SS-04, SS-05, SS-05A, SS-06A, SS-06G, and SS-07. Data are available on a monthly basis with some deviations. Surface water inputs include Grove Gulch, Buffalo Gulch, Montana Pole Treatment Plant, Butte Treatment Lagoons, and the Butte-Silver Bow STP. Input data are not contemporaneous with main stem sampling, but the best available data were used.

Two analyses were conducted: discharge and load. The discharge and loading analyses are used together to determine if the inputs are attributable to ground water gain.

The discharge analysis relies on main stem (Blacktail Creek and Silver Bow Creek below its confluence with Blacktail Creek) and surface water input (outfalls and tributaries) discharge measurements and aids in identifying stream flow gains and losses. It is assumed that the discharge measurement error is no more than 10 percent and that all surface water discharges are known. The discharge analysis compares point measurements along the main stem stations (instantaneous discharge) to a summation of measured inputs. If all inputs are measured, the point measurements should match the summation. Any deviation greater than measurement error indicates that the stream is gaining flow from or losing flow to ground water or there is an unaccounted input.

Mass loads were calculated for Silver Bow Creek using flow and concentration data as follows:

$$\text{Load (lb/day)} = C\ (\mu g/L) * Q\ (\text{cfs}) * K$$

Where,

C = the concentration of the parameter in the water

Q = the flow rate of the input

K = Units conversion factor (0.0053954120)

Flow and concentrations were measured directly in the field and in a laboratory, and therefore represent known inputs. When measured in the main stem stream, these are instantaneous loads. When measured in tributaries or outfalls, these are input loads. Loads are subject to both discharge measurement error and sampling and analysis error.

Instantaneous loads are compared to the sum of all known input loads. Any deviation indicates an unknown "reach load" gain or loss of the measured constituent in the stream. These mass loading gains and losses, which cannot be measured directly or easily in the field, may include:

- Ground water inflow or hyporheic exchange (along the main stem or from tributaries)
- Adsorption/desorption of metals from stream sediment (assumed to be minimal)
- Suspended sediment mobilized from settled bed sediment or bank materials (within the reach)

7.2 Discharge and Concentration Inputs

The base flow loading analysis included the following inputs described in Sections 7.1.1 through 7.1.4 (from upstream to downstream):

- Blacktail Creek (SS-01)
- Grove Gulch
- Buffalo Gulch
- Montana Pole Treatment Plant Effluent (SS-MPTP)
- Butte Treatment Lagoon System Effluent (CT-EFS7)
- Butte Metro Sewage Treatment Plant Effluent (SS-STP)

Note that under base flow conditions not all of the above inputs flow into Silver Bow Creek as surface water inputs at all times. In order to gain a better understanding of the loading analysis, each flow input will be described in terms of the flow and potential metals loading sources to Silver Bow Creek. However, because data have not been collected along these sources since December 2009, these data inputs cannot be directly compared with loading data from the in-stream compliance sampling stations. Input data are available, but samples are not contemporaneous with main stem data. A description of available input data is presented in the following sections. In addition, the BRW seep remediation and stream bank sediments work that was completed mid-2011 had major impacts on load reductions; therefore, data post-July 2011 is most reflective of current conditions.

7.2.1 Blacktail Creek

Blacktail Creek samples (at SS-01) generally represent water quality upstream of the BPSOU. Historic milling and smelting operations may have affected areas upstream of SS-01, but the scope of potential impacts has not been investigated (upstream of SS-01 is the West Side Soils OU). For example, the Bell Smelter was reportedly located along Blacktail Creek just west of Harrison Avenue and SS-01 (mine waste was not reported to EPA during recent construction at the site).

Blacktail Creek from SS-01 to SS-04 is a low velocity, low gradient stream flanked by wetlands. This reach is also an area of known ground water discharge (e.g., AR Thermal Imaging and MBMG Bromide tracer dilution Study; EPA 2015). The vertical ground water gradient for nested well pair AMW-13A/AMW-13B is slightly upward most of the year, which is consistent with a ground water discharge area. Detailed sampling of water quality at base flow conditions was conducted during the sodium bromide tracer investigation (MBMG 2014). Dissolved copper concentrations were nearly constant from Oregon Avenue to the mouth of Blacktail Creek indicating an absence of loading sources for dissolved copper during the investigation in that reach. However, dissolved copper concentrations increased over two-fold from the confluence at SS-04.5 through Slag Canyon to SS-05A (from 1.32 to 2.84 µg/L)(MBMG 2014). Similarly, dissolved zinc concentrations increased in the reach beginning ¼ mile upstream of Lexington Avenue to 300 feet downstream of Lexington Avenue corresponding with ground water gain in the area. Dissolved zinc also nearly doubled in the reach from SS-04.5 to SS-05A (4.04 to 6.98 µg/L) and increased an addition three fold over that observed in Blacktail Creek once arriving at SS-06A (12.87 µg/L)(MBMG 2014).

Grove Gulch empties into Blacktail Creek from the south. The watershed is heavily modified, but formerly included the Clark tailings and a railroad embankment constructed of mine waste, both of which have been remediated. Under base flow conditions, Grove Gulch is typically dry or stagnant; however, there may still be underflow contributing metals to Blacktail Creek. Comparison between the loads at stations SS-01 (one mile upstream of Grove Gulch) and SS-04 (one-half mile downstream of Grove Gulch) can be used to determine the impact of underflow in terms of metals loading through this entire reach, though such an approximation is confounded by other ground water inflow to the reach. More recently, since 2007, USGS has monitored water quality in Blacktail Creek below Grove Gulch (Station 12323235). These data can be used in conjunction with the USGS data from Blacktail Creek at Harrison Avenue (Station 12323230) to evaluate approximate loading from Grove Gulch. The tracer study is the best available data for base flow in this reach and, as noted above, dissolved copper concentrations do not indicate a source is present, but dissolved zinc does show an increase at concentrations far below the total recoverable zinc water quality standards.

7.2.2 Montana Pole Treatment Plant Effluent

Effluent from the Montana Pole Treatment Plant discharges to Silver Bow Creek just downstream of station SS-06A. The water is low in metals content, but the added discharge serves to dilute the metals in the receiving stream. COC concentration statistics and discharge data from AR in 2008 and 2009 are presented in Table 7-1. The COC concentration statistics for GWIC from 2011-2013 and discharge data from EPA (2013 only) are presented in Table 7-2.

Table 7-1 Concentration Data and Discharge for the MPTP Input (2008-2009)

	Dissolved Metals (µg/L)	Total Recoverable Metals (µg/L)					Discharge (cfs)
	Al*	As	Cd*	Cu	Pb	Zn	
Median	2.0 U	2.5	0.040 U	1.3	0.051	3.7	0.77
Average	9.6	2.5	0.049	1.4	0.15	5.8	0.75
Standard Deviation	13.7	0.35	0.015	1.1	0.22	4.6	0.03
Minimum	2.0 U	1.7	0.031 U	0.46	0.05 U	2.5 U	0.7
Maximum	50	3.6	0.087 U	5.7	0.86	15 U	0.77
n	23	23	23	23	23	23	23
Detects	8	23	4	23	12	16	

*Most results were not detected
U = Not detected at the value shown

Table 7-2 Concentration Data and Discharge for the MPTP Input (2011-2013)

	Dissolved Metals (µg/L)	Total Recoverable Metals (µg/L)					Discharge 2013 (cfs)
	Al**	As	Cd*	Cu	Pb**	Zn	
Median	**	2.2	*	2.4	**	16	0.47
Average	**	1.9	*	3.1	**	17	0.53
Standard Deviation	**	0.9	*	2.3	**	7.1	0.11
Minimum	0.80 U	0.5 U	0.08 U	1.2	0.15 U	9.0	0.36
Maximum	27.3	2.54	1.25 U	6.4	0.28	26	0.70
n	3	4	4	4	4	4	82
Detects	1	4	0	4	1	4	

*All results were not detected
** Only one detected result
U = Not detected at the value shown

Concentrations are low to non-detected and discharge is low for this input. The large number of non-detected values make selecting a concentration for loading difficult. For arsenic, copper, and zinc, loads are calculated using the median in the same manner as the other inputs. For aluminum, cadmium, and lead, loads are calculated using the average 2008-2009 for all dates. These average values include non-detected values, but reflect the detected values more conservatively than medians which are not detected values. The resulting loads are not significant when compared to in-stream loads.

The arsenic, copper, and zinc loads from the MPTP discharge to Silver Bow Creek are presented in Tables 7-3 and 7-4. The aluminum, cadmium, and lead loads for MPTP are shown in Table 7-5.

Table 7-3 Median Loading for the MPTP Input (2008-2009)

	MPTP Loads (lb/day)		
	As	Cu	Zn
Median	0.010	0.0054	0.015

Table 7-4 Median Loading for the MPTP Input (2011-2013)

	MPTP Loads (lb/day)		
	As	Cu	Zn
Median	0.0050	0.0060	0.041

Table 7-5 Median Loading for the MPTP Input (2008-2013)

	MPTP Loads (lb/day)		
	Al	Cd	Pb
Median	0.039	0.00020	0.00062

7.2.3 Butte Treatment Lagoon System Effluent

The treatment lagoons receive water from area ground water, Missoula Gulch base flow, the BPSOU subdrain, and the West Camp. The system consists of lime addition followed by a series of lagoons designed to settle out sludge and adjust the pH of the water prior to discharge. The pH is increased to 10.2 to 10.4 standard units (su) during lime addition, which removes the majority of the metals from solution (excluding manganese). Equilibration with atmospheric carbon dioxide and biological reactions within the lagoons results in a lowering of the pH to near 9 su and a decrease in manganese concentrations to some extent. The reduced metals in the effluent meet the hardness-based aquatic life standards. The BTL effluent ultimately is a small source of metals loading to Silver Bow Creek. The high hardness of the effluent also raises the hardness of Silver Bow Creek thereby slightly raising the hardness-based standards for copper, cadmium, silver, lead, and zinc.

BTL Input data from AR (station CT-EFS7) were available for 2010-2013, but not 2008-2009. The COC concentration statistics and flow data for the BTL Input are presented in Tables 7-6 and 7-7.

Table 7-6 Concentration Data and Discharge for the BTL Input (2010)

	Dissolved Metals (µg/L)	Total Recoverable Metals (µg/L)					Discharge (cfs)
	Al	As	Cd	Cu	Pb	Zn	
Median	14	2.6	0.14	9.3	0.25	110	2.5
Average	13	2.5	0.18	12	0.39	130	2.5
Standard Deviation	9	0.4	0.14	7.2	0.47	72	0.44
Minimum	2	1.3	0.05	4.5	0.05	47	1.3
Maximum	21	3.3	0.94	51	3.9	370	3.8
n	10	109	109	109	109	109	365

Table 7-7 Concentration Data and Discharge for the BTL Input (2011-2013)

	Dissolved Metals (µg/L)	Total Recoverable Metals (µg/L)					Discharge Jan Sept 2011 (cfs)
	Al	As	Cd	Cu	Pb	Zn	
Median	17	2.8	0.19	7.8	0.35	49	2.45
Average	17	4.0	0.21	9.4	0.73	54	2.49
Standard Deviation	15	3.5	0.12	5.7	1.1	29	0.40
Minimum	6.2	1.7	0.04	2.5	0.02	7.3	1.14
Maximum	28	21	0.97	39	9.2	220	3.77
n	2	313	313	313	313	313	256

The concentration data cover the period January 2011 through December 2013, while the discharge data are for January through September 2011. The median loads are presented in Tables 7-8 and 7-9. Loads for the two periods are very similar except for zinc, which was lower in 2011-2013.

Table 7-8 Median Loading for the BTL Input (2010)

	BTL Loads (lb/day)					
	Al	As	Cd	Cu	Pb	Zn
Median	0.17	0.034	0.0025	0.16	0.0053	1.79

Table 7-9 Median Loading for the BTL Input (2011-2013)

	BTL Loads (lb/day)					
	Al	As	Cd	Cu	Pb	Zn
Median	0.15	0.037	0.0025	0.11	0.0050	0.65

7.2.4 Butte Metro Sewage Treatment Plant Effluent

Discharge from the Butte Metro Sewage Treatment Plant (SS-STP) has a strong influence on water quality in Silver Bow Creek. Copper and zinc concentrations are usually higher in the effluent than in the receiving stream. At the same time, the hardness is lower in the effluent, which reduces the hardness-based aquatic standards. The source of metals loading to the treatment plant has not yet been characterized, but presumably originates from piping in the distribution system, inflow of stormwater from roof drains, gutters, or cross-connections, infiltration of contaminated ground water into the piping network, and may include non-mining urban sources. Using AR's monthly data from 2008 through 2009, COC concentration statistics are shown in Table 7-10. BSB data for 2011 to 2013 are show in Table 7-11; however, it is unclear if the data represent discreet samples or averages. The results are similar for arsenic, zinc, and discharge, but dissimilar for aluminum, cadmium, copper, and lead. The cause of the differences is not known.

Table 7-10 Concentration Data and Discharge for the SS-STP Input (2008-2009)

	Dissolved Metals (µg/L)	Total Recoverable Metals (µg/L)					Discharge (cfs)*
	Al	As	Cd	Cu	Pb	Zn	
Median	17	2.9	0.079	22	0.87	71	6.47
Average	20.3	3.01	0.091	22.2	0.98	73.4	6.4
Standard Deviation	16.3	0.73	0.052	6.5	0.28	18.0	0.88
Minimum	2.4	1.74	0.031	11	0.66	57	4.38
Maximum	71.3	4.8	0.277	37	1.74	143	8.3
n	23	23	23	23	23	23	19

* Discharge measurements discontinued after August 2009.

Table 7-11 Concentration Data and Discharge for the SS-STP Input (2011-2013)

	Dissolved Metals (µg/L)	Total Recoverable Metals (µg/L)					Daily Discharge* 2011 2013 (cfs)
	Al	As	Cd	Cu	Pb	Zn	
Median	58	2.3	0.5	33	3.7	89	5.9
Average	78.5	2.4	0.5	32	3.5	112	5.9
Standard Deviation	50.7	0.4	0.2	6.0	1.9	56	0.48
Minimum	42	2	0.19	25	1.3	64	4.2
Maximum	176	3	0.87	44	6	234	10.2
n	6	8	8	8	8	8	1096

* Discharge reported by BSB from a totalizer.

The loads for the two periods are presented in Tables 7-12 and 7-13. Differences are due to the differences in concentrations seen in Tables 7-10 and 7-11.

Table 7-12 Median Loading for the SS-STP Input (2008-2009)

	SS STP Loads (lb/day)						
	Al (dissolved)	As	Cd	Cu	Pb	SO4	Zn
Median	0.59	0.10	0.0028	0.77	0.030	-	2.5

Table 7-13 Median Loading for the SS-STP Input (2011-2013)

	SS STP Loads (lb/day)						
	Al (dissolved)	As	Cd	Cu	Pb	SO4	Zn
Median	1.8	0.071	0.016	1.0	0.12	-	2.8

7.2.5 Grove Gulch

Available data from Grove Gulch were presented in Section 6.2.1. A statistical summary of these data is presented in Table 7-14. Median loading in Grove Gulch is shown in Table 7-15.

Table 7-14 Concentration Data for Grove Gulch (2008-2009)

	Dissolved Metals (µg/L)	Total Recoverable Metals Concentrations (µg/L)					Discharge (cfs)
	Al	As	Cd	Cu	Pb	Zn	
Median	4.95	10.5	0.061	7.1	1.0	22	0.20
Average	13.2	33	0.082	7.2	1.9	36	0.33
Standard Deviation	13.8	40	0.049	1.25	2.0	40	0.30
Minimum	2 U	7.6	0.026 U	5.6	0.46	14	0.06
Maximum	38.6	130	0.17	10	6.8	140	0.9
n	8	8	8	8	8	8	8

Table 7-15 Median Loading for Grove Gulch (2008-2009)

	Grove Gulch Loads (lb/day)					
	Al (dissolved)	As	Cd	Cu	Pb	Zn
Median	0.0053	0.011	0.000065	0.0076	0.0011	0.024

7.2.6 Buffalo Gulch

Data from Buffalo Gulch are limited to 2008-2009. A statistical summary of these data is presented in Table 7-16. Median loading in Buffalo Gulch is shown in Table 7-17. Note that portions of the Buffalo Gulch trunk line were slip-lined between May 2012 and May 2013 (Figure 3-1) and these data may not be representative of conditions after this period.

Table 7-16 Concentration Data for Buffalo Gulch (2008-2009)

	Dissolved Metals (µg/L)	Total Recoverable Metals Concentrations (µg/L)					Discharge (cfs)
	Al	As	Cd	Cu	Pb	Zn	
Median	19.3	12.4	0.48	35.5	2.92	98.5	0.010
Average	24.0	15.0	1.16	61.1	24.7	374	0.085
Standard Deviation	21.5	9.2	1.44	62.6	59.8	486	0.25
Minimum	2.2	5.1	0.27	19.1	0.61	53	0.001
Maximum	75.6	39.9	5.2	248	218	1700	0.93
n	12	12	12	12	12	12	12

Table 7-17 Median Loading for Buffalo Gulch (2008-2009)

	Buffalo Gulch Loads (lb/day)					
	Al (dissolved)	As	Cd	Cu	Pb	Zn
Median	0.0010	0.00067	0.000026	0.0019	0.00016	0.0053

7.3 Discharge Analysis

To evaluate loading a discharge analysis is required and presented here. Statistics were compiled for two periods: 2008 to 2010; and 2011-2013.

Discharge measurements from monthly main stem sampling were assembled for those dates matching the criteria for base flow in Section 1.7. For the period, 2008-2010, there was some inconsistency in the stations measured and the number of data points varies. For the period 2011 to 2013, there were considerable problems with beaver dams in LAO during 2012 and 2013. Additionally, SS-04 and SS-05 had vegetation which affects measurements. Questionable values were removed. In order to work with synoptic data, all values from event dates with two or more missing values were removed from the analysis.

Main stem discharge statistics for the period 2008-2010 are shown in Figure 7-1. There is considerable spread between the minimum and maximum at station SS-04 through SS-06A, but the median discharge was nearly constant.

Main stem discharge statistics for the period 2011-2013 are shown in Figure 7-2. Note that more than half of the values for 2012 to 2013 have been removed due to beaver dam effects. 2011 which was an unusually high discharge year with few base flow measurements. Base flow data were nearly evenly spread over these three years.

As noted in Section 7.1, the discharge analysis involves comparing main stem discharge measurements to a summation of all known inputs. The difference is the gain or loss of flow. For this analysis, the median discharge from base flow measurements was used for the main stem locations while a median discharge was assigned for the inputs from Section 7.2.

Gain/loss accounting for the period 2008-2010 is shown in Figure 7-3. A notable gain of 3.2 cfs is evident between SS-01 and SS-04. The figure indicates a loss between SS-06G and SS-07. However, the discharge from SS-STP is highly variable and is not measured at the same time as discharge measurements in the stream. It is likely that this short reach has no gains or losses, but data are not available for confirmation. No other gains or losses are notable.

Gain/loss accounting for the period of 2011 to 2013 is shown in Figure 7-4. Again, a notable gain is evident between SS-01 and SS-04. An apparent gain of 1.5 cfs is calculated between SS-05 and SS-05A; however, the reaches upstream and downstream indicate losses of the same magnitude totaling no net gain or loss. It is unclear if there are actual gains and losses or if these values are a result of measurement error. No other gains or losses are notable.

7.4 Main Stem Loading to Blacktail Creek and Silver Bow Creek

In the following sections, median COC concentrations and loads were calculated for each input and each main stem location. The following provides a brief description of the potential sources of loading upstream of each in-stream sampling station identified:

- SS-07 is the last station in the OU and is below the sewage treatment plant discharge (SS-STP), which is a significant source of copper, aluminum, cadmium, silver, and zinc.
- SS-06G is located upstream of SS-STP and is used to determine the final stream loads without the input of SS-STP, and represents water quality below point source inputs from MPTP and BTL.
- SS-06A is located downstream of the Missoula Gulch outlet and directly upstream from the MPTP input. This station provides a comparison point to demonstrate changes that occur in the stream reach between SS-05A and SS-06A.
- SS-05A is located downstream from the slag canyon and the BRW seep remediation project that was completed in July 2011. The copper loading was calculated pre-seep and post-seep remediation to analyze loading improvements following cleanup activities.
- SS-05 is located just below the confluence of the Buffalo Gulch outlet, and at the head of the slag canyon. It is the first Silver Bow Creek station below its confluence with Blacktail Creek. A comparison of SS-04 and SS-05 sampling results indicate the effects eastern Butte Hill and any surface output from the upper Silver Bow Creek channel may have on Silver Bow Creek.
- SS-04 is situated upstream of the confluence of Silver Bow Creek and Blacktail Creek. This station provides a comparison point between waters upstream and downstream of the Butte

Hill sub-drainages, and provides information on surface water conditions prior to the juncture of Blacktail Creek with the Silver Bow Creek. Water quality at SS-04 indicates whether COC concentrations in Silver Bow Creek are derived from sources within the Blacktail Creek sub-drainage.

- SS-01 is considered as a boundary condition because it is the farthest upstream main stem station, located in Blacktail Creek at Harrison Avenue. This station is located east of the BPSOU boundary. Monitoring provides a comparison point between waters downstream of the BPSOU and provides information on surface water conditions prior to entrance of the BPSOU.

In order to calculate main stem loading, the same sampling dates used in the discharge analysis in Section 7.2 were used to generate COC concentration statistics. These statistics for each COC are presented in box and whisker plots within the following sections.

Based on these statistics and those presented in Section 7.2, the median discharges and the median COC concentrations were used to calculate median loads. The loading analysis includes a summation of input loads. Deviation of the main stem load from the summed input loads indicates an unaccounted load. Unaccounted median load for each main stem reach is derived by subtracting the upstream main stem load and any input load from the downstream main stem load. This analysis is presented for each COC in the following section for median loads.

The above loading analysis was also conducted discretely for each synoptic sampling date. The unaccounted load for each reach was then summarized statistically in a box and whiskers plot. The median loads are mostly the same, but not always. The differences reflect variability in the calculated loads sometimes producing different medians.

7.4.1 Review of Total Recoverable Copper Loading

Statistics of total recoverable copper concentrations for the period 2008 to 2010 are shown in Figure 7-5. Copper concentrations generally increased through the site with upstream concentrations mostly less than 5 µg/L increasing to approximately 15 µg/L at SS-07.

The same statistics of total recoverable copper concentrations for the period 2011 to 2013 are presented in Figure 7-6. Concentrations are generally lower except for SS-01, which had a similar median value compared to the 2008 to 2010 period.

Total recoverable copper load accounting based on medians for the period 2008 to 2010 are presented in Figure 7-7. Input loading from SS-STP and BTL effluent are a large portion of the overall load. Although MPTP and BTL are shown as a single value in the figure, BTL represents 97 percent of the combined input load in this reach. The reach from SS-06G to SS-07 is very short and there is probably no discharge gain or loss and any potential reach load is small and uncertain (See Section 7.3). The difference in load between these two stations is almost entirely attributed to SS-STP. For the period 2008 to 2010, the difference in load between these stations was 0.75 lb/day. This compares favorably with the 0.77 lb/day shown in Table 7-12. For the period 2011 to 2013, the difference in load between these stations is 0.69 lb/day. This is less than the 1.0 lb/day from the SS-STP discharge shown in Table 7-13. It is assumed that the in-stream load differences are a more accurate measure of loading from SS-STP than the self-monitoring data provided by the operator. As such, the in-stream loads are used in the following discussion.

The unaccounted loads are shown at the top of Figure 7-7. The largest load is between stations SS-05 and SS-05A at 0.31 lb/day. This is unsurprising as reducing this load was the purpose of the BRW capture extension. The other reaches between SS-01 and SS-06A had small net gains of copper. A loss was calculated between SS-06A and SS-06G.

Using loads generated for each synoptic event, statistics of net copper loading are presented in Figure 7-8. There are considerable differences between minimum and maximum differential loads. This may be due to the span of values seen in the concentration statistics (Figure 7-5). Overall, positive loading is indicated from SS-01 to SS-06A while the reaches below SS-06A are near neutral to losing load.

The graphical copper loading analysis following seep remediation (Figure 7-9) reflects the overall reduction in copper concentrations seen in Figure 7-6. Loading between SS-01 and SS-04 decreased from 0.14 to 0.094 lb/day. A reduction in copper loading occurred in the reach from SS-04 to SS-05 which includes upper Silver Bow Creek and Buffalo Gulch as well as the removal action at the golden triangle waste area. Loading at BRW (SS-05 to SS-05A) decreased from 0.31 to 0.09 lb./day, reflecting the success of the BRW system extension and possibly the golden triangle waste removal. Loading was also decreased in the SS-05A to SS-06A reach. The apparent loss seen between SS-06A and SS-06G in 2008 to 2010 changed to neutral or possibly a small gain for the period 2011 to 2013. The load loss shifted to the last reach above SS-07.

Based on load accounting for each synoptic event, statistics of net gains and loss of copper loads are shown in Figure 7-10. Based on the quartiles, the net loading is more consistent during 2011 to 2013 than in 2008 to 2010. The load loss in the reach ending at SS-07 is clear in Figure 7-10.

A comparison of the in-stream copper loading during earlier (2008-2010) and later (2011-2013) periods is shown in the lower half of Figure 7-11. The upstream station remained essentially constant between the periods while there is a notable difference at SS-05, a larger difference at SS-05A, and smaller difference at SS-06G. The net gain/loss shown in the top half of Figure 7-10 shows a distinct reduction in the net loading at SS-05A.

The decrease in loading at SS-05 is likely attributed to the Silver Bow Creek streambank restoration work that was completed in May 2011. Stream reaches from downstream of SS-04 to upstream of station SS-05 had previously (pre-May 2011) contained contaminated sediments within the banks and stream bed. During base flow, deposits of metals-impacted sediment can act as a continuing source of metals, especially in areas where the stream is gaining ground water through the banks and bottom of the stream channel, in which case the water passes through the impacted sediments, leaching metals, and entering the water column (surface water flow in the stream). A removal action was initiated in October 2010 to address contaminated soil along the streambank at the confluence of Blacktail Creek and Silver Bow Creek, as discussed in Section 3. The removal action addressed bank sediments and some of the bed sediments were removed as a matter of proximity to the banks. However, base flow during this period was lower than pre-July 2011, also potentially contributing to lower loading.

The second decrease seen at SS-05A is likely a result of the BRW extension completed in 2011. Combined, these projects appear to have significantly reduced loading of total recoverable copper to Silver Bow Creek. The apparent load loss at SS-07 is most likely due to uncertainty in the discharge measurements as discussed in Section 7.3 and is probably not an actual loss.

Based on the net gains and input loads shown in Figure 7-7, the largest sources of total recoverable copper loading for 2008 to 2010 are shown in Table 7-18. Treatment plant inputs represent two of the three largest sources of loading for this period. The gain from all stream reaches through the site was ranked second while the individual reach from SS-05 to SS-05a (slag canyon) was a significant contributor to the combined reach total. For this and other COCs, the three largest sources are presented in the tables.

Table 7-18 Largest Loading Sources of Total Recoverable Copper 2008-2010

Rank	Source	Type	Median Total Recoverable Copper Load (lb./day)	Percentage of Total Load[1]
1	SS-STP	Input	0.74[2]	51%
2	SS-01 to SS-06A	Combined Reaches	0.63	43%
3	BTL	Input	0.16	11%
Individual Reaches				
	SS-05 to SS-05A	Reach	0.31	22%
	SS-01 to SS-04	Reach	0.14	9%

[1] Total load includes inputs and reach loads, but excludes load losses. As a result, percentages do not always add up to 100%.

[2] Load based on difference in load from SS-06G to SS-07.

Based on the net gains and input loads show on Figure 7-9, the largest sources of total recoverable copper loading for 2011 to 2013 are shown in Table 7-19. As with the previous time period, inputs represent two of the three largest loading sources for this period. The second ranked loading source is the combined stream reaches through the site. The contribution of the combined reach decreased from 38 to 25 percent of the total load from the previous monitoring period. The slag canyon reach dropped from 19 percent to 7 percent of the total load.

Table 7-19 Largest Loading Sources of Total Recoverable Copper 2011-2013

Rank	Source	Type	Total Recoverable Copper Load (lb./day)	Percentage of Total Load[1]
1	SS-STP	Input	0.69[2]	57%
2	SS-01 to SS-06G	Combined Reaches	0.30	25%
3	BTL	Input	0.11	9%
4	Upstream of SS-01	Input	0.088	7%
Individual Reaches				
	SS-01 to SS-04	Reach	0.09	8%
	SS-05 to SS-05A	Reach	0.09	7%

[1] Total load includes inputs and reach loads, but excludes load losses. As a result, percentages do not always add up to 100%.

[2] Load based on difference in load from SS-06G to SS-07.

7.4.2 Review of Dissolved Copper Loading

As noted in Section 6.2.1, a substantial portion of copper is in the dissolved state. In order to better understand loading of copper, load accounting was conducted for dissolved copper. Very little dissolved data were available for the effluent loads. These were estimated by multiplying the total recoverable copper loads by the median ratio of dissolved copper to total recoverable copper for periods where both values were available. This was generally 2008 to 2009. For SS-STP, the difference in load between stations SS-06G and SS-07 was used.

Load accounting for the period 2008-2009 is shown in Figure 7-12. Dissolved loads are less than total recoverable loads. Notable increases in dissolved copper occurred in the slag canyon reach and at SS-07. The largest sources of dissolved copper loading for 2008 through 2009 are shown in Table 7-20.

Table 7-20 Largest Loading Sources of Dissolved Copper 2008-2009

Rank	Source	Type	Dissolved Copper Load (lb./day)	Percentage of Total Load[1]
1	SS-STP	Input	0.63 [2]	65%
2	SS-01 to SS-06A	Combined Reaches	0.24	25%
3	BTL	Input	0.10 (estimated)	11%
Individual Reaches				
	SS-05 to SS-05A	Reach	0.16	16%

[1] Total load includes inputs and reach loads, but excludes load losses. As a result, percentages do not always add up to 100%.

[2] Load based on difference in load from SS-06G to SS-07.

Load accounting for the period 2011-2013 is shown in Figure 7-13. A constant loading increase in noted from SS-01 to SS-06A, with the largest increase in dissolved copper occurring at SS-07. The largest sources of dissolved copper loading for 2011 through 2013 are shown in Table 7-21. Loading of dissolved copper in the slag canyon reach decreased by 80 percent compared to 2008 through 2009.

Table 7-21 Largest Loading Sources of Dissolved Copper 2011-2013

Rank	Source	Type	Dissolved Copper Load (lb./day)	Percentage of Total Load[1]
1	SS-STP	Input	0.25 [2]	60%
2	SS-01 to SS-06A	Combined Reaches	0.077	19%
3	BTL	Input	0.072 (estimated)	17%
4	Upstream of SS-01	Input	0.050	12%
Individual Reaches				
	SS-05 to SS-05A	Reach	0.033	8%

[1] Total load includes inputs and reach loads, but excludes load losses. As a result, percentages do not always add up to 100%.

[2] Load based on difference in load from SS-06G to SS-07.

7.4.3 Review of Aluminum Loading

Dissolved aluminum concentrations have not exceeded the standard from 2008 through 2013. Statistics for dissolved aluminum are shown in Figure 7-14 along with median discharge. Load accounting is shown in Figure 7-15 for median aluminum loads. Loading was low at each station with the exception of increases at SS-06G and SS-07. SS-STP contributed the largest portion of dissolved aluminum at 1.2 lb/day.

Ranking of aluminum loads are presented in Table 7-22.

Table 7-22 Largest Loading Sources of Dissolved Aluminum 2008-2013

Rank	Source	Type	Dissolved Aluminum Load (lb./day)	Percentage of Total Load[1]
1	SS-STP	Input	0.54[2]	75%
2	BTL	Input	0.16	22%
3	SS-01 to SS-06A	Combined Reaches	0.14	20%
Individual Reaches				
	Upstream of SS-01	Input	0.12	16%
	SS-01 to SS-04	Reach	0.09	13%

[1] Total load includes inputs and reach loads, but excludes load losses. As a result, percentages do not always add up to 100%.

[2] Load based on difference in load from SS-06G to SS-07.

7.4.4 Review of Arsenic Loading

Total recoverable arsenic also has not exceeded the standard from 2008 through 2013. Figure 7-16 shows total arsenic concentration statistics for the period 2008 through 2013 along with median discharges along the main stem stations. Concentrations are generally low with all results below the RG.

Load accounting using median loads is shown in Figure 7-17. Loading was low at each station with the exception of upstream of SS-01 that had a moderate loading gain. The source of this gain is not known at this time, but may be attributable to possible non-point ground water sources upstream of the site. The largest sources of arsenic loading are shown in Table 7-23.

Table 7-23 Largest Loading Sources of Total Recoverable Arsenic 2008-2013

Rank	Source	Type	Total Recoverable Arsenic Load (lb./day)	Percentage of Total Load[1]
1	SS-01 to SS-06A	Combined Reaches	0.14	37%
2	Upstream of SS-01	Input	0.12	32%
3	SS-STP	Input	0.045[2]	12%
Individual Reaches				
	SS-01 to SS-04	Reach	0.070	18%

[1] Total load includes inputs and reach loads, but excludes load losses. As a result, percentages do not always add up to 100%.

[2] Load based on difference in load from SS-06G to SS-07.

7.4.5 Review of Cadmium Loading

Total recoverable cadmium only exceeded the standard once from 2008 through 2013. Figure 7-18 shows cadmium concentration statistics and median discharge. Concentrations gradually increase from SS-04 to SS06G and decrease below SS-06G. Load accounting is shown in Figure 7-19. The sum of inputs is less than the total load at SS-06G indicating a small gain of cadmium through this reach. As shown in Figure 7-19, loading gains along the main stem stations were low, with the largest reach load occurring between stations SS-05 and SS-05A. The largest loads are listed in Table 7-24. SS-STP is the largest loading source followed by the slag canyon reach. This analysis includes data before and after the BRW extension work, and it is expected that this load has been reduced.

Table 7-24 Largest Loading Sources of Total Recoverable Cadmium 2008-2013

Rank	Source	Type	Total Recoverable Cadmium Load (lb./day)	Percentage of Total Load[1]
1	SS-01 to SS-06G	Combined Reaches	0.0059	57%
2	BTL	Input	0.0025	24%
3	SS-STP	Input	0.00039[2]	4%
Individual Reaches				
	SS-05 to SS-05A	Reach	0.0027	26%
	SS-06A to SS-06G	Reach	0.0016	15%

[1] Total load includes inputs and reach loads, but excludes load losses. As a result, percentages do not always add up to 100%.

[2] Load based on difference in load from SS-06G to SS-07.

7.4.6 Review of Lead Loading

Total recoverable lead had few exceedances of the standard, generally less than 15 percent occurrence, with the maximum number of exceedances occurring at station SS-06A (four total). Figure 7-20 shows the total recoverable lead concentration statistics and median discharge for main stem stations. Concentrations are fairly constant through the site with the upstream station, SS-01, at a lower beginning concentration.

Gain accounting of total recoverable lead is presented in Figure 7-21. The summation of inputs is less than the main stem loads from SS-04 through SS-06G indicating overall gains while the reverse occurs at SS-07 indicating a loss of lead loading. Even though loading gains are occurring, total recoverable lead compliance exceedances are low.

The largest sources of loading are presented in Table 7-25. The largest loading source is the combined stream reaches while loading from SS-STP is the next largest source.

Table 7-25 Largest Loading Sources of Total Recoverable Lead 2008-2013

Rank	Source	Type	Total Recoverable Lead Load (lb./day)	Percentage of Total Load[1]
1	SS-01 to SS-06A	Combined Reaches	0.10	84%
2	SS-STP	Input	0.017[2]	14%
3	Upstream of SS-01	Input	0.011	9%
Individual Reaches				
	SS-01 to SS-04	Reach	0.040	34%
	SS-05 to SS-05A	Reach	0.027	23%
	SS-05A to SS-06A	Reach	0.027	22%

[1] Total load includes inputs and reach loads, but excludes load losses. As a result, percentages do not always add up to 100%.

[2] Load based on difference in load from SS-06G to SS-07.

7.4.7 Review of Zinc Loading

Total recoverable zinc has not exceeded the standard from 2008 to 2013. Zinc concentration statistics and median discharge are shown in Figure 7-22. There is a steady increase in zinc concentrations through the site.

Load accounting is shown in Figure 7-23. For completeness, zinc loading was calculated as is shown for copper in Figure 7-7. Most reaches indicated a small load, but the effluent sources were significantly larger.

The largest sources of zinc loading are shown in Table 7-26. The largest source of total recoverable zinc was the effluent of the sewage treatment plant. Combined stream reaches had the second largest loading and BTL provided the third largest zinc load. All other stations had low loading gains.

Table 7-26 Largest Loading Sources of Total Recoverable Zinc 2008-2013

Rank	Source	Type	Total Recoverable Zinc Load (lb./day)	Percentage of Total Load[1]
1	SS-STP	Input	2.8[2]	52%
2	SS-01 to SS-06A	Combined Reaches	1.8	33%
3	BTL	Input	1.2	22%
Individual Reaches				
	SS-05A to SS-06A	Reach	0.60	11%
	SS-05 to SS-5A	Reach	0.58	11%

[1] Total load includes inputs and reach loads, but excludes load losses. As a result, percentages do not always add up to 100%.

[2] Load based on difference in load from SS-06G to SS-07.

7.4.8 Review of Silver Loading

Total recoverable silver has not exceeded the standard from 2008 to 2013. In general, silver was not detected in most samples. Stations SS-01 through SS-06G had less than 15 percent detects and there was no synoptic event where silver was detected at all stations. Based on the lack of data, silver loading analysis was not conducted.

7.4.9 Review of Iron Loading

Exceedances of the standard for iron were limited to once in several stations during the period 2008 to 2013. Exceedance rates were greater in Grove Gulch. Due to the lack of exceedances in Blacktail and Silver Bow Creeks, iron loading analysis was not conducted.

7.5 Summary of Base Flow Loading

The load ranking presented in Section 7.4 is combined into Table 7-27 and shown in Figure 7-24. Overall, the SS-STP input represents the largest load of six COCs and is ranked second for a seventh COC during base flow conditions. All COCs except copper and lead have concentrations less than the applicable standards during base flow and are not a significant concern. The only station with significant exceedances is SS-07 for total recoverable copper. The load ranking indicates that the SS-STP is the largest contributor to those exceedances.

Table 7-27 Summary of Base Flow COC Load Ranking

Rank	Dissolved Aluminum	Total Recoverable Arsenic	Total Recoverable Cadmium	Total Recoverable Copper	Dissolved Copper	Total Recoverable Lead	Total Recoverable Zinc
1	SS-STP (75%)[1]	Combined Reaches (37%)	Combined Reaches (57%)	SS-STP (57%)	SS-STP (60%)	Combined Reaches (84%)	SS-STP (52%)
2	BTL (22%)	Upstream of SS-01 (32%)	BTL (24%)	Combined Reaches (25%)	Combined Reaches (19%)	SS-STP (14%)	Combined Reaches (33%)
3	Combined Reaches (20%)	SS-STP (12%)	SS-STP (4%)	BTL (9%)	BTL (17%)	Upstream of SS-01 (9%)	BTL (22%)

[1] The load rankings present only the top three load inputs and/or reach loads, and exclude load losses. As a result, percentages do not always add up to 100%.

Section 8

Normal High Flow Compliance Analysis

Similar to Section 6 (base flow compliance analysis), this section compares recent normal high flow data to numeric water quality standards at points of compliance along Silver Bow Creek and Blacktail Creek as required in the ROD; interpretation of these data is the focus of Section 12. RAOs require surface water to meet water quality standards, and this section evaluates progress toward that requirement. Normal high flow conditions are defined in Section 1.7.

As mentioned in Section 6, mercury analysis is not presented in this section. The data quality issues need to be resolved before these data can be presented and analyzed. Mercury data from an outside source (SSTOU) are presented and evaluated in Chapter 12.

As part of review of the surface water data, non-COCs including sulfate and dissolved organic content data are presented and evaluated in Chapter 12.

8.1 In-Stream Compliance Stations

For normal high flow conditions, the following in-stream compliance stations were sampled and are presented in this section:

- SS-01 (Blacktail Creek at Harrison Avenue);
- SS-04 (Blacktail Creek above its confluence with Silver Bow Creek)
- SS-05 (Silver Bow Creek below its confluence with Blacktail Creek and Buffalo Gulch);
- SS-05A (Silver Bow Creek below "slag canyon");
- SS-06A (Silver Bow Creek below Missoula Gulch storm channel outfall);
- SS-06G (Silver Bow Creek below Butte Treatment Lagoons effluent); and
- SS-07 (Silver Bow Creek below wastewater treatment plant

Although GG-01 (Grove Gulch) is a compliance station for normal high flow, all available data were presented in Section 6 and are not repeated herein.

8.2 Compliance Analysis of Individual COCs

For surface water standards, the ROD used Circular DEQ-7 February 2006 for acute and chronic aquatic life standards as well as human health standards, whichever is more protective. These numeric standards of interest are presented in Table 1-1. Normal high flow results are compared to chronic standards because, similar to base flow, normal high flow is representative of longer than a 1-hour average of COC concentrations.

For each COC, normal high flow concentration data are presented on a time scale along with the surface water standard. This provides a discreet view of compliance from 2008 through 2013 and makes it possible to visually identify the COC, station, and date period that are of most concern.

For clarity in this compliance analysis and given that copper, cadmium, lead and zinc have a variable standard based on hardness, COC concentrations were converted to a ratio of the COC concentration and the standard ("compliance ratio"). When the COC concentration is equal to the calculated standard, the compliance ratio is 1. When the COC concentration is less than the standard, the compliance ratio is less than 1. When the COC concentration is in exceedance of the standard, the compliance ratio is greater than 1.

The compliance data are presented in two formats as follows:

- Box and whisker plots
- Statistical comparisons of stations.

For this analysis, the data are grouped according to in-stream monitoring station and analyzed statistically. Statistics include 1st and 3rd quartile (25th and 75th percentile), median, maximum and minimum values. This provides a clear comparison of compliance throughout Blacktail and Silver Bow Creeks, from upstream to downstream, for the period 2008 through 2013. This systematic station comparison allows the analyst to identify stream reaches and stormwater inputs in reaches that are having the greatest degradation effect on the stream. A map showing the surface water sampling stations in the BPSOU is shown on Figure 6–1. Surface water standards are applicable only to those stations within Blacktail Creek, Grove Gulch, and Silver Bow Creek.

8.2.1 Review of Compliance for Copper

Copper results, limited to normal high flow at SS-07, are shown in Figure 8-1. Copper concentrations are lower in the 2011 through 2013 period compared to 2008 to 2009, specifically following the BRW seep remediation and bank sediment removal in the George Street to Montana Street area by early-2011. From 2008 through 2009, total recoverable copper exceeded the chronic standard in 83 percent of sample results. Since April 2011, total recoverable copper only exceeded the chronic standard in 35 percent of sample results. In comparison to the upstream stations (see below), the 35 percent exceedance rate at SS-07 is high relatively, and is impacted by discharge from the sewage treatment plant.

As shown in Figure 8-2, copper concentrations at SS-06G also have decreased from 2008 to 2013. From 2008 through 2010, total recoverable copper exceeded the chronic standard in 61 percent of sample results, compared with one exceedance since 2011. The decreasing copper concentrations is also observed at SS-06A (Figure 8-3), SS-05A (Figure 8-4), and SS-05 (Figure 8-5). Concentrations at SS-04 (Figure 8-6) and SS-01 (Figure 8-7) appear to be slightly decreasing. Since copper concentration decreases are also occurring at the upstream stations, it may indicate a basin-wide or regional decrease independent of remedy, which is discussed later in this section.

Sample locations SS-05 through SS-01 had lower percentages of exceedances of the chronic standard, ranging from 39 percent at SS-05 to 17 percent at SS-01 prior to 2011. However, since April 2011, exceedances of the total recoverable copper chronic standard occurred from 15 percent (SS-06A) to 5 percent each at SS-06G, SS-04 and SS-01. Note that the decrease in exceedances at all stations may be partially indicative of a regional decrease that is unrelated to remedy. These data are presented in Figures 8-1 through 8-7, respectively. Table 8-1 provides a summary of the total recoverable copper concentrations compared to the chronic standard before 2011.

Table 8-1 Normal High Flow Total Recoverable Copper Comparison to Chronic Standard (2008 - 2010)

Station	n	Minimum (µg/L)	Maximum (µg/L)	Number of Exceedances	Percent Exceedances
SS-07	12	12.0	28.0	10	83%
SS-06G	18	10.	23.0	11	61%
SS-06A	18	9.7	24.3	15	83%
SS-05A	18	8.4	23.1	15	83%
SS-05	18	4.4	42.0	7	39%
SS-04	18	3.2	82.0	7	39%
SS-01	12	3.1	8.9	2	17%

Table 8-2 provides a similar comparison as Table 8-1; however, it summarizes the total recoverable copper statistics from 2011 through 2013. Concentrations (and thereby exceedances) have decreased noticeably in comparison to pre-2011 data.

Table 8-2 Normal High Flow Total Recoverable Copper Comparison to Chronic Standard (2011- 2013)

Station	n	Minimum (µg/L)	Maximum (µg/L)	Number of Exceedances	Percent Exceedances
SS-07	20	7.7	16.0	7	35%
SS-06G	20	3.2	13.0	1	5%
SS-06A	20	3.1	13.0	3	15%
SS-05A	20	4.2	31.0	2	10%
SS-05	20	2.7	16.0	2	10%
SS-04	20	2.9	9.1	1	5%
SS-01	19	1.6	9.0	1	5%

Figure 8-8 presents summary statistics for the compliance ratios based on total recoverable copper results at normal high flow prior to 2011. As described in Section 6.1, a compliance ratio greater than 1 indicates an exceedance of the chronic standard, and a ratio less than 1 indicates the chronic standard is not exceeded. At all stations, the maximum detected value exceeded the chronic standard. Median compliance ratios all exceed 1 at stations SS-05A through SS-07.

A summary of compliance ratio statistics since 2011 through 2013 is shown in Figure 8-9. The median total recoverable copper compliance ratios did not exceed 1 at any station, although SS-07 was nearly 1. All stations had maximum total recoverable copper compliance ratios that exceed 1.

However, note that when comparing Figures 8-8 and 8-9, there was a measureable reduction in total recoverable copper at Station SS-01 (the station upstream of the Operable Unit). There are accompanying changes including lower discharge and higher hardness in the later data. A summary of these differences is presented in Table 8-3. 2010 and 2011 were high flow years based on USGS discharge data at SS-04. All other years were near average flow.

Table 8-3 Summary of Changes in Water Quality and Discharge at SS-01 (median values)

Period	Total Recoverable Copper (µg/L)	Dissolved Copper (µg/L)	Discharge (cfs)	Hardness (mg/L)	Chronic Copper Standard (µg/L)
2008-2009	4.8	3.5	15.4	93.5	8.8
2011-2013	3.6	2.5	12.1	110	10.1

The overall improvement in compliance for copper can be, in part, attributed to a small decrease in total recoverable copper concentrations at the upstream station, SS-01. The upstream change may be a continuing trend or may be related to climatic fluctuations, but should be considered in examination of the data, highlighting the importance of considering upstream conditions outside the OU in assessing compliance. Incoming total recoverable copper loads, as calculated in Section 9, are a significant part of the total load exiting the site. However, the decrease in load from the early to later period is much smaller than the total decrease at the site (see Section 9.3.1) indicating that there is a combination of factors resulting in lower copper concentrations and loads exiting the site.

8.2.2 Review of Compliance for Aluminum

Aluminum concentrations at SS-07 are shown in Figure 8-10. Dissolved aluminum concentrations were all below the chronic standard. Of the remaining samples at all other main stem stations, one dissolved aluminum exceedance occurred at SS-01 on April 6, 2011 at a concentration of 100 µg/L (total recoverable concentration was 93 µg/L). The aluminum concentration time plot is shown in Figure 8-11 for station SS-01. Because the dissolved aluminum concentration was above total recoverable and the concentration was 2 to 3 times greater than the maximum concentrations at the other compliance stations, this result may be compromised and may need further qualification. Table 8-4 provides a summary of the dissolved aluminum statistics in comparison to the chronic standard from 2008 to 2013 (and includes the potentially compromised result).

Table 8-4 Normal High Flow Dissolved Aluminum Comparison to Chronic Standard (2008 – 2013)

Station	n	Minimum (µg/L)	Maximum (µg/L)	Number of Exceedances	Percent Exceedances
SS-07	32	2	37.8	0	0%
SS-06G	38	1.5	37	0	0%
SS-06A	38	1.5	40.7	0	0%
SS-05A	38	1.8	62.8	0	0%
SS-05	38	1.5	57.6	0	0%
SS-04	38	1.6	49.6	0	0%
SS-01	31	2	100	1	3%

Note: Date range evaluated from April 11, 2008 to November 6, 2013.

A single exceedance occurred at SS-01 on April 6, 2011. The next downstream station concentration was much lower, therefore this value is considered an outlier.

Figure 8-12 presents summary statistics for the compliance ratios based on dissolved aluminum results at normal high flow from 2008 to 2013. With the exception of the maximum dissolved aluminum compliance ratio at SS-01, all other sample results were below 1 (equivalent to the chronic standard).

8.2.3 Review of Compliance for Arsenic

The human health standard of 10 µg/L is below the chronic standard (150 µg/L), so it is the standard for this compliance evaluation. Total recoverable and dissolved arsenic results for station SS-07, SS-06G, SS-06A, SS-05A, SS-05, SS-04, and SS-01 are shown in Figures 8-13 through 8-19. Arsenic concentrations were very similar at each station and showed a general relationship to discharge (i.e., higher discharge equates to higher arsenic concentrations). In general, concentrations of arsenic were greater during spring runoff. Arsenic concentrations were also higher during high flow years such as 2010 and 2011 indicating that arsenic compliance is sensitive to inter-year climatic fluctuations. Arsenic concentrations exceeded the human health standard during spring high flow in the wet years 2008, 2010, and 2011. Table 8-5 provides a summary of total recoverable arsenic exceedances of the human health standard. There were no exceedances of the chronic standard.

Table 8-5 Normal High Flow Total Recoverable Arsenic Comparison to Human Health Standard (2008-2013)

Station	n	Minimum (µg/L)	Maximum (µg/L)	Number of Exceedances	Percent Exceedances
SS-07	32	2.4	15	2	6%
SS-06G	38	2.8	16	7	18%
SS-06A	38	3.3	18	7	18%
SS-05A	38	2.5	17	6	16%
SS-05	38	2.3	16	6	16%
SS-04	38	2.5	17	7	18%
SS-01	31	1.9	17	4	13%

Note: Date range evaluated from April 11, 2008 to November 6, 2013.

Figure 8-20 presents summary statistics for the compliance ratios based on total recoverable arsenic results at normal high flow for 2008 to 2013. As shown in the figure, the median total recoverable arsenic compliance ratios are all below 1 (i.e., human health standard). Note that there is little change in arsenic concentrations between stations within the Operable Unit (SS-04 to SS-07) indicating that the arsenic is derived from upstream sources beyond the OU and outside the influence of remedy. An increase in arsenic concentrations is observable between Stations SS-01 and SS-04 when concentrations are low (see Tables 6-5 and 8-5). This increase may be potentially from the ground water inflow between SS-01 and SS-04. This increase is not observed when arsenic concentrations are greater than 3 µg/L at SS-01.

Arsenic only exceeds the human health standard during spring high flow during wet years and there were no exceedances during base flow conditions (see Section 6.2.3).

8.2.4 Review of Compliance for Cadmium

Cadmium concentrations at SS-07 are shown in Figure 8-21. Station SS-05 and SS-04 each had one total recoverable cadmium exceedance of the chronic standard (see Figure 8-22 and 8-23, respectively). Those exceedances are well above typical values, and are suspect as potential outliers. A statistical summary of total recoverable cadmium concentrations in surface water at normal high flow is shown in Table 8-6.

Table 8-6 Normal High Flow Total Recoverable Cadmium Comparison to Chronic Standard (2008-2013)

Station	n	Minimum (µg/L)	Maximum (µg/L)	Number of Exceedances	Percent Exceedances
SS-07	32	0.05	0.23	0	0%
SS-06G	38	0.05	0.32	0	0%
SS-06A	38	0.03	0.21	0	0%
SS-05A	38	0.04	0.32	0	0%
SS-05	38	0.02	0.37	1	3%
SS-04	38	0.02	0.69	1	3%
SS-01	31	0.02	0.12	0	0%

Note: Date range evaluated from April 11, 2008 to November 6, 2013.

Figure 8-24 presents summary statistics for the compliance ratios based on total recoverable cadmium results at normal high flow for 2008 to 2013. In general, cadmium is below the chronic standard in most instances. Median compliance ratios of total recoverable cadmium gradually increased from upstream to downstream, with a slight decrease at station SS-05 and SS-06G, with the highest median value of 0.359 at SS-07.

8.2.5 Review of Compliance for Lead

Total recoverable lead was generally below the chronic standard, with the exception of several exceedances at SS-07, SS-05A, SS-05, and SS-04. These exceedances are shown in Figures 8-25 through 8-28, respectively. Some of these total recoverable lead exceedances, which are substantially greater than typical values, are suspect as potential outlier values. Table 8-7 provides a summary of total recoverable lead exceedances of the chronic standard.

Table 8-7 Normal High Flow Total Recoverable Lead Comparison to Chronic Standard (2008-2013)

Station	n	Minimum (µg/L)	Maximum (µg/L)	Number of Exceedances	Percent Exceedances
SS-07	32	0.77	8.5	2	6%
SS-06G	38	0.56	5.3	0	0%
SS-06A	38	0.31	4.4	0	0%
SS-05A	38	0.6	18	3	8%
SS-05	38	0.56	13	3	8%
SS-04	38	0.23	26	2	5%
SS-01	31	0.22	1.4	0	0%

Note: Date range evaluated from April 11, 2008 to November 6, 2013.

Figure 8-29 presents summary statistics for the compliance ratios based on total recoverable lead results at normal high flow for 2008 to 2013. In general, lead is below the chronic standard in most instances, with the exception of several sample results. Median ratios of total recoverable lead increased from station SS-01 through SS-06A, then slightly decreased through SS-06G and SS-07. Median compliance ratios of total recoverable lead did not exceed 1.

8.2.6 Review of Compliance for Zinc

Zinc concentrations at SS-07 are shown in Figure 8-30. Total recoverable zinc was below the chronic standard, with the exception of one sample result collected November 18, 2009 at SS-04 (150 µg/L) (see

Figure 8-31). This zinc concentration is almost an order of magnitude greater than the total recoverable concentrations reported between 2008 and 2013 at SS-04; therefore, it is suspect as a potential outlier. A statistical summary of total recoverable zinc concentrations in surface water at normal high flow conditions is shown in Table 8-8. Again, only one total recoverable zinc concentration exceedance was reported, at SS-04.

Table 8-8 Normal High Flow Total Recoverable Zinc Comparison to Chronic Standard (2008-2013)

Station	n	Minimum (µg/L)	Maximum (µg/L)	Number of Exceedances	Percent Exceedances
SS-07	32	32	69	0	0%
SS-06G	38	14	65	0	0%
SS-06A	38	9.4	67.6	0	0%
SS-05A	38	11	85	0	0%
SS-05	38	7.6	81	0	0%
SS-04	38	5.5	150	1	3%
SS-01	31	1.9	22.9	0	0%

Note: Date range evaluated from April 11, 2008 to November 6, 2013.

The zinc concentration at SS-04 on November 18, 2009 is considered to be an outlier.

Figure 8-32 presents summary statistics for the compliance ratios based on total recoverable zinc results at normal high flow for 2008 to 2013. Total recoverable zinc is well below the chronic standard for all statistics. Median compliance ratios of total recoverable zinc generally increase from upstream to downstream stations, with the exception of SS-06G that has a slight decrease when compared with the upstream station (SS-06A).

8.2.7 Review of Compliance for Silver

Silver concentrations at SS-07 are shown in Figure 8-33. A statistical summary of total recoverable silver in surface water during normal high flow conditions is shown in Table 8-9 and Figure 8-34. No exceedances of the silver acute standard occurred from 2008 to 2013. There is no chronic aquatic standard for silver.

Table 8-9 Normal high Flow Total Recoverable Silver Comparison to Acute Standard (2008-2013)

Station	n	Minimum (µg/L)	Maximum (µg/L)	Number of Exceedances	Percent Exceedances
SS-07	32	0.04 U	0.82	0	0%
SS-06G	38	0.04 U	0.66	0	0%
SS-06A	38	0.04 U	0.37	0	0%
SS-05A	38	0.04 U	0.37	0	0%
SS-05	38	0.04 U	0.37	0	0%
SS-04	38	0.04 U	0.60	0	0%
SS-01	31	0.04 U	0.37	0	0%

Note: Date range evaluated from April 11, 2008 to November 6, 2013.

8.2.8 Review of Compliance for Iron

Iron concentrations in surface water at SS-07, from 2008 to 2013, are shown in Figure 8-35. Two exceedances occurred during the high flow year of 2011. A statistical summary of total recoverable iron is shown in Table 8-10 and on Figure 8-36. Median iron concentrations are nearly constant through the site with only minor differences from the concentrations at the upstream station, SS-01.

Table 8-10 Normal High Flow Total Recoverable Iron Comparison to Chronic Standard in Surface Water (2008-2013)

Station	n	Minimum (µg/L)	Maximum (µg/L)	Number of Exceedances	Percent Exceedances
SS-07	32	100	1500	2	6%
SS-06G	38	120	1500	3	8%
SS-06A	38	140	1600	5	13%
SS-05A	38	270	2500	7	18%
SS-05	38	260	3300	7	18%
SS-04	38	250	6000	7	18%
SS-01	31	250	1800	5	16%

Note: Date range evaluated from April 11, 2008 to November 6, 2013.

The maximum value at SS-04 is four times greater than the next highest result and is considered an outlier value.

8.3 Summary of Normal High Flow Compliance

For samples collected during normal high flow conditions, exceedances of standards occurred for copper and arsenic. No or very few exceedances of standards occurred for aluminum, cadmium, zinc, and silver were observed. Lead exceedances were potentially related to outliers.

The greatest number of exceedances of the total recoverable copper chronic standard occurred at SS-07, downstream of the Metro sewage treatment plant. SS-05 to SS-06A, downstream of the confluence of Silver Bow Creek and Blacktail Creek and the inputs from Buffalo Gulch, also had several exceedances. The exceedance rates decreased from the early period of 2008 through 2010 to the later period of 2011 through 2013.

Arsenic exceedances occurred throughout the site including at the upstream station. Median compliance ratios for arsenic were fairly constant from SS-04 through SS-06G with no obvious sources of arsenic.

Section 9

Normal High Flow Loading Analysis

This section evaluates mass loading of metals to surface water in the BPSOU during normal high flow conditions with an emphasis on determining sources of metals loading.

9.1 Methodology

This metals loading analysis was used to determine where metals loading is entering the streams during normal high flow conditions. The main stem stations on Blacktail Creek and Silver Bow Creek below its confluence with Blacktail Creek consist of SS-01, SS-04, SS-05, SS-05A, SS-06A, SS-06G, and SS-07. Surface water inputs include Grove Gulch, Montana Pole Treatment Plant, Butte Treatment Lagoons, and the Butte-Silver Bow STP. Data from inputs are identical to those used in Section 7.

Mass loads were calculated for Silver Bow Creek using flow and concentration data as described in Section 7.1. Flow and concentrations were measured directly in the field and in a laboratory analyses and therefore represent known inputs. When measured in the main stem stream, these are instantaneous loads. When measured in tributaries or outfalls, these are input loads. Loads are subject to both discharge measurement error and sampling and analysis error.

Instantaneous loads are compared to the sum of all known input loads. Any deviation indicates a potential unknown "reach load" input or loss of the measured chemical in the stream. These mass loading gains and losses, which cannot be measured directly or easily in the field, may include:

- Groundwater inflow (along the main stem or from tributaries)
- Adsorption/desorption of metals from stream sediment
- Bed or bank originated suspended sediment

The normal high flow loading analysis included the following inputs (from upstream to downstream):

- Grove Gulch
- Blacktail Creek (SS-01)
- Buffalo Gulch
- Montana Pole Treatment Plant Effluent (SS-MPTP)
- Butte Treatment Lagoon System Effluent (CT-EFS7)
- Butte Metro Sewage Treatment Plant Effluent (SS-STP)

Section 7.1.1 further describes the inputs. Note that under normal high flow conditions, inputs have not been monitored since 2009 and it is not certain that they flow into Blacktail and Silver Bow Creeks during all sampling events, nor was it confirmed that they have remained stationary (static) over time. Loads from inputs are set as fixed values as calculated in Section 7.1.

9.2 Discharge Analysis

The discharge analysis for normal high flow conditions was conducted in the same manner as base flow as described in Section 7.2. Beaver dams were noted at SS-06A and SS-05A in October, November, and December 2012 and October and November, 2013. These data were retained for this analysis, but may be imprecise or inaccurate. Discharge was not measured and samples were not collected from SS-01 and SS-07 in 2010.

Main stem discharge statistics for the period 2008-2010 are shown in Figure 9-1. There is considerable spread between the minimum and maximum at station SS-04 through SS-06A, but the median discharge was nearly constant. Increases in median flow are evident at SS-04 and from SS-06A to SS-07.

Main stem discharge statistics for the period 2011-2013 are shown in Figure 9-2. In June 2011 there was very high flow making it unsafe to sample and gage by wading, so June 2011 sampling was delayed until the 28th when discharge was significantly less. Additionally, the median discharge is generally lower in 2011-2013 than in 2008-2010 due to low flows in 2013. The five dates affected by beaver dams at two stations were retained in the statistics.

As noted in Section 7.1, the discharge analysis involves comparing main stem discharge measurements to a summation of all known inputs. The difference is the gain or loss of flow. For this analysis, the median discharge was used for the main stem locations while a fixed value was assigned for the inputs from Section 7.1. Gains or losses within 10 percent of the main stem discharge values may be affected by measurement error.

Gain/loss accounting for the period 2008-2010 is shown in Figure 9-3. A significant gain of 6.3 cfs is evident between SS-01 and SS-04. Because Grove Gulch data were sparse, a small portion of this gain may have resulted from ungaged Grove Gulch discharge. A loss less than 10 percent of main stem discharge is evident between SS-06G and SS-07, which is within the range that could be attributed to measurement error. No other gains or losses are greater than 10 percent of main stem discharge.

Gain/loss accounting for the period 2011 to 2013 is shown in Figure 9-4. Again, a significant gain is noted between SS-01 and SS-04. A loss less than 10 percent of main stem discharge occurred at SS-07, which is within the range that could be attributed to measurement error. No other gains or losses are notable.

9.3 Loading to Blacktail Creek and Silver Bow Creek

Similar to Section 7.2, loads were calculated for each input and each main stem location. Discharge and loading for each COC are graphically represented in the figures in this section. For main stem stations, the median concentration and median discharge were used to calculate a median load. Input loads from Section 7.1 were used as the best available data. Load accounting was conducted by summing all input loads including the upstream station SS-01. The summed load is compared to the main stem load and any difference is considered a gain or loss. The 10 percent uncertainty that comes from measurement error in the discharge data translates to 10 percent uncertainty in the loading data as well.

In addition, load accounting was performed for each normal high flow sampling event and the statistics of these calculations are presented in a box and whisker plot. As with the discharge analysis, sampling dates affected by beaver ponds were retained and samples were not collected at SS-01 and SS-07 in 2010.

9.3.1 Review of Total Recoverable Copper Loading

Total recoverable copper loading was calculated between each main stem station before and after the BRW seep remediation. The graphical copper analyses for pre-seep remediation load accounting from 2008 through 2010 are shown in Figure 9-5. Significant loads are shown from the treatment plants, and tributary loads are minimal. There is a large difference between summed inputs and main stem load indicating significant reach loading. Reach loads greater than 10 percent of the main stem load include 0.51 lb/day at SS-04, 0.44 lb/day at SS-05A, and 0.24 lb/day at SS-06G.

Using reach loads generated for each sampling event, statistics of copper loading for 2008 through 2010 are presented in Figure 9-6. Some of the minimum and maximum gains and losses are large, reflecting the potential outlier concentrations discussed in Section 8. Significant reach loads include SS-04, and SS-05A as well as upstream (SS-01). The reach from SS-04 to SS-05 shows a near zero reach load.

Load accounting for the period 2011 through 2013 is shown in Figure 9-7. Significant loads occurred at the treatment plant inputs, while other input loads are minimal. The summed input load deviates from the main stem load through most of the site indicating reach loading. The largest reach load is at SS-05A followed by a loss at SS-06A. It is uncertain if the adjacent gains and losses are accurate or are a result of imprecision of the underlying data.

Using reach loads generated for each sampling event, statistics of copper loading for 2011 through 2013 are presented in Figure 9-8. Some of the minimum and maximum gains and losses are large, reflecting the potential outlier concentrations discussed in Section 8. Significant reach loads (greater than 10 percent of main stem load) include SS-04 and upstream (SS-01). The reach from SS-04 to SS-05 shows a near zero reach load. A negative load is seen at SS-07.

Based on the input load and net gains and losses shown in Figure 9-5, the largest sources of total recoverable copper from 2008 through 2010 are shown in Table 9-1. As with base flow loading analysis in Section 7.4.1, the reported load from SS-STP was replaced by the load difference between stations SS-06G and SS-07. Combined reaches represent the largest loading source while SS-STP also contributes a significant load. Loads from Figure 9-6 are also shown as a different calculation of median reach loads. The same reaches are significant using this metric.

Table 9-1 Largest Loading Sources for Total Recoverable Copper at Normal High Flow 2008 - 2010

Rank	Source	Type	Median Total Recoverable Copper Load (lb/day)	Percentage of Total Load[1]
1	SS-01 to SS-06G	Combined Reaches	1.33	40%
2	SS-SPT	Input	0.71[2]	21%
3	Upstream of SS-01	Input	0.40	12%
Individual Reaches				
	SS-01 to SS-04	Reach	0.51	15%
	SS-05 to SS-05A	Reach	0.44	13%

[1] Total load includes inputs and reach loads, but excludes load losses.

[2] Load based on difference in load from SS-06G to SS-07.

Based on the input load and net gains and losses shown in Figure 9-7, the largest sources of total recoverable copper from 2011 through 2013 are shown in Table 9-2. The largest loading sources are the same (different order) as the 2008 through 2010 period. The SS-STP represents the largest loading source while the combined reaches contribute the same load. A significant copper load enters the stream in the reach from SS-05 to SS-05A under normal high flow conditions. Loads from Figure 9-8 are also shown as a different calculation of median reach loads. The same reaches are primary contributors of loading using this metric; however, the median load at SS-05 to SS-05A is less. This is an artifact of using two different calculations.

Table 9-2 Largest Loading Sources for Total Recoverable Copper at Normal High Flow 2011 - 2013

Rank	Source	Type	Median Total Recoverable Copper Load (lb/day)	Percentage of Total Load[1]
1	SS-SPT	Input	0.73[2]	39%
2	SS-01 to SS-06G	Combined Reaches	0.72	39%
3	Upstream of SS-01	Input	0.23	12%
Individual Reaches				
	SS-05 to SS-05A	Reach	0.50	27%
	SS-01 to SS-04	Reach	0.19	10%

[1] Total load includes inputs and reach loads, but excludes load losses.
[2] Load based on difference in load from SS-06G to SS-07.

9.3.2 Review of Dissolved Copper Loading

In order to better understand loading of copper, load accounting was conducted for dissolved copper. Very little dissolved data were available for the effluent loads. These were estimated by multiplying the total recoverable copper loads by the median ratio of dissolved copper to total recoverable copper for periods where both values were available. This was generally performed for 2008 to 2009.

Load accounting for 2008-2010 is shown in Figure 9-9. As seen, dissolved loads are less than total recoverable loads. Significant increases in dissolved copper occurred in the slag canyon reach. The largest sources of dissolved copper loading for 2008 through 2010 are shown in Table 9-3.

Table 9-3 Largest Loading Sources of Dissolved Copper 2008-2010

Rank	Source	Type	Median Dissolved Copper Load (lb/day)	Percentage of Total Load[1]
1	SS-STP	Input	0.66[2]	39%
2	SS-01 to SS-06G	Combined Reaches	0.62	37%
3	Upstream of SS-01	Input	0.29	17%
Individual Reaches				
	SS-05 to SS-05A	Reach	0.46	27%
	SS-01 to SS-04	Reach	0.10	6%

[1] Total load includes inputs and reach loads, but excludes load losses.
[2] Load based on difference in load from SS-06G to SS-07.

Load accounting for 2011-2013 is shown in Figure 9-10. The only significant reach load change in dissolved copper occurred at SS-07 as a loss, which is likely due to the approximation of the SS-STP input at this location. The largest sources of dissolved copper loading for 2011 through 2013 are shown in Table 9-4. Loading of dissolved copper in the slag canyon reach decreased by 90 percent compared to 2008 through 2009.

Table 9-4 Largest Loading Sources of Dissolved Copper 2011-2013

Rank	Source	Type	Median Dissolved Copper Load (lb/day)	Percentage of Total Load[1]
1	SS-STP	Input	0.27	42%
2	Upstream of SS-01	Input	0.15	24%
3	SS-01 to SS-06G	Combined Reaches	0.13	20%
Individual Reaches				
4	SS-01 to SS-04	Reach	0.060	9%
5	SS-05 to SS-05A	Reach	0.050	8%

[1] Total load includes inputs and reach loads, but excludes load losses.
[2] Load based on difference in load from SS-06G to SS-07.

9.3.3 Review of Aluminum Loading

Figure 9-11 shows load accounting for dissolved aluminum. Loading was low at each station with the exception of between SS-06G and SS-07. The dissolved aluminum gain between the stations was 0.44 lbs./day which is much less than the 1.2 lb/ day from the SS-STP effluent resulting in a loss of load in this reach, or erroneous measurement of either the SS-STP discharge or the concentration.

The largest sources of dissolved aluminum loading for 2008 through 2013 are shown in Table 9-5. In addition to SS-STP, upstream of SS-01 and the reach from SS-01 to SS-04 provide significant loads. Based on Section 8.2.2, aluminum did not exceed the compliance standard except for one sample at SS-01.

Table 9-5 Largest Loading Sources of Dissolved Aluminum during Normal High Flow 2008-2013

Rank	Source	Type	Median Dissolved Aluminum Load (lb/day)	Percentage of Total Load[1]
1	SS-STP	Input	0.45[2]	39%
2	Upstream of SS-01	Input	0.41	35%
3	SS-01 to SS-06G	Combined Reaches	0.31	27%
Individual Reaches				
4	SS-01 to SS-04	Reach	0.29	25%

[1] Total load includes inputs and reach loads, but excludes load losses.
[2] Load based on difference in load from SS-06G to SS-07.

9.3.4 Review of Arsenic Loading

Total recoverable arsenic samples during normal high flow exceeded the chronic standard by a range of 6 to 1818 percent at all stations from 2008 to 2013. Figure 9-12 shows loading along the main stem stations. Loading was moderate to low at each station with the exception of between SS-01 and SS-04 that had a loading gain of 0.29 lb/day and upstream at SS-01. This gain could be attributed to possible non-point ground water sources between these stations, such as the wetland area. The largest sources of total recoverable arsenic loading for 2008 through 2013 during normal high flow conditions are shown in Table 9-6.

Table 9-6 Largest Loading Sources of Total Recoverable Arsenic during Normal High Flow 2008-2013

Rank	Source	Type	Median Total Recoverable Arsenic Load (lb/day)	Percentage of Total Load[1]
1	Upstream of SS-01	Input	0.37	43%
2	SS-01 to SS-06G	Combined Reaches	0.37	42%
3	SS-STP	Input	0.085[2]	10%[2]
Individual Reaches				
4	SS-01 to SS-04	Reach	0.29	34%

[1] Total load includes inputs and reach loads, but excludes load losses.
[2] The load based on difference in load from SS-06G to SS-07 is negative (loss). The load shown in this table is based on monitoring data discussed in Section 7.2.4.

9.3.5 Review of Cadmium Loading

Total recoverable cadmium during normal high flow only exceeded the chronic standard twice between 2008 and 2013. Load accounting for cadmium is shown in Figure 9-13, the largest sources of cadmium loading are listed in Table 9-7. Loading is spread over several sources with no individual source causing large increases or exceedances, with the SS-STP and SS-05 to SS-05A being the greatest contributors.

Table 9-7 Largest Loading Sources of Total Recoverable Cadmium during Normal High Flow 2008-2013

Rank	Source	Type	Median Total Recoverable Cadmium Load (lb/day)	Percentage of Total Load[1]
1	SS-01 to SS-06G	Combined reaches	0.0096	47%
2	SS-STP	Input	0.0051[2]	25%
3	Upstream of SS-01	Input	0.0028	14%
Individual Reaches				
	SS-05 to SS-05A	Reach	0.0046	23%
	BTL	Input	0.0025	12%

[1] Total load includes inputs and reach loads, but excludes load losses.
[2] Load based on difference in load from SS-06G to SS-07

9.3.6 Review of Lead Loading

Total recoverable lead during normal high flow had few exceedances, generally less than 8 percent at each station, with the maximum number of exceedances (three each) occurring at stations SS-05 and SS-05A. Lead load accounting during normal high flow conditions is shown in Figure 9-14. The largest sources of total recoverable lead are listed in Table 9-8. Lead loading occurred over the reach from upstream of the site to SS-05A plus the SS-STP effluent. Even though loading gains are occurring, total recoverable lead compliance exceedances are low.

Table 9-8 Largest Loading Sources of Total Recoverable Lead during Normal High Flow 2008-2013

Rank	Source	Type	Median Total Recoverable Lead Load (lb/day)	Percentage of Total Load[1]
1	SS-01 to SS-06G	Combined Reaches	0.20	73%
2	Upstream of SS-01	Input	0.040	14%
3	SS-STP	Input	0.028[2]	10%
Individual Reaches				
	SS-01 to SS-04	Reach	0.10	37%
	SS-05 to SS-05A	Reach	0.043	15%

[1] Total load includes inputs and reach loads, but excludes load losses.
[2] Load based on difference in load from SS-06G to SS-07.

9.3.7 Review of Zinc Loading

Total recoverable zinc during normal high flow only exceeded the chronic standard once from 2008 to2013. For completeness, zinc loading was calculated and is shown in Figure 9-15. The largest sources of total recoverable zinc are listed in Table 9-9. The SS-STP effluent is the largest loading source for zinc followed by the combined stream reaches and BTL effluent.

Table 9-9 Largest Loading Sources of Total Recoverable Zinc during Normal High Flow 2008-2013

Rank	Source	Type	Median Total Recoverable Zinc Load (lb/day)	Percentage of Total Load[1]
1	SS-STP	Input	3.16[2]	41%
2	SS-01 to SS-06G	Combined Reaches	2.35	31%
3	BTL	Input	1.22	16%
Individual Reaches				
	SS-05 to SS-05A	Reach	0.95	12%
	SS-01 to SS-04	Reach	0.95	12%

[1] Total load includes inputs and reach loads, but excludes load losses.
[2] Load based on difference in load from SS-06G to SS-07.

9.3.8 Review of Silver Loading

Total recoverable silver during normal high flow did not exceed the chronic standard from 2008 to 2013. The majority of values for silver were not detected. The non-detected values were accepted at the reporting limit and included in the analysis. As a result, the loading analysis may be biased high and should be used with caution.

The total recoverable silver load accounting for normal high flow is shown in Figure 9-16. The largest total recoverable silver gain was between upstream of SS-01. Due to the uncertainty caused by the large number of non-detected values, no ranking is presented.

9.3.9 Review of Iron Loading

Total recoverable iron during normal high flow exceeded the chronic standard at all stations with exceedances ranging from 6 to 18% from 2008 to 2013. Iron loading was calculated and is shown in Figure 9-17. Iron is easily attenuated in surface water and the load varies significantly between main stem locations resulting in some large negative loads. The largest sources of total recoverable iron are listed in Table 9-10. Upstream of SS-01 and the reach from SS-01 to SS-04 comprise nearly all the iron loading sources. Negative loads (losses) occurred in the reach from SS-05A to SS-07.

Table 9-10 Largest Loading Sources of Total Recoverable Iron during Normal High Flow 2008-2013

Rank	Source	Type	Median Total Recoverable Iron Load (lb/day)	Percentage of Total Load[1]
1	Upstream of SS-01	Input	43.4	50%
2	SS-01 to SS-05A	Combined Reaches	39.6	45%
3	SS-STP	Input	2.65[2]	3%
Individual Reaches				
	SS-01 to SS-04	Reach	30.2	35%
	SS-05 to SS-05A	Reach	7.0	8%

[1] Total load includes inputs and reach loads, but excludes load losses.
[2] The load based on difference in load from SS-06G to SS-07 is negative (loss). The load shown in this table is based on monitoring data discussed in Section 7.2.4.

9.4 Summary of Normal High Flow Loading

The ranking of loading sources for each COC are summarized in Table 9-11 and Figure 9-18 for 2011 to 2013 for copper and 2008 to 2013 for other COCs. Section 8.8 indicated that the most significant exceedances of chronic standards were for copper and arsenic. The largest sources of total recoverable copper were at the SS-STP followed by the reach within the slag canyon. Examination of Table 9-11, reveals a similar patterns seen in Section 7.0. It appears the SS-STP and combined BPSOU reaches are primarily loaders of COCs to Silver Bow Creek, with the addition of the upstream condition during normal high flow.

Table 9-11 Ranking of loading for Each Contaminant of Concern During Normal High Flow 2011-2013

Rank[1]	Total Recoverable Copper	Dissolved Copper	Dissolved Aluminum	Total Recoverable Arsenic	Total Recoverable Cadmium	Total Recoverable Lead	Total Recoverable Zinc	Total Recoverable Iron
1	SS-STP (39%)	SS-STP (42%)	SS-STP (39%)	Upstream of SS-01 (43%)	Combined Reaches (47%)	Combined Reaches (73%)	SS-STP (41%)	Upstream of SS-01 (50%)
2	Combined Reaches (39%)	Upstream of SS-01 (24%)	Upstream of SS-01 (35%)	Combined Reaches (42%)	SS-STP (25%)	Upstream of SS-01 (14%)	Combined Reaches (31%)	Combined Reaches (45%)
3	Upstream of SS-01 (12%)	Combined Reaches (20%)	Combined Reaches (27%)	SS-STP (10%)	Upstream of SS-01 (14%)	SS-STP (10%)	BTL (16%)	SS-STP (3%)

[1] The load rankings present only the top three load inputs and/or reach loads, but exclude load losses. As a result, percentages do not always add up to 100%.

Section 10

Wet Weather Flow Compliance Analysis

This section compares recent wet weather flow monitoring data to acute aquatic life standards at points of compliance along Silver Bow Creek and Blacktail Creek as required in the ROD; interpretation of these data is the focus of Section 12. RAOs require surface water to meet water quality standards, and this section evaluates progress toward that requirement. Wet weather flow conditions are defined in Section 1.7.

As mentioned in Sections 6 and 8, mercury analysis is not presented this section. The data quality issues need to be resolved before these data can be presented and analyzed. Mercury data from an outside source (SSTOU) are presented and evaluated in Chapter 12.

10.1 In-Stream Storm Water Concentrations

Wet weather flow samples are generally collected in-stream in Blacktail and Silver Bow creeks at the same stations as base flow monitoring. Additional sampling is performed at Buffalo Gulch and upper Silver Bow Creek. The stations are listed below and were shown previously on Figure 6-1. The Butte Hill sub-drainages are discussed in Section 5 and presented in Figures 5-1 through 5-12.

In-Stream Stations:

- SS-01 (Blacktail Creek at Harrison Avenue, USGS 123231230)
- GG-01/GG-BTC (Grove Gulch at the mouth)
- SS-04 (Blacktail Creek above its confluence with Silver Bow Creek, USGS 12323240)
- SS-05 (Silver Bow Creek below its confluence with Blacktail Creek and below Buffalo Gulch)
- SS-05A (Silver Bow Creek below “slag canyon”)
- SS-06A (Silver Bow Creek below new channel below Catch Basin 9)
- SS-06G (Silver Bow Creek below treatment lagoon effluent)
- SS-07 (Silver Bow Creek below wastewater treatment plant)

10.2 Types of Sampling

Wet weather flow conditions are defined as short duration periods when runoff is occurring from the Butte Hill as measured at storm drain outfalls and/or when samples are collected at any of the wet weather discharge points. In general, wet weather flow conditions are highly variable and typically occur during rainfall and snowmelt events from spring through late summer and early fall.

- Because wet weather events and their subsequent effect on Silver Bow Creek flows are typically short-lived (a few hours or less), automatic samplers are relied upon for wet weather sample collection. When personnel are readily available, field grab samples are also collected. Two types of automatic samplers are utilized, “ISCO” and “DTEC” samplers (AR 2007, AR 2013a). The ISCO samplers begin sample collection at a pre-set stage (bubbler flow activator) and collect four, 2-liter samples at 1-hour intervals. The ISCO samplers require a power supply and continuous flow above the stage bubbler. The DTEC samplers are mechanical samplers that do not require power to collect a sample. The sampler is mounted on a secure post at a pre-determined stage. The sample container fills when the water level in the channel reaches the top of the container, and a spring-loaded mechanism, connected to an internal float, trips closed when the bottle is filled, preserving the integrity of the sample. The DTEC samplers collect "first flush" samples and are utilized in sub-drainages that are normally dry. ISCO samplers measure concentrations throughout the storm hydrograph and are located at in-stream stations in Blacktail and Silver Bow creeks.

- At certain stations, ISCO and DTEC samplers collect a sample at a single point in the stream, and inputs from wet weather may not be well combined at the sampling point. Of particular concern are stations SS-05 and SS-07. The ISCO intake for Station SS-05 is located near the left bank, and stormwater inputs from upper Silver Bow Creek and Buffalo Gulch are located a very short distance upstream from the right bank. The ISCO sampler at Station SS-07 is located near the center of the stream only tens of feet downstream of the Metro Wastewater Treatment Plant outfall. The ROD was specific about the method of normal flow sampling for Station SS-07 stating that "*Because of poor mixing at station SS-07, and the critical nature of this station, samples at SS-07 shall be collected using the depth and width integrating technique (used by the USGS), breaking the stream into 20 to 25 sections from bank to bank, and a churn splitter.*" (ROD, Section 12.6.3.2). Because of the concern, stormwater data in general and samples from Stations SS-05 and SS-07 collected using automatic samplers specifically are less representative of true conditions than data from normal flow samples collected using the equal width increment method. This is a reflection of the limitations of the sampling equipment operated within its capabilities and according to its instructions.

The ROD requires that all in-stream compliance stations be monitored using automatic samplers to obtain concentration information throughout the storm hydrograph. Stations SS-01, GG-BTC, SS-04. SS-05, SS-05A, SS-06A, SS-06G, and SS-07 have ISCO samplers installed.

10.3 Compliance Analysis of Individual COCs

For wet weather flow, compliance is defined in the ROD as follows:

- Compliance during wet weather conditions means consistently measuring concentrations of COCs at in-stream compliance monitoring locations that are below the Montana DEQ-7 acute aquatic life standards. This ROD establishes points of compliance for wet weather conditions at monitoring stations GG-01 (Grove Gulch), SS-04 (Blacktail Creek), and stations SS-05, SS-05A, SS-06A, SS-06G, and SS-07 in Silver Bow Creek.

- For clarity in this compliance analysis and given that copper, cadmium, lead and zinc have a variable standard based on hardness, COC concentrations were converted to a ratio of the COC concentration to the standard ("compliance ratio"). Where the COC concentration is equal to the calculated standard, the compliance ratio is 1. If the COC concentration is less than the standard, the compliance ratio will be less than 1. An exceedance of the standard results in a compliance ratio greater than 1. The acute aquatic life standards are based on a one-hour average and most of the data presented herein were collected hourly during runoff events. For compliance purposes, samples collected one hour apart would be averaged and compared to the standard. The analysis presented in this section does not conduct this averaging and uses discrete data only. As a result, the number and rates of exceedances may be somewhat overstated. Since this accounting of exceedances is used for characterization, not assessment of penalties, this potential overstatement is acceptable for this purpose.

The compliance data are presented as follows:

- Time plots of total recoverable and dissolved metals concentrations with acute standards.
- For this analysis, the data are grouped according to in-stream monitoring station and analyzed statistically. Statistics include 1st and 3rd quartile, median, maximum and minimum values. This provides a clear comparison of compliance throughout Blacktail and Silver Bow, from upstream to downstream, for the period 2008 through 2010 and 2011 through 2013. This systematic station comparison allows the analyst to identify stream reaches and stormwater inputs in reaches that are having the greatest degradation effect on the stream.

In analyzing the dataset, the first four individual ISCO samples from each storm event were included in the analysis; however, during 2012 and 2013, up to an additional four extra samples were collected. Since these extra samples were likely collected after the wet weather event had passed, they were not included in the dataset since they would have biased the statistics low. Field grab samples were also included.

10.3.1 Review of Compliance for Copper

Total recoverable and dissolved copper concentrations during wet weather conditions from 2008 through 2013 at Station SS-07 are shown in Figure 10-1. Similar plots for stations SS-06G through GG-BTC are shown in Figures 10-2 through 10-8. Total recoverable copper concentrations always exceeded the acute standard at both stations SS-07 and SS-06G (see Figures 10-1 and 10-2) and almost always exceeded the acute standard for Station SS-06A to SS-01. From 2008 to 2013, total recoverable copper exhibits no apparent trend. Table 10-1 provides a statistical summary of total recoverable copper concentrations compared to the acute standard from 2008 to 2010 and Table 10-2 provides a statistical summary of total recoverable copper concentrations compared to the acute standard from 2011 to 2013. Both periods had a high percentage of exceedances, especially in the downstream stations. It is notable that the upstream station, SS-01, had a high rate of exceedances for both periods. The maximum copper concentrations were lower overall in the later period. The rates of exceedance are lower at GG-BTC. Based on the location of that station at the confluence of Grove Gulch and Blacktail Creek, it is possible that the samples could represent Grove Gulch, Blacktail Creek, or a blend depending on the timing of the sample and the relative stages of the two creeks.

Table 10-1 Total Recoverable Copper Comparison to Acute Standard in Surface Water (2008-2010)

Station	n	Minimum (µg/L)	Maximum (µg/L)	Number of Exceedances	Percent Exceedances
SS-07	94	24	870	94	100%
SS-06G	99	20	1000	99	100%
SS-06A	80	23	1100	80	100%
SS-05A	77	18.8	1600	77	100%
SS-05	98	14	1500	97	99%
SS-04	71	8.5	7300	59	83%
SS-01	76	10	5900	71	93%
GG-01/GG-BTC	46	7.3	340	30	65%

Note: Date range evaluated from April 15, 2008 to September 8, 2010.

Table 10-2 Total Recoverable Copper Comparison to Acute Standard in Surface Water (2011-2013)

Station	n	Minimum (µg/L)	Maximum (µg/L)	Number of Exceedances	Percent Exceedances
SS-07	67	19	860	67	100%
SS-06G	82	20	530	82	100%
SS-06A	82	8.5	590	76	93%
SS-05A	86	10	1800	85	99%
SS-05	102	11	980	98	96%
SS-04	92	4.3	420	78	85%
SS-01	65	8.4	890	58	89%
GG-BTC	76	3.1	380	38	50%

Note: Date range evaluated from April 15, 2008 to September 8, 2010.

Figure 10-9 and 10-10 present summary statistics for the compliance ratios based on total recoverable copper results in main stem stations and Grove Gulch during wet weather flow for 2008 through 2010 and 2011 through 2013, respectively. Median and lower quartile total recoverable copper compliance ratios exceed 1 for all main stem monitoring stations, and frequently are between 2 and 7 times the acute standard. More importantly, the third quartile values increase by a factor of approximately 2.5 times between stations SS-04 and SS-05 and then stay fairly consistent for the remainder of the downstream stations. This indicates that upper Silver Bow Creek and Buffalo Gulch are sources of total recoverable copper during wet-weather events. Maximum compliance ratios were more than one hundred times the acute standard from 2008 to 2010 and decreased to be consistently less than one hundred times the acute standard during 2011 through 2013. Minimum compliance ratios were also greater than one in Silver Bow Creek from 2008 through 2010, but were at or less than one from 2011 through 2013. Silver Bow Creek is rarely in compliance with the acute standard during wet weather conditions.

10.3.2 Review of Compliance for Aluminum

Figures 10-11 through 10-18 present the aluminum concentrations over time at stations SS-07 through GG-BTC, respectively. According to DEQ-7, the acute standard for aluminum is based on the dissolved fraction, and is applicable on for a pH range between 6.5 and 9.0. Dissolved aluminum concentrations were below the acute standard with the exception of a few maximum recorded concentrations at stations SS-04 through SS-06G. Some of the results for samples collected in 2013 were notably higher than results for samples collected within the same timeframe and are possible outliers. Although most of these were validated as enforcement quality data in the 2013 Draft Final DSR (AR 2013c), the values being a full one to two orders of magnitude greater than other sample results from the same sampling event including one where the dissolved values exceeded the total recoverable value makes these suggests that these data are suspect and should be classified as outliers. Consequently, these outliers (concentrations greater than 2000 µg/L) are not used in this report. As a result, no exceedances of the acute standard have been recorded in the valid data set. A summary of dissolved aluminum concentrations and exceedances of the acute standard is shown in Table 10-3.

Table 10-3 Dissolved Aluminum Comparison to Acute Standard in Surface Water (2008-2013)

Station	n	Minimum (µg/L)	Maximum (µg/L)	Number of Exceedances	Percent Exceedances
SS-07	161	2.0	96	0	0%
SS-06G	179	1.9	410	0	0%
SS-06A	162	2.1	250	0	0%
SS-05A	171	4.1	280	0	0%
SS-05	198	2.0	290	0	0%
SS-04	161	1.5	200	0	0%
SS-01	141	3.4	240	0	0%
GG-BTC	124	1.5	240	0	0%

Note: Date range evaluated from April 15, 2008 to October 1, 2013. The acute standard for aluminum is 750 µg/L.

Figure 10-19 presents summary statistics for the compliance ratios based on dissolved aluminum results during wet weather flow for 2008 through 2013. As seen, all concentrations of dissolved aluminum were well below the acute standard.

10.3.3 Review of Compliance for Arsenic

Wet weather flow concentrations for arsenic in surface water from 2008 to 2013 at SS-07 through GG-BTC are shown in Figures 10-20 through 10-27. Total recoverable arsenic exceeded the acute standard (340 µg/L) only once at SS-04 on June 15, 2009 (see Figure 10-25). All other total recoverable arsenic concentrations did not exceed the acute standard. Table 10-4 provides a statistical summary of total recoverable arsenic from 2008 to 2013 compared to the acute standard.

Table 10-4 Total Recoverable Arsenic Comparison to Acute Standard in Surface Water (2008-2013)

Station	n	Minimum (µg/L)	Maximum (µg/L)	Number of Exceedances	Percent Exceedances
SS-07	161	5	91	0	0%
SS-06G	180	5.5	81	0	0%
SS-06A	162	5.4	67	0	0%
SS-05A	172	4.8	240	0	0%
SS-05	199	4.8	110	0	0%
SS-04	163	1.6	370	1	1%
SS-01	141	3.6	220	0	0%
GG-BTC	125	2.9	94	0	0%

Note: Date range evaluated from April 15, 2008 to October 1, 2013.

Figure 10-28 presents summary statistics for the compliance ratios based on total recoverable arsenic results during wet weather flow for 2008 through 2013. All median compliance ratios for total recoverable arsenic were well below 1. Maximum concentrations of total recoverable arsenic exceeded the acute standard once at SS-04 only. SS-01 had the lowest median concentration.

10.3.4 Review of Compliance for Cadmium

Total recoverable cadmium had a low number of exceedances at all main stem stations; wet weather flow concentrations for cadmium from 2008 through 2013 at SS-07 to GG-BTC are shown in Figures

10-29 through Figure 10-36. Total recoverable cadmium exceedances ranged from 12 percent at SS-05A to 2 percent at SS-04. Table 10-5 provides a statistical summary of total recoverable cadmium from 2008 to 2013 compared to the acute standard.

Table 10-5 Total Recoverable Cadmium Comparison to Acute Standard in Surface Water (2008-2013)

Station	n	Minimum (µg/L)	Maximum (µg/L)	Number of Exceedances	Percent Exceedances
SS-07	161	0.14	7.9	11	7%
SS-06G	180	0.12	14	21	12%
SS-06A	163	0.06	6.8	19	12%
SS-05A	173	0.07	15	23	13%
SS-05	198	0.06	14	26	13%
SS-04	163	0.03	40	4	3%
SS-01	141	0.02	30	9	6%
GG-BTC	122	0.03	3	1	1%

Note: Date range evaluated from April 15, 2008 to October 1, 2013.

Figure 10-37 presents summary statistics for the compliance ratios based on total recoverable cadmium results during wet weather flow for 2008 through 2013. Median total recoverable cadmium compliance ratios are all less than 1, but exceedances still occur (i.e., maximum concentrations). It should be noted that between stations SS-04 and SS-05, the third quartile value increases by a factor of approximately 2.5 times. As with copper, this is a clear indication that upper Silver Bow Creek and Buffalo Gulch are large sources of total recoverable cadmium.

10.3.5 Review of Compliance for Lead

Wet weather flow concentrations for lead from 2008 to 2013 at SS-07 to GG-BTC are shown in Figures 10-38 through 10-45. Total recoverable lead had a moderate number of exceedances from 2008 to 2013. Total recoverable lead concentrations ranged from 0.39 µg/L to 2,800 µg/L (both extremes occurred at SS-04). These large variations in concentration are indicative of variability in flushing of suspended solids during wet weather events. Table 10-6 presents concentrations and percent exceedances of total recoverable lead from 2008 to 2013 compared to acute standard.

Table 10-6 Total Recoverable Lead Comparison to Acute Standard in Surface Water (2008-2013)

Station	n	Minimum (µg/L)	Maximum (µg/L)	Number of Exceedances	Percent Exceedances
SS-07	161	2.8	650	25	16%
SS-06G	180	3.5	800	32	18%
SS-06A	162	2.2	700	33	20%
SS-05A	172	2.05	1100	41	24%
SS-05	198	1.4	1200	47	24%
SS-04	163	0.39	2800	11	7%
SS-01	141	0.84	2400	15	11%
GG-BTC	122	0.46	220	8	7%

Note: Date range evaluated from April 15, 2008 to October 1, 2013.

Figure 10-46 presents summary statistics for the compliance ratios based on total recoverable lead results during wet weather flow for 2008 through 2013. Median and third quartile total recoverable lead compliance ratios are all less than 1, but exceedances still occur. Stations SS-01 and SS-04 had the lowest main stem median compliance ratios, but also represent stations that recorded the highest maximum ratios. The median compliance ratios (and percentiles) increased between SS-04 and SS-05 and remained stable through SS-07. It should be noted that between stations SS-04 and SS-05, the third quartile value increases by a factor of approximately 5.3 times. As with copper, this is a clear indication that upper Silver Bow Creek and Buffalo Gulch are large sources of total recoverable lead.

10.3.6 Review of Compliance for Zinc

Wet weather flow concentrations for zinc from 2008 to 2013 at SS-07 to GG-BTC are shown in Figure 10-47 through Figure 10-54. Total recoverable zinc exceeded the acute standard in approximately 50 percent of samples analyzed at stations SS-05 through SS-07. Stations SS-01 and SS-04 had a lower number of exceedances, 24 and 19 percent, respectively. In addition, zinc reported large fluctuations in concentrations between the minimum and the maximum reported values. For example, at station SS-04, the total recoverable zinc concentrations ranged from 8.5 µg/L to 10,900 µg/L. These variations are likely attributed to re-suspension of solids either from along the stream bank or from other sources along the creek. Table 10-7 presents concentrations and percent exceedances of the acute standard for total recoverable zinc concentrations from 2008 to 2013.

Table 10-7 Total Recoverable Zinc Comparison to Acute Standard in Surface Water (2008-2013)

Station	n	Minimum (µg/L)	Maximum (µg/L)	Number of Exceedances	Percent Exceedances
SS-07	161	39	1800	87	54%
SS-06G	180	30	2200	107	59%
SS-06A	162	22	1800	89	55%
SS-05A	172	23	3700	108	63%
SS-05	208	16	4700	91	44%
SS-04	163	8.5	10900	31	19%
SS-01	141	5.8	9100	34	24%
GG-BTC	122	7.4	1100	14	11%

Note: Date range evaluated from April 15, 2008 to October 1, 2013.

Figure 10-55 presents summary statistics for the compliance ratios based on total recoverable zinc results during wet weather flow for 2008 through 2013. As seen, median total recoverable compliance ratios exceed 1 for stations SS-05A through SS-07 and approach exceedance at SS-05. Median total recoverable compliance ratios were well below the acute standard at SS-01, SS-04, and GG-BTC. It should be noted that between stations SS-04 and SS-05, the median and third quartile value increases by a factor of approximately 2 to 3 times. As with copper, this is a clear indication that upper Silver Bow Creek and Buffalo Gulch are significant sources of total recoverable zinc.

10.3.7 Review of Compliance for Silver

Total recoverable silver concentrations at SS-07 to GG-BTC from 2008 to 2013 are shown in Figure 10-56 through 10-63. Most dissolved silver results are non-detected and are shown at the reporting limit. An apparent downward trend seen in the total recoverable silver results at all stations reflects lower detection limits. The higher concentrations do not show any trend. At SS-07, total recoverable silver only exceeded the acute standard twice and represented the station with the lowest exceedance rate. All other stations had a low number of exceedances that ranged from 2 percent (SS-06G) to 7 percent

(SS-05A). Table 10-8 presents total recoverable silver concentrations from 2008 to 2013 along with percentages of acute standard exceedances.

Table 10-8 Total Recoverable Silver Comparison to Acute Standard in Surface Water (2008-2013)

Station	n	Minimum (µg/L)	Maximum (µg/L)	Number of Exceedances	Percent Exceedances	Percent Non detected
SS-07	161	<0.04	5.0	2	1%	33%
SS-06G	180	<0.05	6.6	4	2%	31%
SS-06A	162	<0.05	5.8	8	5%	29%
SS-05A	172	<0.05	8.8	12	7%	28%
SS-05	200	<0.04	8.2	10	5%	45%
SS-04	163	<0.04	13	3	2%	56%
SS-01	141	<0.04	8.5	5	4%	61%
GG-BTC	122	<0.04	2.3	0	0%	56%

Note: Date range evaluated from April 15, 2008 to October 1, 2013.

Figure 10-64 presents summary statistics for the compliance ratios based on total recoverable silver results during wet weather flow for 2008 through 2013. As seen, median and 3rd quartile (i.e., 75th percentile) compliance ratios of total recoverable silver were all well below 1. Only the maximum concentrations exceeded the acute standard, likely attributed to flushing and re-suspending solids in the water column during wet weather events.

10.4 Summary of Wet Weather Compliance

Total recoverable copper had a large number of exceedances of the acute standard at all stations during all periods. Stations SS-06G and SS-07 exceeded the acute standard in all samples. There was little difference between the 2008-2010 period and the 2011-2013 period.

Cadmium, lead, and zinc all had a significant number of exceedances with the greatest rates of exceedance at stations SS-05 through SS-07. Few to no exceedances were recorded for aluminum, arsenic, and silver.

Section 11

Wet Weather Flow Loading Analysis

This section evaluates mass loading of metals in surface water in the BPSOU during wet weather flow conditions with emphasis on determining sources of metals loading. Interpretation of the loading analysis is presented in Section 12.

11.1 Methodology

Metals loading analysis was used to help identify where contaminated stormwater is entering the streams during wet weather flow conditions. The main stem stations on Blacktail and Silver Bow Creeks consist of SS-01, SS-04, SS-05, SS-05A, SS-06A, SS-06G, and SS-07.

Data collected during wet weather conditions are much more variable than those collected during normal flow. For example, most main stem wet weather data include hourly samples collected using an ISCO sampler while input data are collected using an automatic grab sampler and represent a single sample collected on the rising limb of an event hydrograph. Concentrations data collected by these two methods are not comparable for the purposes of load accounting. Additionally, wet weather flow is not measured in the field during wet weather monitoring, but rather it is calculated from a recorded stage using a stage discharge rating curve. As a result, the loading analysis conducted using wet weather data is different than the loading analysis presented in Sections 7 and 9. For this analysis, data were assembled as follows:

- Event data where all seven main stem stations, upper Silver Bow Creek, and Buffalo Gulch input data were available were assembled. This step eliminated all snowmelt data as these were incomplete data sets.
- Events where either concentrations data or discharge data were incomplete were filtered out. Discharge data were missing for all wet weather data collected in 2012 resulting in a full year of unusable data for analysis.
- Data for only the first three hours of ISCO sampler sample collection were filtered for consistency between years. The assembled data included 22 events available for analysis.

Concentrations were measured using laboratory analyses and therefore represent known inputs. Discharge was typically derived from stage data which were converted to discharge using a stage-discharge relationship curve. Concentration and discharge were used to calculate instantaneous loads. When more than one sample was collected per event, these were arithmetically averaged to obtain an event mean load. This is typically the case for main stem stations and some inputs in 2013. For wet weather flow conditions, even though loading is calculated in lbs./day, the actual loading only occurs during the wet weather events, and thus is normalized to days by multiplying the instantaneous flow observation in ft^3/s by the number of seconds per day (86,400). These events typically do not extend beyond a 24 hour period.

Because main stem and input loads are not directly comparable due to differing collection methodology, this section will analyze these data separately.

11.2 Loading to Blacktail Creek and Silver Bow Creek

Event mean loading in main stem stations are used to evaluate loading in the Blacktail and Silver Bow Creeks. For each COC, event mean loading is calculated and statistics for the event mean loading are presented and discussed. The differences in event mean loading between stations are calculated and the median differences are presented and discussed to evaluate loading within each main stem reach. The difference between the median of event means at each station shown in the figures is not always equal to the median of the difference between event means because of the order of calculation. The net main stem load can be either a positive or negative number, depending on whether a gain or loss was calculated. Input loads are not directly comparable and are discussed in Section 11.3.

11.2.1 Main Stem Copper Loading

For the 22 events that data were assembled, event mean total recoverable copper loads were compiled and statistics including median, minimum, maximum and first and third quartiles were calculated. These are presented in Figure 11-1. Station SS-01 is similar to SS-04 while the remaining stations are higher, but similar to each other. The primary change is an increase in loading from SS-04 to SS-05 which is the reach that includes upper Silver Bow Creek and Buffalo Gulch inputs.

The stream bank removal action at the confluence of Blacktail Creek and Silver Bow Creek was conducted in 2011 and the hydrodynamic devices were installed in upper Silver Bow Creek and Buffalo Gulch areas in 2012. In order to evaluate whether these actions resulted in reduced loading to Silver Bow Creek below its confluence with Blacktail Creek, statistics of loading are presented for periods before and after these actions.

For the period 2008 through 2010, 13 events were available and loading statistics of these events are presented in Figure 11-2. Again, a significant increase in loading is observable between SS-04 and SS-05.Loading statistics for 2013 including five events are shown in Figure 11-3. Loading at SS-01 is lower than previous years due to lower recorded discharge. The increase in loading from SS-04 to SS-05 seen in previous years remains. Loading is lower at SS-06A than in the upstream and downstream stations in 2013. In 2013, SS-06A was sampled on a three hour frequency rather than a one hour frequency for the other stations. Averaging of two samples rather than four apparently resulted in lower event mean loads at this station. The reduction in load at SS-06A is more a result of data availability and less likely to be an actual field phenomenon.

Net change in event mean loads are shown in Figure 11-4. The changes are similar between periods with the exception of 2013 gains and losses surrounding station SS-06A where the large gain and loss are of the same magnitude and are canceled. There is a notablegain at SS-04 to SS-05 which represents the largest observed gain between main stem stations. The gain is larger in 2013 following remedial actions including the stream bank work and installation of HDDs. The sample sizes are small (n= 13 for 2008-2010 and n=5 for 2013), so this difference could be insignificant. As expected, the maximum loading occurred between SS-04 and SS-05 because of the load inputs from the two major stormwater inputs – upper Silver Bow Creek and Buffalo Gulch.

11.2.2 Main Stem Aluminum Loading

Wet weather flow dissolved aluminum loading statistics for 2008 through 2010 are presented in Figure 11-5. There is a slight increase in loading from SS-01 to SS-06A followed by a slight decrease to SS-07.

Aluminum loading statistics for 2013 are shown in Figure 11-6. Nearly all median aluminum concentrations are lower than the 2008 to 2010 period. The pattern of increases is similar to Figure 11-5 with the exception of SS-06A, which is likely lower due to fewer available data. Loading differences between main stem stations are shown in Figure 11-7. Notable increases occurred from from SS-04 to SS-05 in 2008 through 2010. The large change in load around SS-06A in 2013 is likely due to the number of data values used in the calculations.

11.2.3 Main Stem Arsenic Loading

Total recoverable arsenic during wet weather loading statistics for 2008 through 2010 are presented in Figure 11-8. There is little change through the site with only a slight increase from SS-04 to SS-05. Arsenic loading statistics for 2013 are shown in Figure 11-9. SS-01 loading is notably lower than during the earlier period and is lower than the other stations. Flows recorded during the 2013 sampling were much lower than previous years leading to low calculated loads. This low median load value results in a notable increase at stations SS-04 and SS-05. Again, SS-06A is anomalously low due to the lower data availability. Loading differences between main stem stations are shown in Figure 11-10. Both periods show a load increase from SS-04 to SS-05.

11.2.4 Main Stem Cadmium Loading

Total recoverable cadmium during wet weather loading statistics for 2008 through 2010 are presented in Figure 11-11. There is an increase in load from SS-04 to SS-05 with little other change. Cadmium loading statistics for 2013 are shown in Figure 11-12. SS-01 loading is notably lower than during the earlier period and is lower than the other stations. This low load value results in a increase at stations SS-04 and SS-05. The highest cadmium load is at SS-06G. Again, SS-06A is anomalously low due to the data availability. Loading differences between main stem stations is shown in Figure 11-13. The 2008 through 2010 data indicate a significant load increase from SS-04 to SS-05 while the 2013 data are variable.

11.2.5 Main Stem Lead Loading

Total recoverable lead during wet weather loading statistics for 2008 through 2010 are presented in Figure 11-14. There is an increase in load from SS-04 to SS-05 with little other change. Lead loading statistics for 2013 are shown in Figure 11-15. Again, SS-01 loading is significantly lower than during the earlier period and is lower than the other stations. This low load value results in a significant increase at stations SS-04 and SS-05. The highest lead load is at SS-06G. Again, SS-06A is anomalously low due to the data availability. Loading differences between main stem stations is shown in Figure 11-16. The 2008 through 2010 data indicate a significant load increase from SS-04 to SS-05 while the 2013 data are variable.

11.2.6 Main Stem Zinc Loading

Total recoverable zinc loading statistics for 2008 through 2010 are presented in Figure 11-17. There is a substantial (4.4×) increase in load from SS-04 to SS-05 with little other change. Zinc loading statistics for 2013 are shown in Figure 11-18. Again, SS-01 loading is notably lower than during the earlier period and is lower than the other stations. This low load value results in a notable increase at stations SS-04 and SS-05. The highest lead load is at SS-06G. Again, SS-06A is anomalously low due to the data availability. Loading differences between main stem stations are shown in Figure 11-19. The data indicate a significant load increase from SS-04 to SS-05 while the 2013 data are variable with an increase from SS-01 to SS-04. The load increase from SS-06A to SS-06G is greater than the loss upstream of SS-06A indicating loading at SS-06G.

11.2.7 Main Stem Silver Loading

Total recoverable silver loading during wet weather flow for 2008 through 2010 is shown in Figure 11-20 and values for 2013 are shown in Figure 11-21. Silver loading is very similar to cadmium, lead and zinc. The load difference between main stem stations is shown in Figure 11-22. Again the patterns are very similar to the other metals.

11.2.8 Summary of Main Stem Loading

Based on the data and discussion presented in the previous sections, it is clear that the largest loading source during wet weather conditions is between stations SS-04 and SS-05. The reach between stations SS-01 and SS-04 showed loading in 2013, but the loads at SS-01 were unusually low which skewed the net loading results. The highest median main stem loads often occurred at SS-06G, but the source of the loading is not known due to low load values at SS-06A caused by a different sampling scheme.

11.3 Wet Weather Input Loading

When loading is calculated for tributaries and outfalls, it is an input load. Mass loading gains and losses, which cannot be measured directly or easily in the field, but are reflected in the overall set of observational data, include:

- Wet weather inflow
- Ground water inflow (along the main stem or from inputs)
- Erosion of streambed, streambank, and floodplain sediments
- Adsorption/desorption of metals from stream and floodplain sediment

In the case of wet weather, it is assumed that the majority of added load is from the wet weather inputs, which corresponds to the following analyis

The wet weather flow loading analysis includs the following inputs (from upstream to downstream):

- Blacktail Creek (SS-01)
- Grove Gulch (GG-BTC)
- Upper Silver Bow Creek (MSD-3A and MSD-CLV-3A)
- Buffalo Gulch (BG-01 and BG-CLV-01)
- Missoula Gulch Catch Basins (MG-EFS5B)
- Montana Pole Treatment Plant Effluent (SS-MPTP) – See Section 7 for description.
- Butte Treatment Lagoon System Effluent (CT-EFS7) – See Section 7 for description.
- Butte Metro Sewage Treatment Plant Effluent (SS-STP) – See Section 7 for description.

Each of the inputs above are briefly described in the sections below and their spatial location is designated in Figures 11-1 through 11-7 to understand the importance of each input on the loading balance between each of the surface water quality monitoring stations in Silver Bow Creek.

11.3.1 Blacktail Creek

As mentioned in Section 7.1.1, Blacktail Creek samples at SS-01 represent water quality upstream of the BPSOU. There are few known source areas upstream of SS-01, however characterization of the area will be done as part of other investigations. Station SS-04 is located nearly ½ mile downstream of the BPSOU boundary and represents water quality in the lowest reach of Blacktail Creek, immediately upstream of upper Silver Bow Creek and Buffalo Gulch stormwater inputs.

SS-01 has been extensively sampled and the loading was discussed in Section 11.2. Median total recoverable copper concentration, discharge, and loading data are presented in Table 11-1.

Table 11-1 Wet Weather Total Recoverable Copper Loading from Blacktail Creek at SS-01

Dates	Median Total Recoverable Copper (µg/L)	Median Discharge (cfs)	Median Load (lb/day)
2008 through 2010	54	44	8.0
2013	143	14	5.4

Median loads for the other COCs are shown in Table 11-2.

Table 11-2 Median Wet Weather Loading from Blacktail Creek at SS-01 for the other COCs

Dates	Dissolved Aluminum (lb/day)	Total Recoverable Arsenic (lb/day)	Total Recoverable Cadmium (lb/day)	Total Recoverable Lead (lb/day)	Total Recoverable Zinc (lb/day)	Total Recoverable Silver (lb/day)
2008 through 2010	5.7	2.9	0.05	5	18	0.06
2011 through 2013	1.9	0.7	0.02	1	8	0.02

11.3.2 Grove Gulch

Stations GG-01 and GG-BTC were established to monitor wet weather flows and concentrations from Grove Gulch that contribute to Blacktail Creek just above Lexington Avenue (Kaw Avenue). However, because GG-BTC is located at the confluence of Grove Gulch and Blacktail Creek, the monitoring results are suspect, as it is unclear whether the monitoring results represent Grove Gulch or Blacktail Creek or a mixture of the two.

Discharge data were evaluated for stormwater samples collected at GG-BTC to estimate the source of the water. The event mean discharge at SS-01 and SS-04, as well as the difference between SS-01 and SS-04, were compared to the event mean discharge recorded at GG-BTC. Discharge data were only available at GG-BC for the period 2009 through 2011. These data are presented in Figure 11-23.

Based on this comparison, no recorded discharge at GG-BTC corresponded with the difference between SS-01 and SS-04. One date, June 15, 2009, indicated that the flows recorded at GG-BTC may have been a mixture of Grove Gulch and Blacktail Creek waters, and 15 events indicated that the flows at GG-BTC corresponded with the flows recorded at SS-01 and SS-04. On this basis, the flows recorded at GG-BTC represent Blacktail Creek, not Grove Gulch, for the majority of discharge data.

Available stormwater data for station GG-01 are limited to two samples collected in 2008 and are presented in Table 11-3. The average total recoverable copper load for these two samples is 0.30 lb/day.

Table 11-3 Average Total Recoverable Copper Loading at Grove Gulch

Date	Total Recoverable Copper (µg/L)	Discharge (cfs)	Load (lb/day)
4/15/2008	22.4	2.4	0.29
6/4/2008	23.3	2.4	0.31
Average	22.9	2.4	0.30

Average Loads for the other COCs are shown in Table 11-4.

Table 11-4 Average Loading at Grove Gulch for other COCs

Dates	Dissolved Aluminum (lb/day)	Total Recoverable Arsenic (lb/day)	Total Recoverable Cadmium (lb/day)	Total Recoverable Lead (lb/day)	Total Recoverable Zinc (lb/day)	Total Recoverable Silver (lb/day)
2008	0.047	0.19	0.0021	0.092	0.72	0.0049

11.3.3 Upper Silver Bow Creek

In 2005, upper Silver Bow Creek was reconstructed with a subdrain and pipeline used to capture contaminated ground water that had previously discharged into Silver Bow Creek. EPA believes that during wet weather there is no longer a large ground water component discharging to Silver Bow Creek at this location (EPA 2012). During wet weather events, flow and concentration are monitored at station MSD-3A (also called MSD-CLV-3) located just above Kaw Avenue. However, the flow results in the dataset provided by TREC include results that range orders of magnitude that seem unreasonable and suspect. Additionally, in some instances flow does not vary through a storm event hydrograph and is therefore suspect.

Regardless of the flow data quality, total recoverable copper loading was calculated and is presented in Table 11-5. Data from MSD-3A are DTEC and field grab samples from 2008 through 2013 while data from MSD-CLV-3A are ISCO samples from 2013.

Table 11-5 Average Total Recoverable Copper Loading at Upper Silver Bow Creek

Station	Total Recoverable Copper (µg/L)	Discharge (cfs)	Load (lb/day)
MSD-3A	370	8.2	21
MSD-CLV-3A	176	8.7	12

Average Loads for the other COCs are shown in Table 11-6.

Table 11-6 Average Load at upper Silver Bow Creek for other COCs

Station	Dissolved Aluminum (lb/day)	Total Recoverable Arsenic (lb/day)	Total Recoverable Cadmium (lb/day)	Total Recoverable Lead (lb/day)	Total Recoverable Zinc (lb/day)	Total Recoverable Silver (lb/day)
MSD-3A	4.5	1.5	0.14	12	43	0.096
MSD-CLV-3A	No Data	0.91	0.050	4.0	15	No Data

11.3.4 Buffalo Gulch

Buffalo Gulch enters Silver Bow Creek from the north just upstream of Montana Street. The drainage area includes the part of the rail yard located west of approximately Delaware Avenue and much of the residential area to the north. Samples were collected at BG-01 using a DTEC sampler or field grab for 2008 through 2013 and at BG-CLV-1 using and ISCO sampler in 2013. Average concentrations, discharges and loads are presented in Table 11-7.

Table 11-7 Average Total Recoverable Copper Loading at Buffalo Gulch

Station	Total Recoverable Copper (µg/L)	Discharge (cfs)	Load (lb/day)
BG-01	1273	6.5	43
BG-CLV-1	343	9.3	29

Average Loads for the other COCs are shown in Table 11-8.

Table 11-8 Average Loads at Buffalo Gulch for other COCs

Dates	Dissolved Aluminum (lb/day)	Total Recoverable Arsenic (lb/day)	Total Recoverable Cadmium (lb/day)	Total Recoverable Lead (lb/day)	Total Recoverable Zinc (lb/day)	Total Recoverable Silver (lb/day)
BG-01	2.5	3.2	0.38	38	154	0.23
BG-CLV-1	No Data	2.5	0.31	36	116	No Data

11.3.5 Missoula Gulch Catch Basins

MG-EFS5B is located in a channel that allows CB-9 over flow to be directed to Silver Bow Creek, and monitors water which is released from CB-9. The outfall of this channel is between Silver Bow Creek stations SS-05A and SS-06A. Nine field grab samples are available for this station from 2008 through 2011. This channel rarely discharges and the lack of samples reflects the overall lack of flow. Additionally, the stormwater ponds cause a delay in the hydrograph with samples being collected at the outfall 28 hours on average after the nearest main stem station, SS-05A, has tripped.

The average total recoverable copper concentration, discharge, and loading information is presented in Table 11-9.

Table 11-9 Average Total Recoverable Copper Loading at Missoula Gulch

Station	Total Recoverable Copper (µg/L)	Discharge (cfs)	Load (lb/day)
MG-EFS5B	40	3.6	1.1

Average Loads for the other COCs are shown in Table 11-10.

Table 11-10 Average Loads at Missoula Gulch for other COCs

Dates	Dissolved Aluminum (lb/day)	Total Recoverable Arsenic (lb/day)	Total Recoverable Cadmium (lb/day)	Total Recoverable Lead (lb/day)	Total Recoverable Zinc (lb/day)	Total Recoverable Silver (lb/day)
MG-EFS5B	1.3	0.20	0.020	0.79	5.7	0.007

11.3.6 Treatment Plant Effluent

Effluent from the three treatment plants is not sampled during wet weather flow, so no loading data are available. Loading data from Section 7 are presented in Table 11-11.

Table 11-11 Median Total Recoverable Copper Loading at Treatment Plants

Treatment Plant	Station	Date Range	Load (lb/day)
Montana Pole Treatment Plant	SS-MPTP	2011 through 2013	0.0060
Butte Treatment Lagoons	CT-EFS-7	2011 through 2013	0.11
Metro Sewage Treatment Plant	SS-STP	2011 through 2013	1.0

Average loads for the other COCs are shown in Tables 11-12, 11-13, and 11-14, where available, for inputs of the Montana Pole, BTL, and Metro Sewer treatment plants.

Table 11-12 Average Loads of other COCs at MPTP

Dates	Dissolved Aluminum (lb/day)	Total Recoverable Arsenic (lb/day)	Total Recoverable Cadmium (lb/day)	Total Recoverable Lead (lb/day)	Total Recoverable Zinc (lb/day)	Total Recoverable Silver (lb/day)
2008 through 2009	No Data	0.010	No Data	No Data	0.015	No Data
2008 through 2013	0.039	No Data	0.0002	0.00062	No Data	No Data
2011 through 2013	No Data	0.005	No Data	No Data	0.041	No Data

Table 11-13 Average Loads of other COCs at BTL

Dates	Dissolved Aluminum (lb/day)	Total Recoverable Arsenic (lb/day)	Total Recoverable Cadmium (lb/day)	Total Recoverable Lead (lb/day)	Total Recoverable Zinc (lb/day)	Total Recoverable Silver (lb/day)
2010	0.17	0.034	0.0025	0.0053	1.79	No Data
2011 through 2013	0.15	0.037	0.0025	0.0050	0.65	No Data

Table 11-14 Average Loads of other COCs at Metro STP

Dates	Dissolved Aluminum (lb/day)	Total Recoverable Arsenic (lb/day)	Total Recoverable Cadmium (lb/day)	Total Recoverable Lead (lb/day)	Total Recoverable Zinc (lb/day)	Total Recoverable Silver (lb/day)
2008-2009	0.59	0.10	0.0028	0.030	2.5	No Data
2011 through 2013	1.8	0.071	0.016	0.12	2.8	No Data

11.3.7 Summary of Input Loading

The three largest instantaneous input loads are presented in Table 11-15 and Figure 11-24 for the most recent period available. Upper Silver Bow Creek and Buffalo Gulch are clearly the largest sources of loading for all COCs during wet weather conditions. Upstream at SS-01 consistently contributes additional load for all COCs. The loading rates listed in Tables 11-1 through 11-14 for the 2011 through 2013 period were summed to provide a total load from inputs. The percentage of each individual load of the total load is also presented in Table 11-15 to provide a guage of the relative contriburtion of each source, but may not reflect the full cumulative load from these particular outfalls. Instantaneous concentrations and loads are important to understand from the perspective of acute standards, because they will likely result in greater exceedances of the standard.

Table 11-15 Ranking of Largest Input Loads

Rank	Dissolved Aluminum	Total Recoverable Arsenic	Total Recoverable Cadmium	Total Recoverable Copper	Total Recoverable Lead	Total Recoverable Zinc	Total Recoverable Silver
1	MSD-3A (37%)	BG-CLV-1 (54%)	BG-CLV-1 (71%)	BG-CLV-1 (59%)	BG-CLV-1 (86%)	BG-CLV-1 (78%)	BG-01 (64%)
2	BG-01 (20%)	MSD-CLV-3A (20%)	MSD-CLV-3A (11%)	MSD-CLV-3A (25%)	MSD-CLV-3A (10%)	MSD-CLV-3A (10%)	MSD-3A (27%)
3	SS-01 (16%)	SS-01 (15%)	SS-01 (5%)	SS-01 (11%)	SS-01 (2%)	SS-01 (5%)	SS-01 (6%)

Section 11.2.8 indicated that the largest sources of COCs are Buffalo Gulch and upper Silver Bow Creek. This aligns with the ranking presented in Table 11-15.

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Section 12

Other Relevant Data Interpretation

The following section provides an interpretation of the other relevant data (non-compliance data) collected from sources that are used in this report to supplement or provide independent measures of water quality and flow data collected by AR on behalf of the responsible parties group. Available data are compared to BPSOU surface water data to assess accuracy of the metals data set.

12.1 Wet Weather Flow Data Interpretation

This section presents the wet weather flow data interpretation for non-compliance wet weather data from 2013 and outfall and in-system wet weather data from 2009 and discusses the implication this data has on other potential source area identification.

12.1.1 Non-Compliance Wet Weather Data in 2013

Wet weather flow and/or stage monitoring data were obtained from the surface water monitoring stations identified in Table 12-1 in accordance with the DSWMP. Samples were collected during wet weather flow conditions (snowmelt runoff and during rainfall events). These sample locations are also shown in Figure 12-1. Wet weather sampling is not conducted during winter months due to freezing conditions and the general lack of wet weather events.

Table 12-1 Summary of Butte Hill Diagnostic Surface Water Monitoring Stations.

Monitoring Station ID	Location	Description
AR-CLV-2	Culvert	Located in the upper portion of the Anaconda Road-Butte Brewery drainage downstream from the Upper Rail Yard area. Empties into a retention basin in the Middle Rail Yard.
AR-HD-IN	Hydrodynamic Device	Located downstream of Hebgen Park, downstream of the storm sewer truck line junction at the inlet of the hydrodynamic device.
AR-HD-OUT	Hydrodynamic Device	Located at the outlet of the hydrodynamic device.
AR-MH-1	Manhole	Located at the outlet point of the Anaconda Road-Butte Brewery drainage. Water from this location discharges into upper Silver Bow Creek.
BG-MH-A5	Manhole	Located in the upper portion of the Buffalo Gulch drainage on W. Copper Street.
BG-MH-A3	Manhole	Located around the mid-point of the drainage, south of Emma Park on W. Silver Street.
BG-MH-A1	Manhole	Located north of the Patriot Rail/Butte Anaconda & Pacific (BA&P) Mainline on W. Iron Street.
BG-HD-IN	Hydrodynamic Device	Located near the intersection of E. First Street and S. Dakota Street at the inlet to the hydrodynamic device.
BG-HD-OUT	Hydrodynamic Device	Located at the outlet of the hydrodynamic device.
BG-CLV-01	Culvert	Located at the outlet point of the Buffalo Gulch (West). Water from this location discharges into Silver Bow Creek.

Monitoring Station ID	Location	Description
BG-MH-B1	Manhole	Located near the west outlet of the Buffalo Gulch (West); collects water from a subdrainage of the Buffalo Gulch (West). Discharges to BG-CLV-01.
BG-CH-C1	Channel	Located at the outlet point of the Buffalo Gulch (East). Water from this location discharges into upper Silver Bow Creek.
MG-CH-10	Concrete Channel	Located at the mid-point of Missoula Gulch drainage, north of the Syndicate Pit. Inflow to catch basin 1.
MG-CLV-9	Culvert	Located at the mid-point of Missoula Gulch drainage, south of the Syndicate Pit. Outflow from catch basin 1.
MG-CLV-2	Culvert	Located in the lower portion of Missoula Gulch drainage, before catch basin 8.
MG-CLV-1	Culvert	Located along the Lower Missoula Gulch Channel; outlet for the catch basin (i.e., outflow for Missoula Gulch and Idaho Street drainages and portion of West Side drainage).
MSD-CLV-HAB	Culvert	Located along upper Silver Bow Creek upstream from Harrison Avenue.
MSD-CLV-CASEY	Culvert	Located along upper Silver Bow Creek from Casey Avenue to MSD-HAB (at Harrison Avenue).
MSD-CLV-3A	Culvert	Located along upper Silver Bow Creek upstream from the MSD-CASEY.
TX-HD-1	Hydrodynamic Device	Located at the Texas Avenue outlet into upper Silver Bow Creek.
WA-HD-1	Hydrodynamic Device	Warren Avenue drainage before the hydrodynamic device.
WA-HD-IN	Hydrodynamic Device	Located north of the Civic Center; inlet of the hydrodynamic device.
WA-HD-OUT	Hydrodynamic Device	Located at the outlet of the hydrodynamic device.
WS-CLV-1	Culvert (Pipe End)	West Side drainage; tributary to catch basin 8.

Samples collected as part of the DSWMP were analyzed for total recoverable and dissolved metals, including arsenic, cadmium, copper, lead, mercury, and zinc as well as total suspended solids and sulfate.

Due to the variable nature of wet weather sample results and the variability of sample population at each sample location, results for total recoverable and dissolved copper concentrations are presented statistically as a box and whisker plot as shown in Figures 12-2 and 12-3, respectively. The whiskers represent the maximum and minimum values at each sample location, the box represents the 25th and 75th percentile of the data, and the median is shown as the diamond-shaped symbol. Sample locations within each drainage area are shown from upstream (left) to downstream (right).

Discharge was calculated based on the stage measured by the automated samplers that is converted to discharge using an established rating curve. Load was calculated for the 2013 diagnostic samples using discharge combined with concentration data. Loading statistics are presented in Figure 12-4 for total recoverable copper and Figure 12-5 for dissolved copper.

The following section describes the results of total recoverable and dissolved copper loading in further details for each drainage. Sample locations are described in Table 12-1 and shown in Figure 12-1.

12.1.1.1 Anaconda Road-Butte Brewery

Results for samples collected at the Anaconda Road-Butte Brewery drainage locations indicated elevated concentrations of total recoverable copper at AR-CLV-2, with a median value of 1,400

Based on the statistical results seen in the figures from stations upstream (AR-HD-IN) and downstream (AR-DH-OUT) of the HDD, it does not appear that there is an appreciable reduction in copper concentrations or loads from the Anaconda Road HDD.

12.1.1.2 Buffalo Gulch

The Buffalo Gulch drainage was evaluated by drainage outfall group; BG-MH-A3 (upstream) to BG-CLV-1 (downstream) represent the western portion of the storm drainage system (including BG-MH-B1 as lower sub-drainage). BH-CH-C1 (downstream) represents the eastern portion of the storm drainage system. The eastern portion of the system splits upstream of the Lower Rail Yard drainage area; the downstream sample location of the eastern portion (BH-CH-C1) is downstream of this split as shown in Figure 12-1. Median total recoverable copper results in the western portion of the drainage system range from 100 to 345 µg/L as shown in Figure 12-2. BG-MH-A5 has the highest concentrations of total recoverable copper in Buffalo Gulch; however, these are fairly consistent with concentrations before and after the hydrodynamic device (BG-HD-IN and BG-HD-OUT) and the downstream sample locations BG-CLV-1. BG-MH-A3 and BG-MH-A1 have the lowest concentrations of total recoverable copper relative to the other sample locations. The downstream locations in the eastern portion of the drainage show similar copper concentrations as the downstream sample location in the western portion. Due to larger discharge, the outlet at BG-CLV-1 has larger loads than the upstream stations (Figures 12-4 and 12-5), including the highest median dissolved copper load of all locations in the sampling program.

12.1.1.3 Missoula Gulch

Concentration results at Missoula Gulch for total recoverable copper were variable throughout the drainage area. The median at MG-CH-10 was an order of magnitude lower than the median concentration just downstream at sample location MG-CLV-9 (120 µg/L to 1,440 µg/L, respectively) as shown in Figure 12-2, though only two samples were recorded at MG-CLV-9. Results for total recoverable copper farther downstream decreased to a median result at MG-CLV-1 of 41 µg/L, which is downstream of the CB-8 and CB-9 stormwater retention ponds, installed to minimize sediment and metals loading to Silver Bow Creek from Missoula Gulch. This result was the lowest median recorded for all wet weather samples collected as part of the DSWMP. As shown in Figure 12-3, the dissolved copper concentrations did not follow a similar pattern as total recoverable copper. The lowest median concentration of dissolved copper occurred at the upstream sample location (MG-CH-10). The concentration continued to increase, with a maximum median concentration at MG-CLV-2 (47 µg/L) then decreased by nearly half at the farthest downstream sample location MG-CLV-1 (26 µg/L) (downstream of CB-8 and CB-9). The loading statistics show that copper loads decrease from the CB-8 inlet (MG-CLV-2) to the CB-9 outlet (MG-CLV-1), indicating that the catch basins reduce overall copper loading (Figures 12-4 and 12-5).

12.1.1.4 Upper Silver Bow Creek

Results for total recoverable copper concentrations along upper Silver Bow Creek were relatively similar between sample locations, with a slight decreasing trend from upstream to downstream. Median sample results ranged from 160 µg/L at MSD-CLV-HAB to 120 µg/L at MSD-CLV-3A as shown in Figure 12-2. Dissolved copper concentrations followed a similar pattern as shown in Figure 12-3, with concentrations ranging from 46 µg/L at MS-CLV-HAB to 33 µg/L at MSD-CLV-3A. Copper loading was similar across the three stations, indicating little change from upstream to downstream (Figures 12-4 and 12-5).

12.1.1.5 Texas Avenue

Samples were collected at only one location downstream of the hydrodynamic device at Texas Avenue. As shown in Figure 12-2, the median concentration of total recoverable copper was 370 µg/L, with a maximum and minimum value of 4,700 µg/L and 75 µg/L, respectively. As shown in

Figure 12-3, the median concentration of dissolved copper was 53 µg/L, with a maximum and minimum value of 350 µg/L and 17 µg/L, respectively. Loading values were similar to those calculated for upper Silver Bow Creek indicating that it is the primary source of loading to upper Silver Bow Creek (Figure 12-4 and 12-5).

12.1.1.6 Warren Avenue

Results for total recoverable copper concentrations in the Warren Avenue drainage were relatively high compared to the other drainage areas. WA-HD-1 (downstream of the HDD) had a maximum concentration of total recoverable copper of 12,600 µg/L (maximum measured concentration as part of the DSWMP). This location had the highest median total recoverable copper load of the stations in the program (Figure 12-4). The median concentration increased before and after the hydrodynamic device (WA-HD-IN and WA-HD-OUT); however, only two samples were collected at these locations in March and June 2012, and discharge was not measured, so loads could not be calculated. As shown in Figure 12-3, dissolved copper concentrations showed a similar pattern but were approximately an order of magnitude lower in concentration.

12.1.1.7 West Side

Samples were collected at only one sample location (WS-CLV-1) at the West Side drainage. As shown in Figure 12-2, the median concentration of total recoverable copper was 180 µg/L, with a maximum and minimum value of 6,500 µg/L and 46 µg/L, respectively. As shown in Figure 12-3, the median concentration of dissolved copper was 39 µg/L, with a maximum and minimum value of 310 µg/L and 0.36 µg/L, respectively. Due to the smaller area of the drainage leading to lower discharge, loads from the West Side drainage were smaller than the other areas (Figures 12-4 and 12-5).

12.1.2 Outfall and In-System Wet Weather Data in 2009

The results of the 2009 wet weather data show the median total recoverable copper concentration in storm water ranged from 77 µg/L to 157 µg/L for central and western areas of Butte Hill (West Side, Missoula Gulch, Idaho Street, and Montana Street subdrainages). The median total recoverable copper concentration was significantly higher in the east part of Butte Hill, including 256 µg/L in Buffalo Gulch, 583 µg/L in Anaconda Road/Butte Brewery, and 591 µg/L in Warren Avenue subdrainages. The highest total recoverable copper concentrations were from Texas Avenue (1,106 µg/L), which had not been previously sampled. Texas Avenue and Warren Avenue also had the greatest variations in total recoverable copper, with concentrations as high as 2,680 µg/L. Summary statistics of total recoverable copper concentrations from 2009 storm water sampling are presented in Figure 12-6.

Site-wide storm water dissolved copper concentrations were significantly lower than total recoverable copper, with all of the median concentrations in the 10 µg/L to 70 µg/L range. The highest dissolved copper concentrations were found in Missoula Gulch (192 µg/L), Buffalo Gulch (139 µg/L), and Texas Avenue (120 µg/L). Summary statistics of dissolved copper concentrations from 2009 storm water sampling are presented in Figure 12-7.

12.1.2.1 Buffalo Gulch Trunk

Storm water samples were collected throughout the Buffalo Gulch subdrainage in 2009 in an effort to identify discrete sources of copper to storm water. Sample locations and subareas are shown in Figure 12-8. Median total recoverable copper concentrations ranged from 63 µg/L to 377 µg/L, with areas B and D having the highest maximum concentrations at 622 µg/L and 518 µg/L, respectively. This indicates that sources of total recoverable copper occur throughout Buffalo Gulch. Samples from location B generally have higher total recoverable copper concentrations.

Summary statistics of total recoverable and dissolved copper in Buffalo Gulch subareas are shown in Figures 12-9 and 12-10, respectively.

12.1.2.2 Buffalo Gulch First Flush

On July 8, 2009, a series of samples was collected over the course of a 2-hour storm event. During the first 45 minutes, samples were collected every 5 minutes followed by a 10-minute sample interval for the remainder of the storm. The results for both dissolved and total recoverable copper are shown in Figure 12-11. Based on this single set of samples, it appears that concentrations are initially high and then dilute as the storm event progresses.

12.1.3 Possible Sources

At this time, it is difficult to determine whether potential problem areas discussed above are indicative of any specific possible sources. Continued monitoring at these locations is recommended. As practicable, flow measurements should be collected to calculate mass loading as variable flow rates are a significant factor in identifying possible sources. For example, elevated concentrations observed at AR-CLV-2 (see Figures 12-2 and 12-3) may not be as significant if the flow rate is very low (which is likely since this location is in the upper reach of the drainage). Another example is a comparison between the downstream sample locations for the Anaconda Road-Butte Brewery and Buffalo Gulch drainages (see Figures 12-2 and 12-3). Both of these drainages have similar median total recoverable copper concentrations of approximately 200 µg/L, but flow measurements would be necessary to differentiate the impact of mass loading into upper Silver Bow Creek.

12.2 Wet Weather Data for Sustained Periods

From 2008 through 2013, a series of incremental samples were collected using automated samplers over the course of individual wet weather events to characterize flushing of sediment and metals through the storm water network. Total recoverable copper was selected for this evaluation since copper tends to be the most prevalent metal to exceed the acute standard. These first flush data were statistically evaluated at three stations, SS-07, SS-06A, and SS-05. SS-07 represents the entire Butte Hill watershed and is representative of water quality as it exits the operable unit. SS-06A includes all storm water inputs, but no effluent from water treatment plants. SS-05 represents the wet weather flow that includes discharges from upper Silver Bow Creek and Buffalo Gulch. Several sampling patterns were used, and data have been arranged based on the time since the initial sample was collected during an event. When the stage rises to the trigger level, the ISCO sampler collects a sample at time zero. Depending on the schedule, another sample may be collected 1 or 3 hours later; this would be hour 1 or 3. These data were compiled and statistically evaluated at each sample interval and graphed to see whether there is an overall observable trend.

Samples collected from 2008 through 2012 were collected hourly for 3 hours. Samples collected in 2013 used a different schedule with stations SS-05 and SS-07, extending the hourly sampling schedule to 4 hours then every 2 hours for 10 hours. The PRI work plan required hourly sampling for 24 hours at Station SS-06A. Due to limitations of the equipment, samples were collected every 3 hours for 21 hours at SS-06A. The different schedules are presented separately to maximize consistency in the available data.

Figure 12-12 shows hourly results at Station SS-07. The hourly sample at hour 1 has a larger median, upper quartile, and maximum than the other samples although all samples are similar. The hourly results from SS-06A are shown in Figure 12-13. The pattern is very similar to SS-07. Hourly results from SS-05 are shown in Figure 12-14. Although all samples are similar, the hourly sample at hour 1 does not have the highest median and upper quartile.

The differences in the sampling intervals were compared using the Kruskal-Wallis nonparametric statistical test. Lilliefors and Shapiro-Wilk normality testing showed that the data were neither normally or log normally distributed, which precluded the use of a parametric test such as an analysis of variance (ANOVA).

Table 12-2 below presents the results of several statistical comparisons that were performed to determine if there are differences between the hourly samples that capture the peak of the storm event, which occurs over the first 3 hours, and the samples collected every 3-hours that capture part of the peak plus the decline of the storm flow.

The first comparison made was between the hour zero and hour 3 samples from both the 2009-2012 period and for 2013. These sampling intervals were the only two that were common to both the hours and every 3-hour samplings schemes. As seen, the groups are very different.

The second comparison was between the protocol that was in place through 2012 in which samples were collected at time zero (IS1) and hourly for the next 3 hours (IS2 through IS4) and the 2013 protocol in which samples were collected at time zero and every 3 hours for the next 21 hours (IS1 through IS8). Again, the groups were very different.

The populations were further refined in the fourth comparison to compare the zero hour samples (IS1) for 2009-2012 to the zero hour samples (IS1) for 2013 and the hour 3 samples (IS4) for these time periods (performed separately in the third and fourth comparison). Again, the groups were very different.

The fifth and last comparison made was between the first 3-hour samples (Is1 to IS4) and the later samples (IS5 to IS8) for 2009-2013. The groups were very different, suggesting that the first 3-hour samples are significantly higher than for the 3- to 21-hour interval.

Table 12-2 - Summary of Kruskal-Wallis Nonparametric Statistical Analyses for Station SS-06A for Dissolved Copper

Comparison	Group 1	Group 2	H Value	p Value	Interpretation (based on alpha of 0.05)
1	IS1 and IS4 2009-2012 (Hourly)	IS1 and IS4 2013 (Every 3 hours)	12.38	0.00043	Different
2	IS1 to IS4 2009-2012 (Hourly)	IS1 to IS8 2013 (Every 3 hours)	42.02	9.05E-11	Different
3	IS1 2009-2012 (Hourly)	IS1 2013 (Every 3 hours)	514	7.50E-114	Different
4	IS4 2009-2012 (Hourly)	IS4 2013 (Every 3 hours)	421	1.79E-93	Different
5	IS1 to IS4 2009-2013	IS5 to IS8 2013	1631	0.00E+00	Different

The 2013 sampling had some higher median concentrations than the 2008 through 2012 data. The 2013 incremental sampling data from SS-07 are shown in Figure 12-15. Although there are only five samples, a clear pattern is seen, with the highest upper and lower quartile and median concentrations occurring at hour 1 and decreasing through hour 8. Hour 10 has one fewer sample, and it has higher maximum and upper quartile results. The 3-hour results from SS-06A are shown in Figure 12-16. Hours 0 and 3 have the highest median and upper quartile, with these statistics decreasing through hour 21. The 2013 incremental results from SS-05 are shown in Figure 12-17. The median and upper quartile concentrations are highest in hours 1 through 3 and decline through hour 8. Again, the hour 10 samples have a higher maximum and third quartile, but fewer samples. These longer time tests indicate that the highest concentrations tend to occur within the first 3 hours of the storm event. The hour 10 results suggest a possible increase, but the 21-hour results indicate that this is not a large peak, and the concentrations decrease as expected with increasing time past hour 3.

The statistical results for 2008 through 2012 (Figures 12-11 through 12-13) indicate that no peak concentrations are evident, but the span from minimum to maximum is large. This may be a result of inter-year variations. To investigate this further, statistics from SS-05 were plotted for each year 2008 through 2012 on Figure 12-18. The year 2011 stands out as having notably lower concentrations whereas 2008 and 2009 have higher concentrations. A comparison of median concentrations for each year and each hour is shown in Figure 12-19, and a comparison of upper quartile concentrations is shown in Figure 12-20. The inter-year differences are large, but the intra-year difference between hours is much smaller. These variations produced the apparent lack of change between hours on figures with multiple years combined (Figures 12-12, 12-13, and 12-14).

For years 2008 and 2009 (Figure 12-18), hour 0 had the highest concentrations. For 2010, the first 2 hours had higher concentrations than hour 3. The wet year of 2011 indicated higher concentrations in hours 2 and 3, but the concentrations were much lower. In 2012, the higher concentrations seem to occur at hours 1 through 3, whereas 2013 has the highest concentrations at hours 1 and 2.

In general, the differences in all of these sample groups is due to variability from one storm event to the next, which appears to be much greater than differences caused by the sampling frequency or duration. The first three hours of each storm event typically have the highest copper concentrations. However, the differences from year to year are greater than the differences from hour to hour.

12.3 Streambed Sediment Copper Trends

Streambed sediment copper concentrations for the period 2008 to 2013 for the <0.063 mm and 0.063 – 1 mm fractions are presented in Figures 12-21 and 12-22, respectively. There is a notable visual increase in sediment copper concentration in the downstream direction, with highest values at SS-06A, slightly lower values at SS-06G, and lower values even yet at SS-01. There appeared to be a decreasing trend for the finest fraction (<0.063 mm) from 2008 through 2010 at all sites, but this stabilized between 2010 and 2013.

Similarly, the coarser fraction (0.063 to 1 mm) shows a similar spatial trend although the temporal trend for the coarser fraction (0.063 to 1 mm) is largely flat or weakly decreasing at best. Both trends appear to be influenced by summer storm events, the most notable occurring on June 27, 2009. The storm events superimpose “spikes” onto whatever trends exist. The reduction in copper concentrations may be due in part to remediation that has occurred over the last few years, such as curb and gutter construction and waste capping, to minimize erosion and transport of metals-bearing soils by stormwater in Butte. However, reductions are also seen at SS-01, upstream of any BPSOU remedial actions.

12.4 Streamside Tailings OU Monitoring

Surface water is monitored for the Streamside Tailings OU (SSTOU), which is immediately downstream of BPSOU. In order to obtain background data for SSTOU, samples are collected within and upstream of BPSOU. Surface water samples are generally collected quarterly at SS-01, SS-05A or SS-06A, SS-06G, and SS-07 although this list has varied. Annual monitoring reports were reviewed from 2008 to 2013, and tabulated data from 2010 to 2013 were reviewed. A QA review of the data was not presented in the 2008 and 2009 reports, and the data do not contain QA review qualifiers due to these omissions. As such, these data will not be used in this section. The 2010 through 2013 reports contain a QA review section, and the data are qualified. The reports are missing some elements required to classify the data as enforcement quality, but the data were collected in a manner that they could be enforcement quality with additional QA review and reporting.

12.4.1 Data Collection

Based on the Interim Long-Term Monitoring Plan for SSTOU (DEQ 2010), surface water samples are collected once per calendar quarter at established stations, including three to four within or upstream of BPSOU. The exact station list has varied somewhat, but stations SS-01, SS-06G, and SS-07 were consistently sampled from 2010 to 2013, and SS-06A was sampled until May 2012. Station SS-05A replaced SS-06A, beginning in September 2012, due to a beaver dam at SS-06A. At least one sample per year is to be collected during high water conditions and one at low water conditions. A review of the sampling dates and field notes indicates that samples are occasionally collected during wet weather conditions, but are not categorized as such. Of the 16 quarterly sampling events from 2010 to 2013, three were conducted during wet weather conditions (December 14, 2010; June 2, 2011; and May 30, 2013).

Sampling methodology includes the same SOPs as used for the BPSOU monitoring. Discharge is measured and samples are collected for field parameters and laboratory analysis, including metals, common ions, and nutrients. SSTOU monitoring uses a different laboratory from BPSOU and detection limits are different.

SSTOU monitoring data were obtained from DEQ for 2008 through 2013. Within BPSOU, the SSTOU data included SS-06G and SS-07 for 2008; SS-01, SS-06A, SS-06G, and SS-07 for 2009 through 2011; and SS-01, SS-05A, SS-06G, and SS-07 for 2012 through 2013. The annual monitoring reports for 2008 and 2009 indicated that sampling followed CFR SOPs. Duplicates, blanks, and laboratory QA samples (e.g., matrix spike, matrix spike duplicate) were reported, but not discussed. None of the data reports followed the required CFRSSI Pilot Data Report and its addendum. Omitted were most laboratory qualifiers; all QA review qualifiers; QA checklists; required tables; and determination of enforcement, screening, or rejected quality for each result. Overall, it appears that the data may have been collected in a manner that would allow a determination if the data are of enforcement quality, but since much documentation is missing, it will be considered screening quality.

12.4.2 Comparison to BPSOU Data

For the SSTOU monitoring, metals analytical results from the upstream station, SS-01, are predominantly reported as not detected. As such, these data are not suitable for analysis. The remaining stations, SS-06G and SS-07 have a much larger proportion of samples with detected results and are more suitable for comparison to BPSOU data. SS-06G data are used for comparison because the data are not influenced by discharge from the Metro wastewater treatment plant.

A comparison of total recoverable cadmium data for non-wet weather conditions is shown in Figure 12-23. The higher frequency of sampling in the BPSOU data set captures a wider range of conditions, thus, a wider range of concentrations. The two data sets generally have similar results and, there does not appear to be a noticeable difference between the sets.

A comparison of total recoverable copper data for non-wet weather conditions is shown in Figure 12-24. As with cadmium, the higher frequency of sampling in the BPSOU data set captures a wider range of conditions, thus, a wider range of concentrations. Both data sets showed higher copper concentrations in 2010 prior to implementation of the BRW capture extension to mitigate the BRW seep. The two data sets generally have similar results, and there does not appear to be a noticeable difference between the sets.

A comparison of total recoverable lead data for non-wet weather conditions is shown in Figure 12-25. As with the other metals, the SSTOU data have concentrations within the range of BPSOU concentrations. The BPSOU data show lower lead concentrations in most of the data beginning in August 2012 that are not reflected in the SSTOU data.

A comparison of total recoverable zinc data for non-wet weather conditions is shown in Figure 12-26. The SSTOU data replicate the BPSOU data very well. Similar to lead, the BPSOU data show lower zinc concentrations in some of the data beginning in May 2012 that are not reflected in the SSTOU data.

Arsenic and mercury data are not shown in charts because most of the arsenic and all of the mercury data are non-detects in the SSTOU data. The SSTOU arsenic results above the reporting limit fall within the range of BPSOU data.

12.4.3 Summary of SSTOU Data Comparison

For the metals reviewed and compared in this section, the SSTOU data compared well with the BPSOU data. There is no apparent bias, suggesting that both data sets have similar accuracy.

12.5 USGS Flow Data Interpretation

12.5.1 Station 12323250

Figure 12-27 shows the daily flow rate measured at USGS station 12323250 (same location as SS-07) compared annually since 2008. During fall and winter months (i.e., September through February) when low precipitation or freezing weather limit wet weather impact on the creeks, the average discharge ranged from 17.5 cfs in 2013 to 22.8 cfs in 2011. During spring and summer months (i.e., March through August) when spring melt and thunderstorm events impact the creek flow, the average discharge ranged from 19.3 cfs in 2013 to 52.6 cfs in 2011. Maximum flow rates at SS-07 typically occur during late spring snowmelt events (see Section 12.7.1 below for snowmelt data discussion). In 2010 and 2011, the Basin Creek SNOTEL snowpack monitoring station indicated a significant drop in snowpack in early June. This timeframe correlates with the maximum measured flow rates at SS-07 of 156 and 250 cfs, in 2010 and 2011, respectively.

12.5.2 Station 12323240

As shown in Figure 12-28, from September through February, the average discharge at USGS station 12323240 (same location as SS-04) ranged from 10.2 cfs in 2013 to 14.4 cfs in 2011. From March through August, the average discharge ranged from 11.9 cfs in 2013 to 43.7 cfs in 2011. Maximum flow rates at SS-04 also occurred in 2010 and 2011 and were 131 cfs and 200 cfs, respectively. Again, the timing of these high flows correlated with spring snowmelt.

12.6 USGS Metals Data

USGS collects surface water quality data under the Clark Fork basin monitoring program, including two sites in BPSOU. The upstream station at SS-01 (USGS station 12323230) has a nearly continuous record from March 1993 to present and provides data on upstream conditions. The downstream station also has a nearly continuous record from March 1993 to present and provides data on water exiting BPSOU. Data are reported in annual reports (e.g., Dodge et al. 2014) and electronically via NWISWeb (2014). Data collection methodology and QA procedures are described in the annual reports. USGS reports various QA statistics in the annual reports regarding replicates, spikes, and blanks, which is very similar to the reporting requirements of CFRSSI. The QA procedures appear to meet the Level B requirements in CFRSSI and probably would be enforcement quality data if all calculations were conducted and reported.

An overall description of the QA program was presented in Sando et al. (2014), which summarized QA results and indicated that the spikes, blanks, and duplicates generally met program requirements. For reported results significantly greater than the detection limits, the entire USGS data set for the Clark Fork basin has met data quality objectives for blank and duplicate samples (Sando et al. 2014). Detected metals in blank samples occurred at a rate less than 5 percent for trace metals except for zinc, which ranged from 14.7 percent (dissolved) to 6.6 percent (total recoverable) (Sando et al. 2014). Additionally, relative standard deviations for natural and duplicate samples were within 20 percent (Sando et al. 2014). Some early data (1993) suffered from contamination from sampling equipment (Lambing et al. 1994), and these were removed from the data set used for analysis. The USGS data are usable for most Superfund purposes; however, there are limitations on data when concentrations are near the reporting limit. These are important when evaluating the effects of upstream sources at station 12323230.

12.6.1 Station 12323230

The area upstream of BPSOU is suburban within the Summit Valley and forested in the mountains. It is possible that changes may have occurred in the upstream watershed that have caused changes in upstream water quality during the period of monitoring. In order to evaluate possible changes in water quality, metals data from station 12323230 were reviewed.

Detected values for total recoverable cadmium, lead, and zinc at station 12323230 are shown in Figure 12-29. Omitting the non-detected results, there appears to be a decline in metals concentrations over time. However, these are believed to be artifacts of data near or below the reporting limits as described later. In order to get a truer picture of changes over time, the non-detected result and reporting limits need to be considered. As noted above, the methodology has changed over time. In order to evaluate these changes, annual reports from the Clark Fork basin monitoring program were reviewed (e.g., Dodge et al. 2014). Each report lists methodology and reporting limits for trace metals. Generally, trace metals were analyzed using Atomic Absorption Spectroscopy (AAS) or Graphite Furnace Atomic Absorption (GFAA) from 1993 to 2003. Trace metals have been analyzed using inductively coupled plasma mass spectrometry (ICP-MS) since 2003.

In order to obtain more detailed information, all metals data from the upstream site (12323230) were downloaded from NWISWeb, including extended attributes, which include some QA review qualifiers. Reporting limits are not reported in NWISWeb for samples with a value greater than the reporting limit (they are reported in the annual reports as a value for the year). Reporting limits are reported only for non-detected results as a less-than value. Estimated values (less than the reporting limit) are rare in the USGS data set. Non-detected results were commonly reported for cadmium (dissolved and total recoverable), dissolved lead, and zinc (dissolved and total recoverable) and are plotted on Figure 12-30. Changes in the reporting limit reflect a change in analytical procedures that are not reported by NWISWeb. Based on the non-detected results presented in Figure 12-30, analytical changes appear to have occurred in November 1997, November 1999, and May 2002. It is likely that the 2002 change was to ICP-MS as indicated in the 2003 annual report (Dodge et al. 2004). Incidentally, beginning in 2003, USGS changed terminology from dissolved metals to filtered metals and from total recoverable metals to unfiltered recoverable metals. USGS made a nationwide change from AAS to ICP-AES in 1996 (USGS 1996).

Analytical reporting limits for the Clark Fork program are reported in the annual reports. Although the exact dates of changes in reporting limits are not given, they are identified to have occurred during a yearly reporting period. These reporting limits through 2012 are presented in Figure 12-31. The 1997 change that was apparent on Figure 12-30 is not seen on Figure 12-31, but the 1999 and 2003 changes are readily apparent. A number of changes in the reporting limits are apparent from 2007 to 2012, but the annual reports do not indicate a change in methodology.

12.6.1.1 Cadmium

Cadmium detects, non-detects, and reporting limits are presented in Figure 12-32. Nearly all samples collected prior to 2002 were non-detected for cadmium. Beginning with the May 29, 2002 sample, detectable concentrations were reported in nearly all samples. This change is due to ICP-MS methodology. Concentrations appear to be slightly lower in data collected after July 2006 than between May 2002 and August 2006. This is subtle and may be an actual change in water chemistry or a small change in analytical procedures. The reporting limit for total recoverable cadmium changed in November 1999 consistent with zinc (see below), but samples were still reported as not detected until 2002. Proposed reporting limits for 2014-2015 (USGS 2014) are 0.03 µg/L for both filtered and unfiltered recoverable cadmium, which may result in most results being either non-detected or estimated for cadmium.

12.6.1.2 Zinc

Zinc detects, non-detects, and reporting limits are presented in Figure 12-33. Two changes in the reporting limit for zinc were observed in the data set. There was a significant change in the reporting limit in November 1999, resulting in lower concentrations being reported. Coincident with the change in the detection limit, reported concentrations are generally higher prior to November 1999, with the four highest total recoverable copper concentrations occurring in this period. The other detection limit change occurred in November 1997 when the reporting limit for dissolved zinc was increased. Most samples collected between November 1997 and November 1999 were less than the detection limit for zinc. No other significant changes are evident after November 1999 for zinc.

12.6.1.3 Lead

Lead detects, non-detects, and reporting limits are presented in Figure 12-34. Nearly all dissolved lead results were reported as non-detected until the reporting limit was lowered in March 2002 as a result of the change to ICP-MS. The detection limit for lead had previously increased slightly in November 1997 and November 1999, but this did not affect the reported data as lead continued to be not detected. The detection limit in 2013 was lower than from 2002 to 2007, but it is not known precisely when the change occurred. Total recoverable lead values shown in Figure 12-34 show a significant decrease beginning in 2003. Although it is possible that a change in water chemistry occurred, there is no discernible trend from 2003 to 2013 or from 1993 to 2002.

12.6.1.4 Arsenic and Copper

Data for total recoverable arsenic and copper and dissolved copper are shown in Figure 12-35. Very few non-detected results are reported for the period of record; therefore, the data are not affected by changes in the reporting limits. A general overview of the data in Figure 12-35 shows no obvious breaks related to changes in analytical procedures. Total recoverable arsenic was reported to one significant figure prior to July 2005, and copper concentrations were reported to one significant figure prior to March 1997 and two significant figures after those dates, indicating changes in the analytical procedures. There is no trend in the data other than lower concentrations in the dry years of 2001 to 2003 and again in 2013.

12.6.1.5 Other Analytes

Although a variety of analytes have been reported at various times, a long history at 12323230 is only available for iron, manganese, and suspended sediment. None of these had a significant number of non-detected results, and effects described for cadmium, lead, and zinc were not apparent.

None of these other analytes indicated a trend over time, with the possible exception that iron and manganese appear to be subtly lower in 2013 than the period from 2006 to 2012; however, the 2013 concentrations are within the historic ranges experienced in the drought years of 2001 to 2003. A similar pattern was noted for arsenic. The 2013 average annual discharge at SS-04 (USGS station 12323240) was significantly lower than the period 2006 to 2012 and comparable to the periods 1989 to 1994 and 2000 to 2005. It is likely that the changes seen in the 2013 arsenic, iron, and manganese data are at least partly due to lower flows in Blacktail Creek.

12.6.1.6 Summary for Station 12323230

Based on metals data from USGS station 12323230, it appears that analytical changes over time have resulted in differences in reported concentrations when results are near the reporting limit. Based on a review of data for cadmium, copper, lead, and zinc, it appears that analytical changes were made around November 1997, November 1999, and May 2002. Analysis of these data needs to recognize these changes where reported concentrations are near the detection limit for a particular metal. Apparent trends seen on Figure 12-29 are artifacts of data near or below the reporting limits.

None of the analytes reviewed displayed a visual trend, and variation in concentrations each year was greater than any general changes over the period of record. Some of the 2013 data all appear to have lower concentrations, but it was not determined if this is due to a change in analytical procedures for metals or an overall change due to lower surface water flows.

12.6.2 Station 12323250

The USGS station at SS-07 (12323250) represents water quality exiting BPSOU. Its long history represents a fairly complete picture of the changes in water quality due to cleanup work in BPSOU. Major remedial activities at BPSOU affecting surface water included the LAO ERA (1997), LAO and

West Camp Treatment (2002), upper Silver Bow Creek treatment (2005), BRW ground water capture (2011), and a number of activities without immediately observable effects on water quality.

Reporting limit issues discussed for station 12323230 do not affect station 12323250 because the concentrations were significantly above the reporting limits prior to 2003 when ICP-MS was implemented. As a result, trends going back to 1993 can be evaluated. An exception is dissolved lead, which is affected by reporting limits; as such, lead will not be evaluated for station 12323250.

12.6.2.1 Copper

Total recoverable and dissolved copper results for station 12323250 are shown in Figure 12-36. The LAO ERA had an immediate and significant effect on copper concentrations. The remaining remedial actions had a cumulative effect of reducing copper concentrations over time. Overall, copper concentrations have decreased by more than one order of magnitude since 1993. Total recoverable copper (USGS started referring to this as unfiltered copper in 2003) is almost always at least 50 percent greater than dissolved copper (filtered copper since 2003), with the disparity increasing following the BRW action.

12.6.2.2 Cadmium

Total recoverable and dissolved cadmium results for station 12323250 are shown in Figure 12-37. Cadmium concentrations decreased following each of the four major remedial actions shown in the chart. An increase is shown in 2004, and this is likely due to dewatering and construction of the BPSOU subdrain prior to treatment of the water. Once treatment of upper Silver Bow Creek water began in 2005, cadmium concentrations decreased significantly.

12.6.2.3 Zinc

Zinc concentrations for station 12323250 are shown in Figure 12-38. Similar to copper, there is a cumulative decrease in cadmium concentrations since 1997. Similar to cadmium, there was an increase in 2004 prior to treatment of upper Silver Bow Creek water.

12.7 Non-COC Analysis

12.7.1 Sulfate

Sulfate can be related to contamination from sulfide mineralization and is viewed as a potential surrogate for metals contamination. Sulfate is also less reactive than metals salts and tends to stay in solution under circumneutral pH conditions.

Sulfate in surface water at non-wet weather conditions along with discharge at USGS station 12323230 is shown in Figure 12-39. Winter season is shown in blue while summer season is shown in white. There is a pattern of sulfate concentrations increasing in winter and decreasing in summer. Discharge is the opposite, with higher flows in summer. All stations upstream of the BTL effluent discharge have very similar concentrations and patterns of change of sulfate.

A scatter plot of sulfate and discharge is shown in Figure 12-40. Stations SS-01, SS-05A, and SS-6G were selected as representative of upstream, mid-OU, and downstream of treatment plant effluent OU locations, respectively. Sulfate at SS-01 and SS-05A decreases with increased discharge, indicating that the higher flow dilutes the sulfate. SS-05 has slightly higher sulfate concentrations, indicating a possible onsite source between SS-01 and SS-05A. This pattern is common to all stations upstream of the BTL effluent discharge. SS-06G has significantly higher sulfate concentrations due to the BTL effluent. Similar to the other stations, sulfate becomes diluted at higher flows.

Limiting data to base flow conditions, sulfate concentrations from 2008 through 2013 in Blacktail and Silver Bow Creeks are shown in Figure 12-41. Concentrations are the highest in SS-06G immediately downstream of the BTL discharge and somewhat lower at SS-07, most likely due to dilution. The other stations upstream of BTL are very similar. Overall, no strong trends are observed for sulfate concentrations.

12.7.2 Dissolved Organic Carbon

Dissolved organic carbon (DOC) has been monitored since 2011, and concentrations are shown in Figure 12-42 along with discharge from USGS station 12323230. Stations SS-01 through SS-06G show similar patterns and concentrations, with concentrations generally higher during summer months at higher discharge. Station SS-07 has significantly higher DOC due to treated wastewater effluent.

A scatter plot of DOC and discharge is shown in Figure 12-43. Stations SS-01, SS-05A, and SS-6G were selected as described for sulfate. All stations are similar, with higher DOC concentrations occurring at higher discharge.

12.8 Meteorological Data Interpretation

12.8.1 SNOTEL Data

As shown in Figure 12-44, snowpack at high elevations begins to accumulate in October and continues to accumulate until late April through May. Since 2008, the earliest snow depth accumulation was reported on September 26, 2013, and the latest snow depth accumulation was reported on June 15, 2008. However, in 2011, a deeper and more persistent snowpack lasted until June 14, 2011.

In general, even though this SNOTEL station is neither located on the Butte Hill, nor does it directly correlate with discharge data for Silver Bow Creek and Blacktail Creek, it does provide a general correlation with when snowmelt begins and when relative increases in stage height in the creeks are expected to occur. As shown in Figure 12-44, a decreasing snowpack is expected between mid-April and mid-June at which time an increase in streamflow is expected. The deepest snowpack occurred in 2011, with a maximum snow depth of 49 inches, whereas snowpack data from 2012 and 2013 indicate a drier winter.

12.8.2 Precipitation Data

As shown in Figure 12-45, precipitation since 2008 is presented in time series. These data are the maximum precipitation values recorded at either CB-1, HKMR2, HKMR3, or MTPOLE stations and form a composite of all Butte Hill weather stations. The maximum daily rainfall of 1.48 inches occurred on June 16, 2010.

12.8.3 Notable Meteorological Events

In order to assess any deviations from typically observed weather, Figure 12-46 was developed to evaluate the effects of precipitation and snowmelt on the flow rate of Blacktail Creek at sampling station SS-04. In general, snowmelt has the greatest influence on Blacktail Creek as shown by the increase in flow rate between early April to mid-June. Precipitation also influences Blacktail Creek; however, these impacts are minor and generally result in limited duration increases in flow rate. Several deviations from normal include the following:

- In April 2009, even though the winter snowpack was moderately high, a dry spring resulted in only a small increase in flow rate during the typical snowmelt period.

- In 2010 to 2011, heavy winter snowfall and a wet spring resulted in a large increase in flow rate in Blacktail Creek.
- On June 16, 2010, 1.48 inches of rain at the tail end of the snowmelt period caused the flow rate in Blacktail Creek to significantly increase over a short period of time.
- On June 8, 2011, 1.12 inches of rain also resulted in a significant increase in flow rate.

In 2012 to 2013, low snowpack and a relatively dry spring resulted in a small increase in flow rate during the typical snowmelt period.

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Section 13
Summary

This report evaluates surface water data collected from 2008 through 2013. Some of the key remedial activities, including source area removal and capping, capture and treatment of ground water, and the construction of various BMPs within the BPSOU boundary, were performed and completed by 2008 when the previous surface water characterization report was completed (EPA 2012). Additional major remedial actions impacting surface water, completed since 2008, include installation of HDDs within the storm drain system, removal of stream bank wastes at the confluence of Blacktail and Silver Bow Creeks, and extension of the ground water collection in the BRW area.

This report presents the current understanding of the surface water quality conditions and evaluates remaining sources and distribution of metal concentrations in surface waters within the BPSOU. Although results outlined in the report indicate surface water quality has improved considerably, exceedances of ARARs still occur. A brief summary of the key elements identified in the previous sections is presented below.

13.1 Flow Regimes

Surface water within the BPSOU is categorized into three flow regimes according to Section 1.7 and that analysis in this surface water characterization report has been structured as such:

- Base Flow
- Normal High Flow
- Wet weather Flow

13.2 Available Data

13.2.1 Base and Normal High Flow Conditions

Base and normal high flow sampling at main stem stations (SS-01 through SS-07) is conducted manually on a monthly basis. Effluent sampling is conducted by treatment plant operators and is not coordinated with main stem monthly sampling. As a result, effluent data are used on an average basis rather than synoptically.

Base and normal high flow samples were collected using width integrated sampling, in which the channel was divided into 5-10 equal intervals, depending on the width of the stream. At each width interval, a depth integrated subsample was collected. The subsamples were then combined in equal volume to obtain the surface water sample.

13.2.2 Wet Weather Conditions

Monitoring data from main stem locations in Blacktail Creek and Silver Bow Creek both upstream and within the BPSOU have been assessed as part of this report and were provided by AR’s contractor, TREC, from April 2008 to September 2013. Wet weather data have been assessed from established main stem sampling stations, from SS-01, upstream of the site, to SS-07, at the downstream edge of the site. Additionally, routine wet weather monitoring occurred at major outfalls, including:

- Texas Avenue
- Warren Avenue
- Buffalo Gulch East
- Buffalo Gulch
- Missoula Gulch

In 2013, additional wet weather monitoring was conducted on the Butte Hill at more than 20 locations within the stormwater system.

Sample collection methods varied and included the following methods:

- ISCO automatic time series sampler – first four to eight samples collected during a storm event
- DTEC automatic sampler – first flush samples collected
- Opportunistic grab sampling during wet weather events primarily at stations without ISCO or DTEC automated samplers

13.3 Upstream Sources

Station SS-01, located on Blacktail Creek at Harrison Avenue, is the farthest upstream sampling location and is considered a tributary, or boundary condition. It represents water quality entering the BPSOU. Monitoring data provide a comparison point between waters upstream and within the BPSOU, and provide information on surface water conditions prior to entering BPSOU. Historic milling and smelting operations may have affected areas upstream of SS-01, but the scope of potential impacts has not been investigated (upstream of SS-01 is the West Side Soils OU). For example, the Bell Smelter was reportedly located along Blacktail Creek just west of Harrison Avenue and SS-01. Additionally, this site is also potentially affected by urban stormwater runoff from the eastern parts of Butte, MT.

13.3.1 Upstream Water Quality

At SS-01 during base flow from 2008 to 2013, all copper concentrations are low and well below the chronic standard, other than one potential outlier value in 2008. There is only a small separation between total recoverable and dissolved values, indicating that suspended sediments are comparatively low at SS-01 during base flow (Figure 6-9). Similar to copper, there has also been one exceedance for lead during base flow in 2008 (Figure 6-24). Aluminum, arsenic, cadmium, silver, and zinc had no base flow exceedances at SS-01 from 2008 to 2013.

During normal high flow, loading of arsenic, copper, and iron from sources upstream of SS-01 is evident. From 2008 to 2013, the number of arsenic and iron exceedances at SS-01 are similar to the number of exceedances at the downstream stations; thus, the main source of arsenic and iron appears to be related to snow melt upstream of the site (Figure 8-19). Ground water upstream of SS-01 does not appear to be a major source of arsenic to the downstream stations based on the lack of exceedances in the base flow analysis. The number of copper exceedances at SS-01 (i.e., 3) was comparatively fewer than the stations downstream for the period from 2008 to 2013 (Figure 8-7), indicating that, while upstream sources of copper contribute to loading, other contributions of copper loading are present on site during normal high flow. Arsenic, iron, and copper appear to be generally affected by discharge, with higher concentrations of each constituent observed during the higher flows. Detailed discussion of high normal flow compliance and loading analyses are provided in Sections 8 and 9.

Upstream wet weather copper has a high rate of exceedances (approximately 90 percent) at SS-01, again indicating an upstream source of copper exists (Figure 10-7). Notable, although fewer, exceedances of cadmium (6 percent), lead (11 percent), and zinc (24 percent) also occurred at SS-01 during wet weather flows from 2008 to 2013. While sources upstream of SS-01 consistently contribute additional load they are a much smaller magnitude than those within the OU. Detailed discussions of wet weather flow compliance and loading analyses are provided in Sections 10 and 11.

13.4 Summary of 2008-2013 Water Quality Results at Points of Compliance

13.4.1 Base Flow Summary

Copper results show a considerable difference between dissolved and total recoverable concentrations at most stations, indicating that colloids or fine sediments containing copper are suspended in the surface water during base flow and that changes in water quality are occurring over the OU. From 2008 through 2010 (when construction to remediate the BRW seep was completed), total recoverable copper exceeded the chronic standard on a regular basis, whereas, from 2011 through 2013, far fewer exceedances occurred except at station SS-07 downstream of the Metro STP. For stations upstream of Metro STP, copper exceeded the standard no more than once in the 3-year period of 2011 through 2013. The largest sources of copper loading during base flow are effluent from Metro STP (57 percent), combined OU reaches from unknown COC transport mechanisms (25 percent) and BTL (9 percent) (Table 7-27).

Station SS-06A had one total recoverable cadmium exceedance of the chronic standard, with that sample collected prior to the bank sediment removal work in 2010. No other exceedances occurred from 2008 through 2013 at base flow.

One to two exceedances in total recoverable lead concentrations occurred at each station, including SS-01(except at SS-07) in the 6-year period from 2008 through 2013.

All sample results for total recoverable arsenic, silver, and zinc and dissolved aluminum from 2008 to 2013 were below the relevant standards. Overall, surface water quality standards are being met at an allowable frequency and duration during base flow conditions except for copper at SS-07.

Overall, the Metro STP input represents the largest load of six COCs and is ranked second for a seventh COC during base flow conditions, whereas the combined reaches within the OU rank highest for cadmium, and are second for both copper and zinc. The latter reflect unquantified sources in these reaches, presumably from pore water, ground water, or sediments. All COCs except copper and lead have concentrations less than applicable standards during base flow. The only station with significant exceedances is SS-07 for total recoverable copper. The load ranking indicates that the Metro STP is the largest contributor to those exceedances.

13.4.2 Normal High Flow Summary

Copper concentrations were lower in the 2011 through 2013 period compared to 2008 to 2009, specifically following the BRW seep remediation and bank sediment removal in the Blacktail-Silver Bow Creek confluence to Montana Street area by early-2011, but still had a number exceedances during both periods. From 2008 through 2009, total recoverable copper exceeded the chronic standard in 83 percent of sample results at stations SS-05A, SS-06A, and SSS-07. Since 2011, total recoverable copper only exceeded the chronic standard in 10 to 15 percent of sample results at SS-05A and SS-06A, with the rate at SS-07 decreasing to 35 percent. The largest source of total recoverable copper loading during high normal flow conditions includes discharge of effluent from the Metro STP (39 percent), sediment in the reaches upstream of SS-06G (39 percent), and up gradient sources upstream SS-01 (12 percent). The reach from SS-05 to SS-05A (Slag Canyon) was estimated to be 27 percent of the overall reach load, making it a large loading source over a fairly short reach. With the exception of one potential outlier each, dissolved aluminum and total recoverable zinc were all below the chronic standard.

Arsenic and iron concentrations were very similar at each station and showed a general relationship to discharge – higher discharge equates to higher arsenic and iron concentrations. Exceedances at the stations ranged from 13 to 18 percent for arsenic and 8 to 18 percent for iron. In general, concentrations of arsenic and iron were greater during spring runoff. Total recoverable lead concentrations were typically below the chronic standard, with the exception of two to three exceedances at each of the following stations; SS-07, SS-05A, SS-05, and SS-04. These results were notably greater than the dissolved fraction and adjacent sample results, and are related to suspended sediment.

Overall, the largest source of loading to surface water for copper was the Metro STP, tied with the summation of loadings from the OU stream reaches between SS-01 and SS-06G. The reach between SS-05 and SS-05A comprised nearly 70 percent of the entire reach load during normal high flow. Based on a relationship between total suspended sediment and metals concentrations, sediment is a primary loading source for these two metals. Upstream sources were identified as the largest source of loading for arsenic and iron.

13.4.3 Wet Weather Flow Summary

Total recoverable copper concentrations always exceeded the acute standard at stations SS-07 and SS-06G and almost always exceeded the acute standard from Stations SS-06A to SS-01 for both periods of 2008 to 2010 and 2008 to 2013. The maximum copper concentrations were lower overall in the later period. Further discussion of the copper results during wet weather flow is provided in Section 10, for which the following loading distribution was approximated: Buffalo Gulch (59 percent), upper SBC (25 percent), and SS-01 (11 percent).

Samples also indicated a moderate number of exceedances for other COCs that were analyzed across the OU. Total recoverable arsenic exceeded the acute standard only once, at SS-04. All other total recoverable arsenic concentrations were within the acute standard. Total recoverable cadmium had a low number of exceedances at all main stem stations, with exceedances ranging from 3 to 13 percent.

Total recoverable lead had a moderate number of exceedances from 2008 to 2013; however, there were large variations in lead concentrations at SS-04 that are considered indicative of variability in the flushing of suspended solids during wet weather events. Total recoverable zinc exceeded the acute standard in approximately 50 percent of samples analyzed at stations SS-05 through SS-07. Similar to lead, zinc exhibited large fluctuations in concentrations between the minimum reported values and the maximum. For example, at station SS-04, the total recoverable zinc concentrations ranged from 8.5 µg/L to 10,900 µg/L. These variations are likely due to re-suspension of sediments, either from along the stream bank, or from point sources along the creek.

The largest sources of loading during wet weather conditions are outfalls at Buffalo Gulch (20–86 percent, depending on the COC) and upper SBC (10–37 percent), with additional loading entering the site from upstream in Blacktail Creek (2–16 percent).

13.5 Other Relevant Data Summary

This section provides a summary of the other relevant data (non-compliance data) from Section 12 that discussed the collection from sources used to supplement or provide independent measures of water quality and flow data collected by AR on behalf of the responsible parties' group. Available data were compared to BPSOU surface water data to assess accuracy of the metals data set.

13.5.1 Wet Weather Flow Data Summary

13.5.1.1 Non-Compliance Wet Weather Data in 2013

Wet weather flow and stage monitoring data were obtained from the surface water monitoring stations identified in various drainages in the BPSOU in 2013 in accordance with the DSWMP (AR 2013b). These drainages include Anaconda Road-Butte Brewery, Buffalo Gulch, Missoula Gulch, upper SBC, Texas Avenue, Warren Avenue, and West Side. Samples were collected during wet weather flow conditions (snowmelt runoff and during rainfall events) and analyzed for total recoverable and dissolved metals, including arsenic, cadmium, copper, lead, mercury, and zinc as well as total suspended solids and sulfate.

Results at the Anaconda Road-Butte Brewery drainage sample locations indicated elevated concentrations of total recoverable copper at the upstream station (AR-CLV-2), with a median value of 1,400 µg/L. This culvert empties into a retention basin in the Middle Rail Yard which has not discharged since construction of the outfall riser in 2008. In comparison, results from the downstream stations have much lower total recoverable copper concentrations of approximately 200 µg/L, respectively. Dissolved copper concentrations have similar results (with higher concentrations at the upstream station than the downstream station) below 100 µg/L.

The Buffalo Gulch Drainage is split into western and eastern portions. Median total recoverable copper results in the western portion of the drainage system range from 100 µg/L to 345 µg/L. The downstream locations in the eastern portion of the drainage show similar copper concentrations as the downstream sample location in the western portion.

Results at Missoula Gulch for total recoverable copper were variable throughout the drainage area. The total recoverable median at MG-CH-10 was an order of magnitude lower than the total recoverable median concentration just downstream at sample location MG-CLV-9 (120 to 1,440 µg/L, respectively). Results for total recoverable copper farther downstream decreased to a median result at MG-CLV-1 of 41 µg/L downgradient of Catch Basins 8 and 9. Dissolved results were dissimilar, increasing downgradient and then decreasing slightly at MG-CLV-1 (26 µg/L). The loading statistics show that copper loads decrease from the CB-8 inlet (MG-CLV-2) to the CB-9 outlet (MG-CLV-1), indicating that the catch basins reduce overall copper loading. Based on the underlying data from Figure 12-4, the inlet to CB-8 (MG-CLV-2) had a median total recoverable copper load of 3.02 lb/day. The outlet to CB-9 had a median load of 0.40 lb/day. This is a removal efficiency of 87 percent. The inlet dissolved copper load was 0.57 lb/day and the outlet load was 0.22 lb/day for a removal efficiency of 61 percent. Given the timing difference between inflow and outflow, calculation of a removal efficiency is an estimate.

Results for total recoverable and dissolved copper concentrations along upper Silver Bow Creek were relatively similar between sample locations, with a slight decreasing trend from upstream to downstream. Representative medians for total recoverable and dissolved copper were approximately 150 and 40 µg/L, respectively.

Samples were collected at only one sample location at the hydrodynamic device at Texas Avenue. The median concentration of total recoverable copper was 370 µg/L, and the median concentration of dissolved copper was 53 µg/L. West Side also only had one sample location. The median concentrations of total recoverable and dissolved copper were 180 and 39 µg/L, respectively.

Results for total recoverable copper concentrations in the Warren Avenue drainage were relatively high compared to the other drainage areas. WA-HD-1 had a maximum concentration of total recoverable copper of 12,600 µg/L (maximum measured concentration as part of the DSWMP). The hydrodynamic device had little effect on total recoverable and dissolved copper concentrations.

Samples were collected at only one sample location (WS-CLV-1) at the West Side drainage. Due to the smaller area of the drainage leading to lower discharge, loads from the West Side drainage were smaller than the other areas.

13.5.1.2 Outfall and In-System Wet Weather Data in 2009

The results of the 2009 wet weather data (collected as part of interim monitoring Plan) show the median total recoverable copper concentration in stormwater ranged from 77 to 157 µg/L for central and western areas of Butte Hill (West Side, Missoula Gulch, Idaho Street, and Montana Street sub-drainages). The eastern areas had notably higher median copper concentrations ranging from 256 µg/L in Buffalo Gulch to 1106 µg/L at Texas Avenue with Anaconda Road/Butte Brewery and Warren Avenue having copper concentrations between these median values. Site wide stormwater dissolved copper concentrations were notably lower than total recoverable copper, with all of the median concentrations in the 10 µg/L to 70 µg/L range.

Stormwater samples were also collected throughout the Buffalo Gulch sub-drainage in 2009 in an effort to identify discrete sources of copper to stormwater. Median total recoverable copper concentrations ranged from 63 to 377 µg/L, with the highest maximum concentrations from 518 to 622 µg/L. The sampling indicated that sources of total recoverable copper occur throughout Buffalo Gulch, and no particular subarea contributes a majority portion of the copper load.

13.5.2 Summary of Wet Weather Data for Sustained Periods

From 2008 through 2013, a series of incremental samples were collected using automated samplers over the course of individual wet weather events to characterize flushing of sediment and metals through the stormwater network. Total recoverable copper data were statistically evaluated at three stations, SS-07, SS-06A, and SS-05.

The median concentrations of total recoverable copper at SS-07 and SS-06A had a larger median, upper quartile, and maximum in the first hour compared to the other hours sampled (i.e., 0, 2, and 3). This pattern is consistent with a typical hydrograph, whereby the bulk flushing occurs once water from the upper watershed reaches the sampling location. The pattern at SS-05 was similar although the hour 1 sample does not have the highest median and upper quartile. The analysis concluded that during sustained wet weather, the peak concentrations generally occur within the first 3 hours of an event, and the variation between years is greater than the variation between samples in the first 3 hours of an event.

Streambed sediment copper concentrations appeared to have a decreasing trend for the finest fraction (<0.063 mm) from 2008 through 2010, but stabilized between 2010 and 2013. The trend for the coarser fraction (0.063 to 1 mm) is largely flat or weakly decreasing at best. Both trends appear to be influenced by summer storm events, the most notable occurring on June 27, 2009. The storm events superimpose “spikes” onto whatever trends exist. The reduction in copper concentrations may be due in part to remediation that has occurred over the last few years, such as curb and gutter construction and waste capping, to minimize erosion and transport of metals-bearing sediments by stormwater in Butte. However, reductions are also seen at SS-01, upstream of any BPSOU remedial actions.

13.5.3 Streamside Tailings OU Monitoring

In order to obtain background data for Streamside Tailings OU (SSTOU), samples are collected within and upstream of BPSOU. Surface water samples are generally collected quarterly at SS-01, SS-05A or SS-06A, SS-06G, and SS-07 although this list has varied. Sampling methodology includes the same SOPs as used for the BPSOU monitoring. SSTOU monitoring uses a different laboratory from BPSOU and detection limits are different. It appears that the data may have been collected in a manner that would allow a determination if the data are of enforcement quality, but since much documentation was missing, it was considered screening quality for the purposes of this report.

For the SSTOU monitoring, metals analytical results from station SS-01 and the arsenic and mercury data from the remaining stations are predominantly reported as non-detect. As such, these data are not suitable for analysis. In general, the higher frequency of sampling in the BPSOU data set captures a wider range of conditions, thus, a wider range of concentrations. The two data sets generally have similar results, and there does not appear to be a noticeable difference between the sets. However, one variation noted is the BPSOU data show lower lead and zinc concentrations starting about mid-2012 that are not reflected in the SSTOU data. Overall, the SSTOU data compared well with the BPSOU data with no apparent bias, suggesting that both data sets have similar accuracy.

13.5.4 Summary of USGS Data

At USGS station 12323230 (SS-01), results for cadmium, lead, and zinc were largely non-detect until detection limits were lowered in the late 1990s through early 2000s. No discernable trends were noted in the cadmium, lead, and zinc data. For arsenic and copper, very few non-detect results were reported for the period of record; therefore, the data are not affected by changes in the reporting limits. There was no trend in the arsenic and copper data other than lower concentrations in the dry years of 2001 to 2003 and again in 2013.

The data from USGS station 12323250 (SS-07) represent water quality exiting the BSPOU. Its long history represents a fairly complete picture of the changes in water quality due to cleanup work in BPSOU. Reporting limit issues discussed for station 12323230 do not affect station 12323250 because the concentrations were notably above the reporting limits prior to 2003 when ICP-MS was implemented. As a result, trends going back to 1993 can be evaluated. An exception is dissolved lead, which is affected by reporting limits and, thus, was not evaluated in detail.

At USGS station 12323250 (SS-07), remedial actions in the LAO area had significant and cumulative effects that reduced copper concentrations over time. Overall, copper concentrations have decreased by more than one order of magnitude since 1993. Similarly, cadmium and zinc concentrations decreased following each of the four major remedial actions although, there was an increase in 2004 prior to treatment of BPSOU subdrain water.

13.5.5 Summary of Non-COC and Meteorological Data

Sulfate concentrations tended to decrease with increased discharge, indicating that the higher flow dilutes the sulfate. Compared to SS-01, SS-05 has slightly higher sulfate concentrations, indicating a possible onsite source. Station SS-06G has notably higher sulfate concentrations due to the BTL effluent. In addition, there is a pattern of sulfate concentrations increasing in winter and decreasing in summer; in summer, flows are higher, resulting in reduced sulfate concentrations.

DOC has been monitored since 2011. Stations SS-01 through SS-06G show similar patterns and concentrations, with concentrations generally higher during summer months at higher discharge. Station SS-07 has notably higher DOC due to treated wastewater effluent.

Section 14

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Figures

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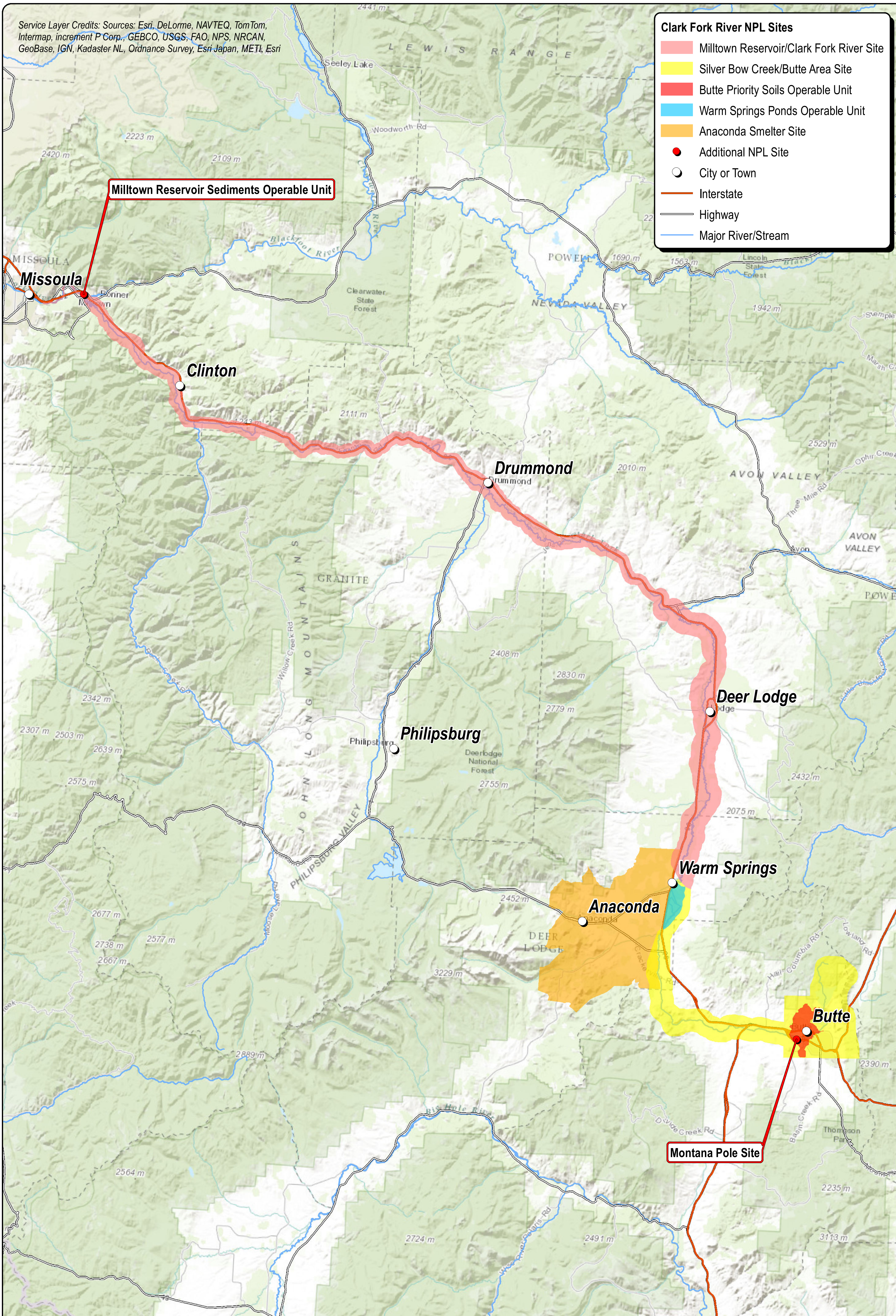

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Figure 1-1
Site Location
Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

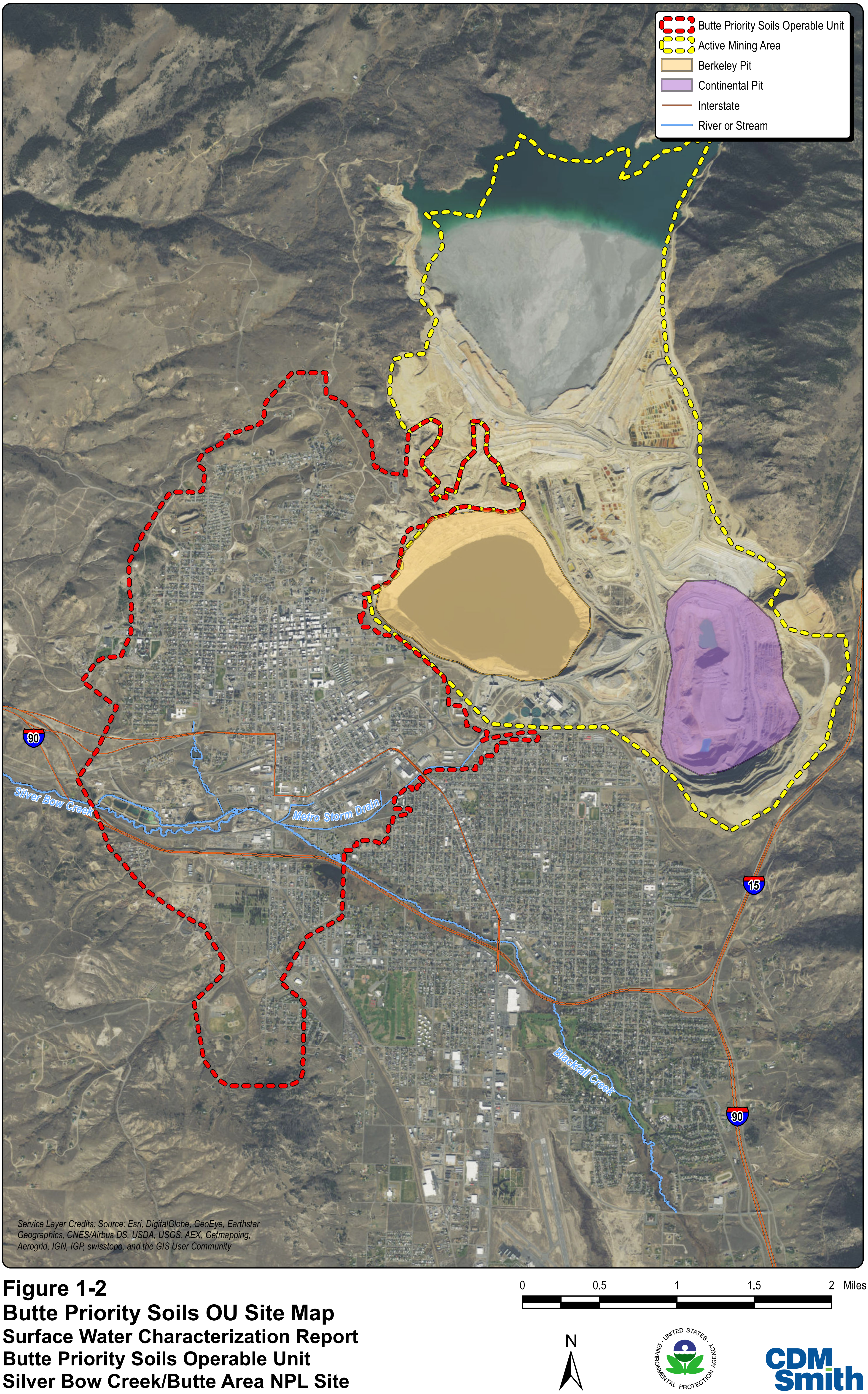


Figure 1-2
Butte Priority Soils OU Site Map
Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

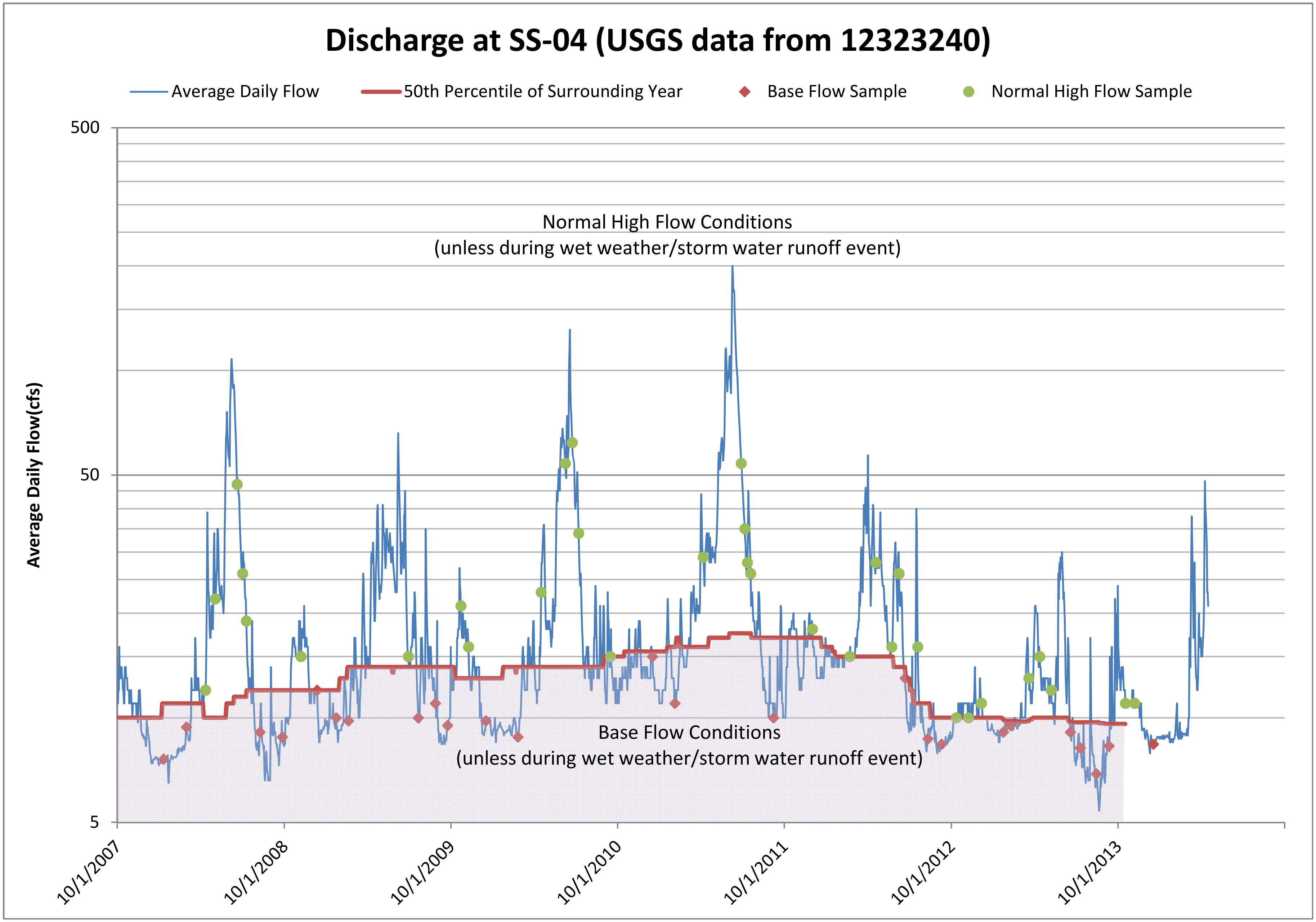


Figure 1-3
Base Flow and Normal High Flow Differentiation

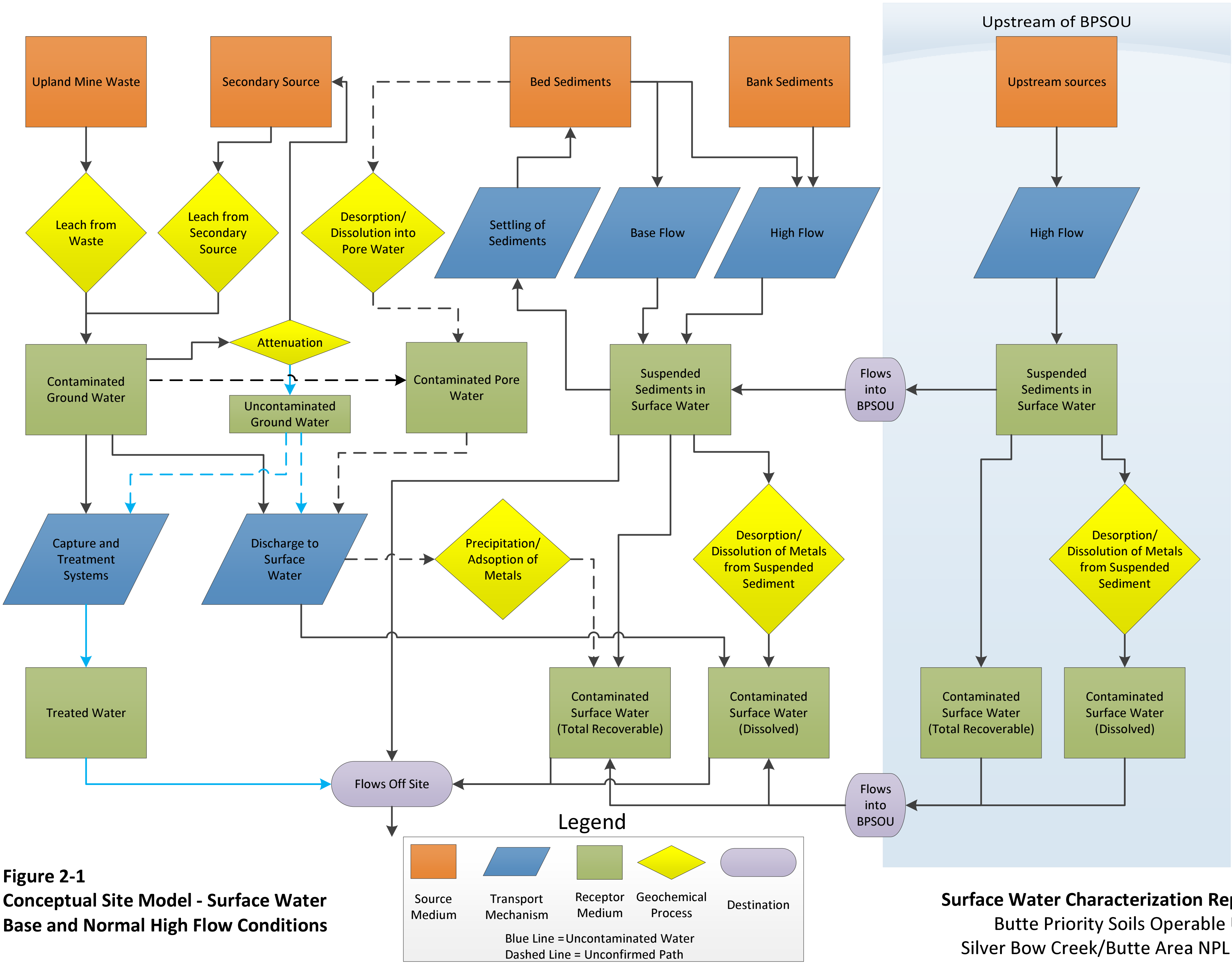


Figure 2-1
Conceptual Site Model - Surface Water
Base and Normal High Flow Conditions

Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

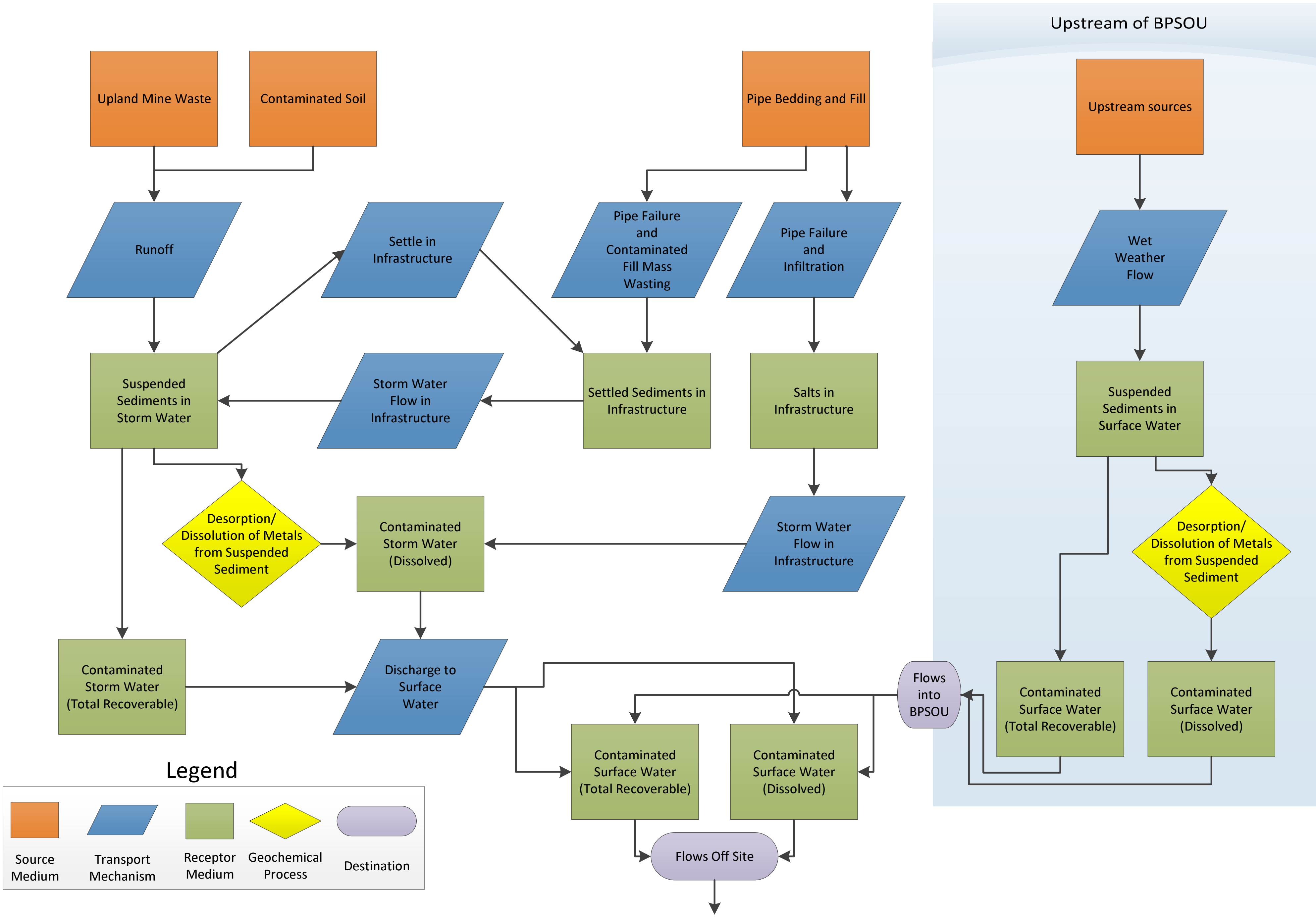
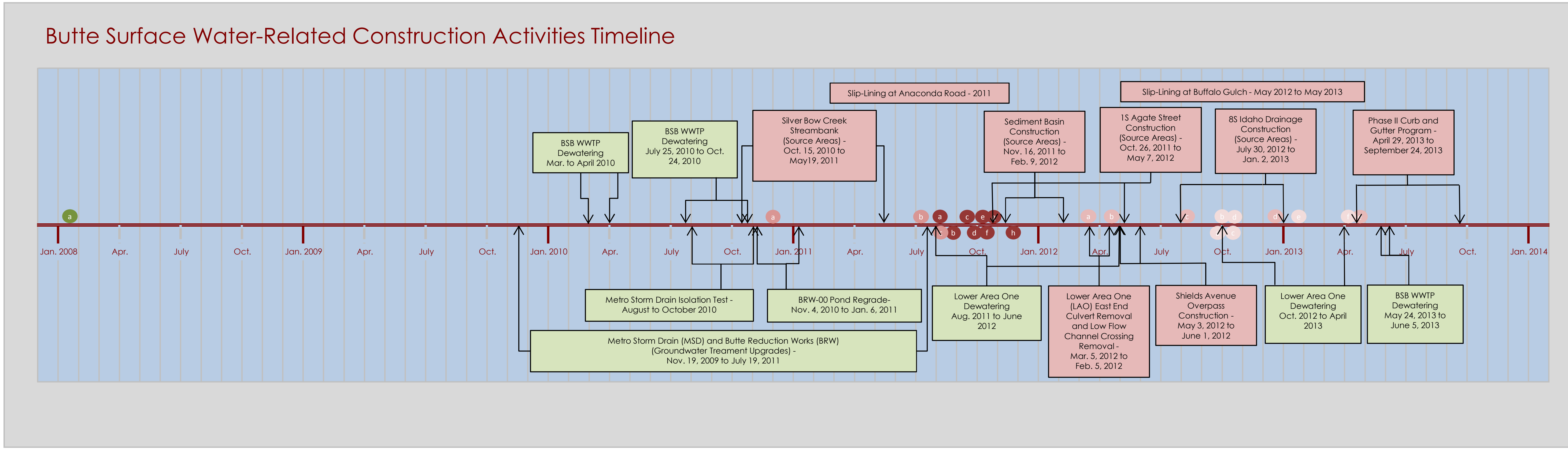


Figure 2-2
Conceptual Site Model - Surface Water
Wet Weather Flow Conditions

Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site



Key:

BASE FLOW-RELATED CONSTRUCTION ACTIVITIES

WET WEATHER FLOW-RELATED CONSTRUCTION ACTIVITIES

Curb and Gutter Construction (Wet Weather Flow)

- a Boardman Street - August 12, 2011
- b Agate, Copper/Alaska, and Porphyry Street - August 26, 2011
- c Colorado/Fremont Street - September 22, 2011
- d Warren Avenue - September 29, 2011
- e 3rd Street - October 14, 2011
- f Gagnon and Iron Street - October 17, 2011
- g 2nd Street - October 21, 2011
- h Casey/Olympia Street - November 23, 2011

Metro Storm Drain Pump Station (Base Flow)

- a New Dry Well Pump Vault - Early 2008

Valley Gutter Construction (Wet Weather Flow)

- a Porphyry Street - December 1, 2010
- b 2nd Street East/West - July 12, 2011
- c Iron (East/West), Washington, Mercury, Platinum (East/West), and Aluminum (West) Street - August 12, 2011

Hydrodynamic Device Installation (Wet Weather Flow)

- a Warren Avenue - March 9, 2012
- b Buffalo Gulch - April 26, 2012
- c Anaconda Road - August 9, 2012
- d Texas Avenue - December 28, 2012
- e Montana Street - April 26, 2013

Phase II Source Control Construction (Wet Weather Flow)

- a 6S Franklin Street - September 25, 2012
- b 4S Alley near Copper and Alaska Streets - Oct. 1, 2012
- c New and Mahoney - October 15, 2012
- d 15S Civic Center Parking Lot - October 18, 2012
- e 9S Nevada Avenue - January 22, 2013
- f 12S MSD North of Shields - April 9, 2013

Figure 3-1
Butte Surface Water-Related Construction Activities Timeline

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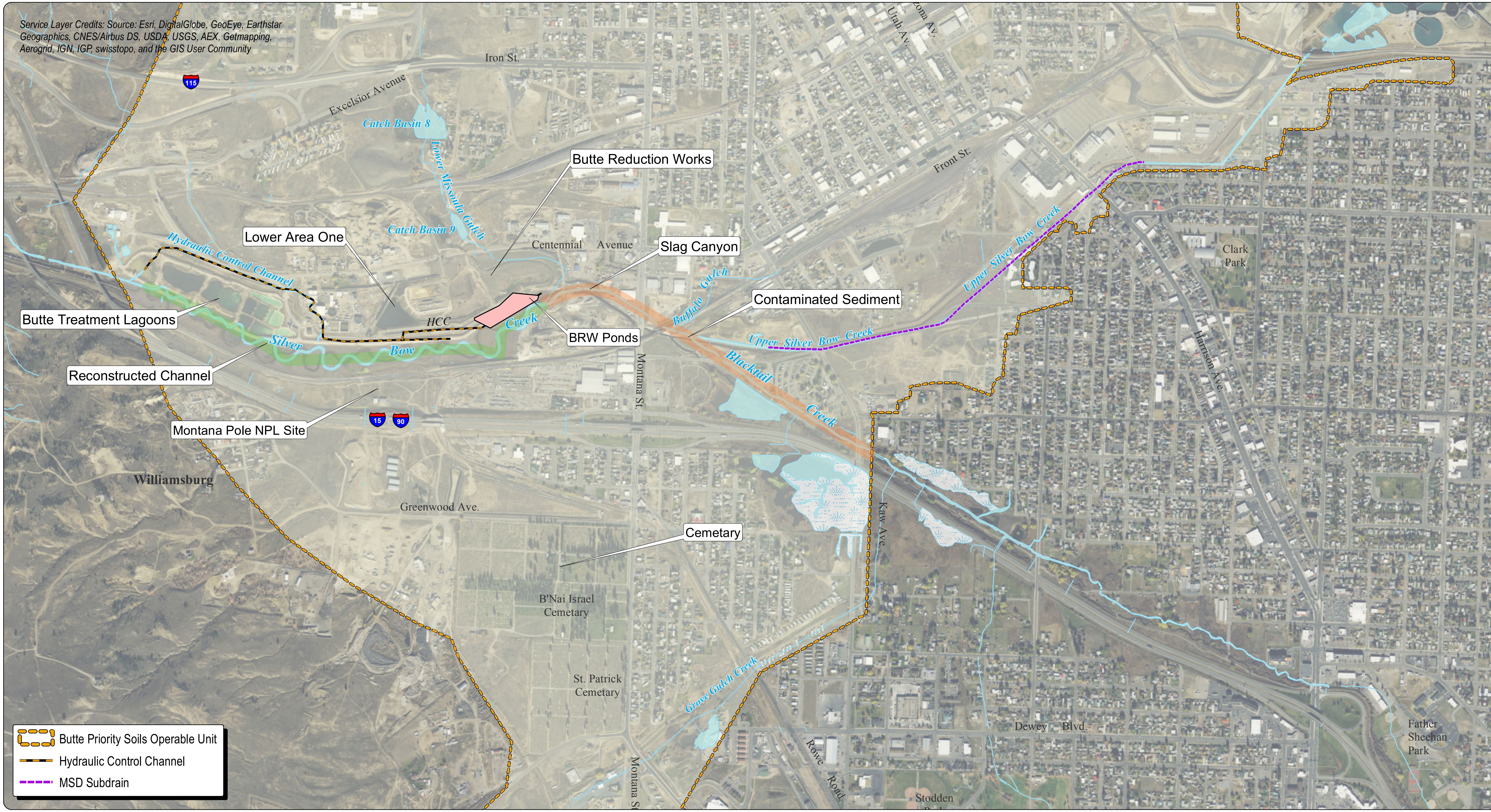

Figure 3-2
Area of Interest
Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

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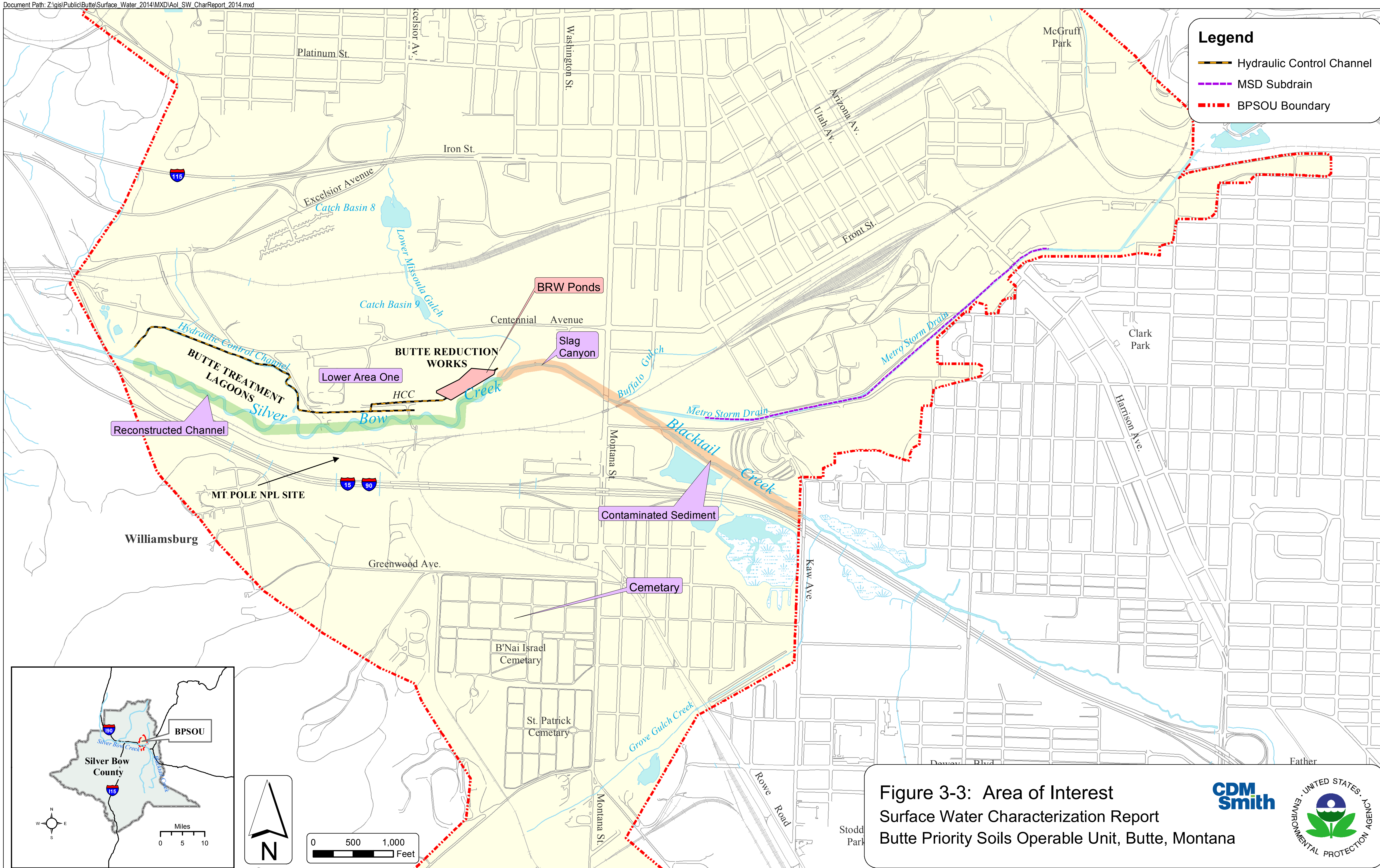

Figure 3-3: Area of Interest
Surface Water Characterization Report
Butte Priority Soils Operable Unit, Butte, Montana

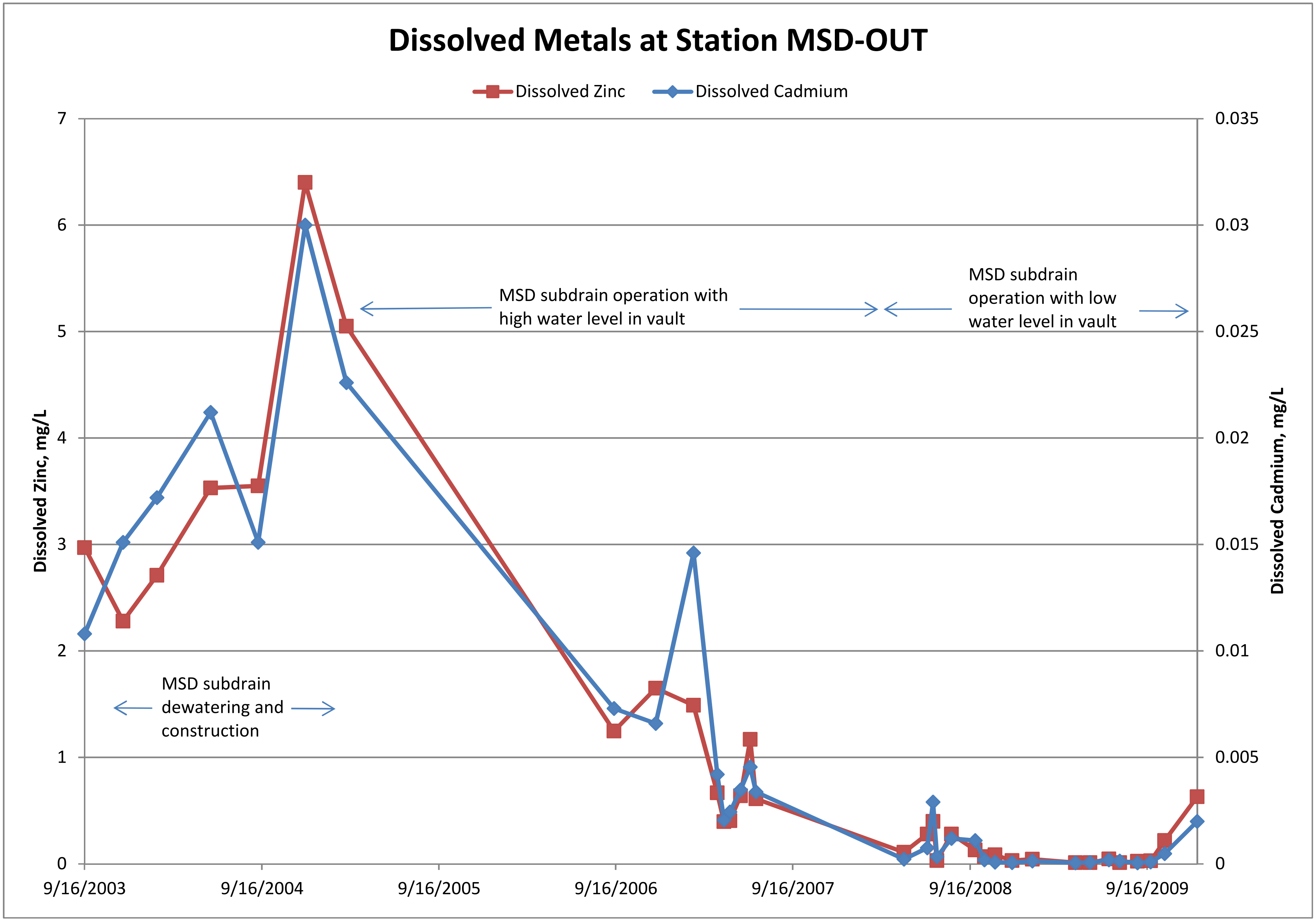

Figure 3-4
Dissolved Metals at Station MSD-OUT

Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow/Butte Area NPL Site

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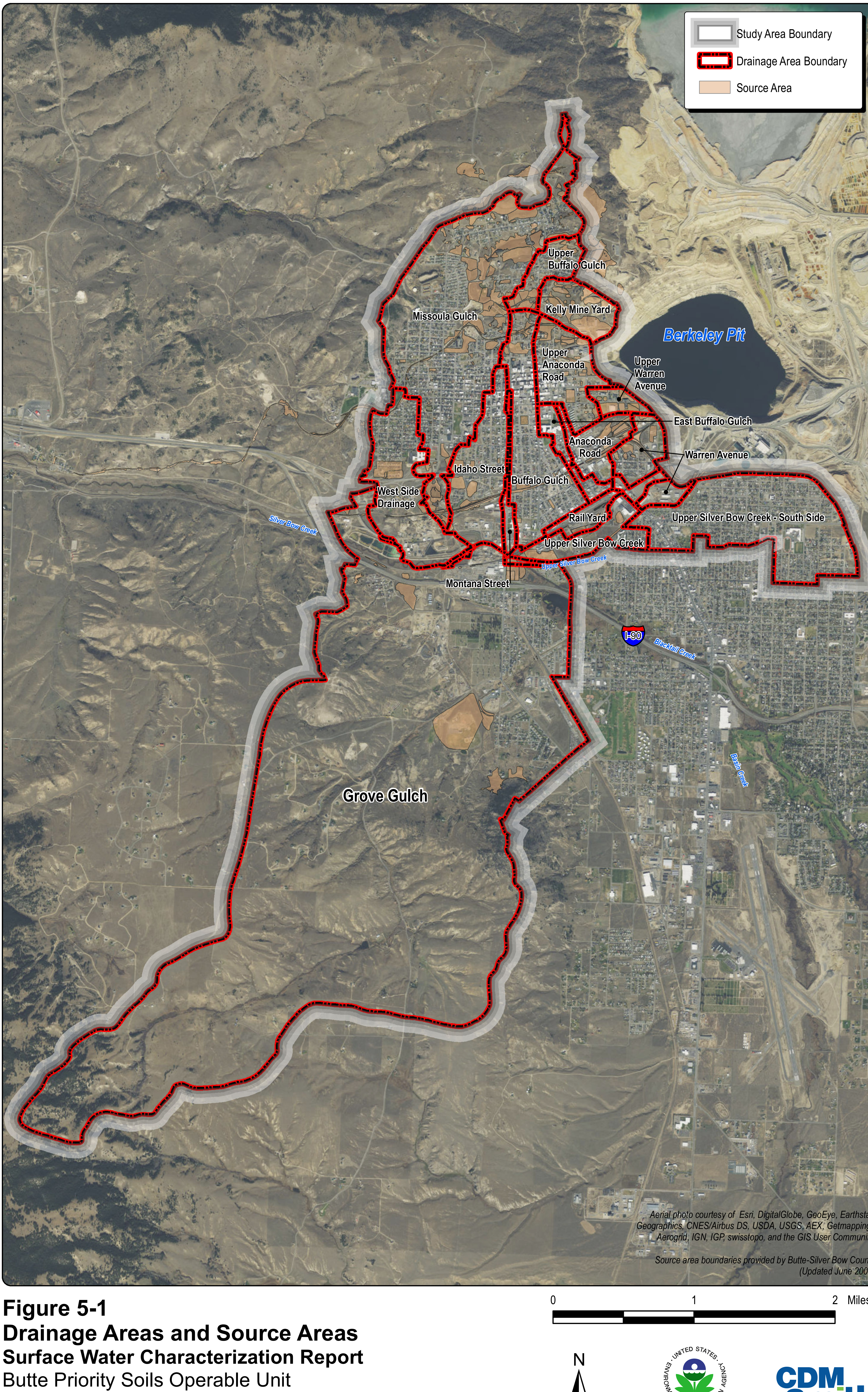

Figure 5-1
Drainage Areas and Source Areas
Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

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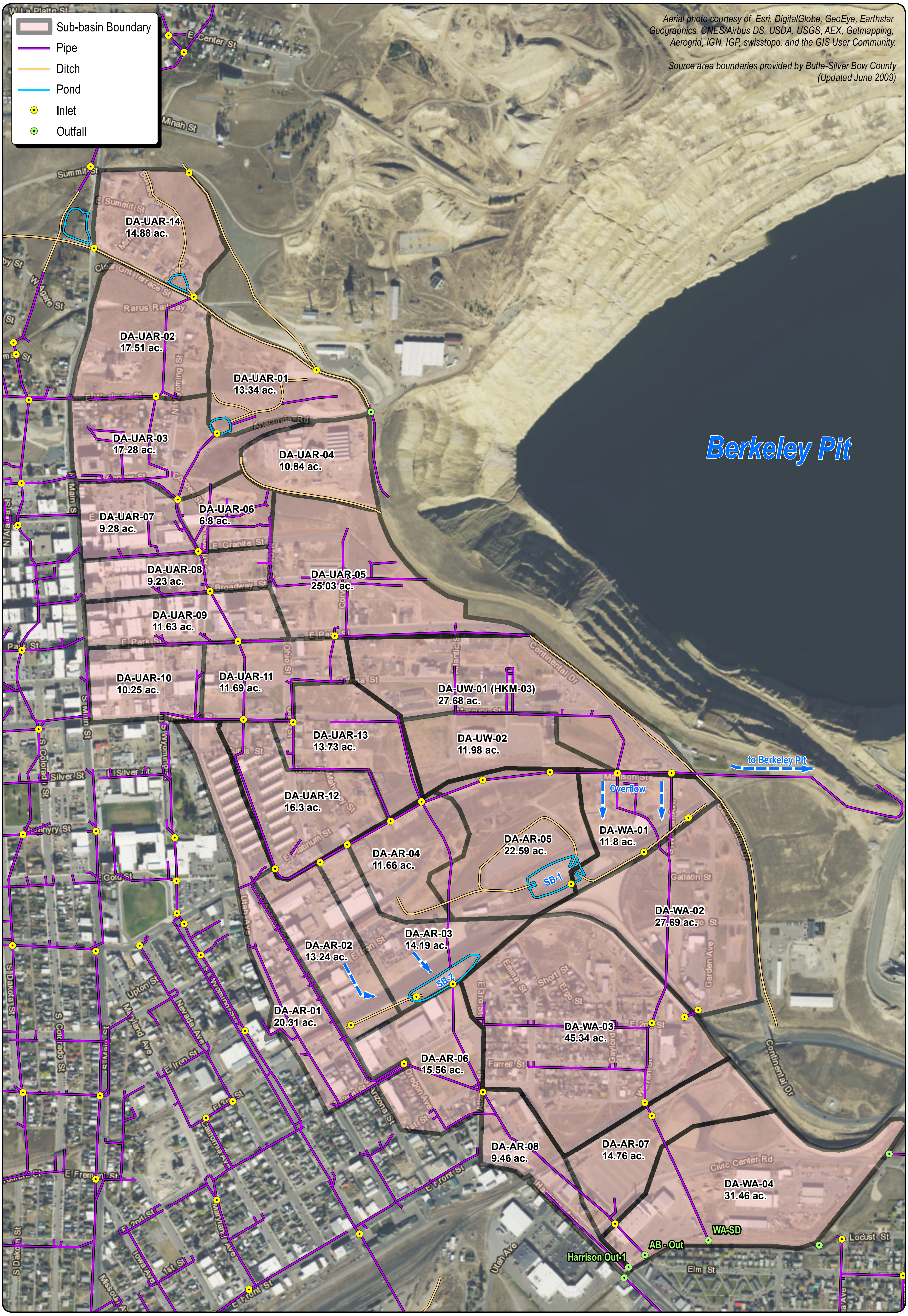

Figure 5-2
Anaconda Rd, Upper Anaconda Rd, Warren Ave, and Upper Warren Ave Drainage Area Parameters
Surface Water Characterization Report

Butte Priority Soils Operable Unit

Silver Bow Creek/Butte Area NPL Site

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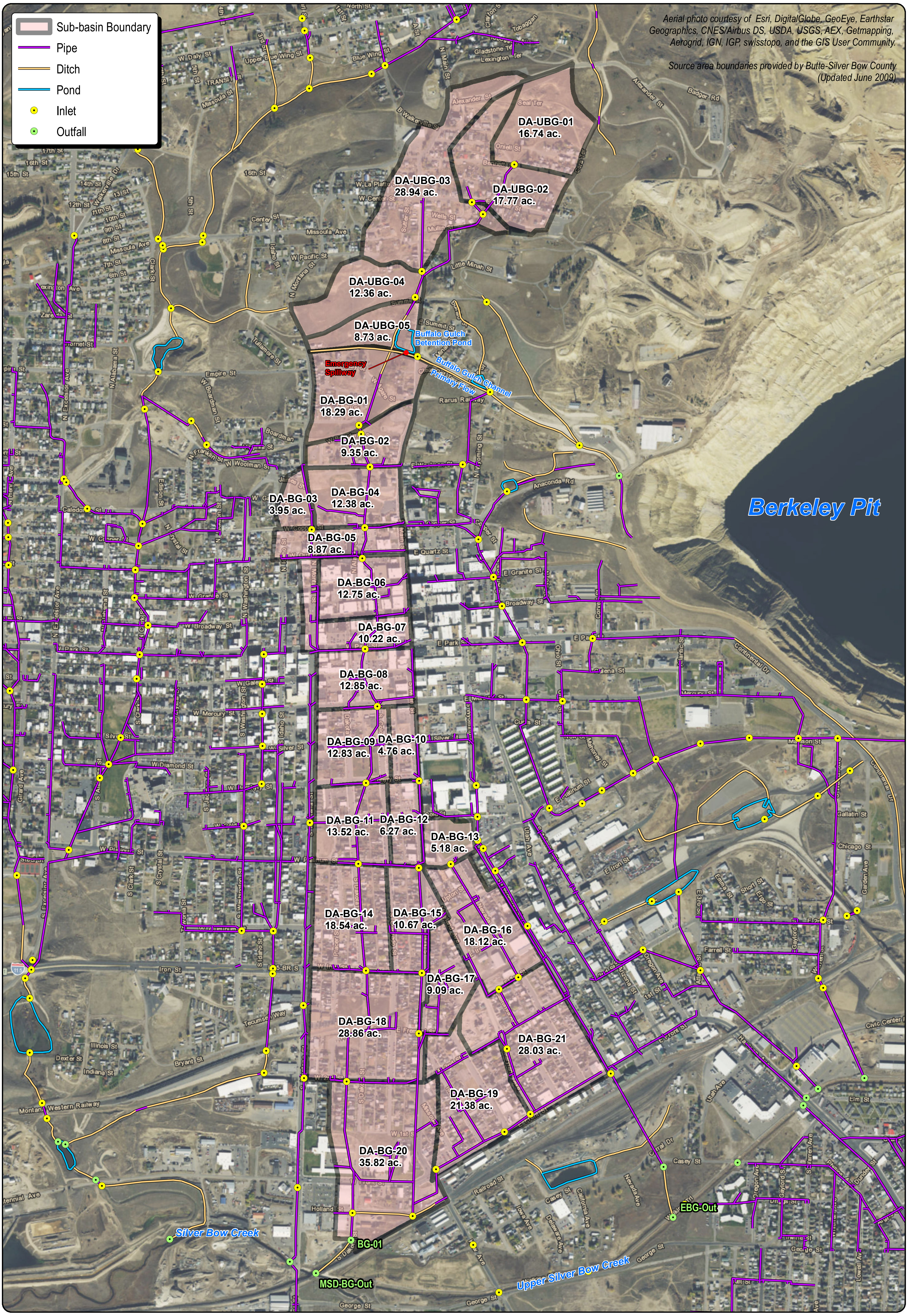

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Figure 5-3
Buffalo Gulch and Upper Buffalo Gulch Drainage Area Parameters
Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

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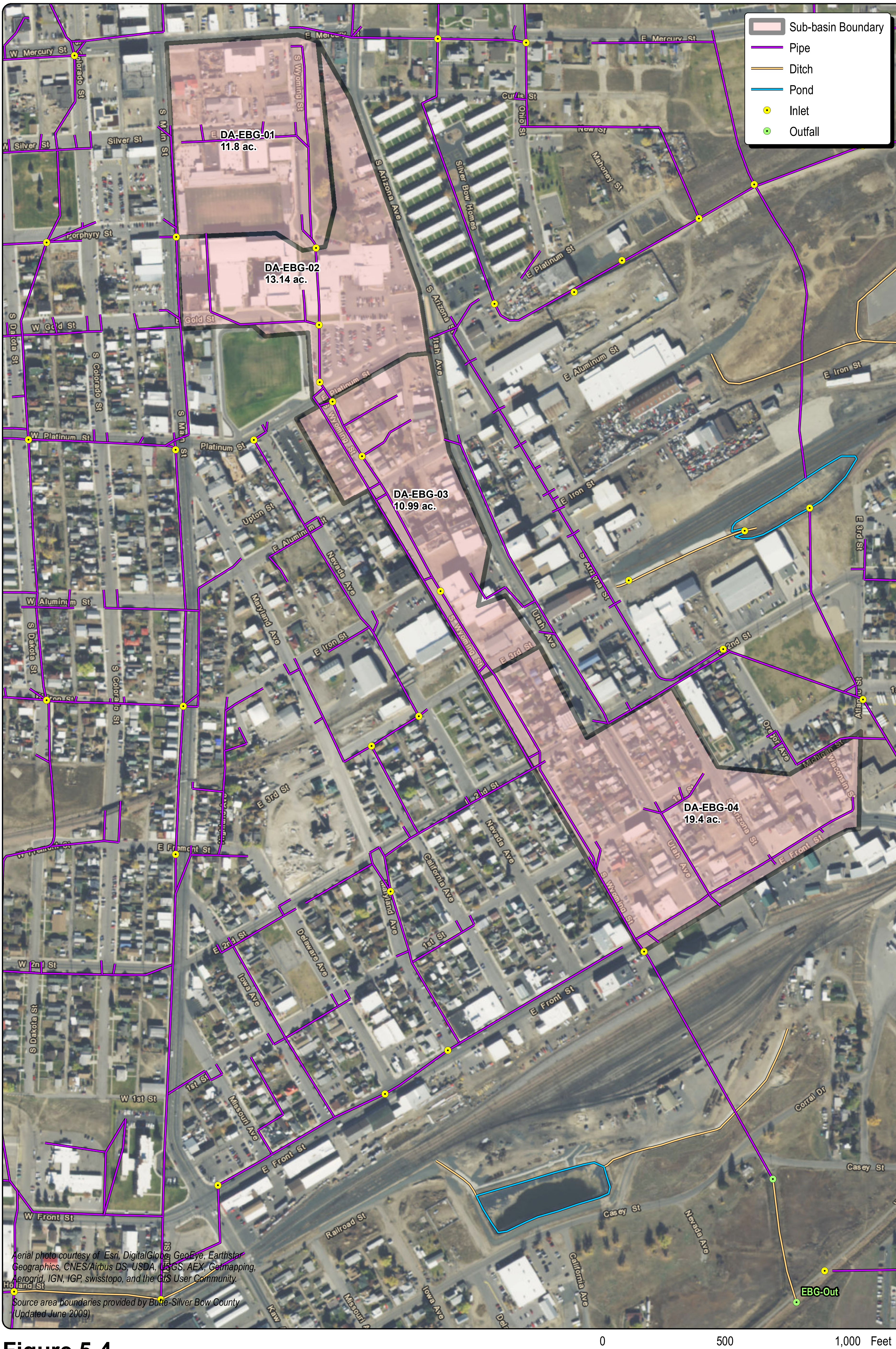

Figure 5-4
East Buffalo Gulch Drainage Area Parameters
Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

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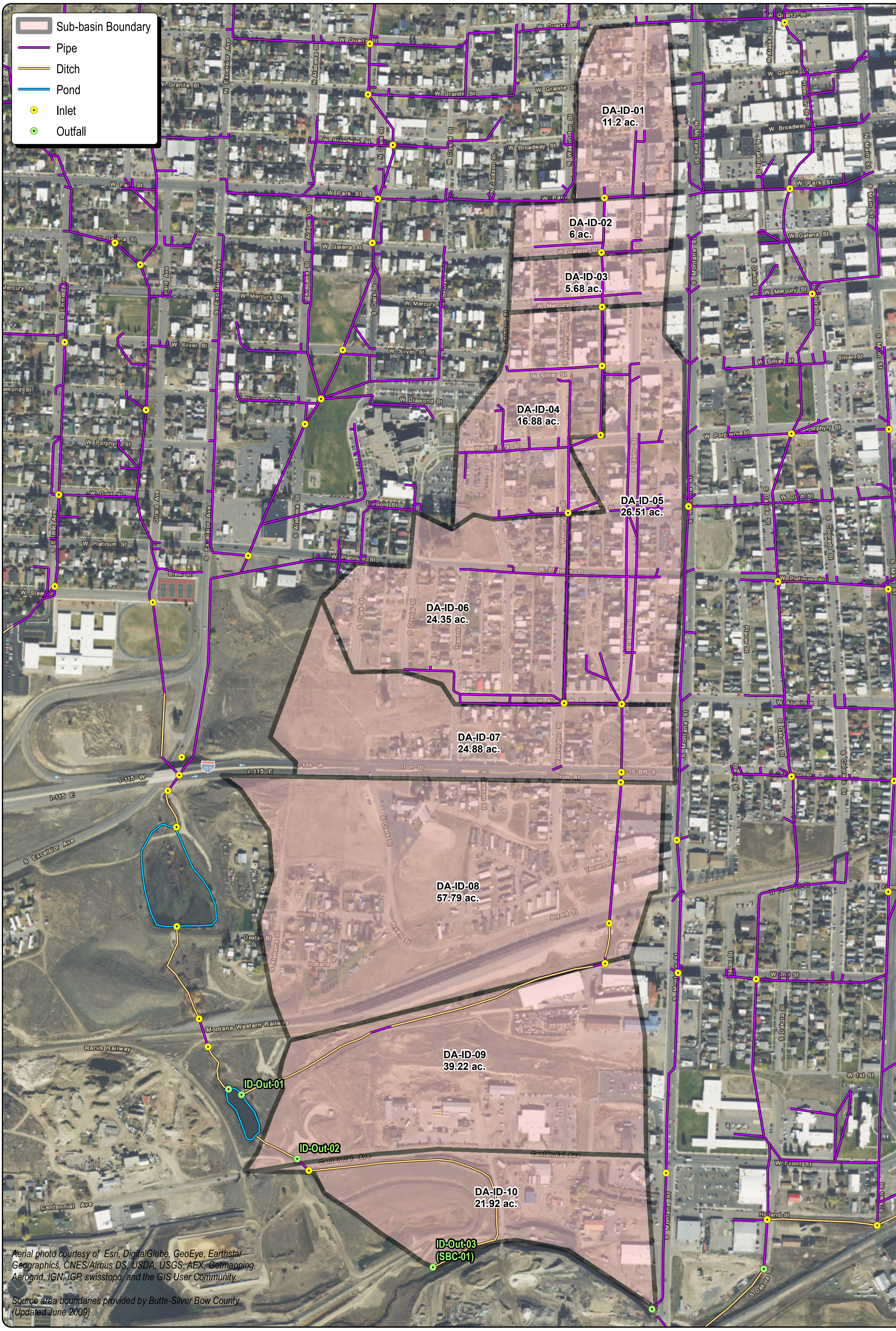

Figure 5-5
Idaho Street Drainage Area Parameters
Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

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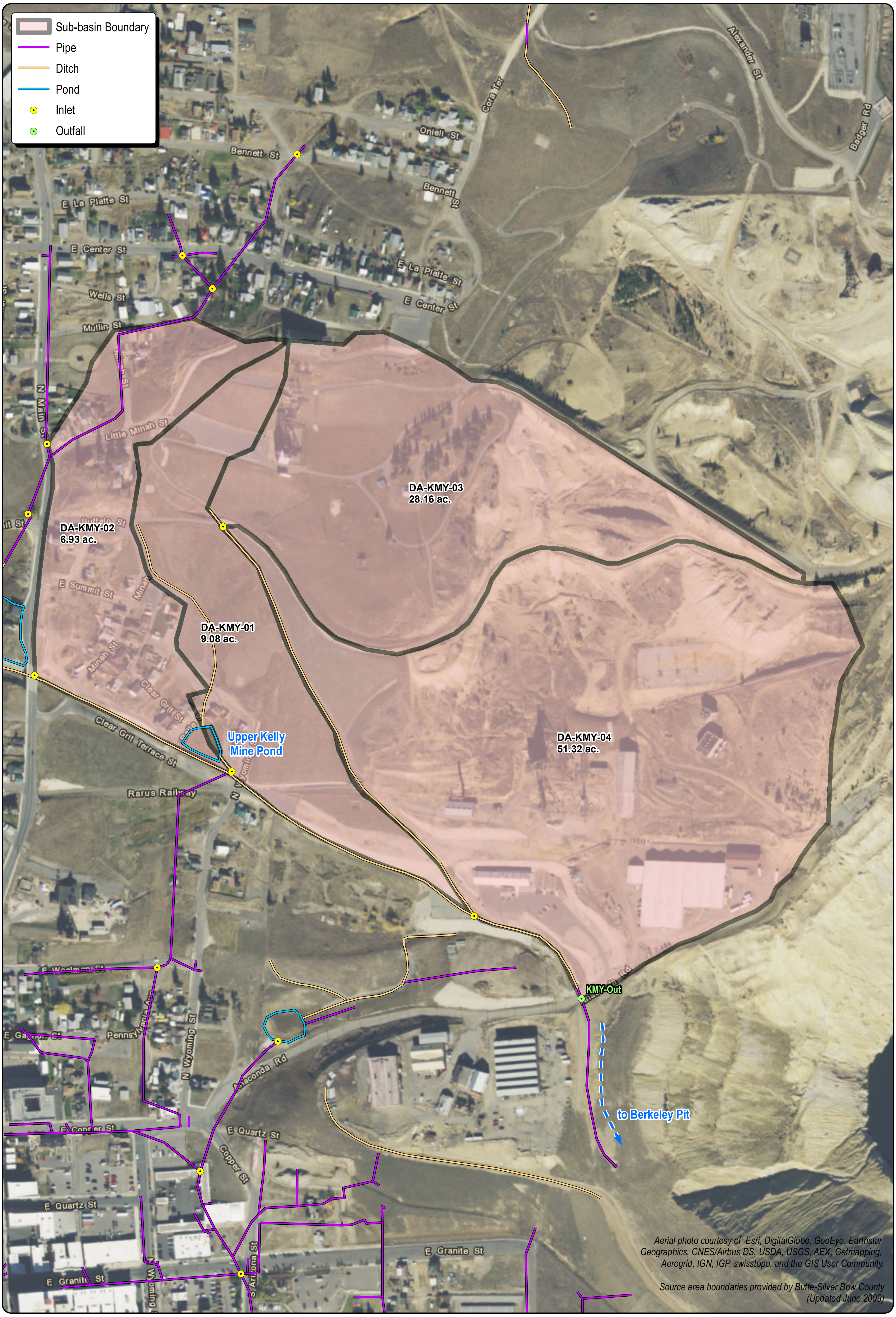

Figure 5-6

Kelly Mine Yard Drainage Area Parameters

Surface Water Characterization Report

Butte Priority Soils Operable Unit

Silver Bow Creek/Butte Area NPL Site

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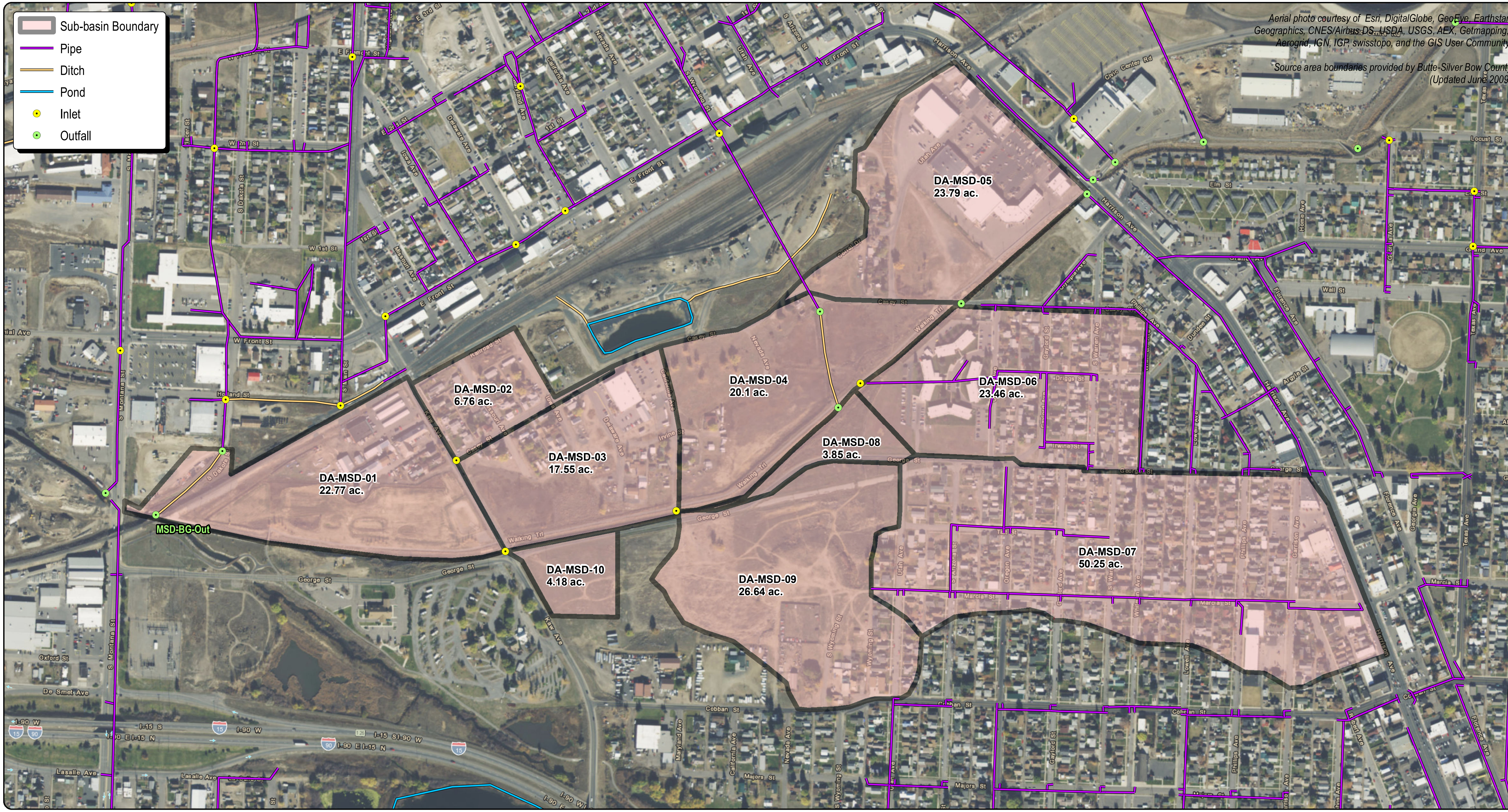

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Figure 5-7
Upper Silver Bow Creek Area Parameters
Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

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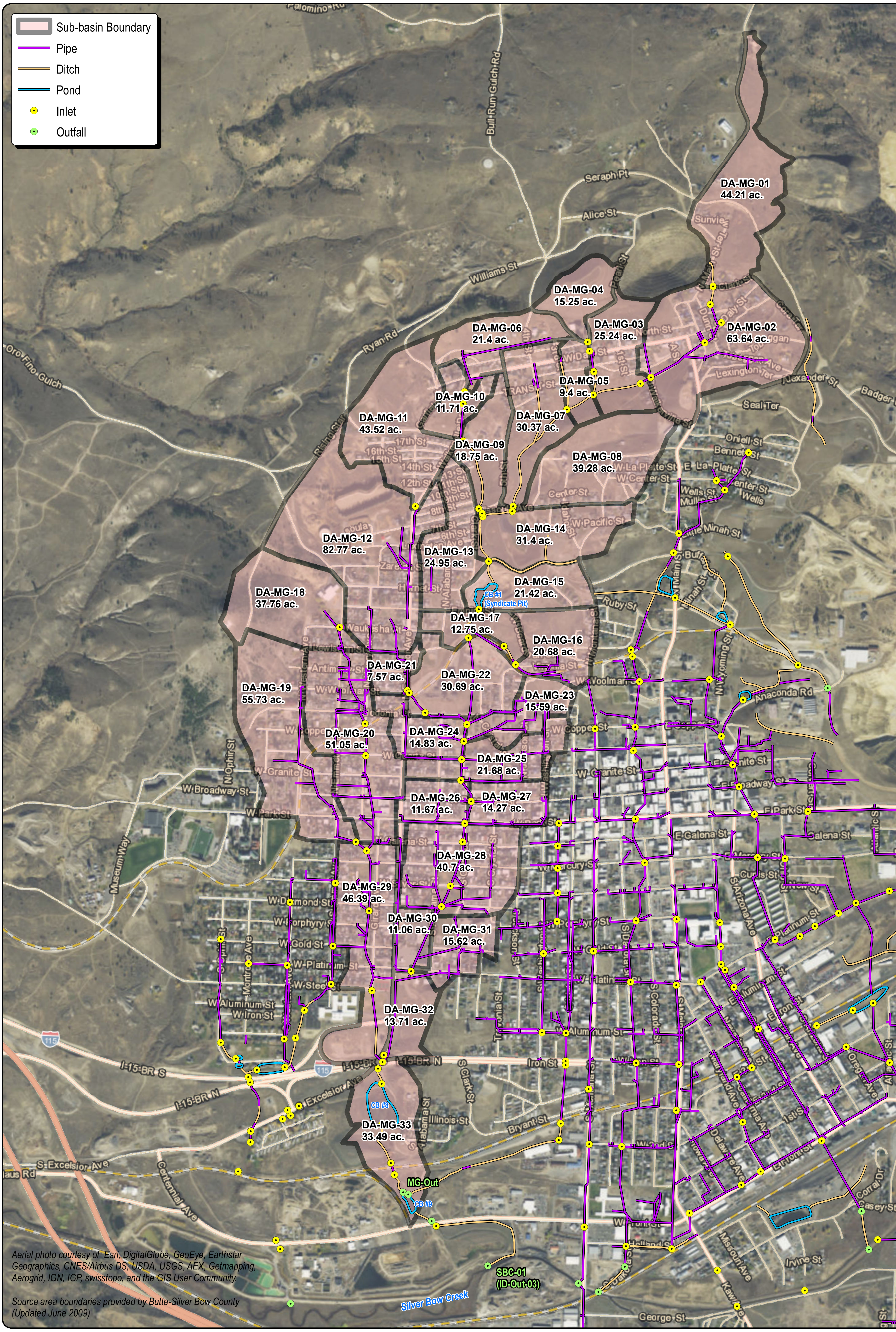

Figure 5-8
Missoula Gulch Drainage Area Parameters
Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

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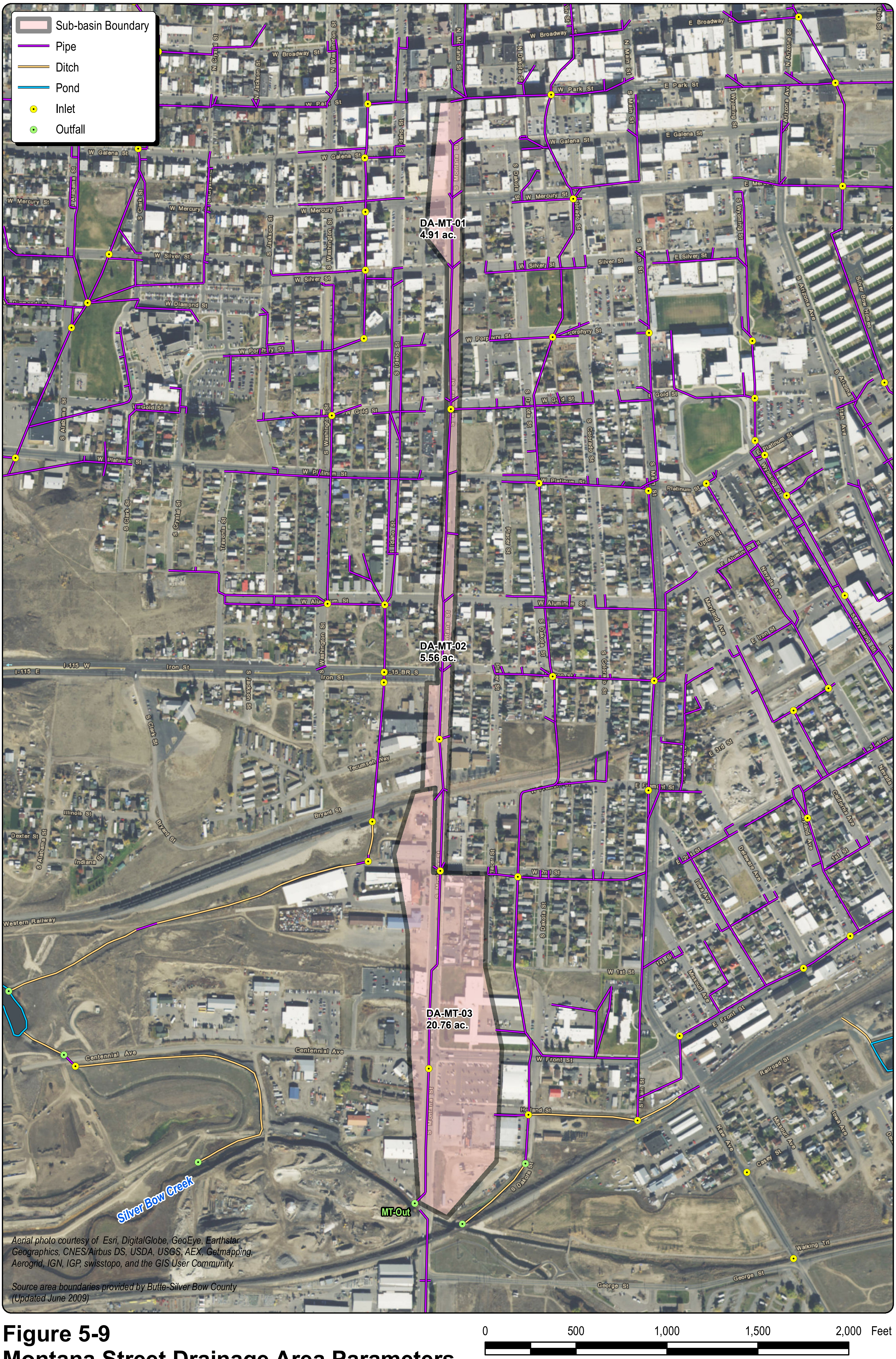

Figure 5-9
Montana Street Drainage Area Parameters
Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

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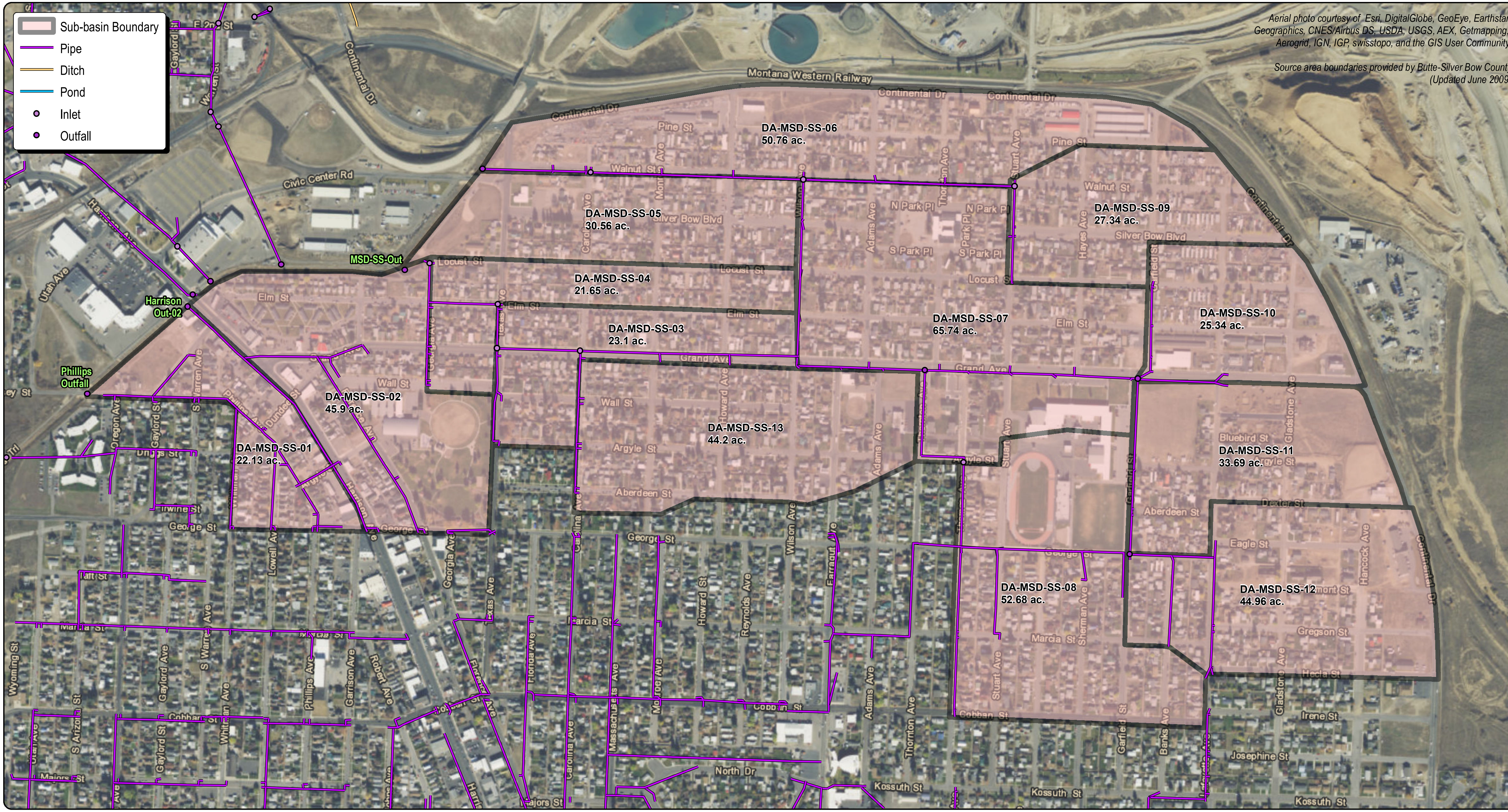

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Figure 5-10
Upper Silver Bow Creek South Side Drainage Area Parameters
Surface Water Characterization Report
Butte Priority Soils Operable Unit

Silver Bow Creek/Butte Area NPL Site

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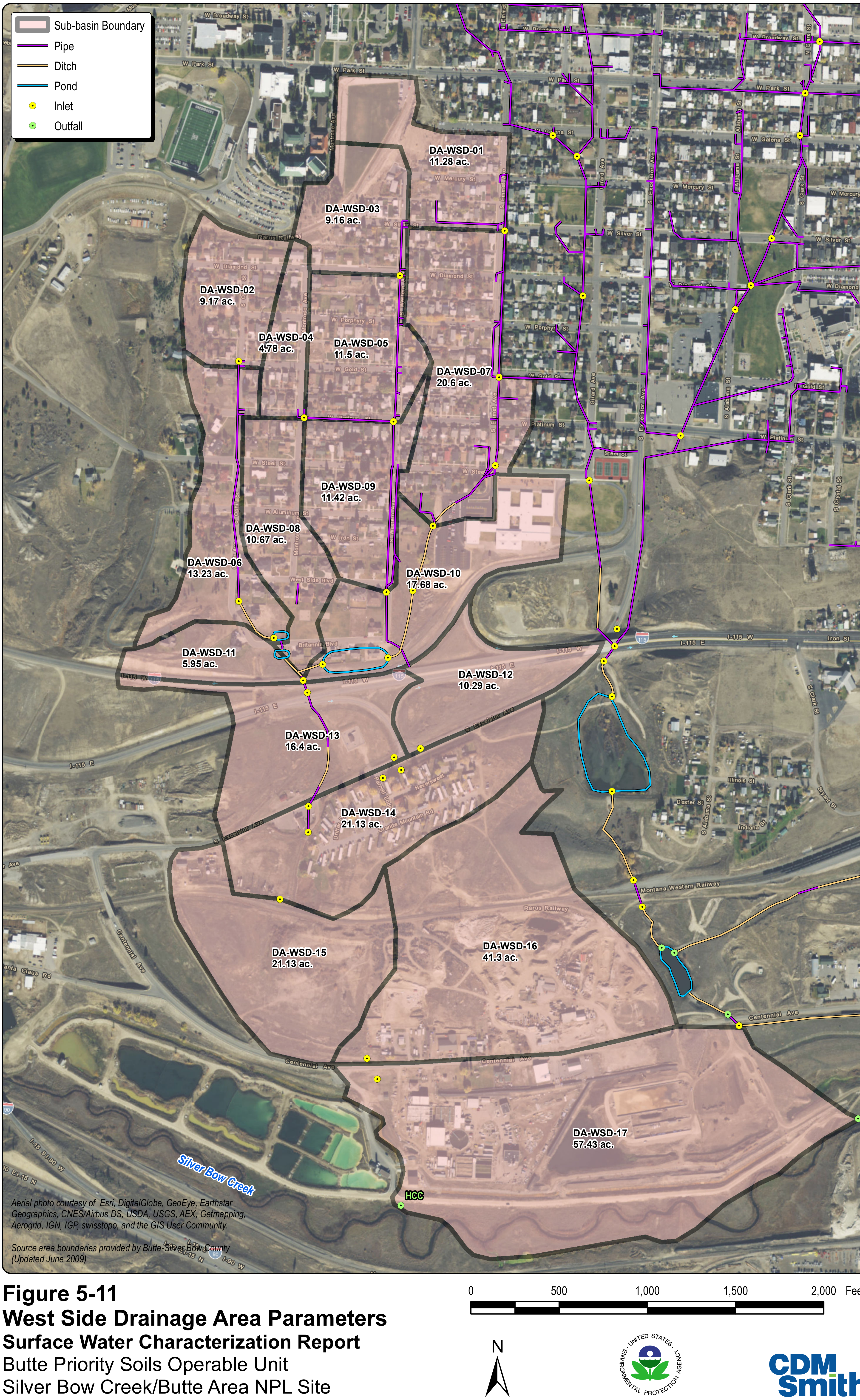

Figure 5-11
West Side Drainage Area Parameters
Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

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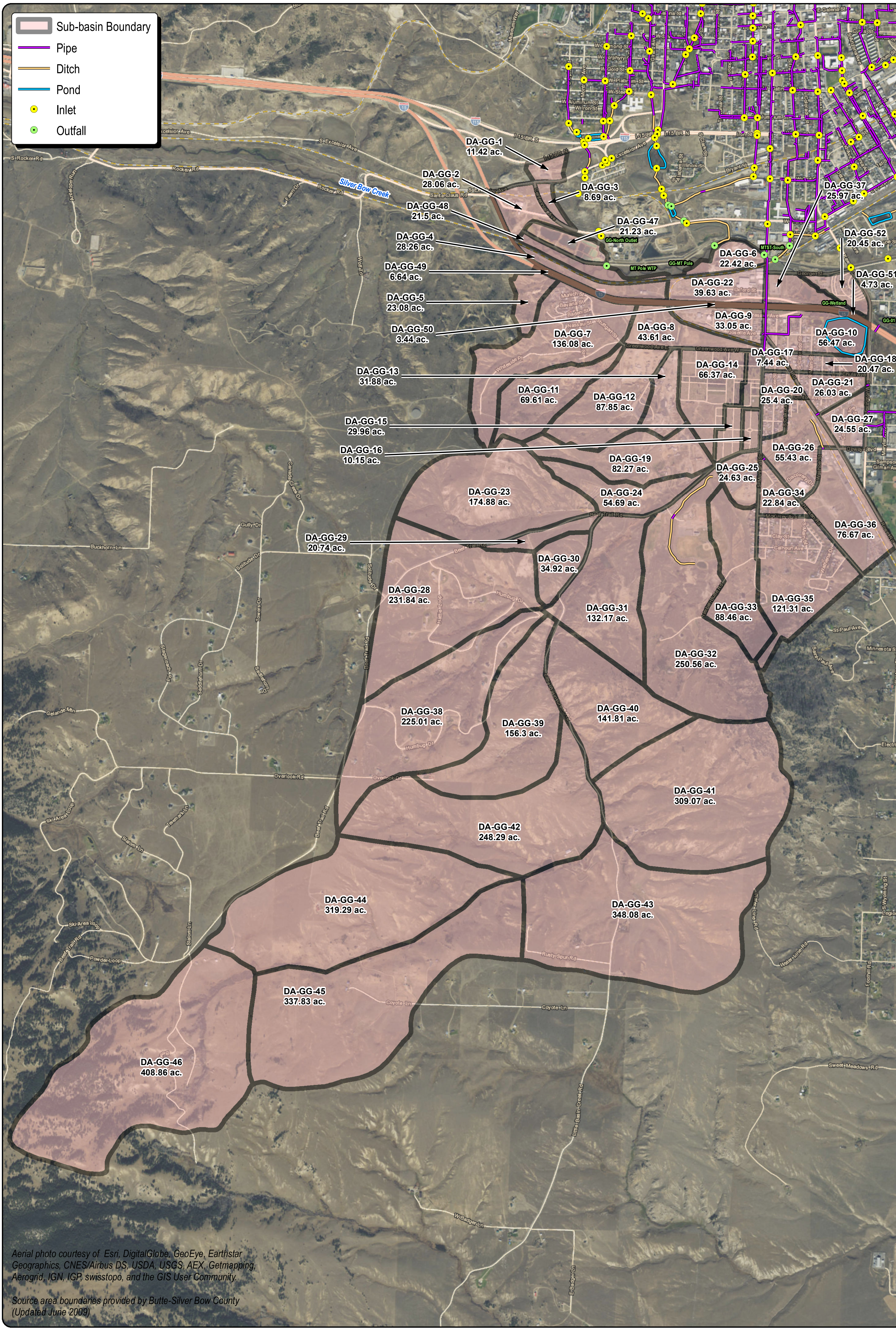

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Figure 5-12
Grove Gulch Drainage Area Parameters
Surface Water Characterization Report
Butte Priority Soils Operable Unit

Silver Bow Creek/Butte Area NPL Site

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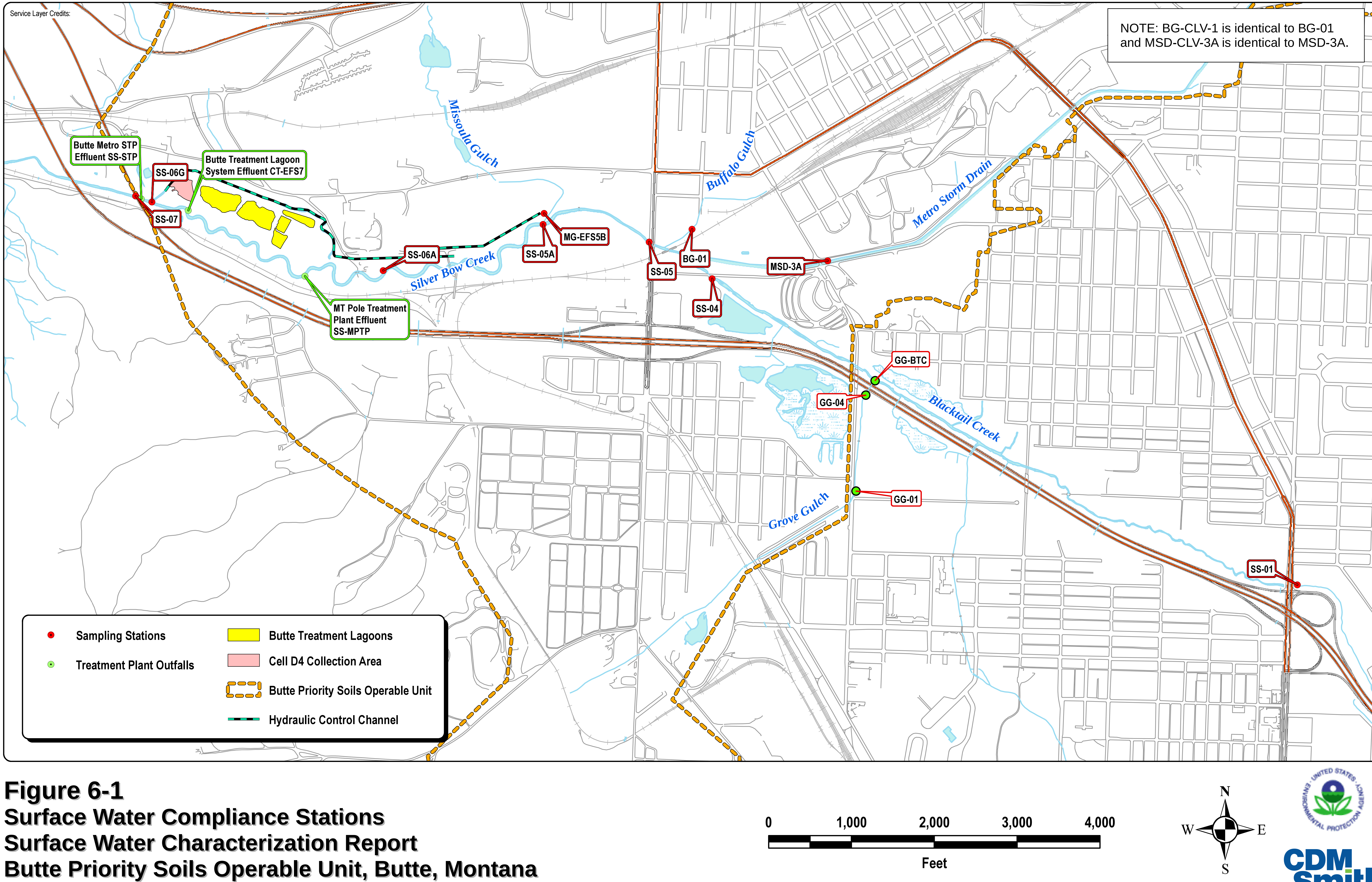

Figure 6-1
Surface Water Compliance Stations
Surface Water Characterization Report
Butte Priority Soils Operable Unit, Butte, Montana

CDM Smith

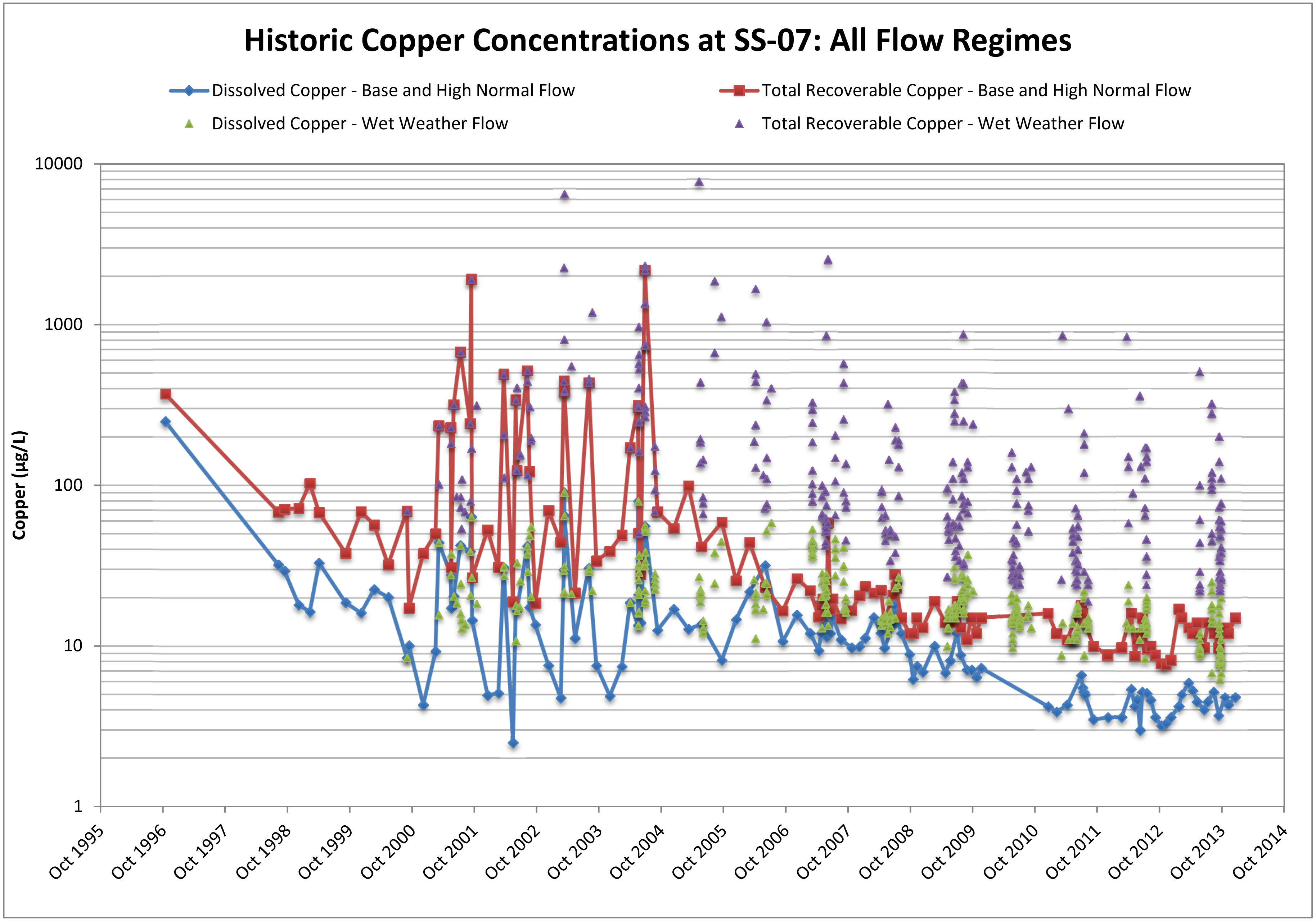

Figure 6-2
Historic Copper Concentrations at SS-07

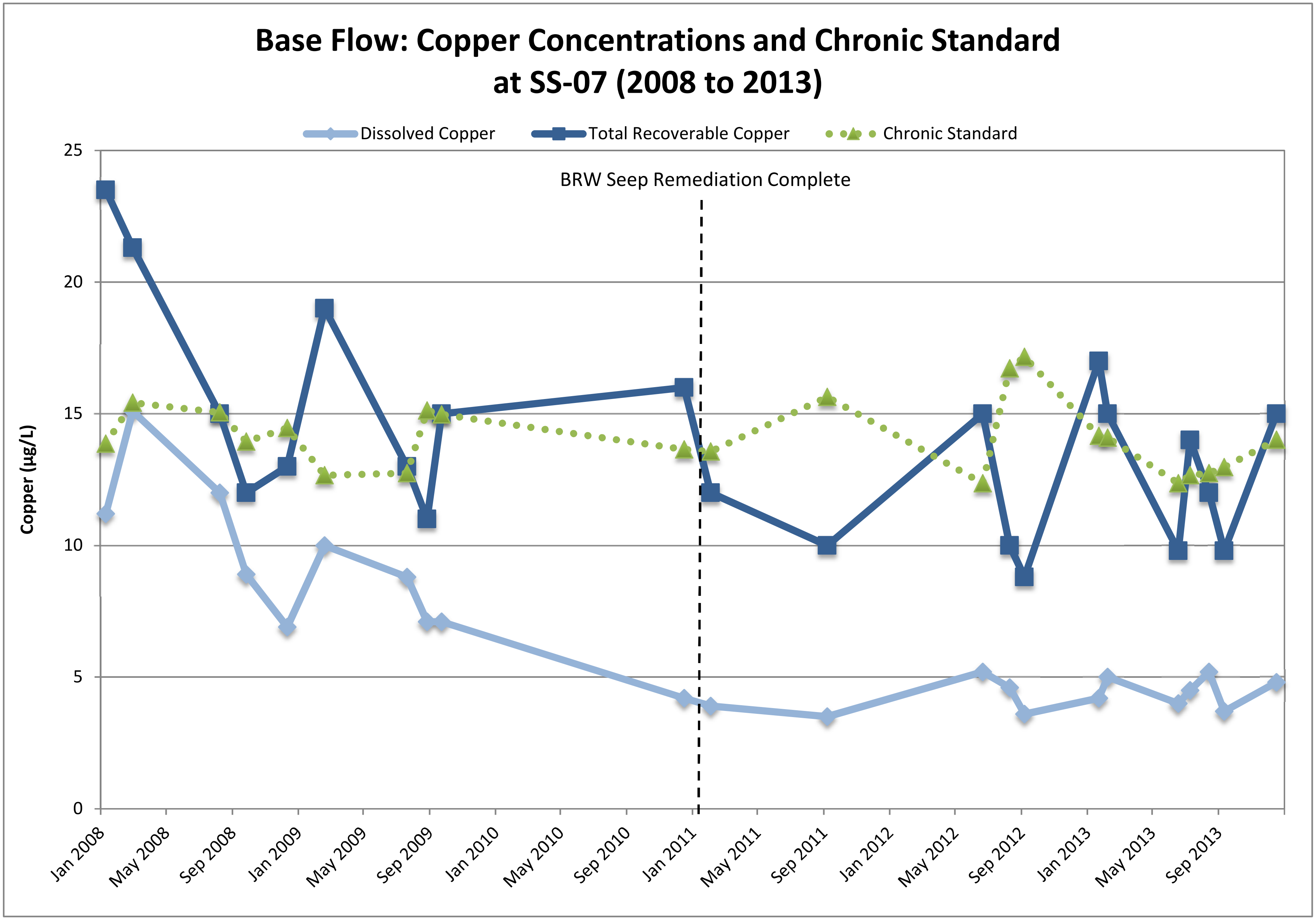

Figure 6-3
Base Flow Copper Concentrations SS-07 - 2008 to 2013

Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

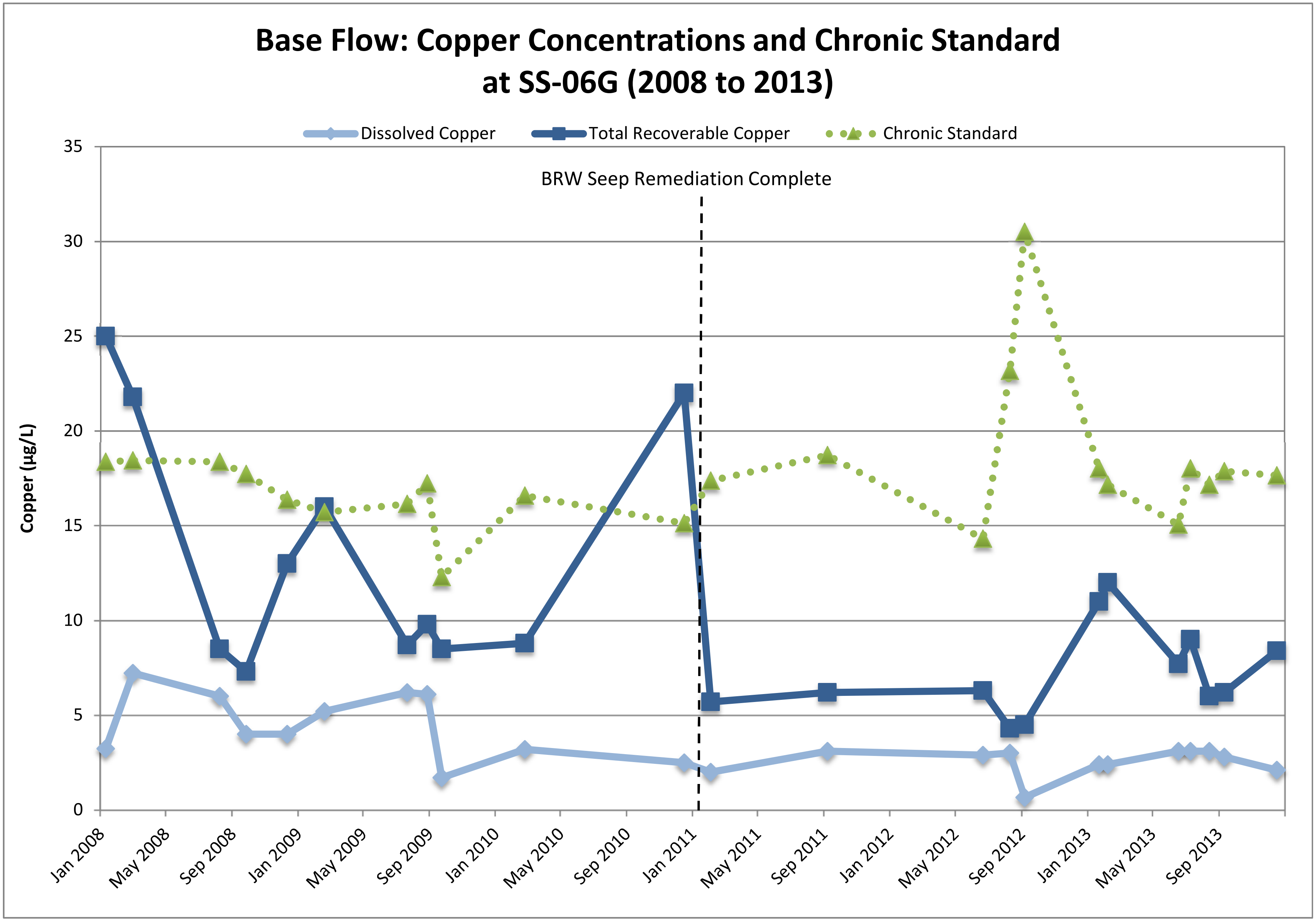

Figure 6-4
Base Flow Copper Concentrations SS-06G - 2008 to 2013

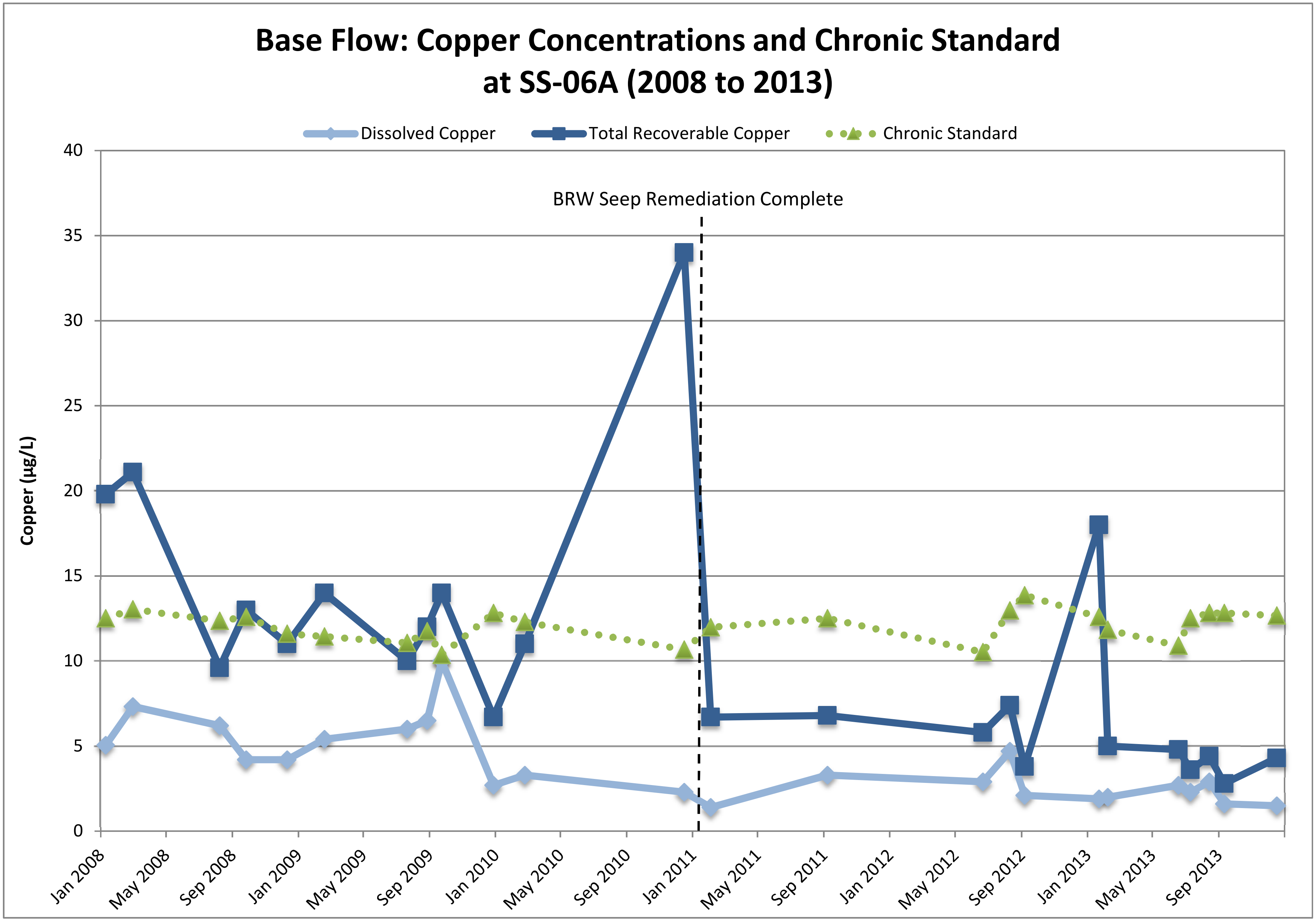

Figure 6-5
Base Flow Copper Concentrations SS-06A - 2008 to 2013

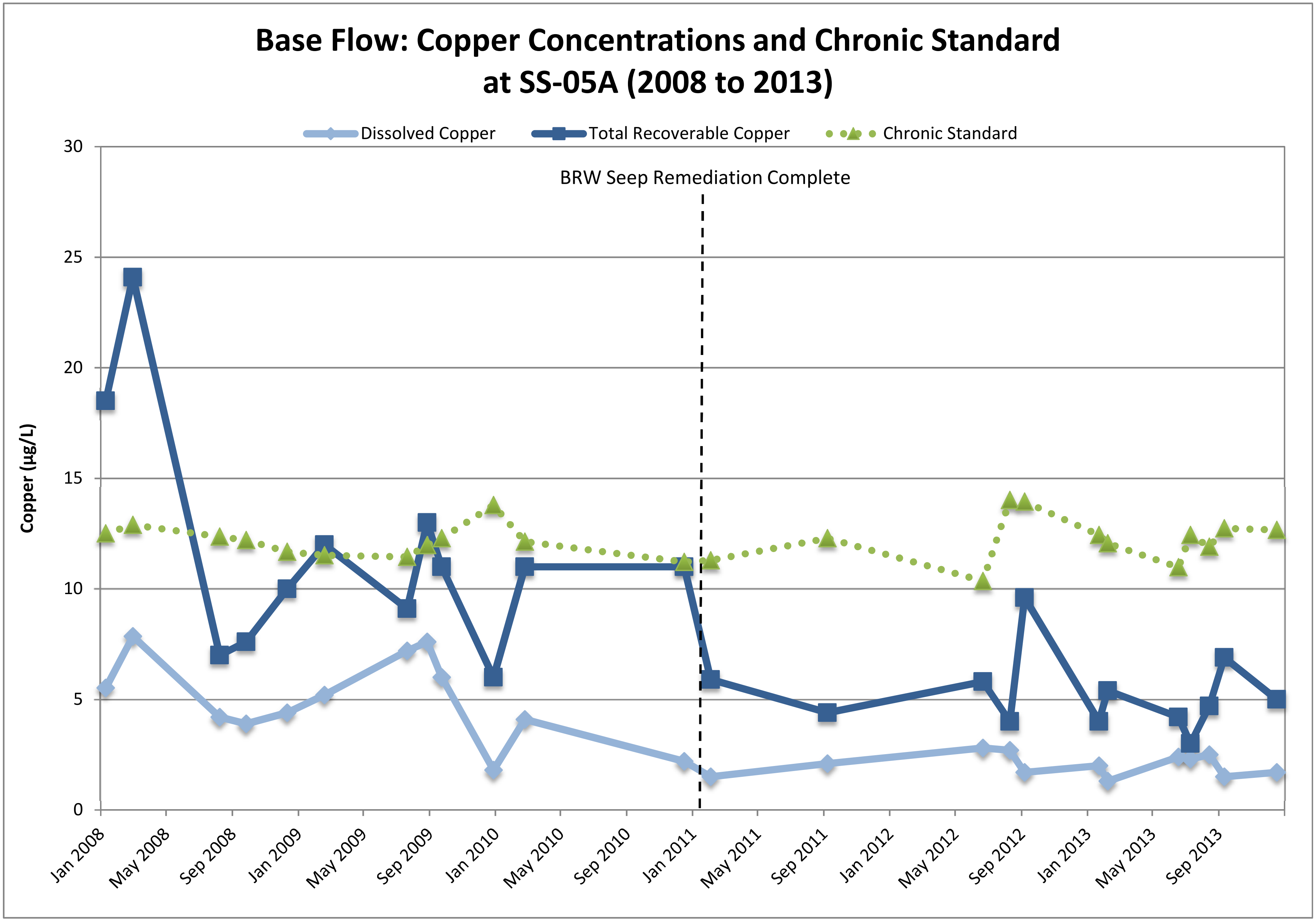

Figure 6-6
Base Flow Copper Concentrations SS-05A - 2008 to 2013

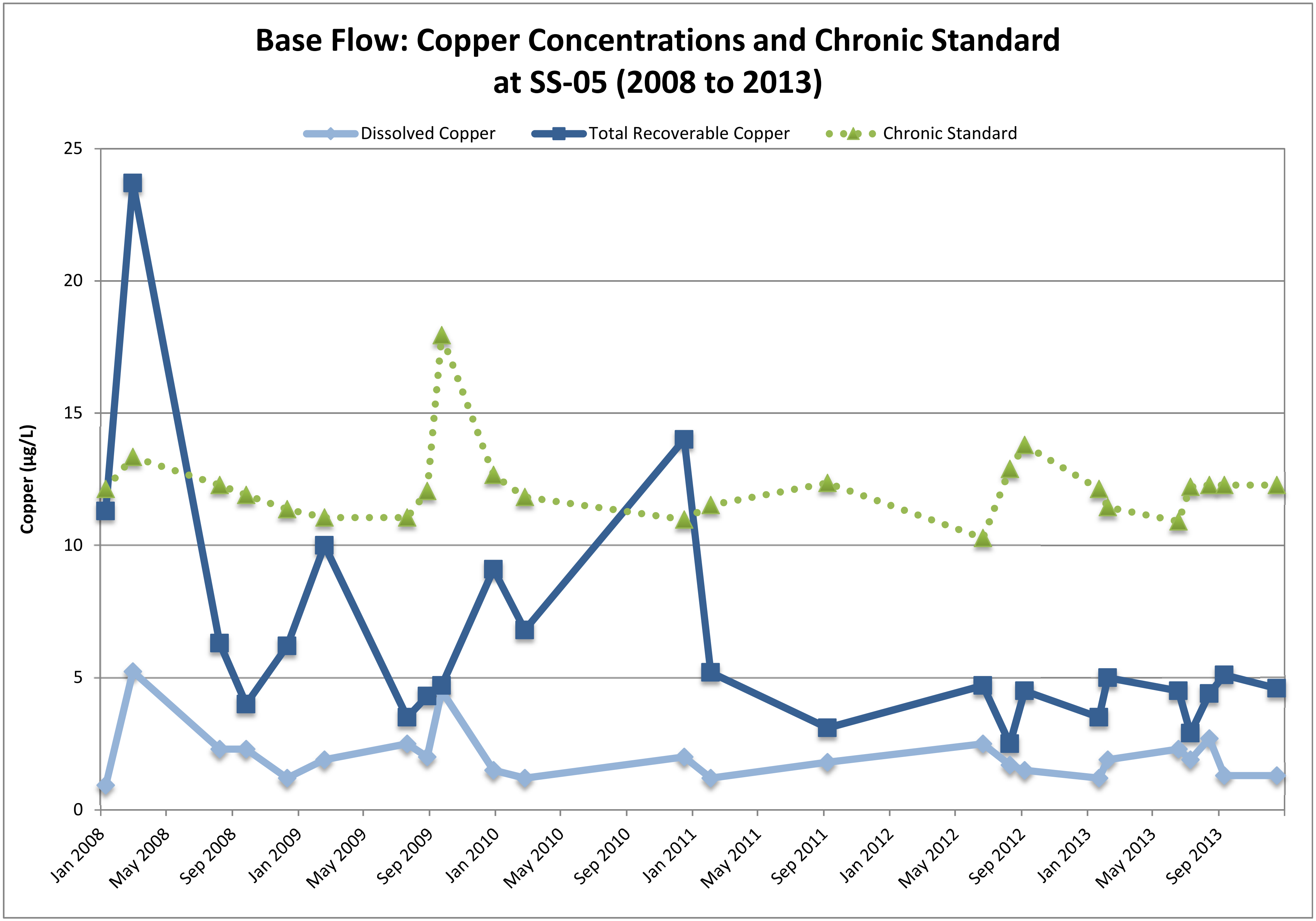

Figure 6-7
Base Flow Copper Concentrations SS-05 - 2008 to 2013

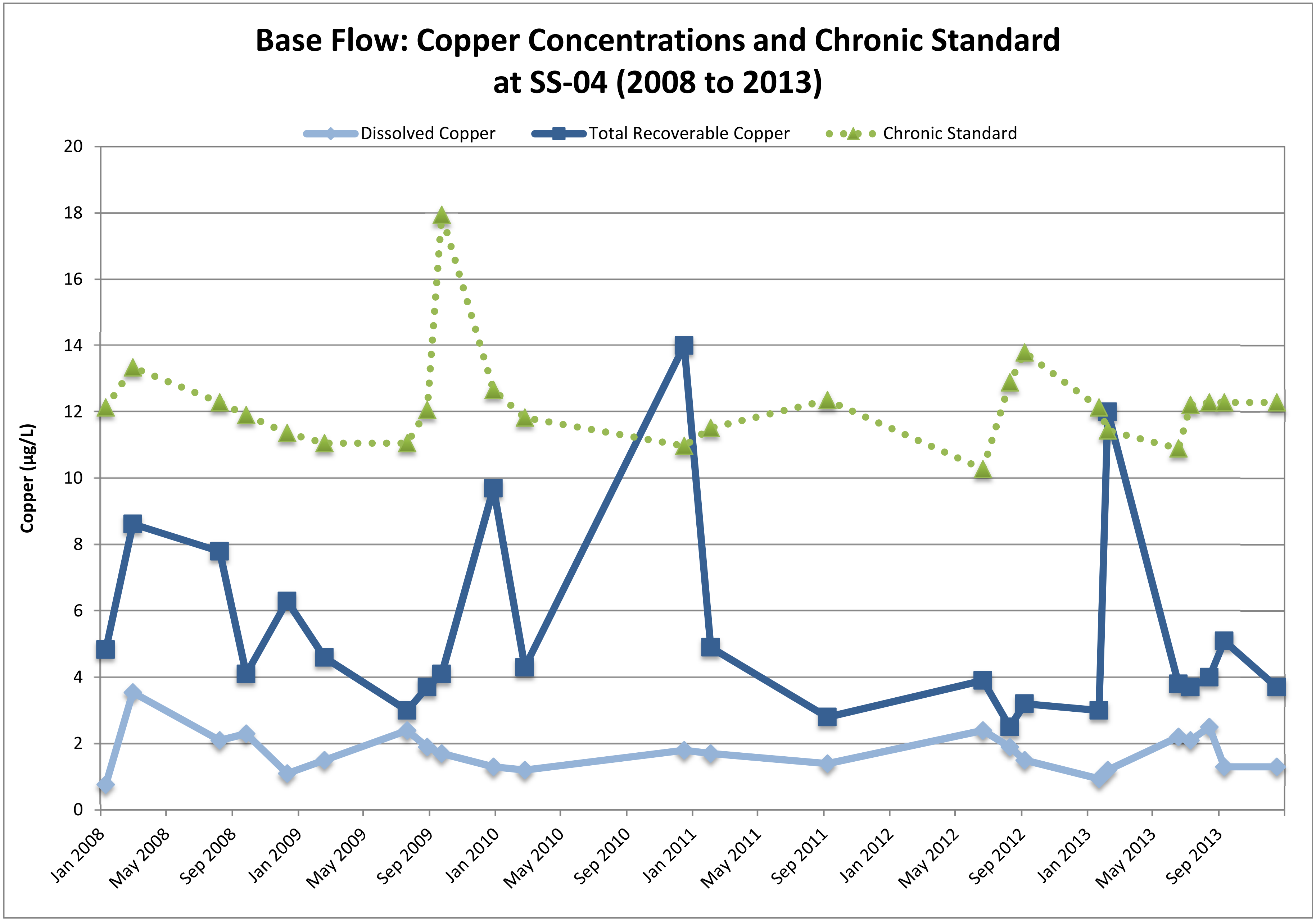

Figure 6-8
Base Flow Copper Concentrations SS-04 - 2008 to 2013

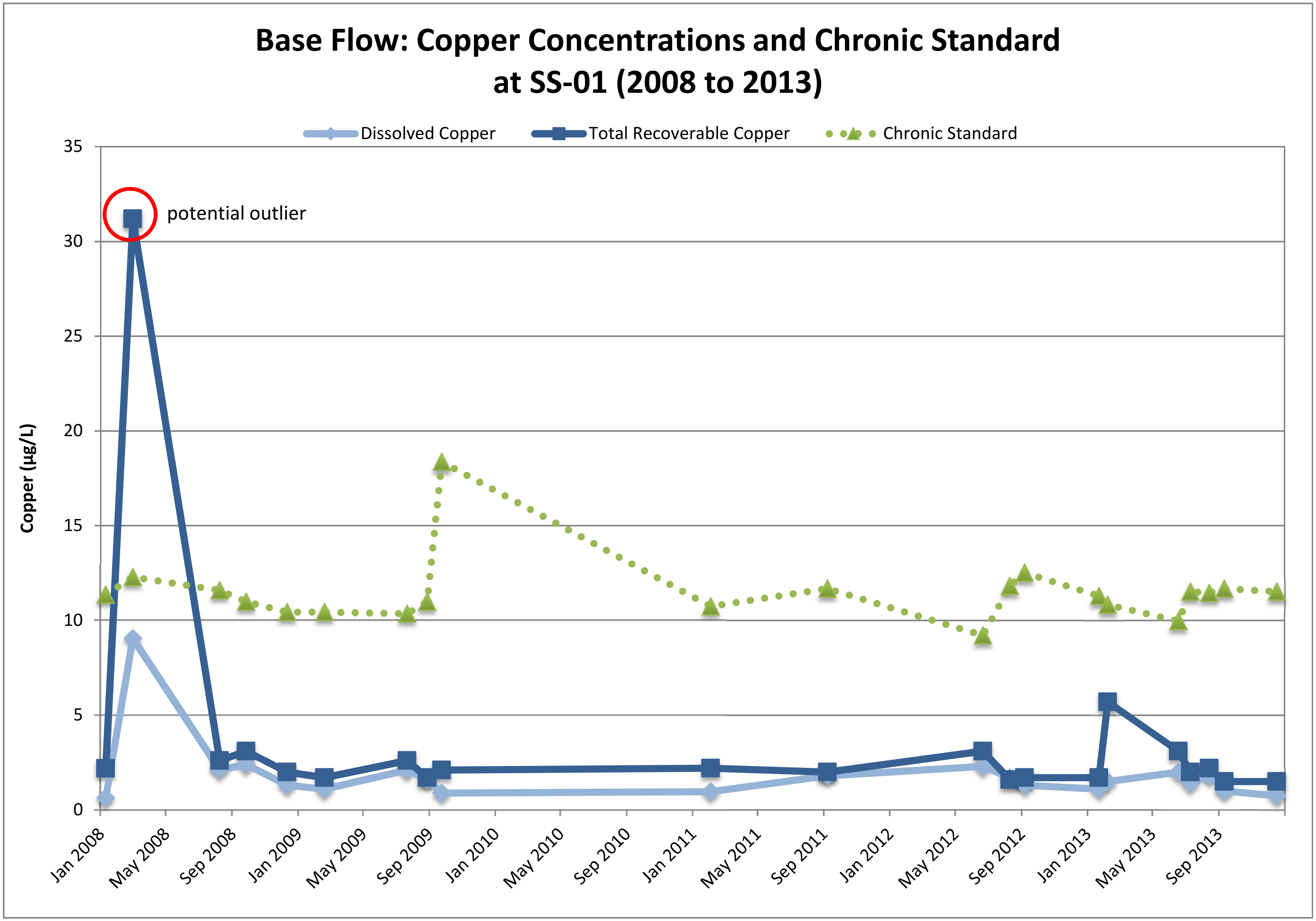

Figure 6-9
Base Flow Copper Concentrations SS-01 - 2008 to 2013

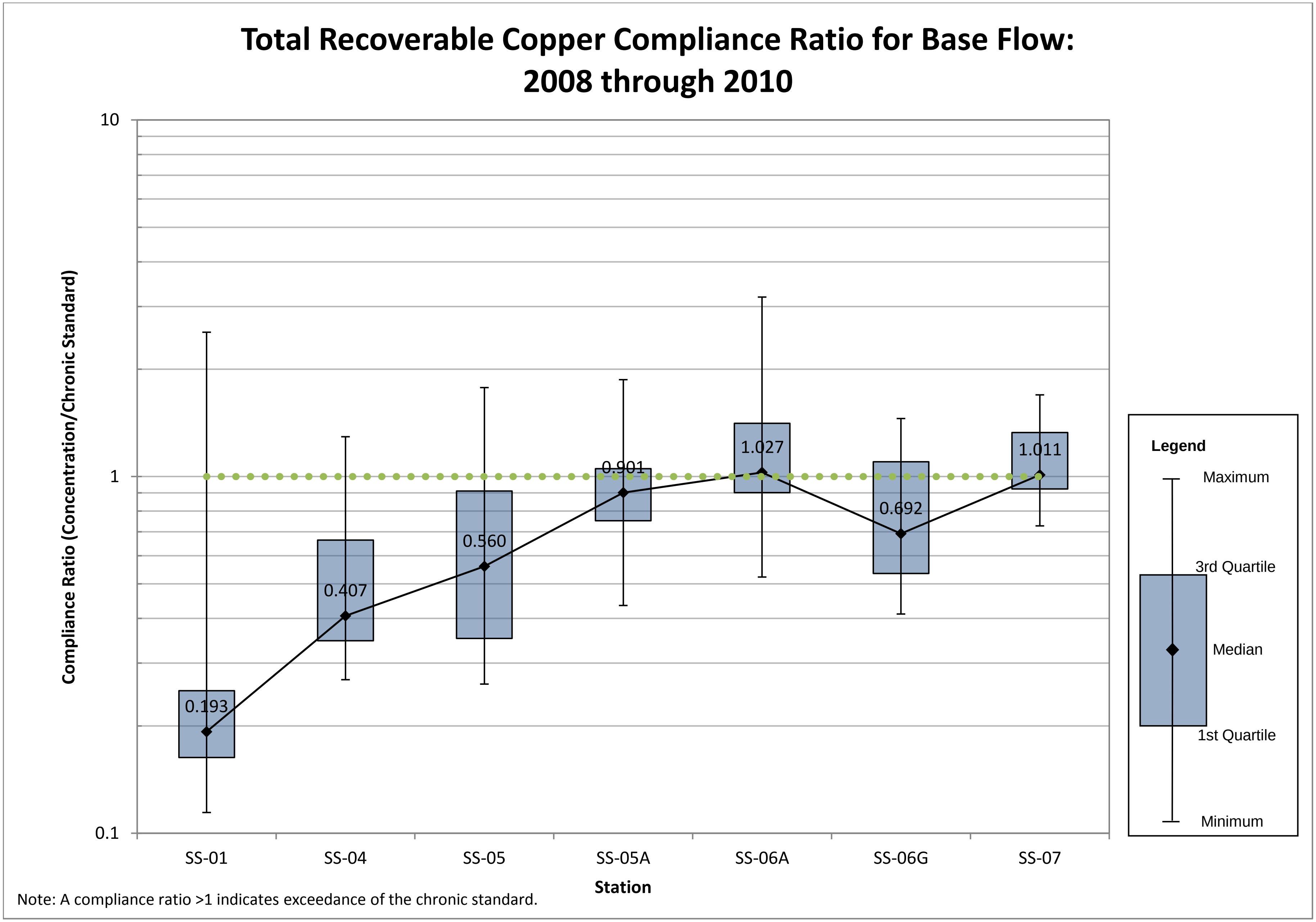

Figure 6-10
Base Flow TR Copper Compliance Ratio Statistics - 2008 to 2010

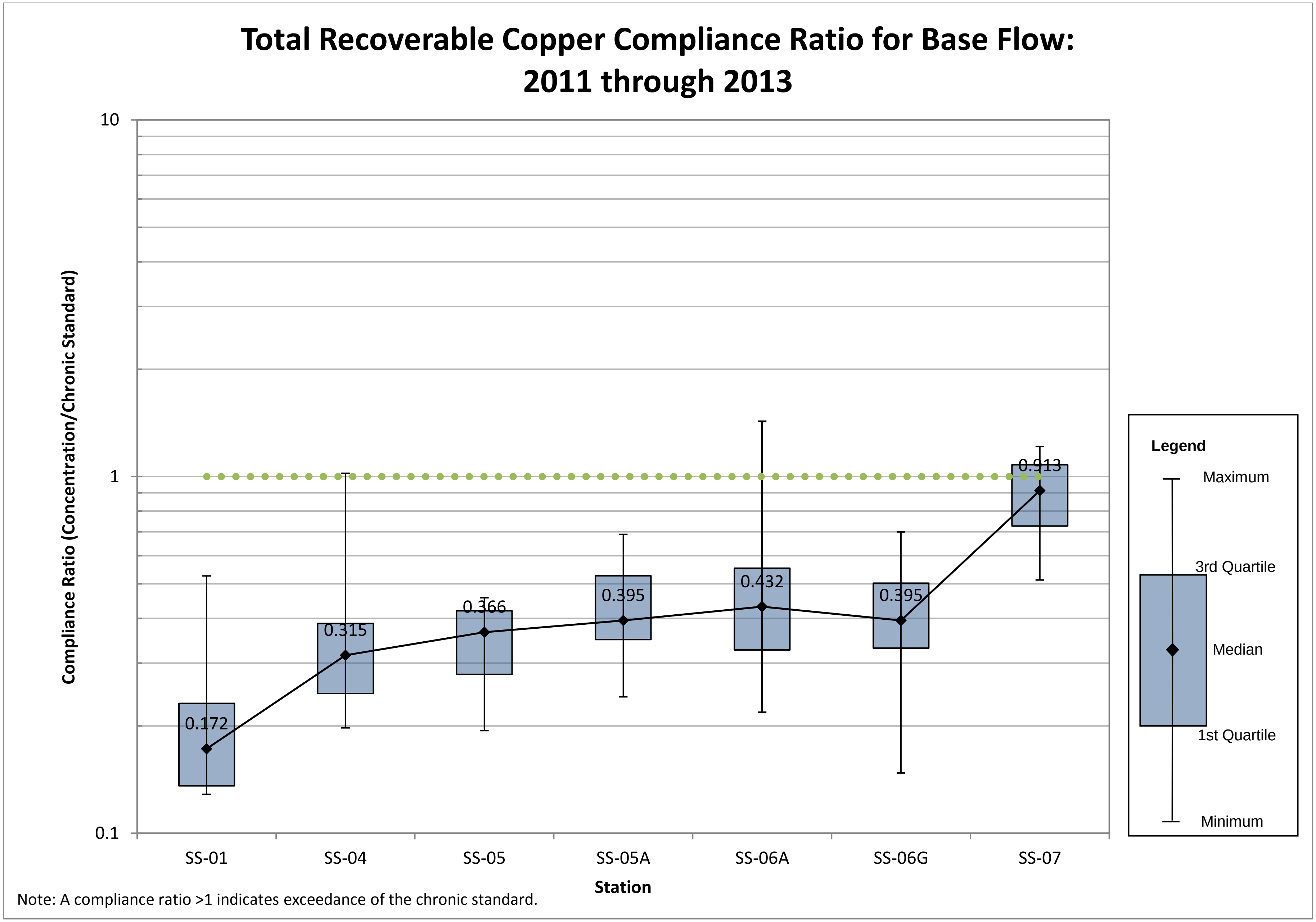

Figure 6-11
Base Flow TR Copper Compliance Ratio Statistics - 2011 to 2013

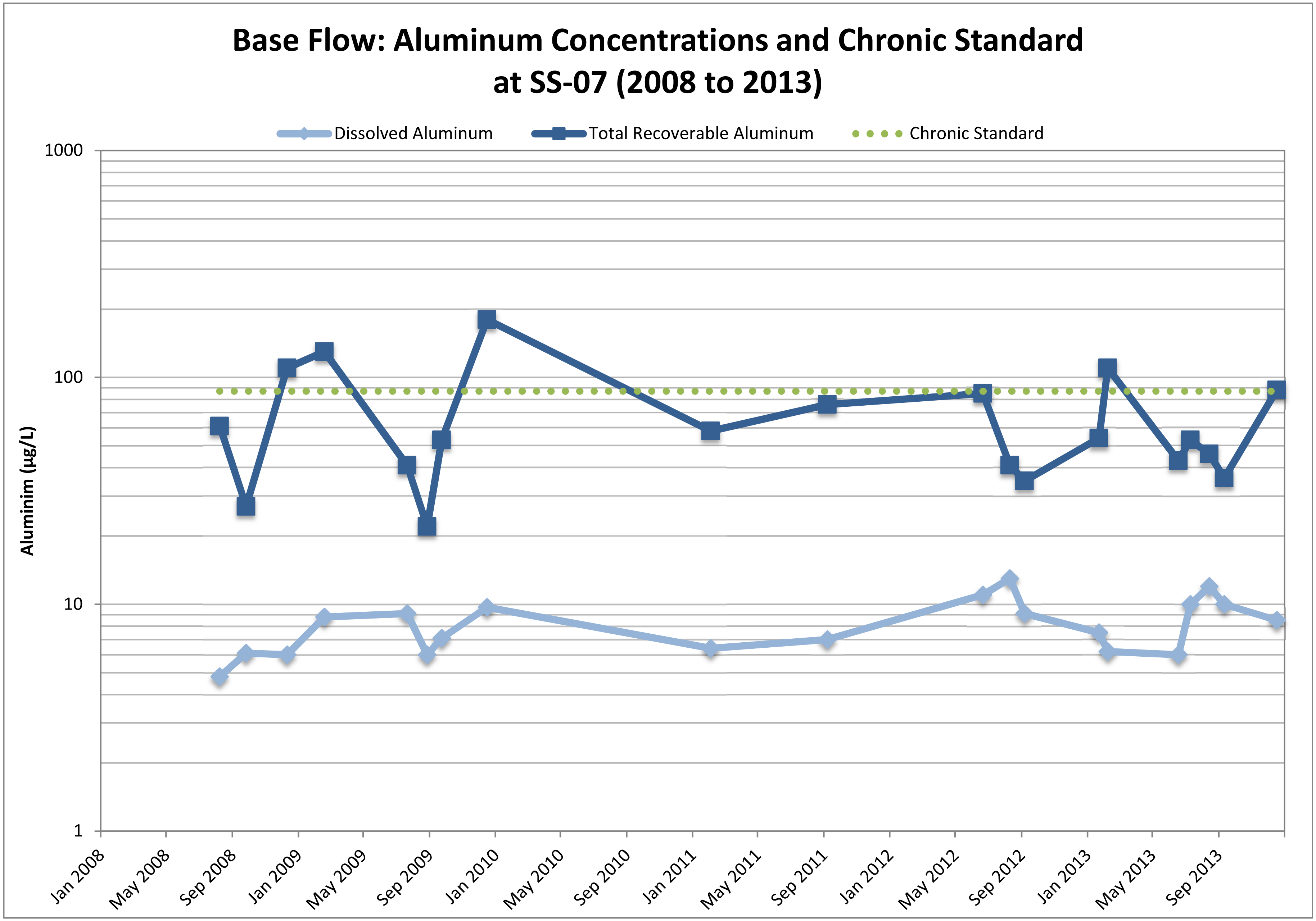

Figure 6-12
Base Flow Aluminum Concentrations SS-07 - 2008 to 2013

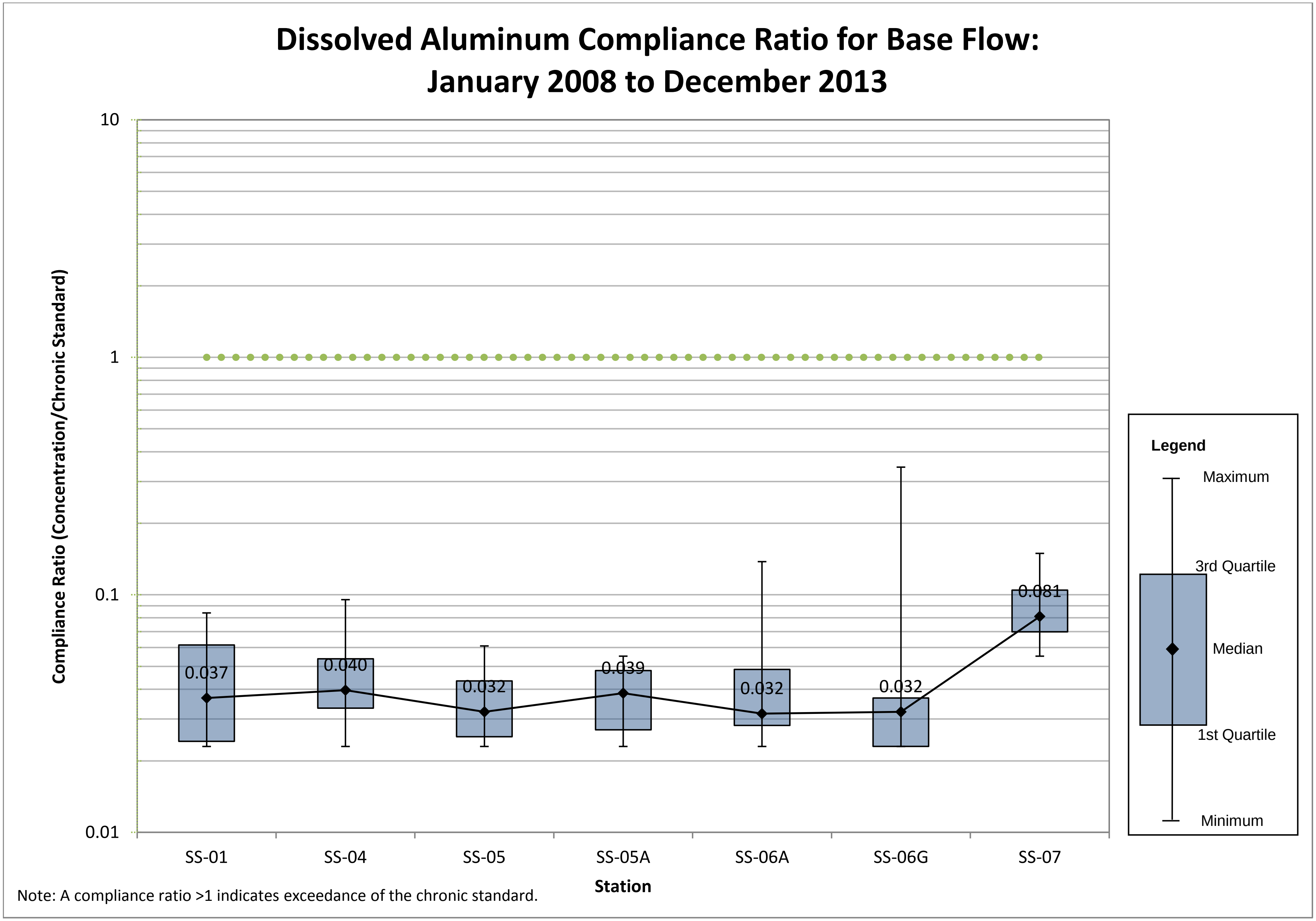

Figure 6-13
Base Flow Dissolved Aluminum Compliance Ratio - 2008 to 2013

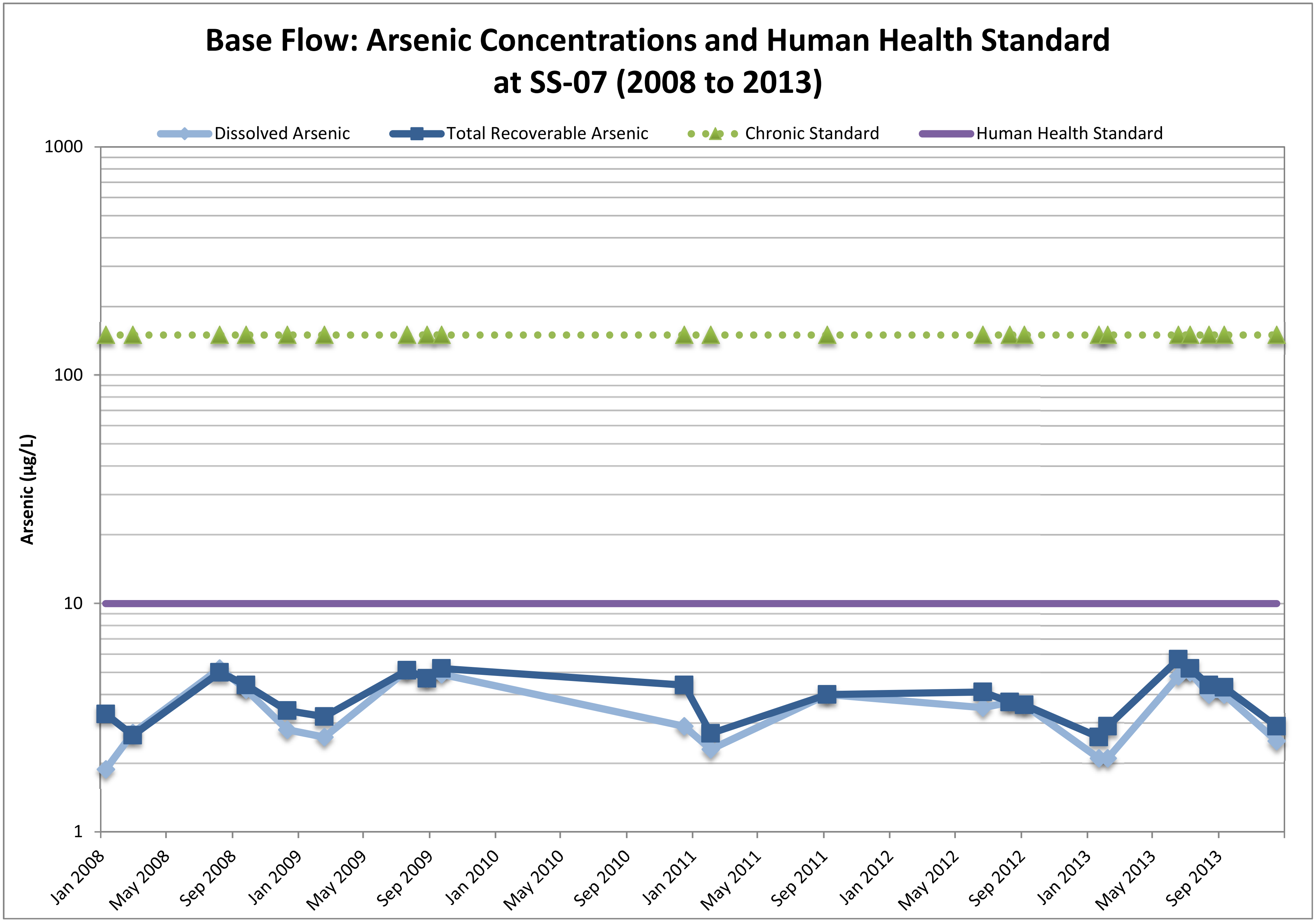

Figure 6-14
Base Flow Arsenic Concentrations SS-07 - 2008 to 2013

Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

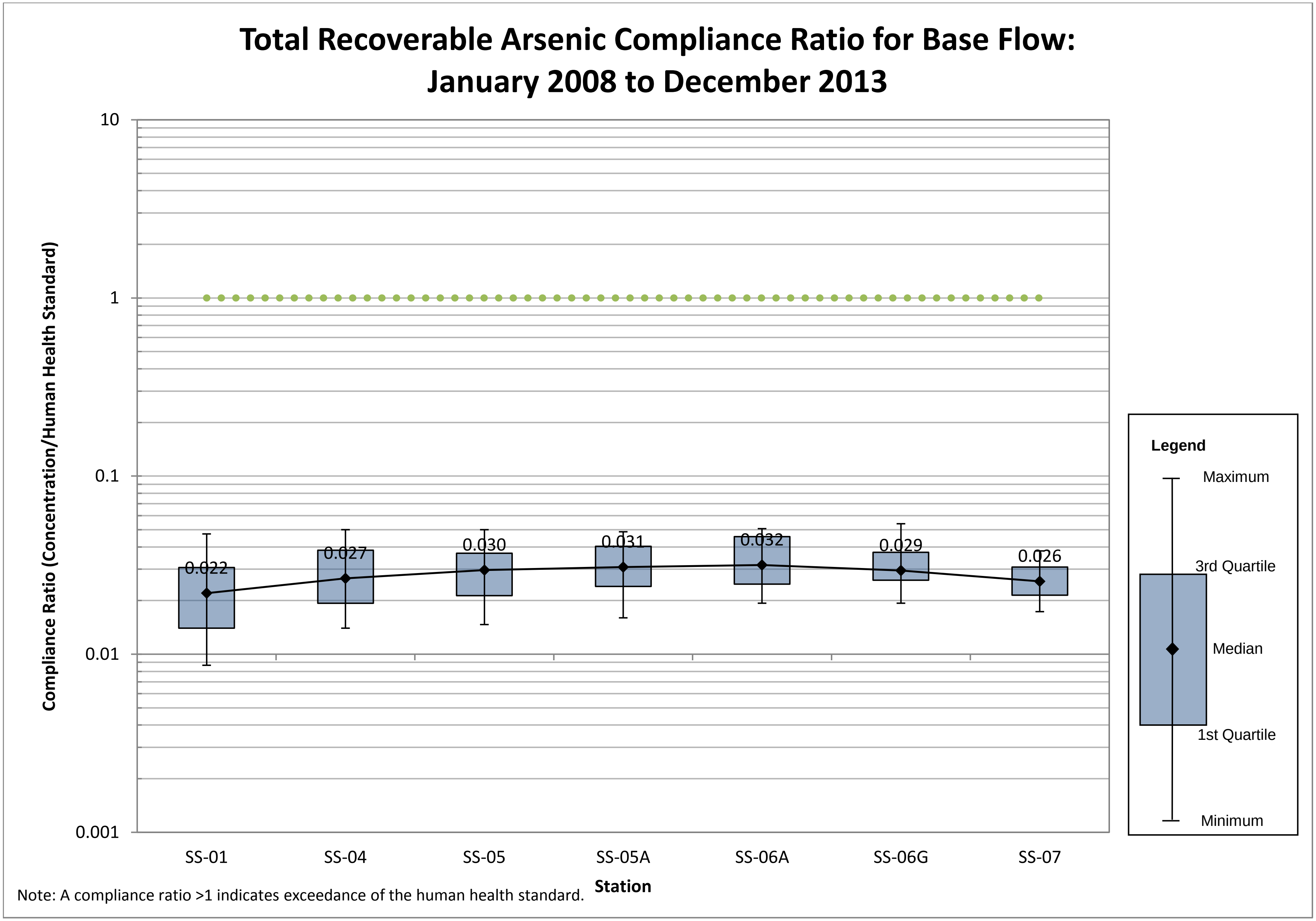

Figure 6-15
Base Flow Total Arsenic Compliance Ratio - 2008 to 2013

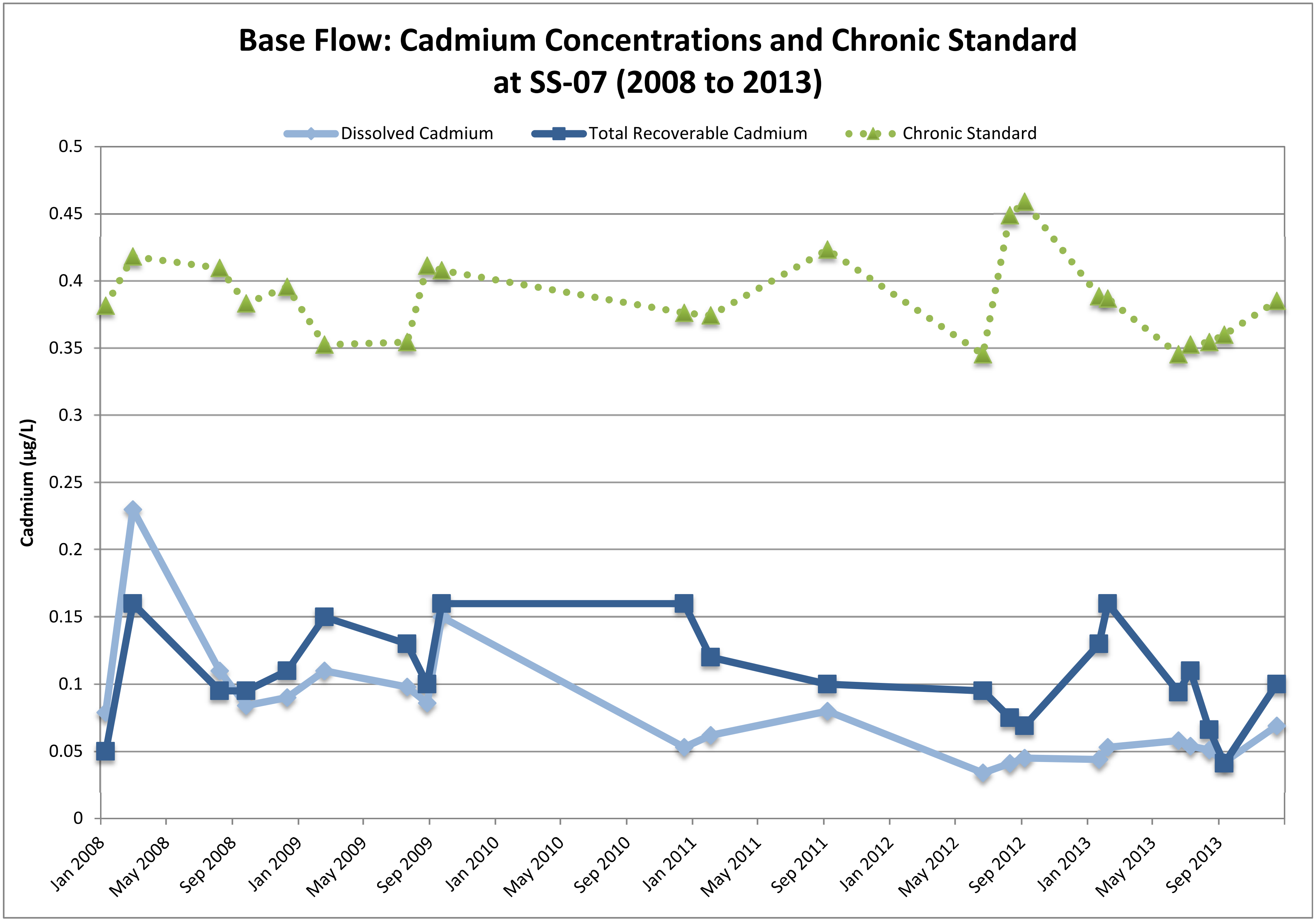

Figure 6-16
Base Flow Cadmium Concentrations SS-07 - 2008 to 2013

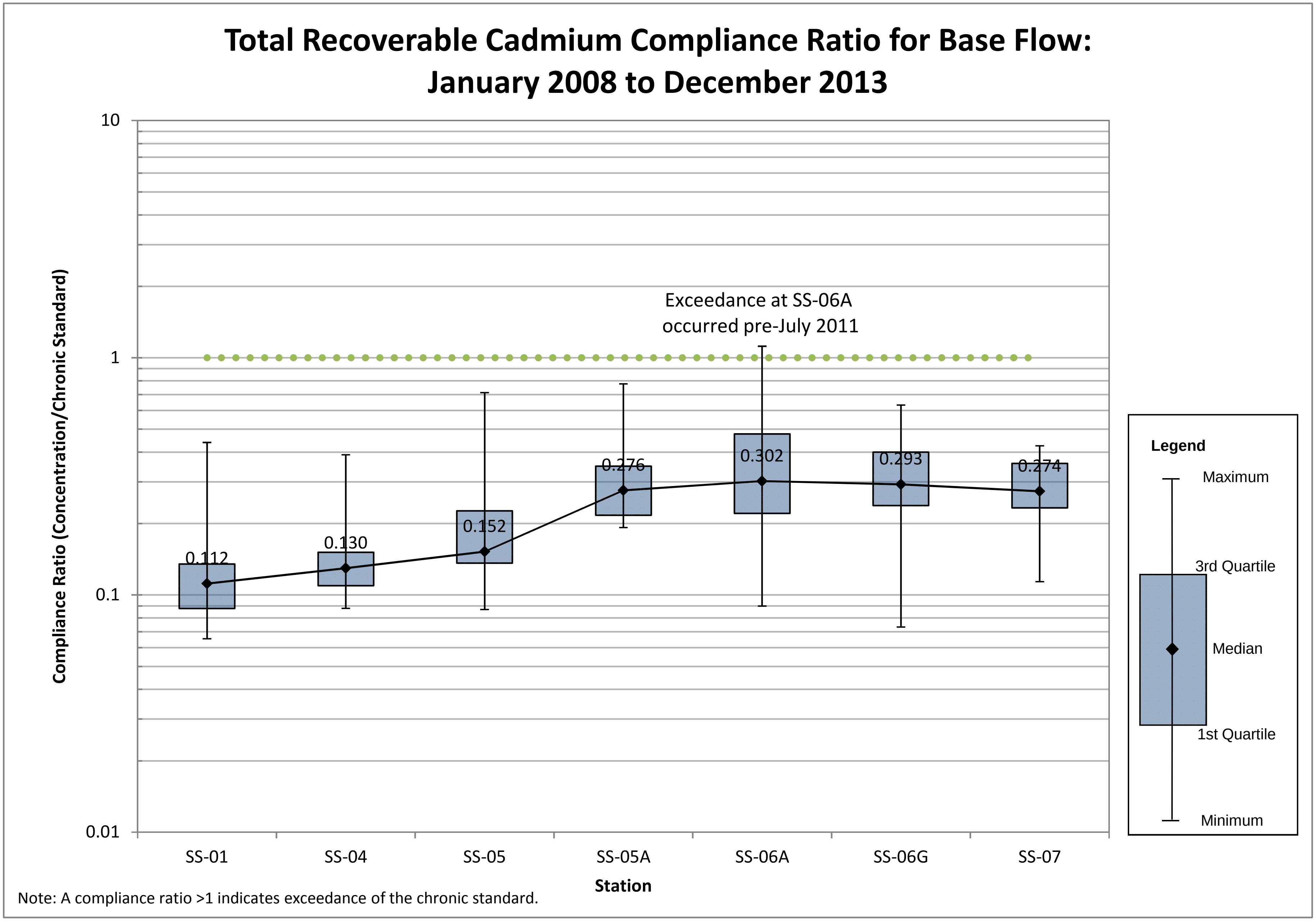

Figure 6-17
Base Flow Total Cadmium Compliance Ratio - 2008 to 2013

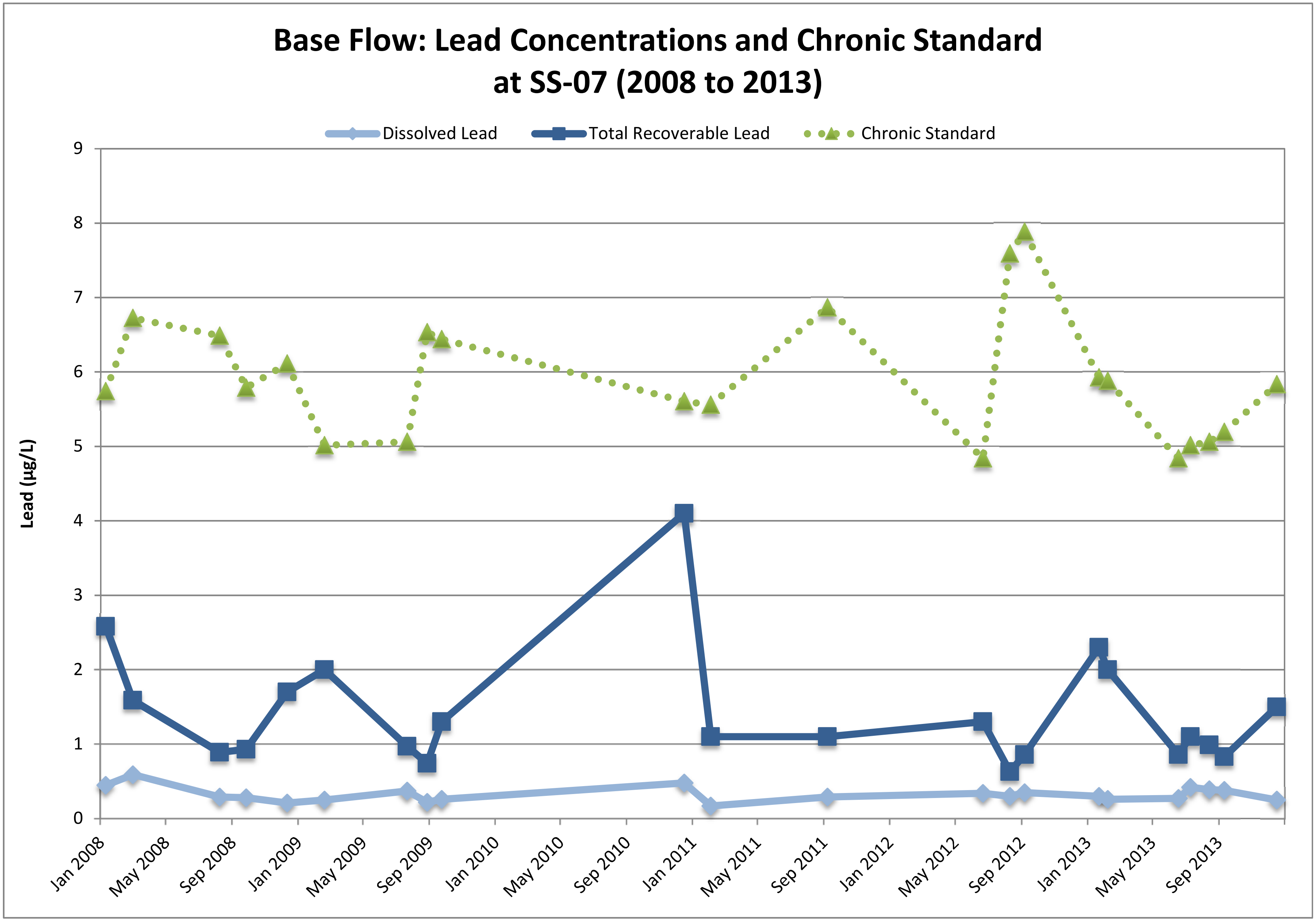

Figure 6-18
Base Flow Lead Concentrations SS-07 - 2008 to 2013

Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

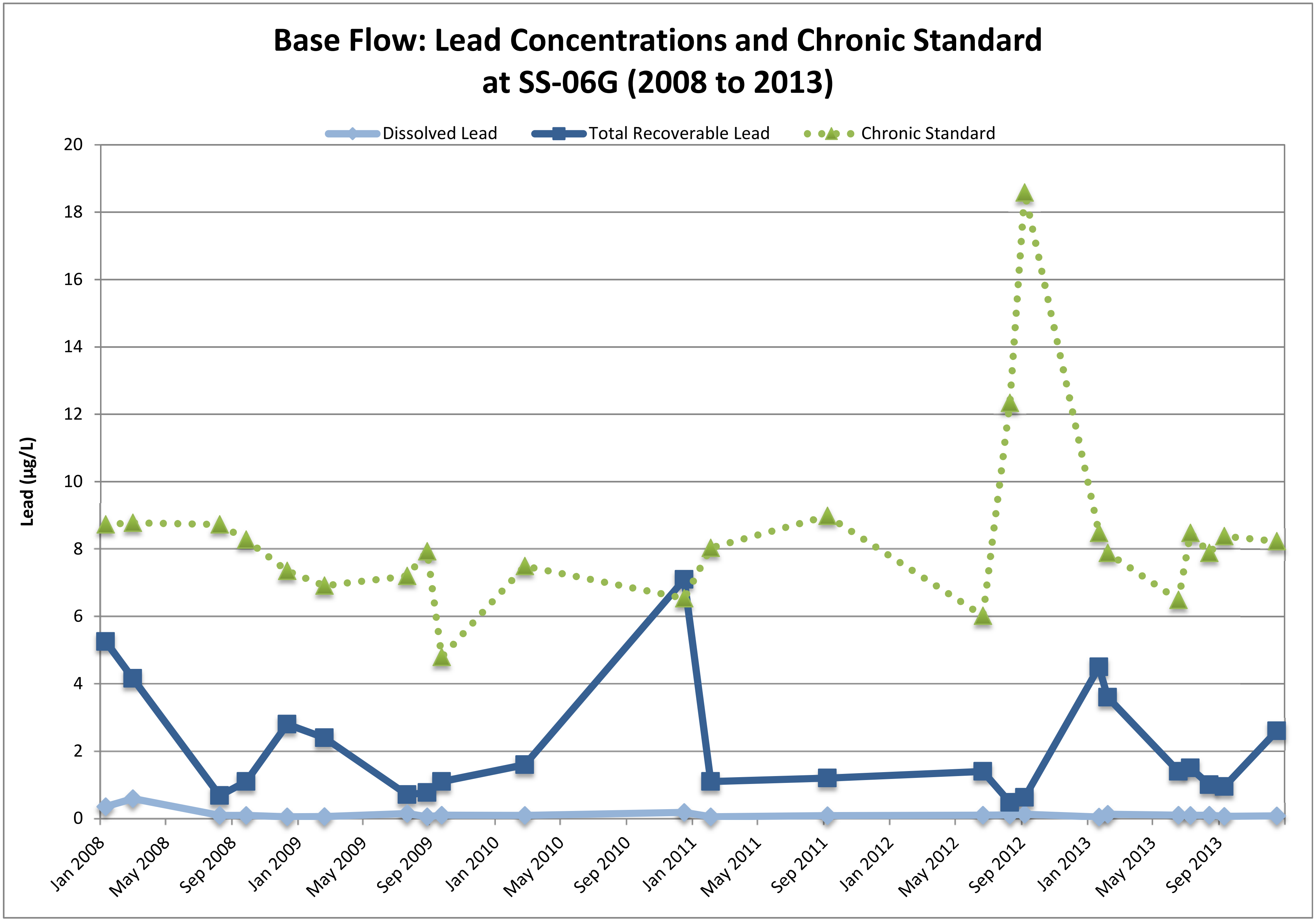

Figure 6-19
Base Flow Lead Concentrations SS-06G - 2008 to 2013

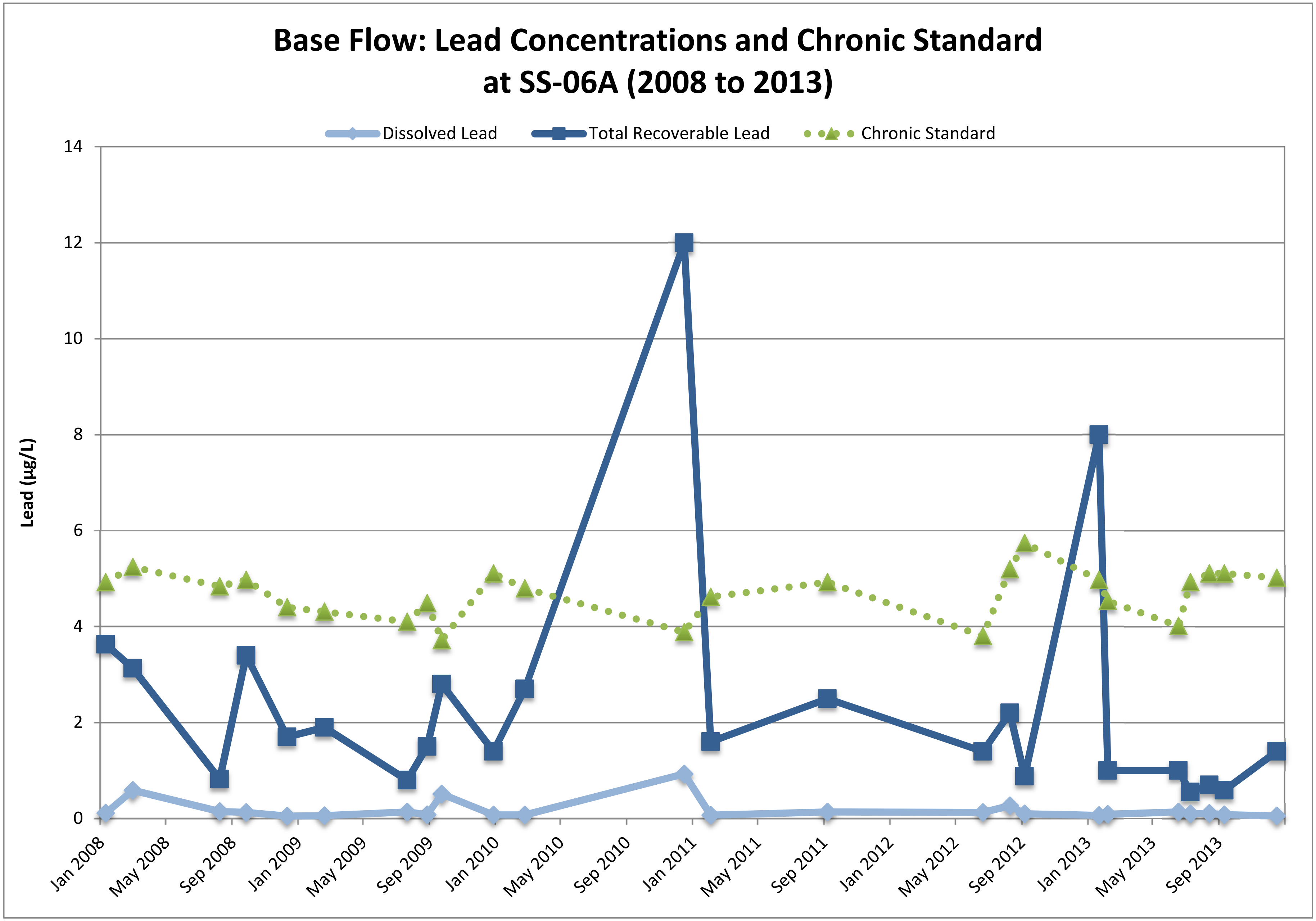

Figure 6-20
Base Flow Lead Concentrations SS-06A - 2008 to 2013

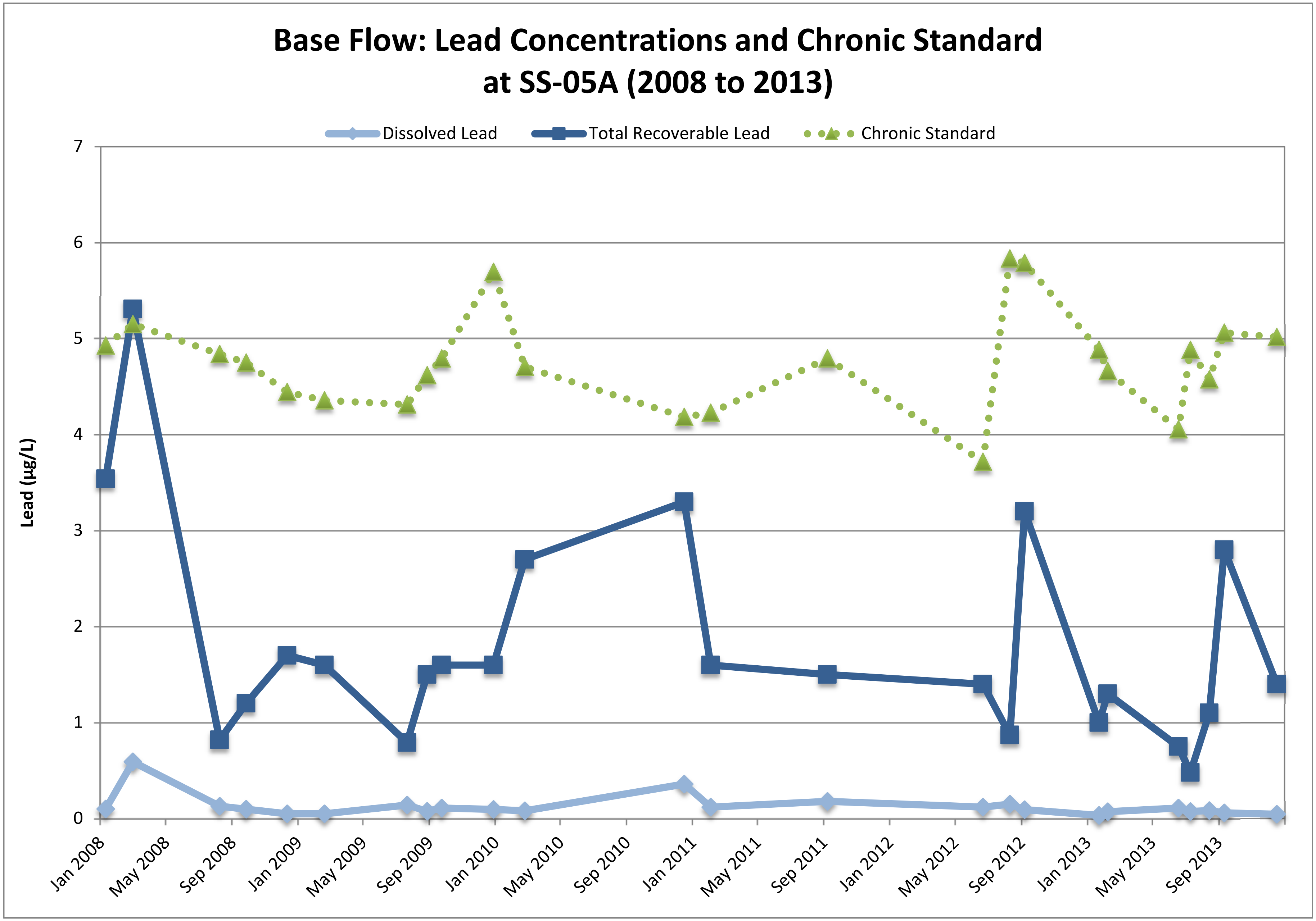

Figure 6-21
Base Flow Lead Concentrations SS-05A - 2008 to 2013

Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

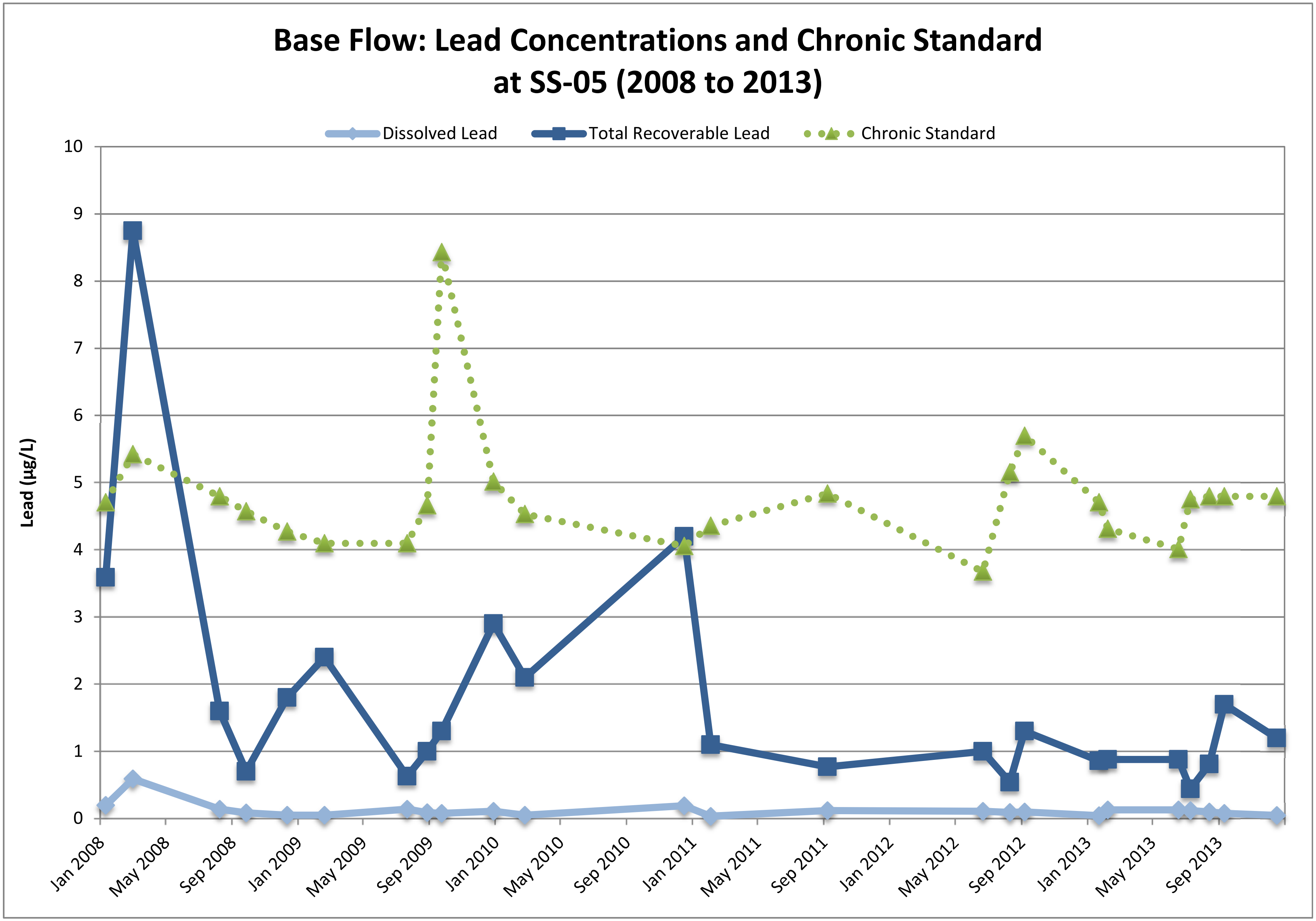

Figure 6-22
Base Flow Lead Concentrations SS-05 - 2008 to 2013

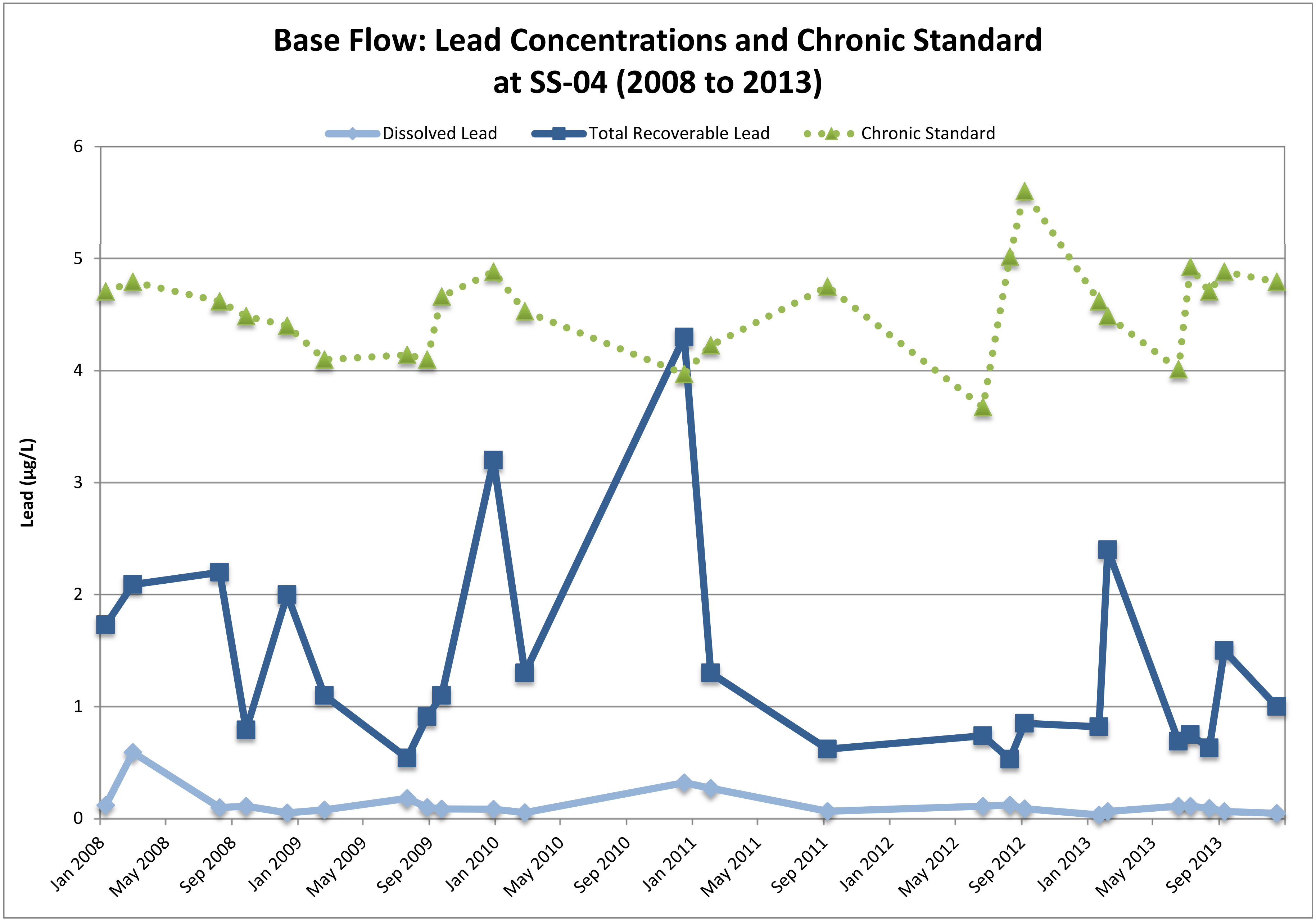

Figure 6-23
Base Flow Lead Concentrations SS-04 - 2008 to 2013

Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

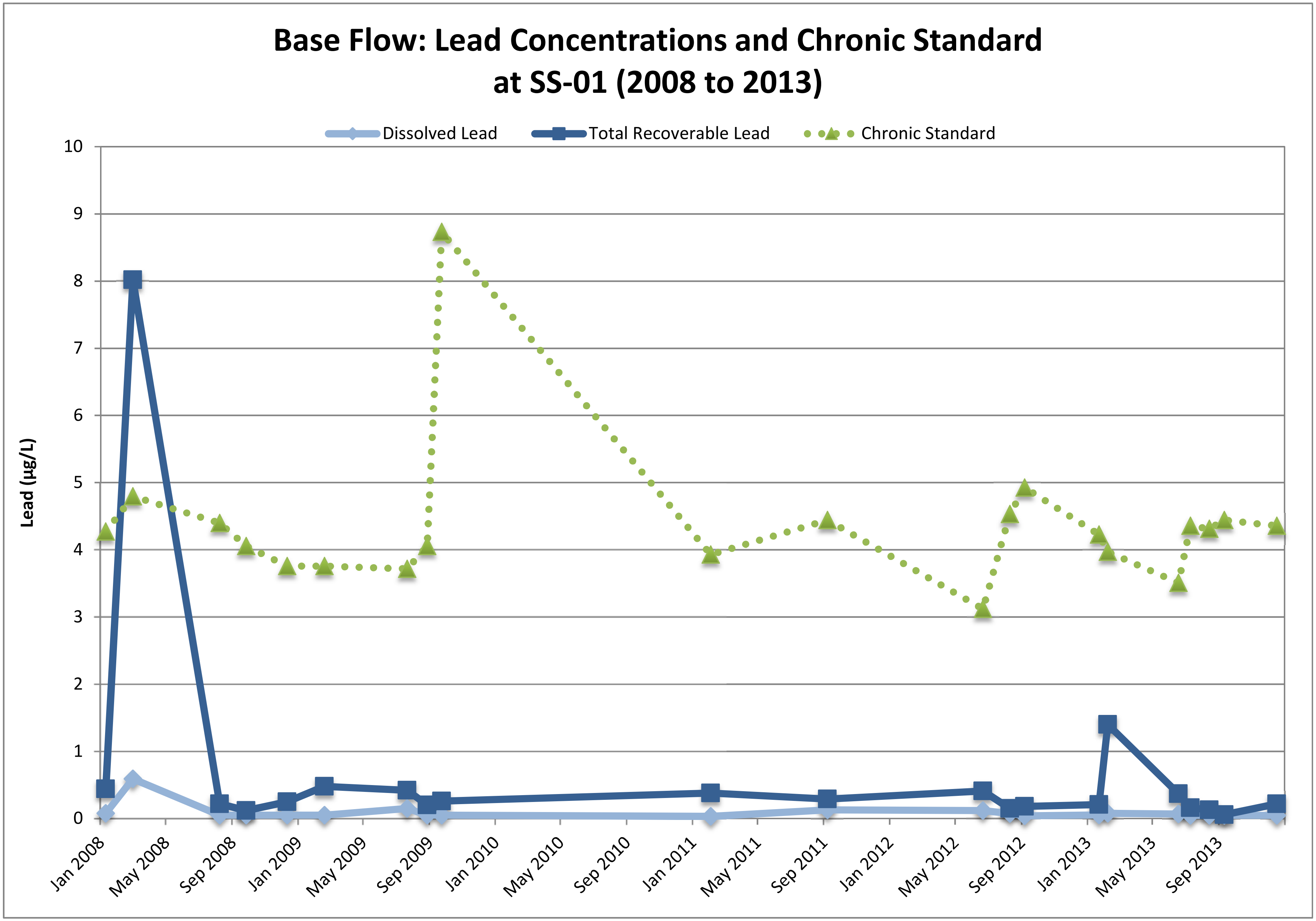

Figure 6-24
Base Flow Lead Concentrations SS-01 - 2008 to 2013

Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

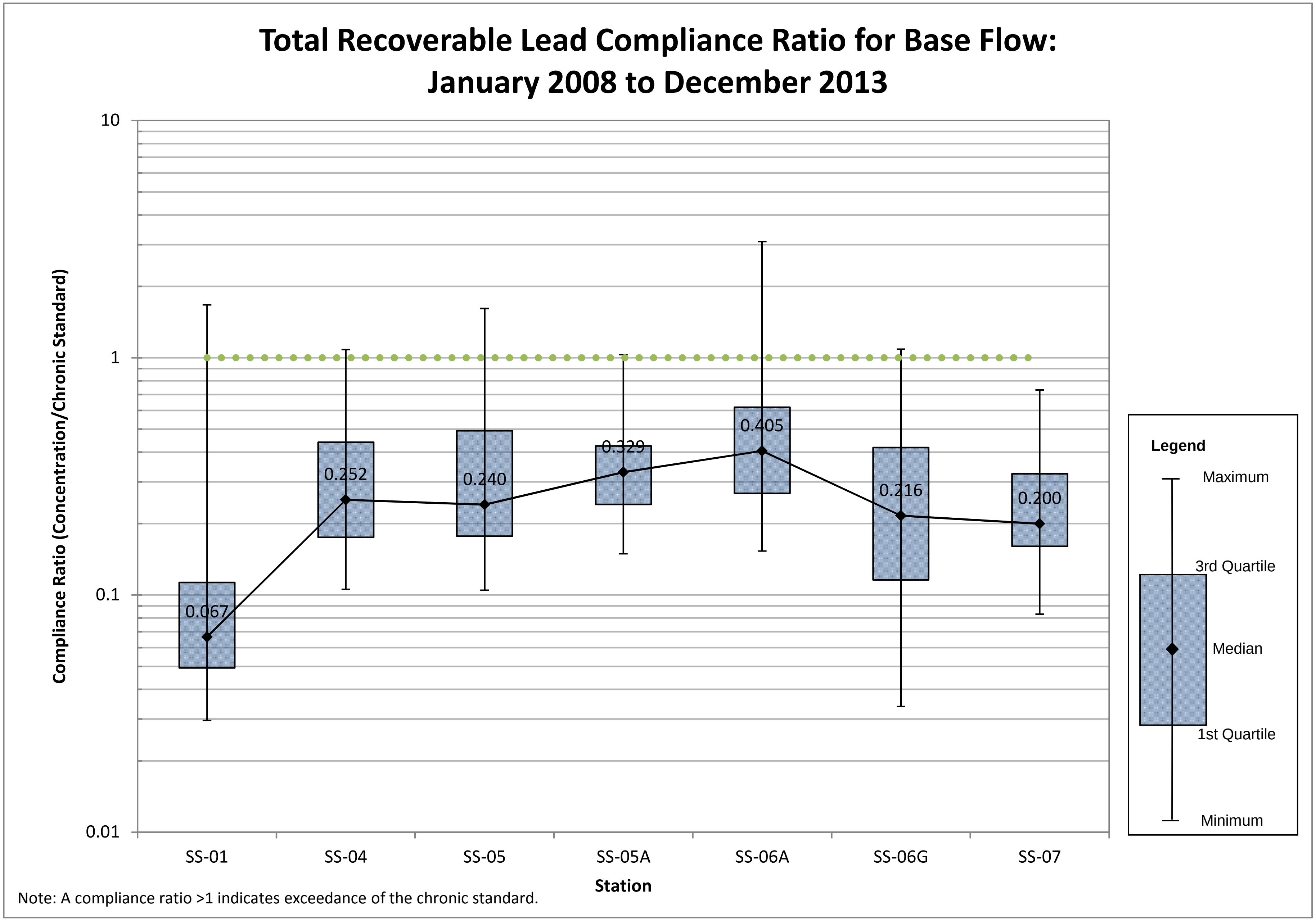

Figure 6-25
Base Flow Total Lead Compliance Ratio - 2008 to 2013

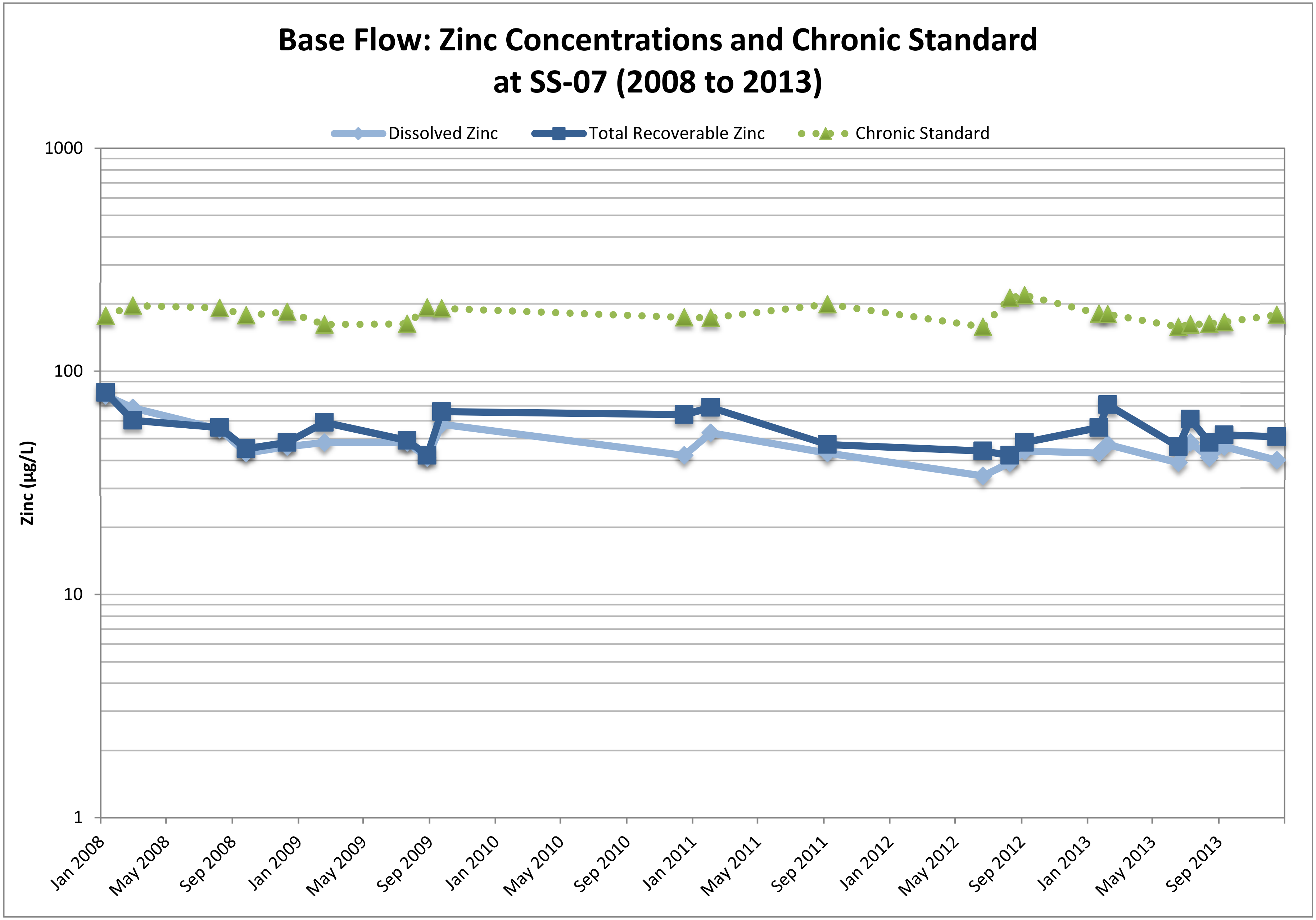

Figure 6-26
Base Flow Zinc Concentrations SS-07 - 2008 to 2013

Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

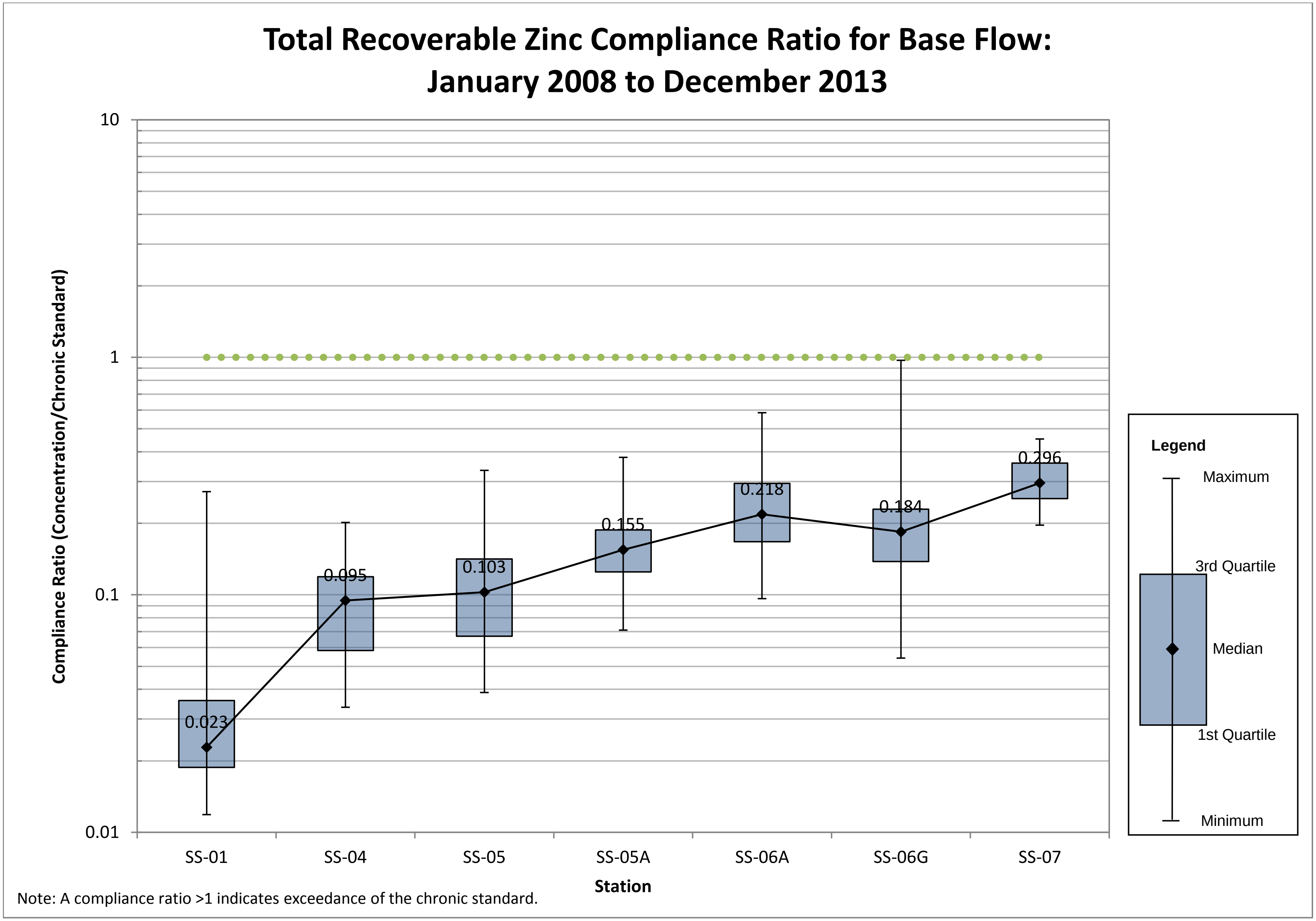

Figure 6-27
Base Flow Total Zinc Compliance Ratio - 2008 to 2013

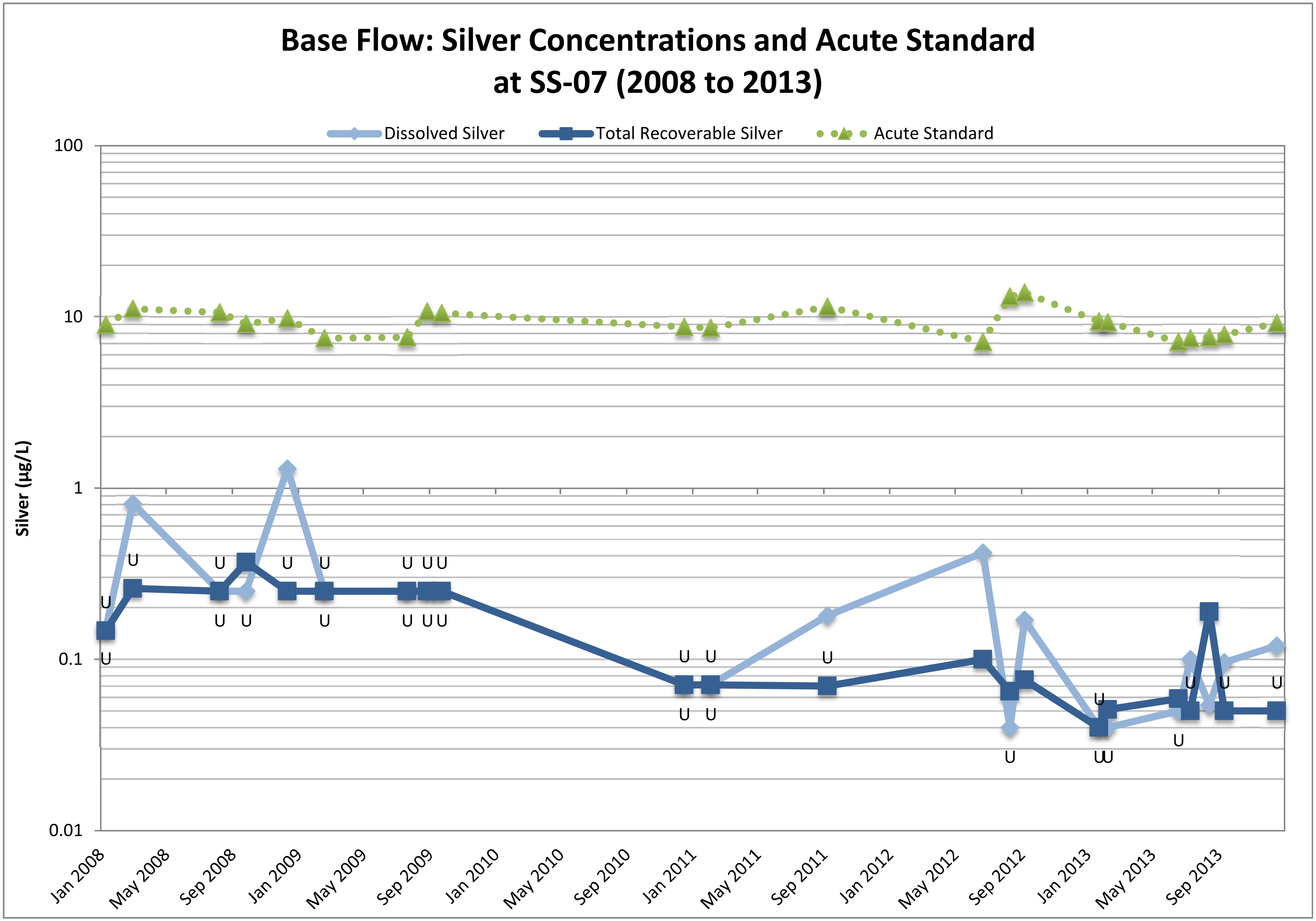

Figure 6-28
Base Flow Silver Concentrations SS-07 - 2008 to 2013

Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

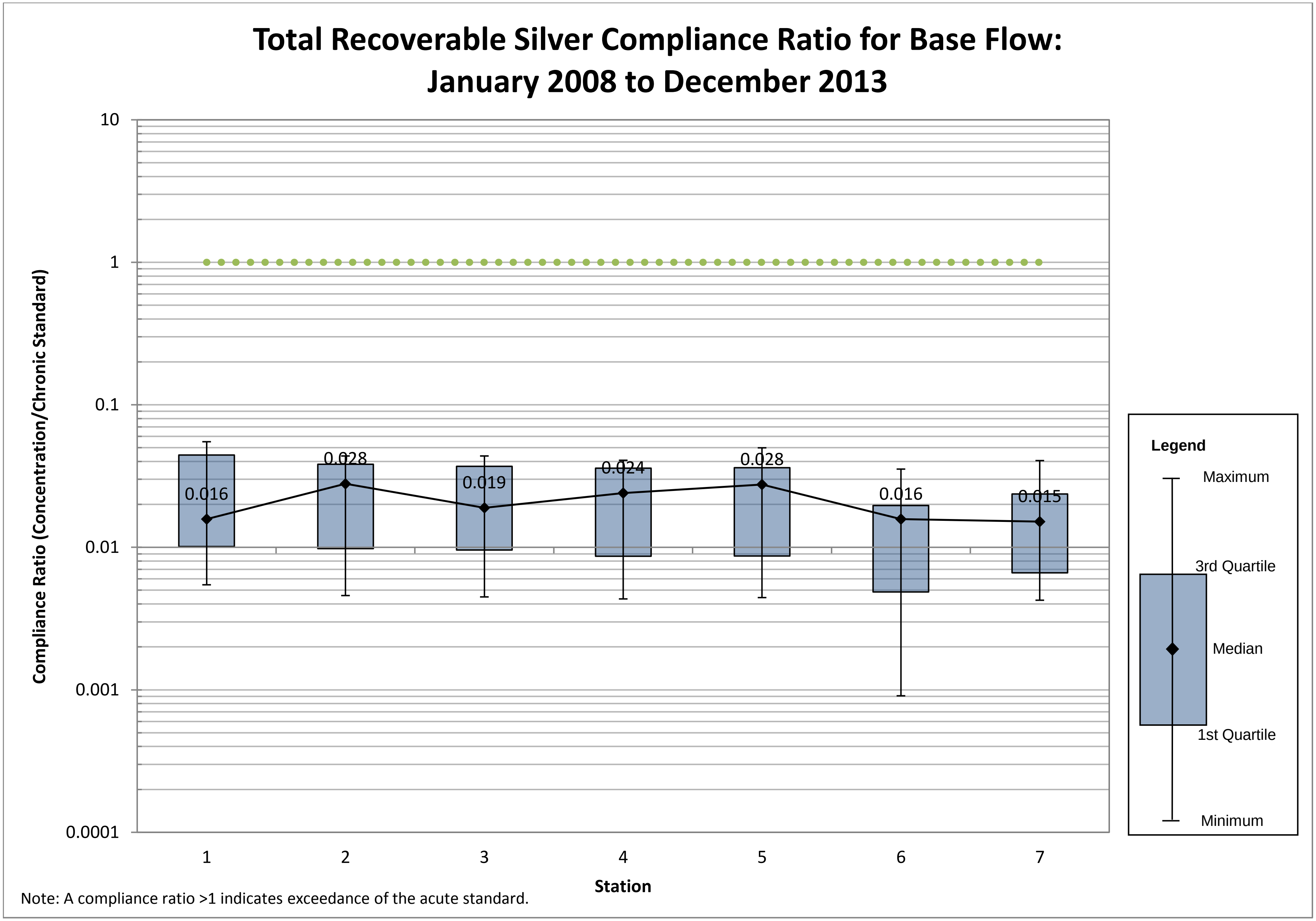

Figure 6-29
Base Flow Total Silver Compliance Ratio - 2008 to 2013

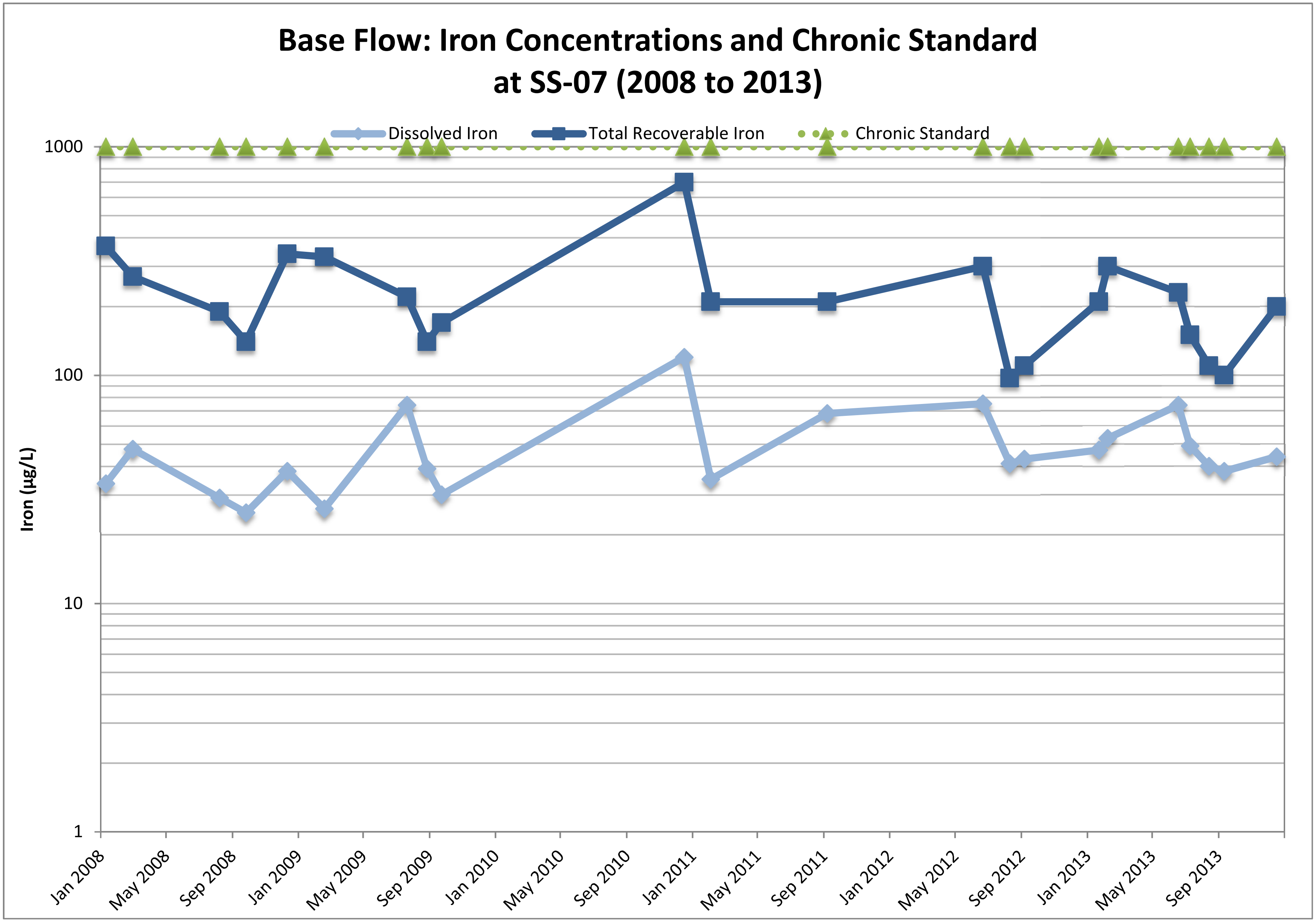

Figure 6-30
Base Flow Iron Concentrations SS-07 - 2008 to 2013

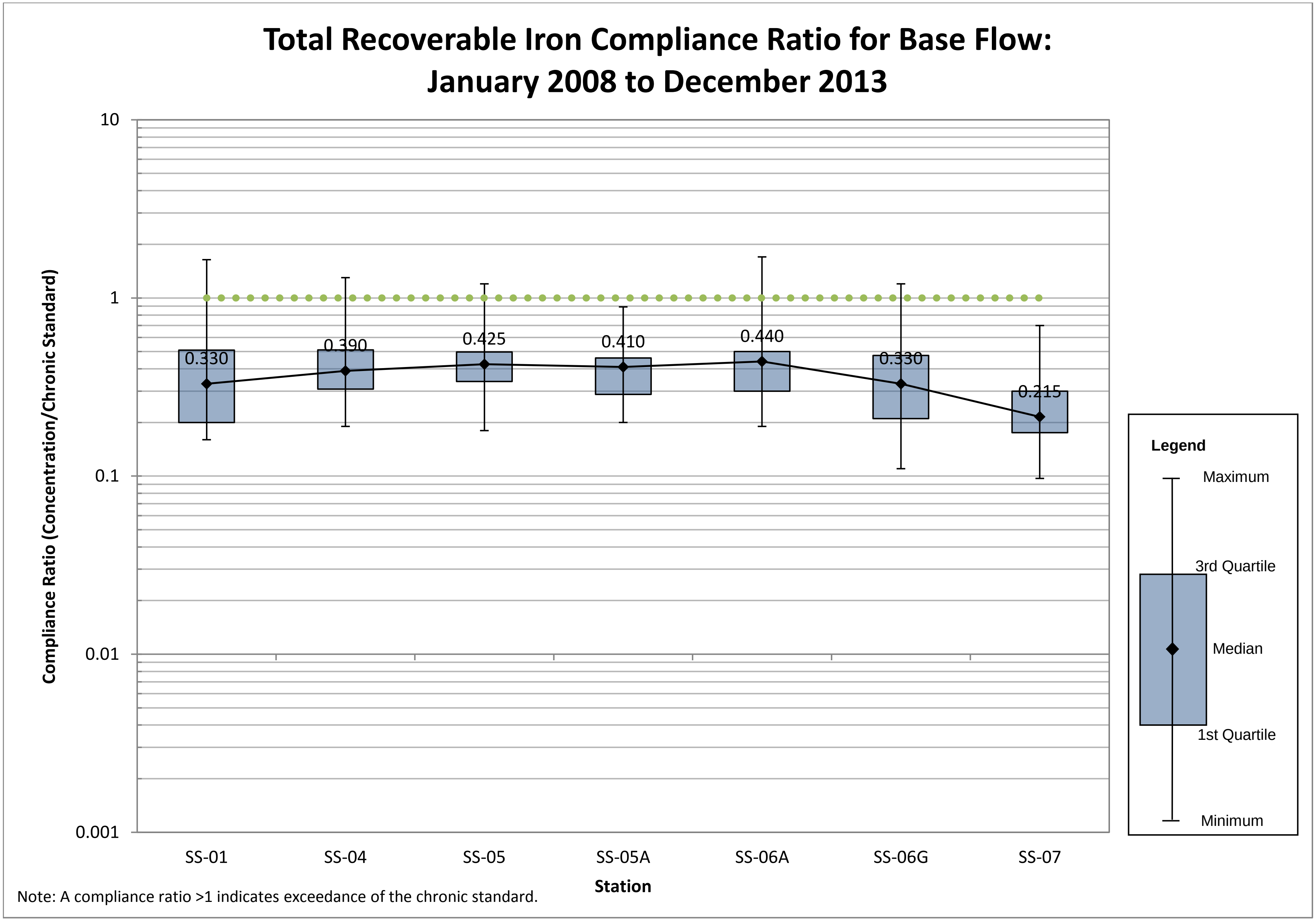

Figure 6-31
Base Flow Total Iron Compliance Ratio - 2008 to 2013

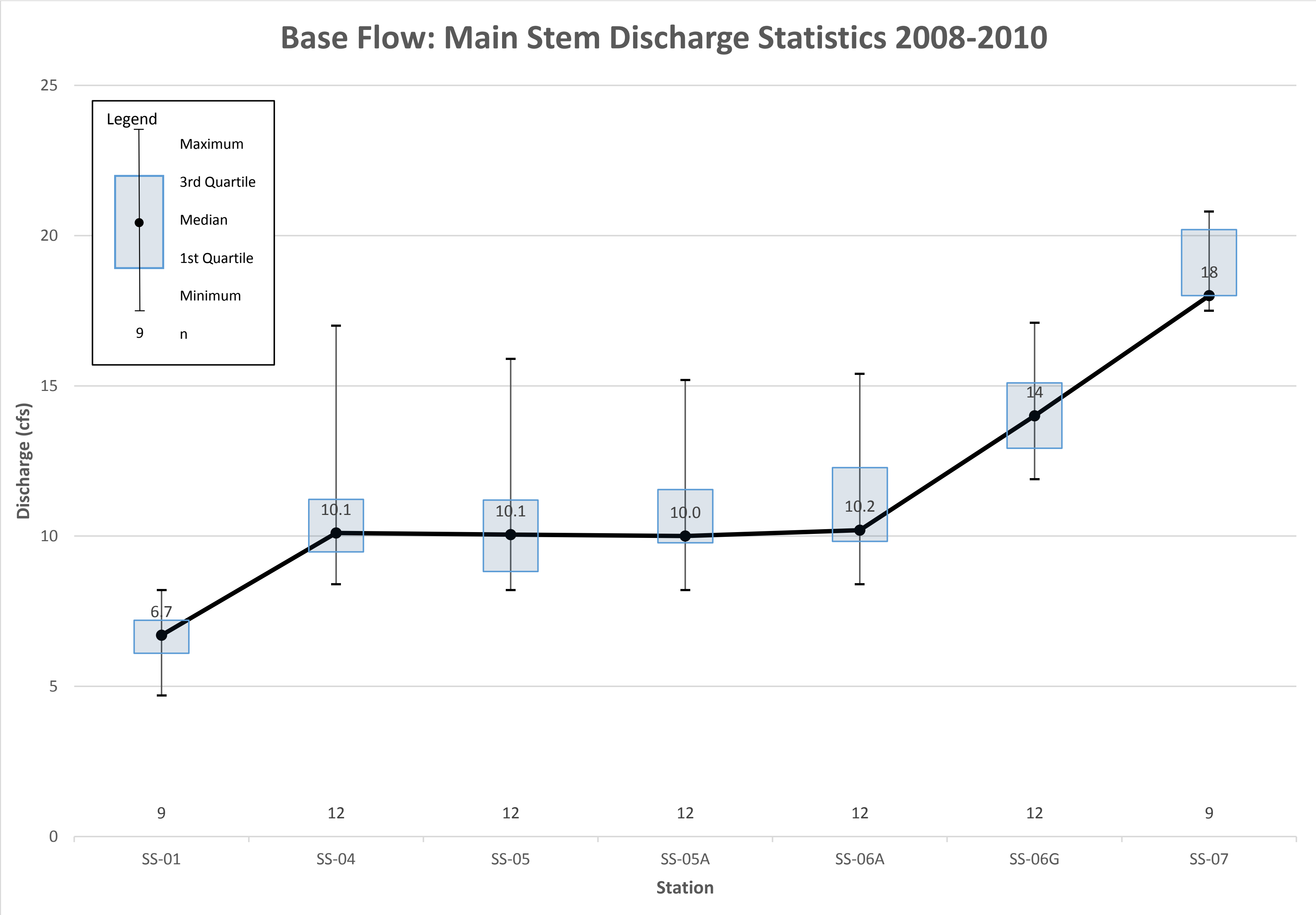

Figure 7-1
Base Flow: Main Stem Discharge Statistics 2008-2010

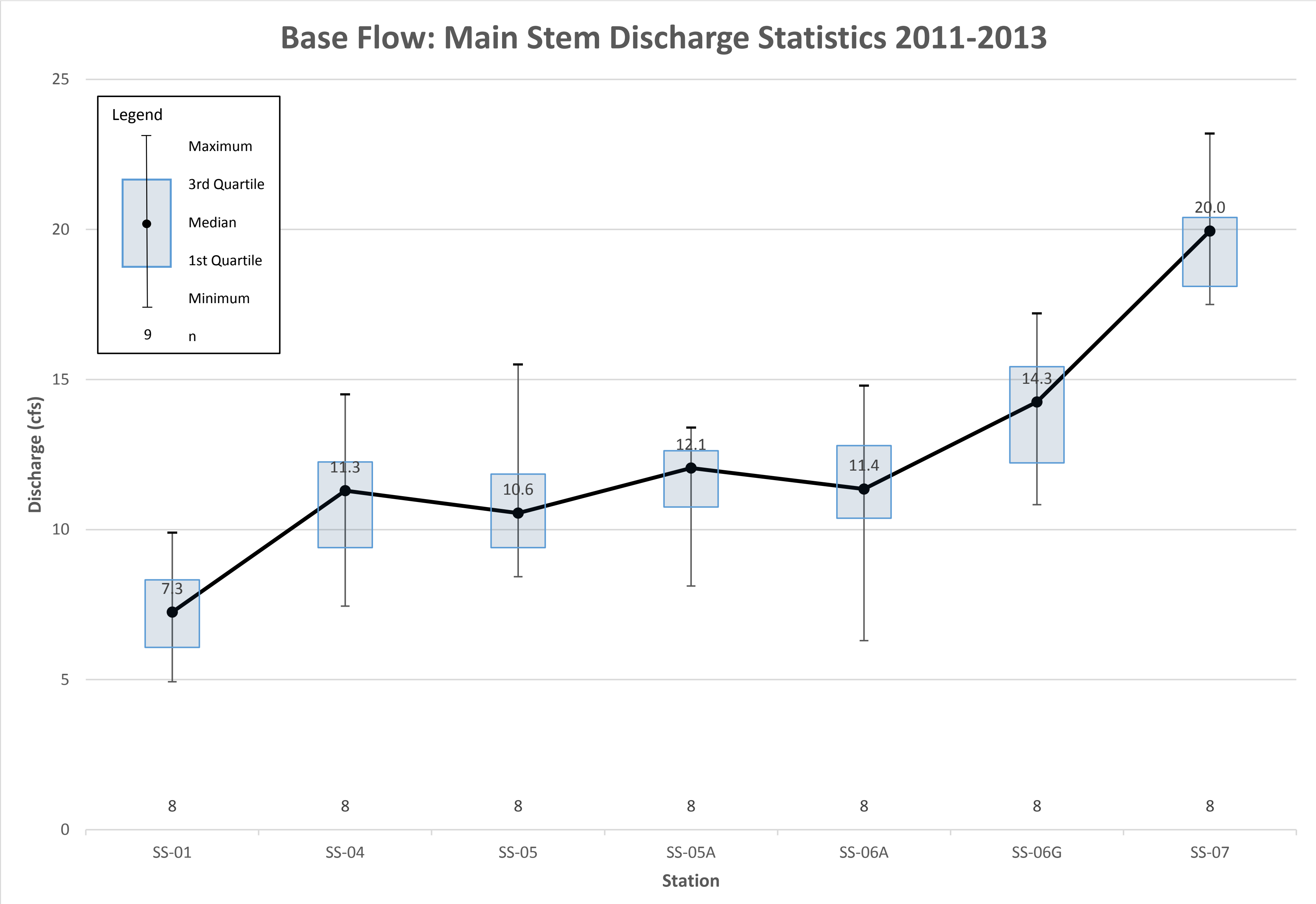

Figure 7-2
Base Flow: Main Stem Discharge Statistics 2011-2013

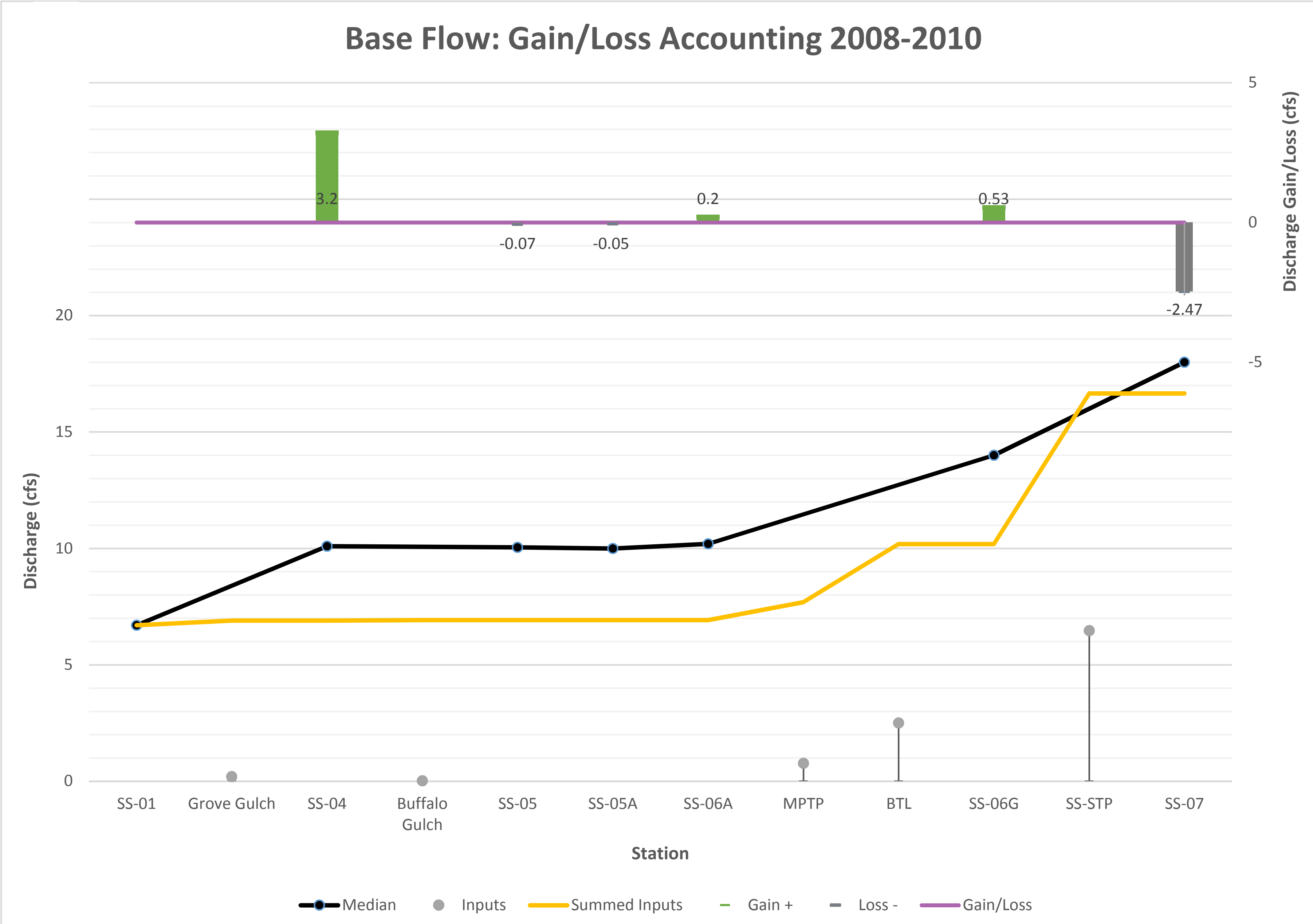

Figure 7-3
Base Flow: Gain/Loss Accounting 2008-2010

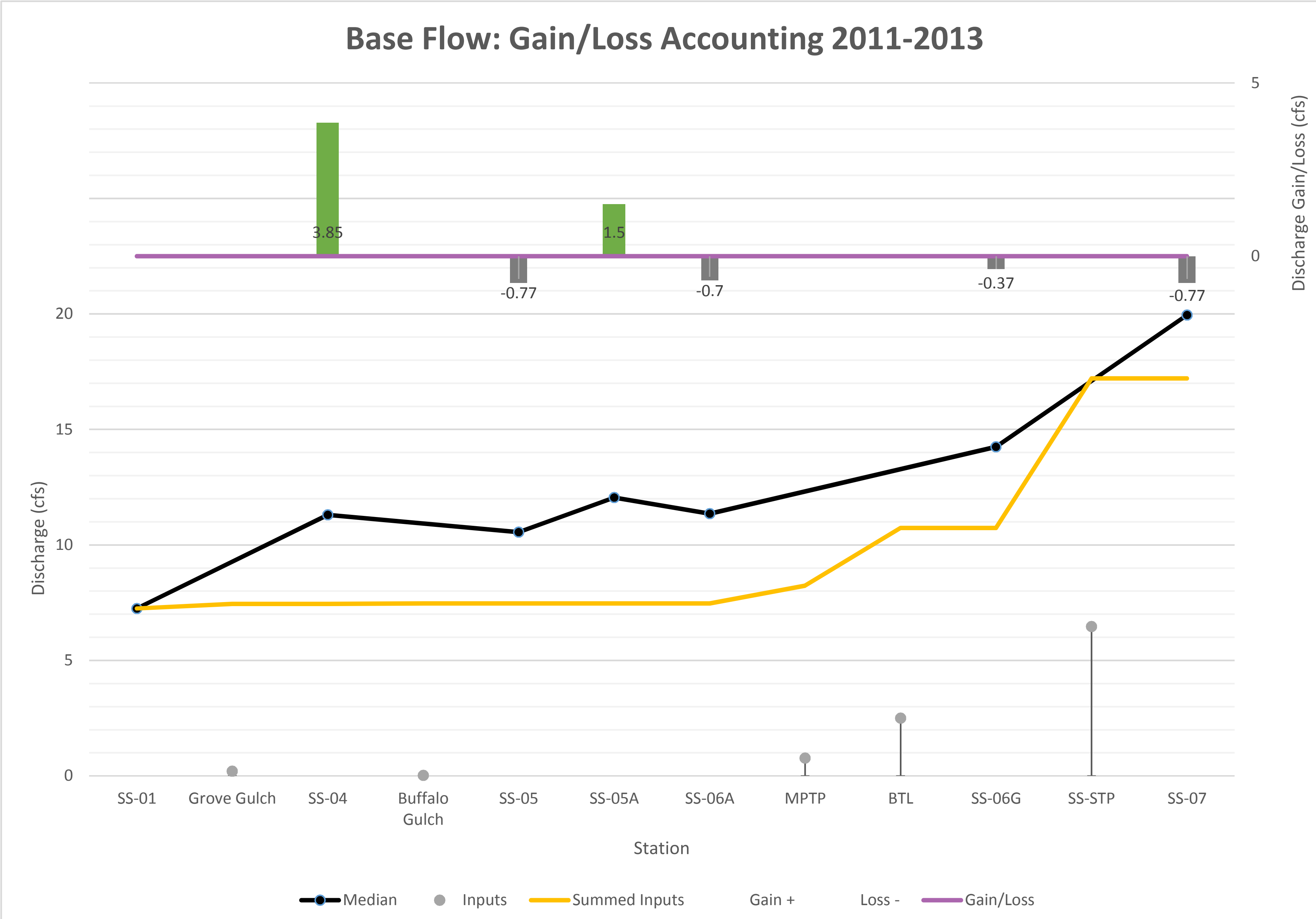

Figure 7-4
Base Flow: Gain/Loss Accounting 2011-2013

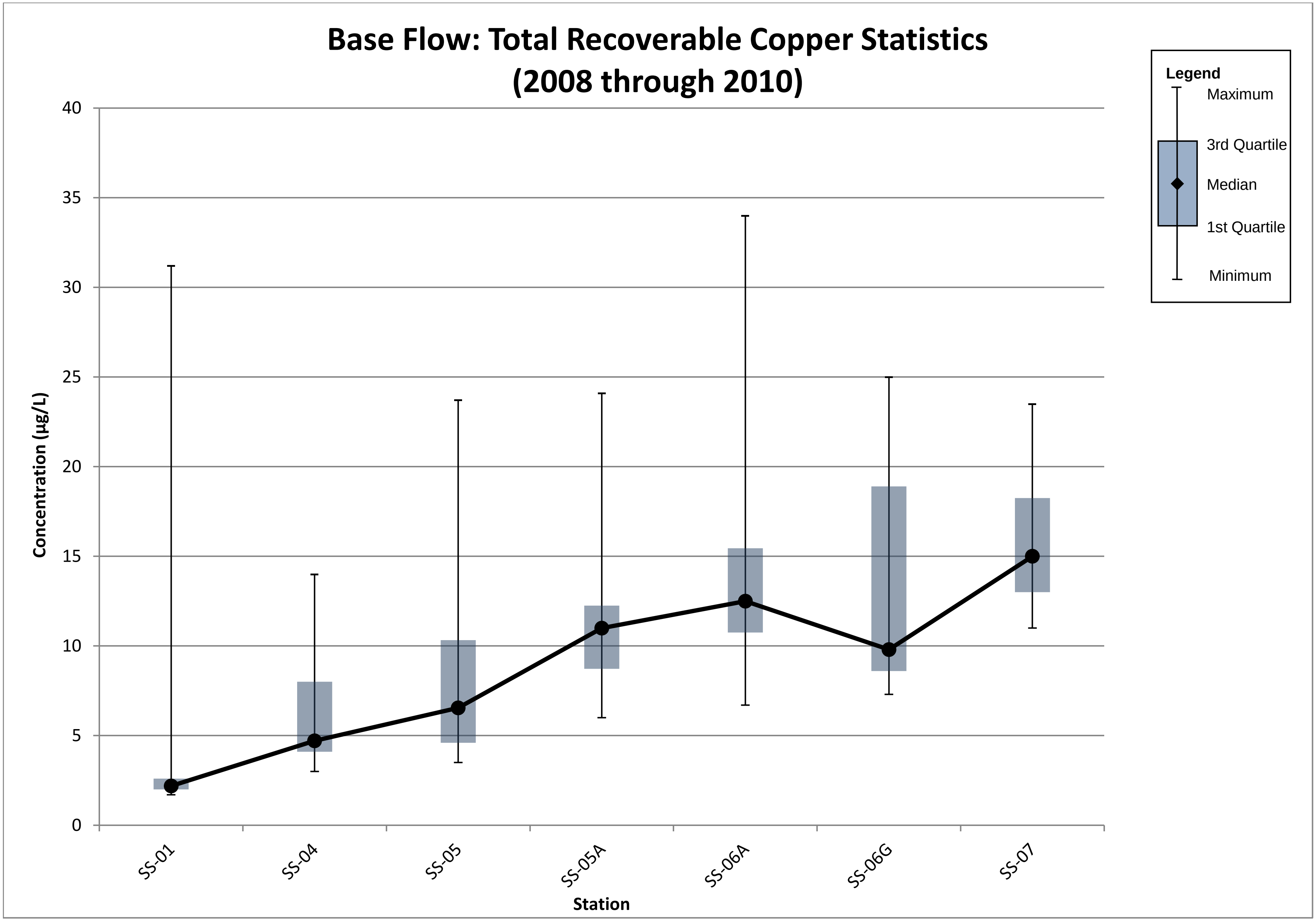

Figure 7-5
Total Recoverable Copper Loading - 2008 to 2010

Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

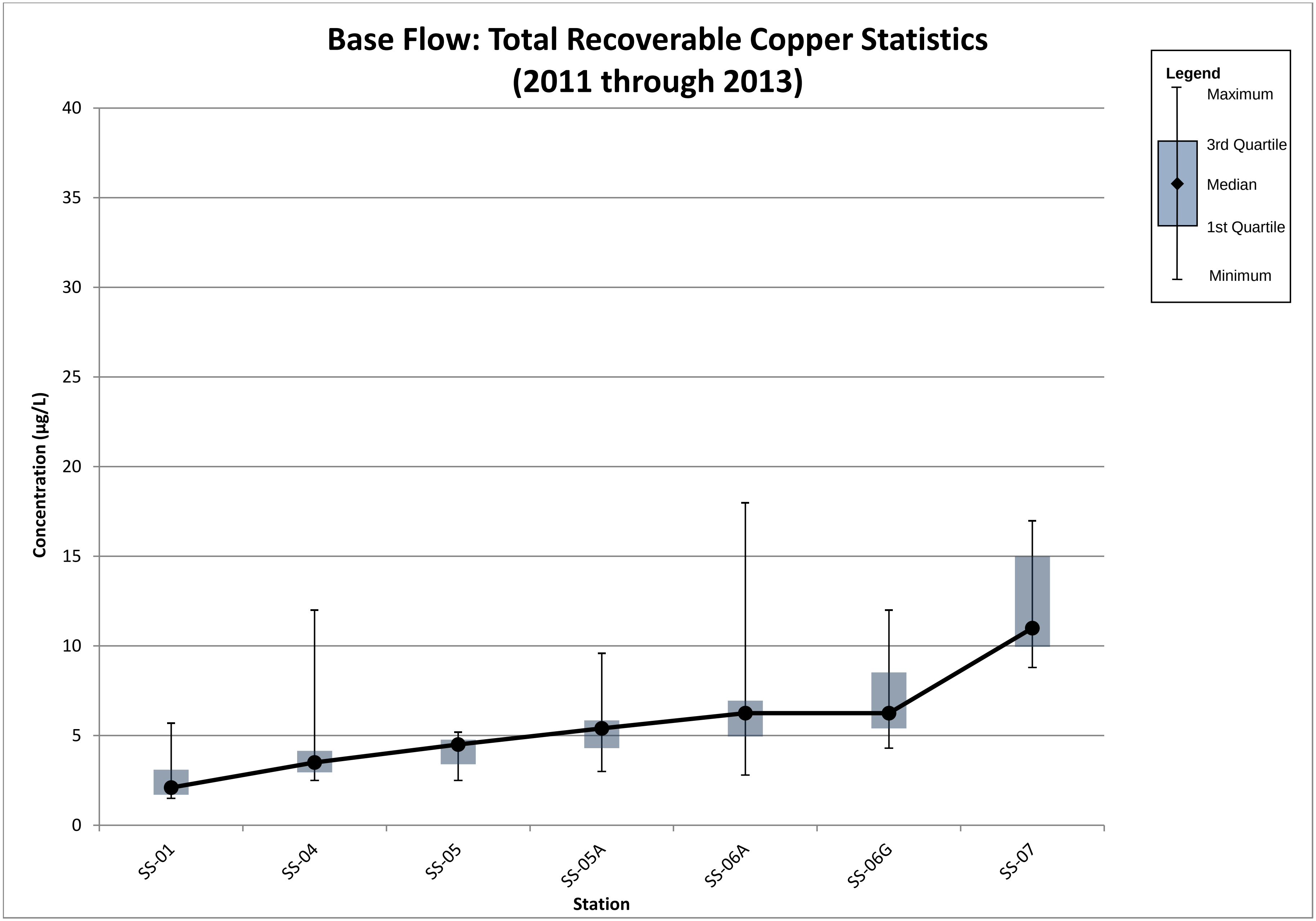

Figure 7-6
Total Recoverable Copper Loading - 2011 to 2013

Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

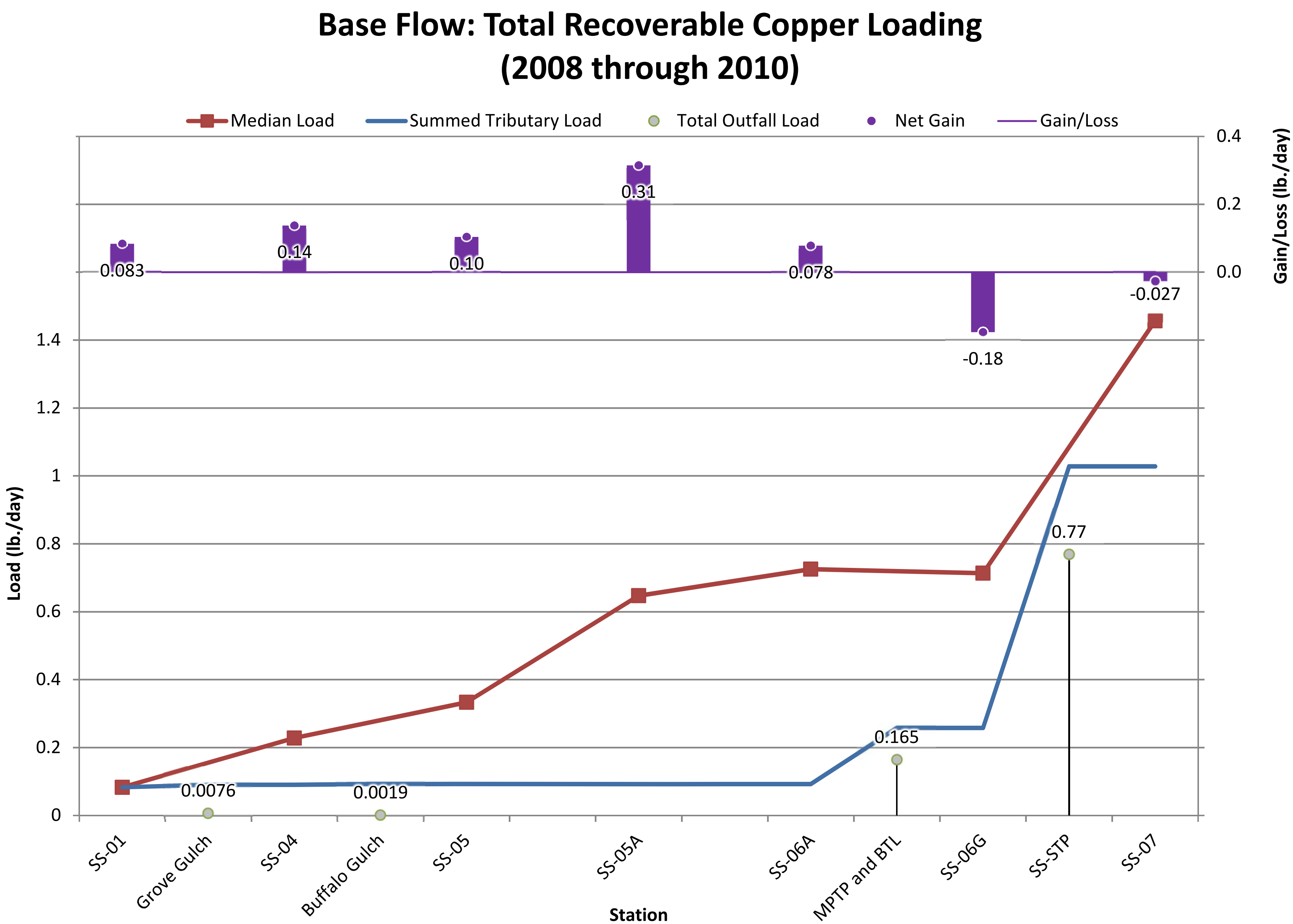

Figure 7-7
Total Recoverable Copper Load Accounting - 2008 to 2010

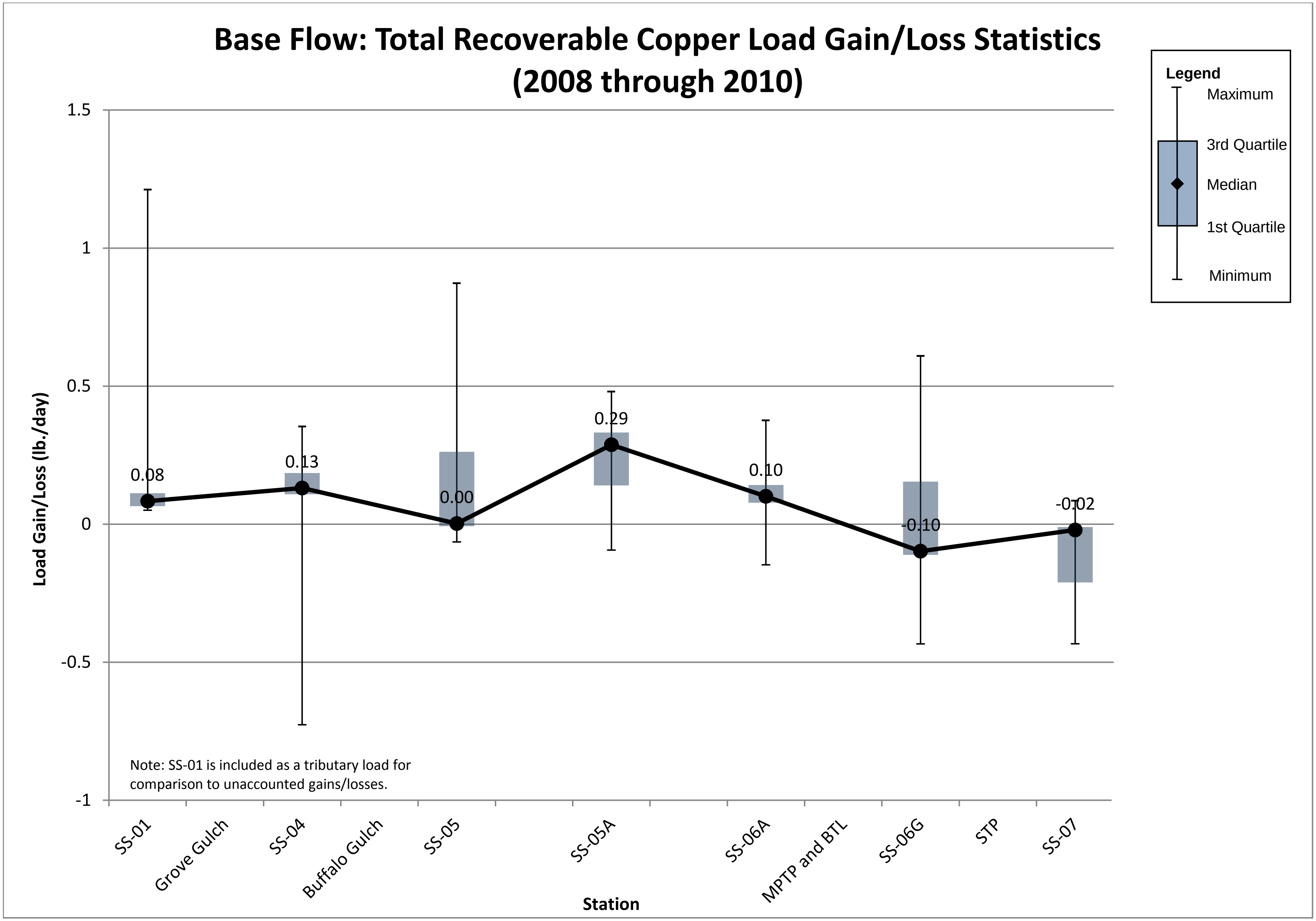

Figure 7-8
Total Recoverable Copper Load Gain/Loss Statistics - 2008 to 2010

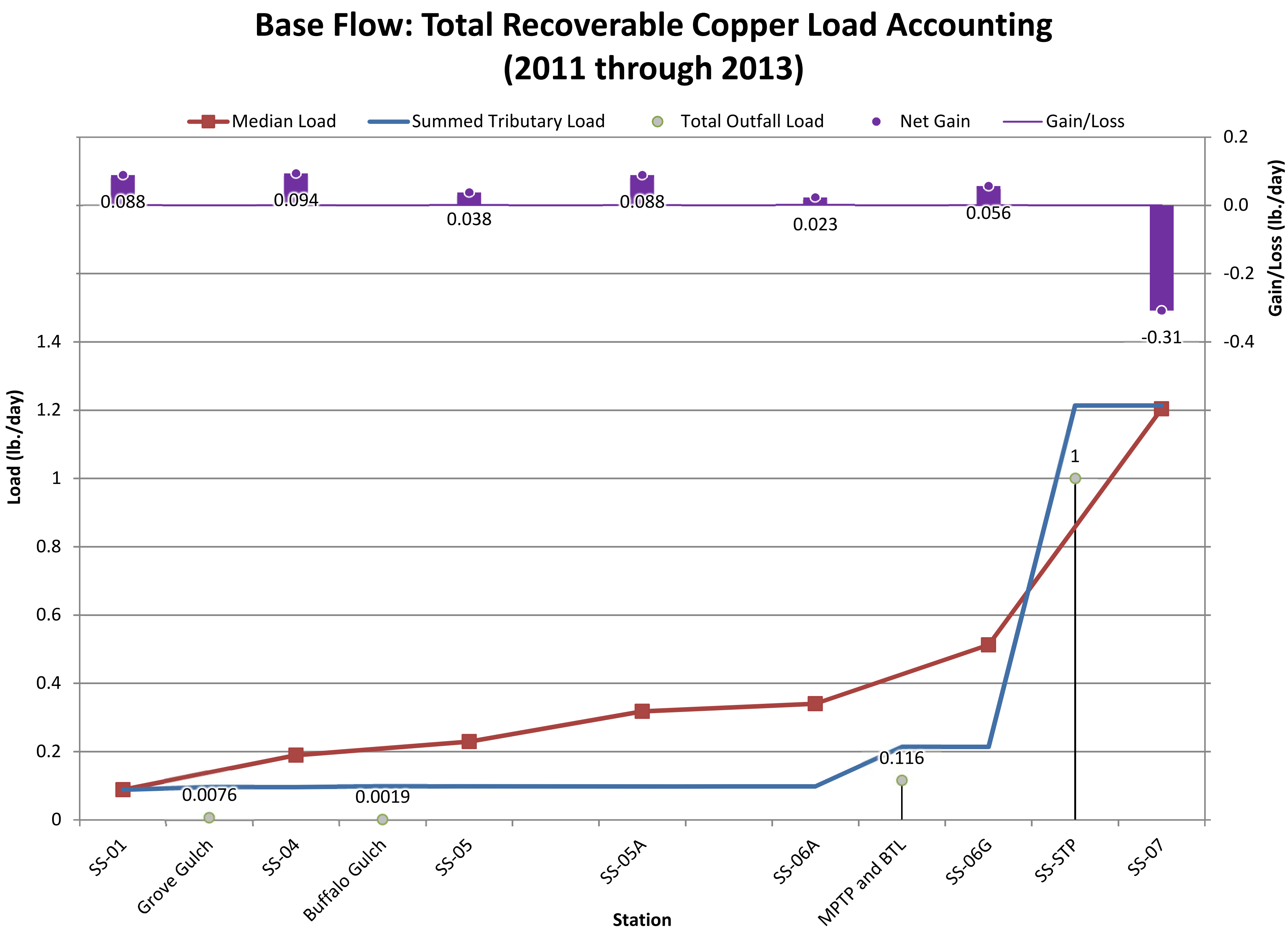

Figure 7-9
Total Recoverable Copper Load Accounting - 2011 to 2013

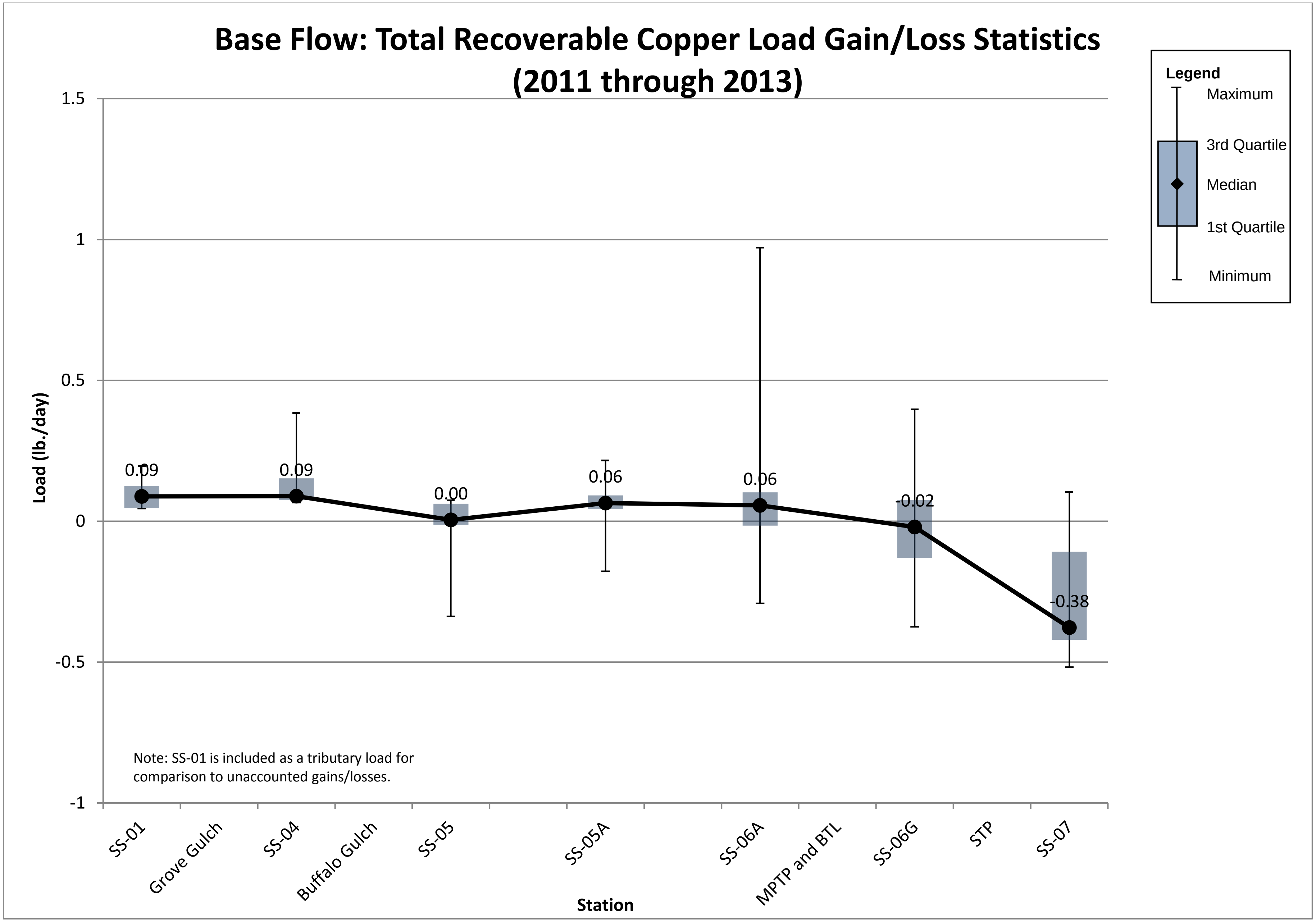

Figure 7-10
Total Recoverable Copper Load Gain/Loss Statistics 2011 to 2013

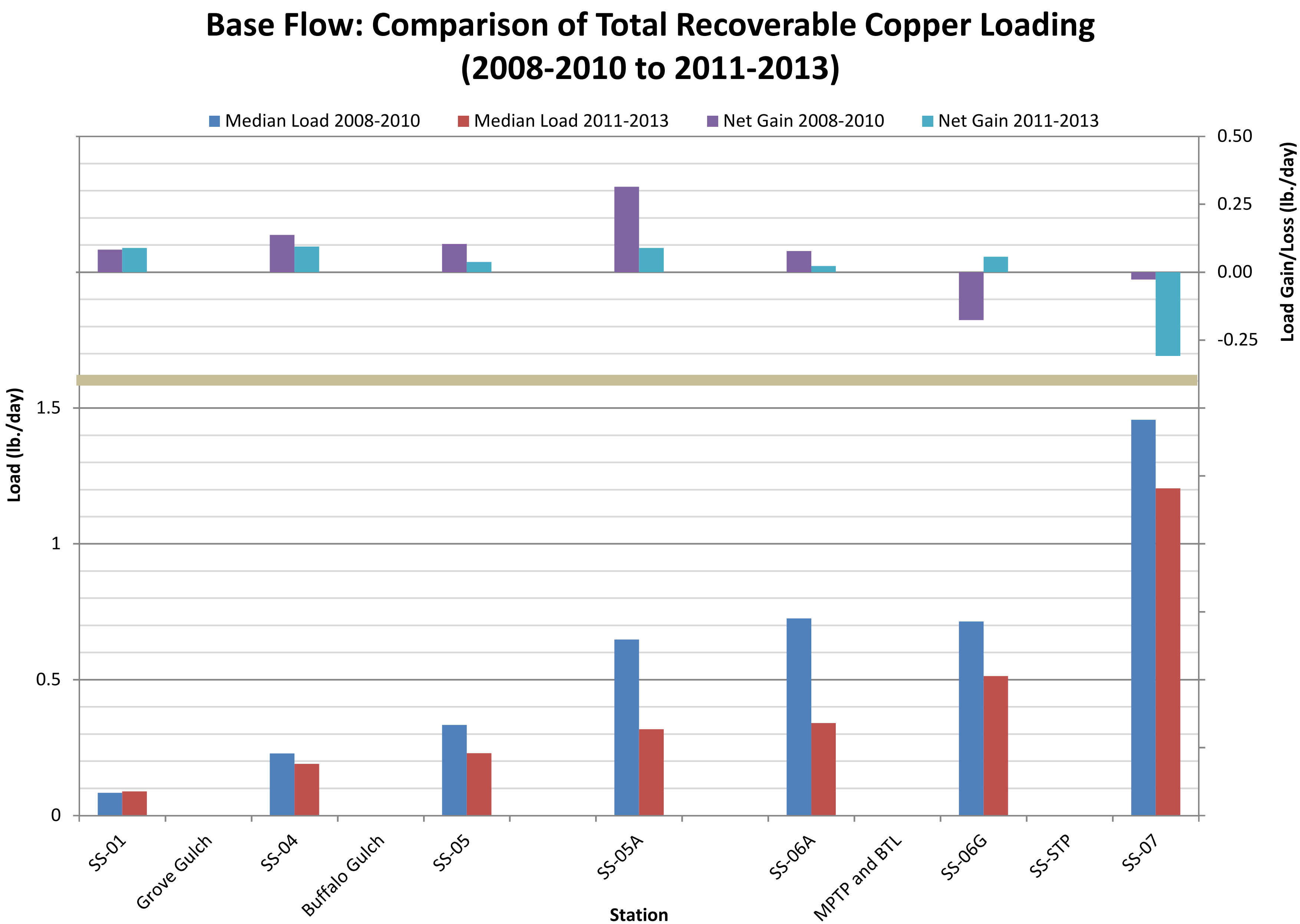

Figure 7-11
Comparison of Total Recoverable Copper Loading (2008-2010 to 2011-2013)

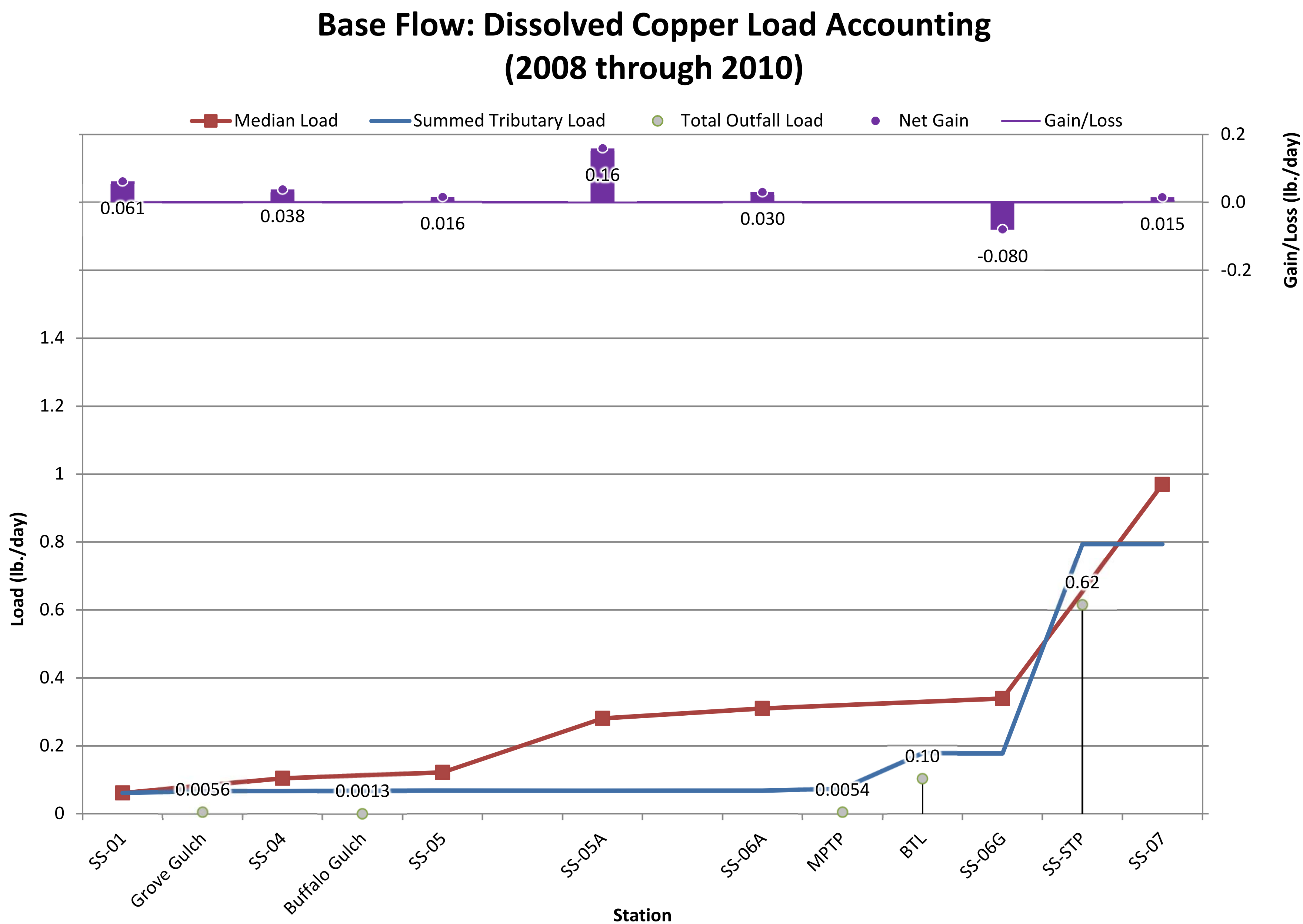

Figure 7-12
Dissolved Copper Load Accounting - 2008 to 2010

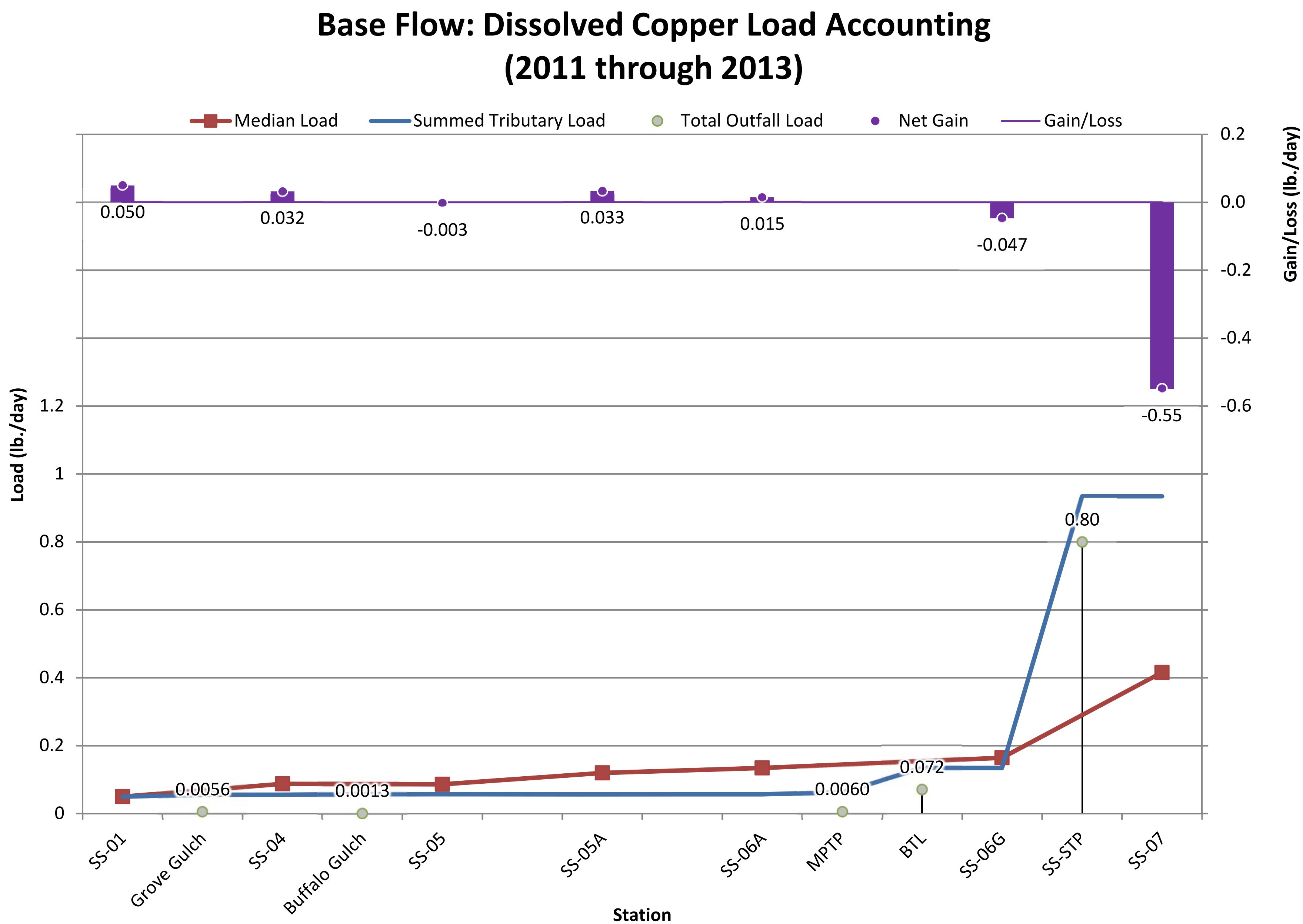

Figure 7-13
Dissolved Copper Load Accounting - 2011 to 2013

Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

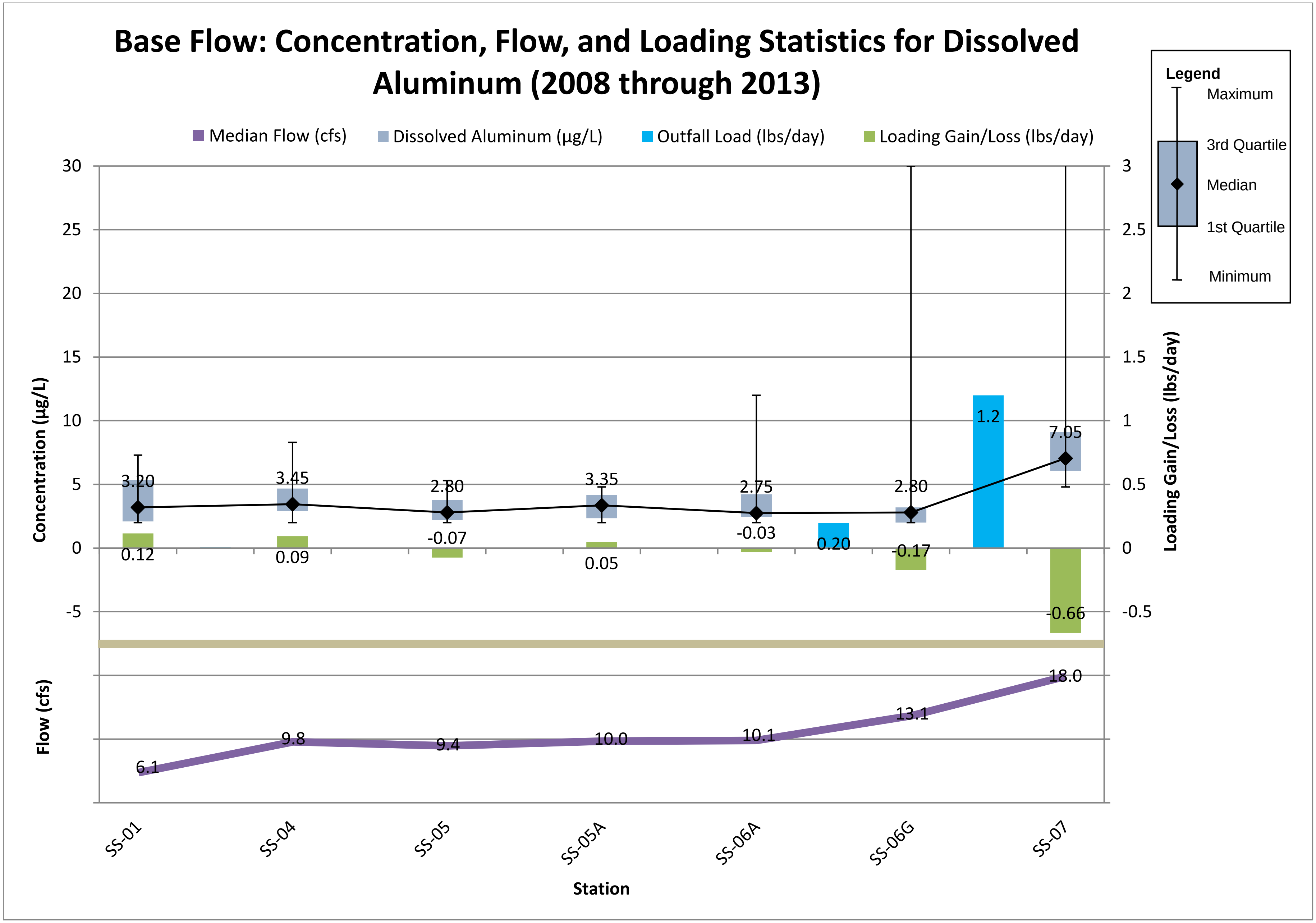

Figure 7-14
Base Flow Statistics and Discharge for Dissolved Aluminum 2008 - 2013

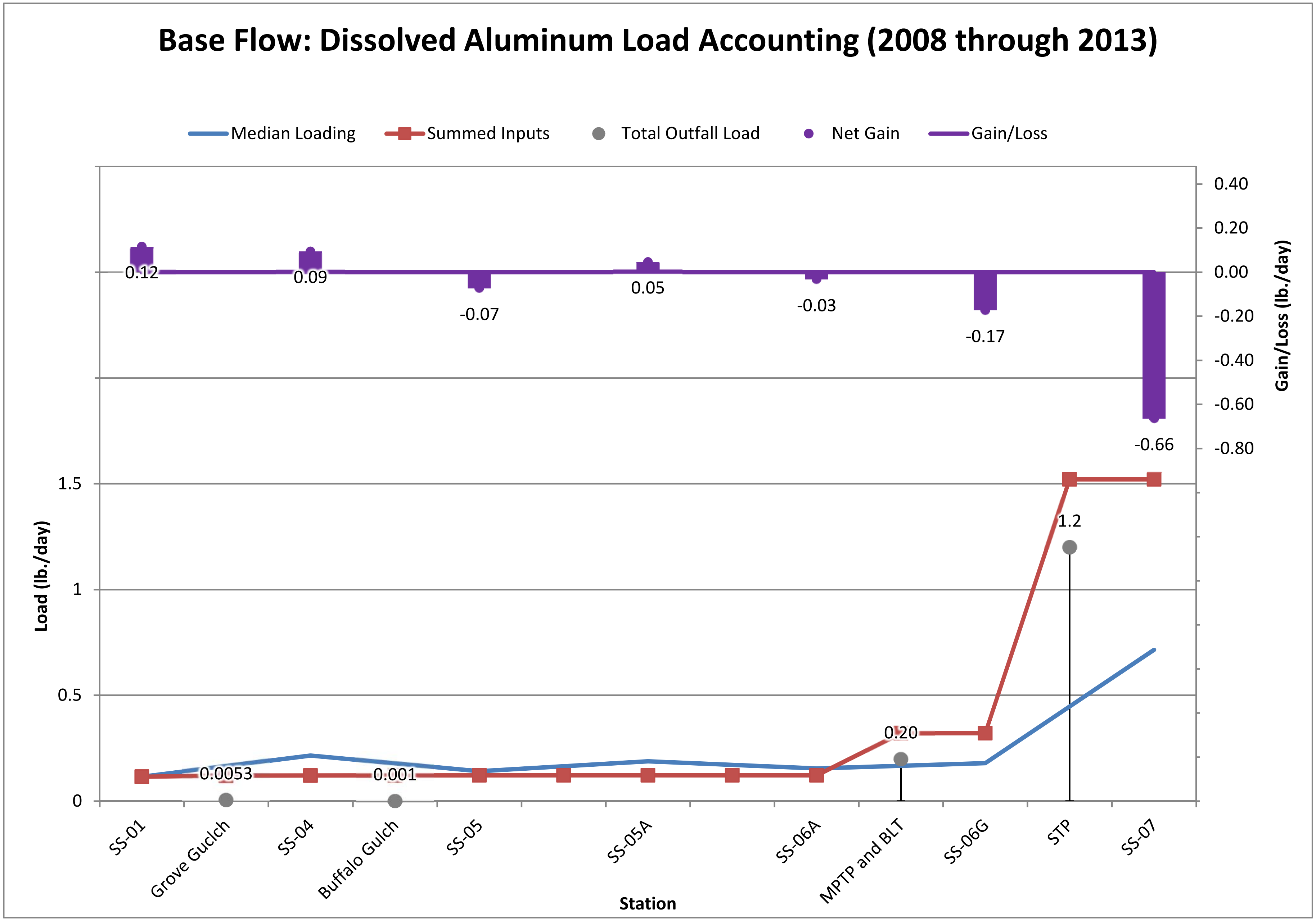

Figure 7-15
Base Flow Dissolved Aluminum Load Accounting - 2008 to 2013

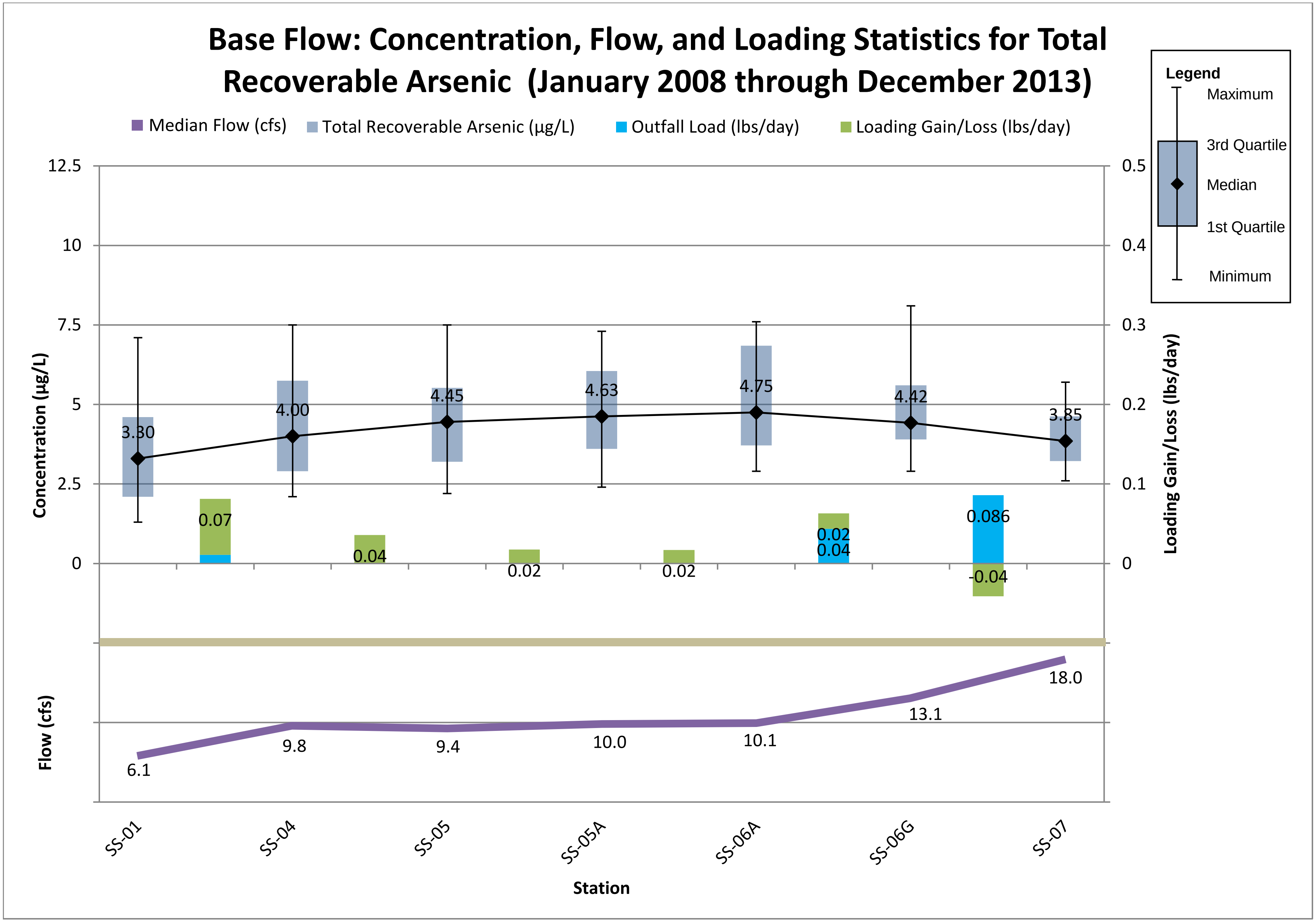

Figure 7-16
Total Recoverable Arsenic Statistics and Discharge - 2008 to 2013

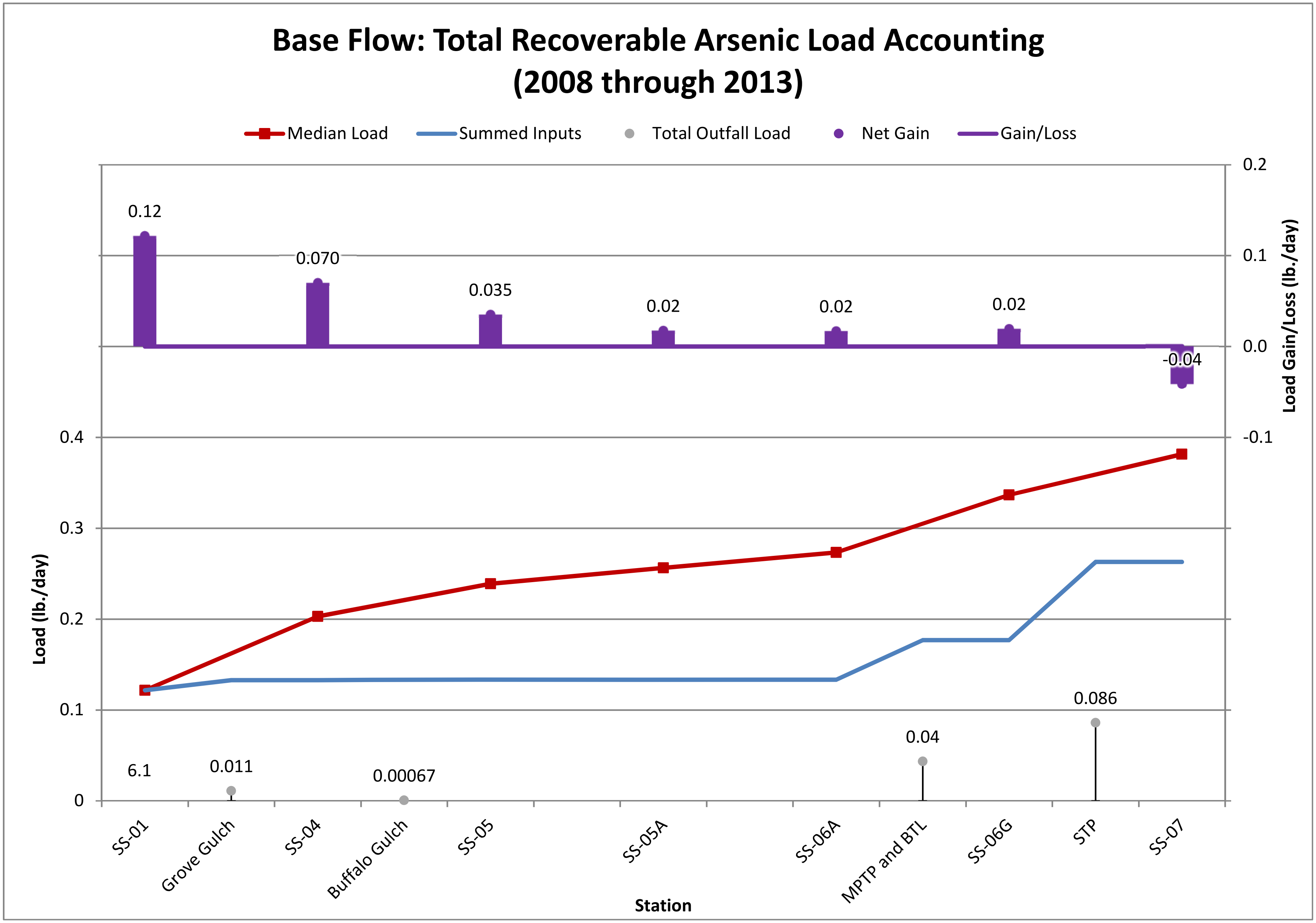

Figure 7-17
Total Recoverable Arsenic Load Accounting - 2008 to 2013

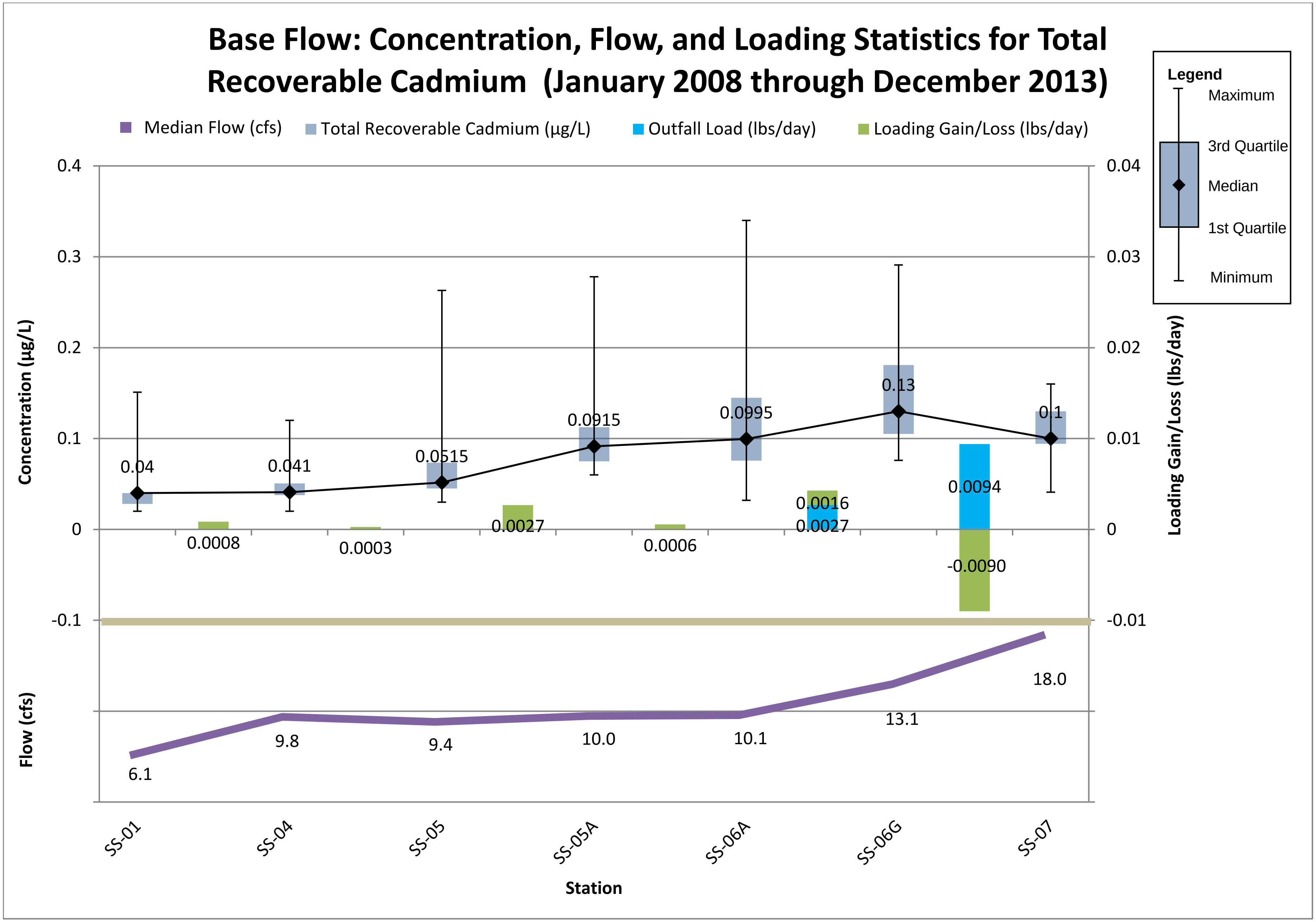

Figure 7-18
Total Recoverable Cadmium Statistics and Discharge - 2008 to 2013

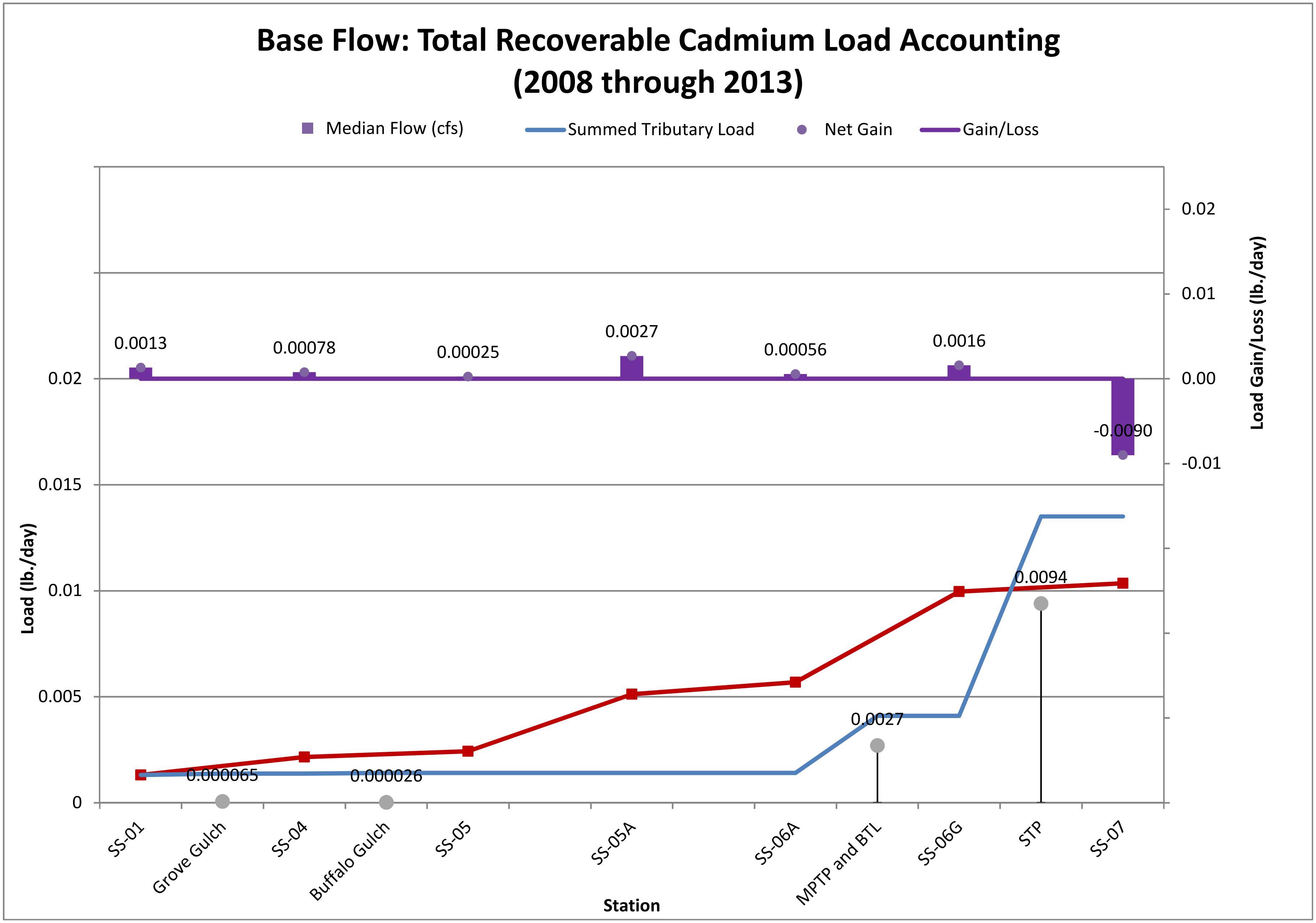

Figure 7-19
Total Recoverable Cadmium Load Accounting - 2008 to 2013

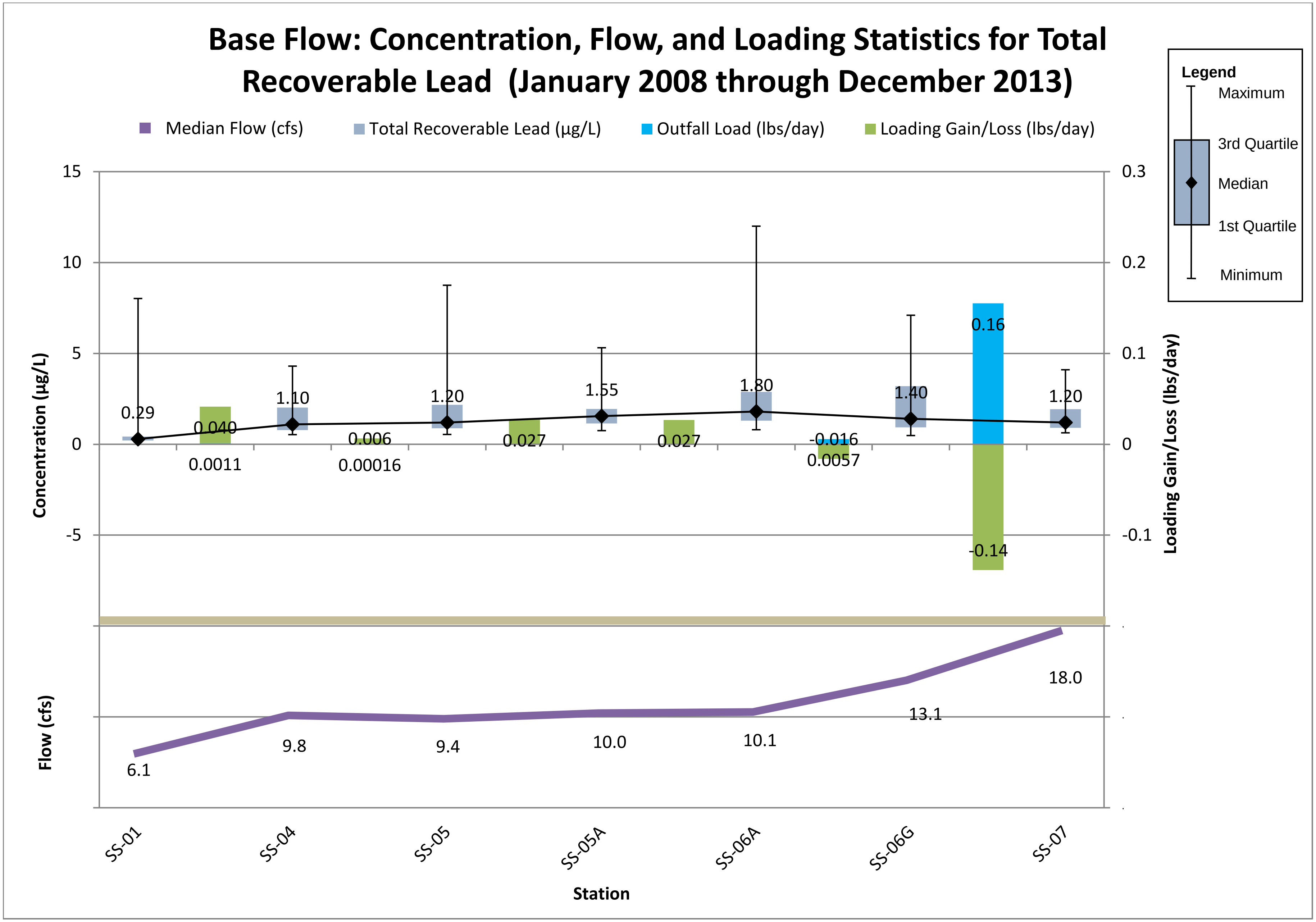

Figure 7-20
Total Recoverable Lead Statistics and Discharge - 2008 to 2013

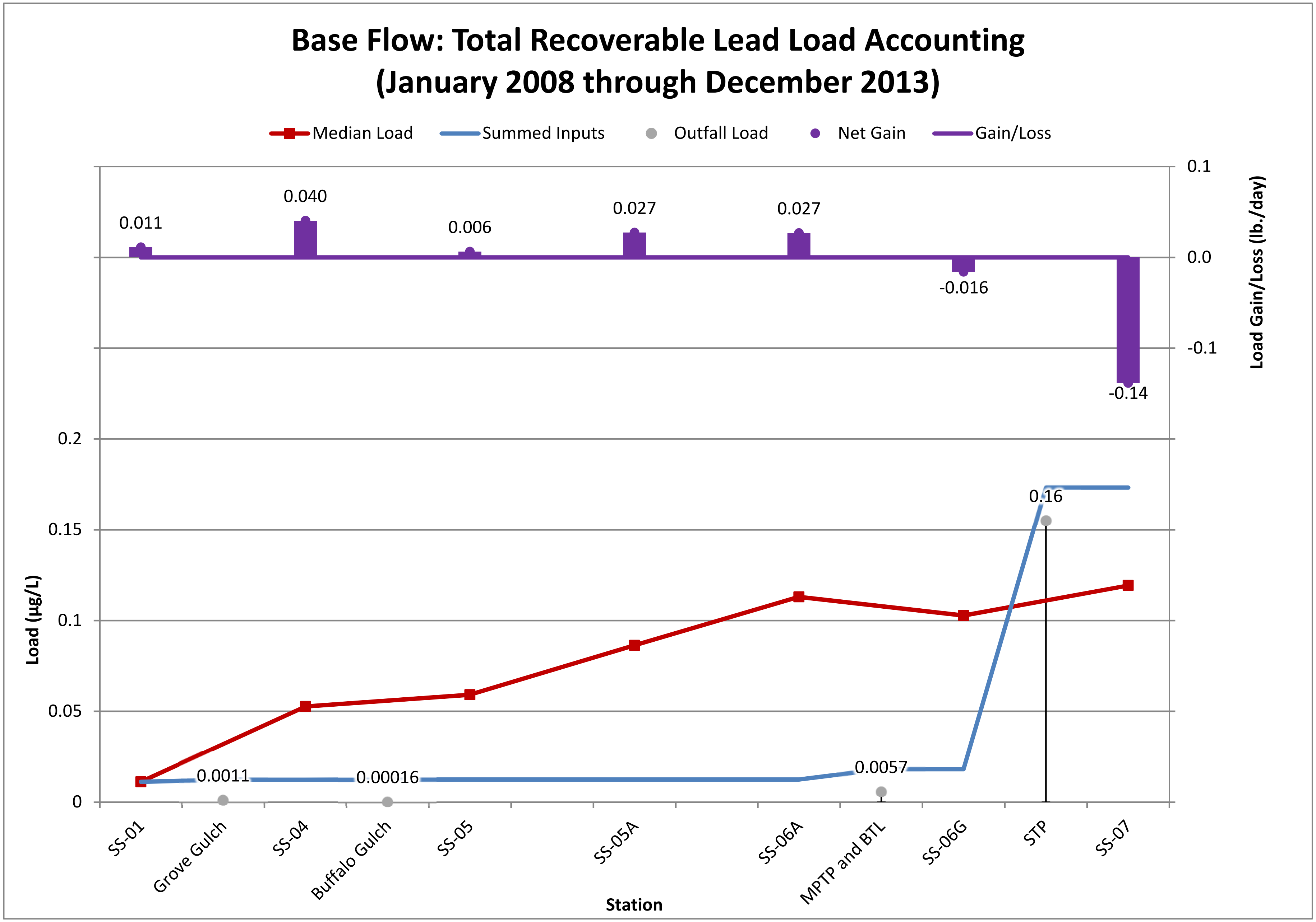

Figure 7-21

Total Recoverable Lead Load Accounting - 2008 to 2013

Surface Water Characterization Report

Butte Priority Soils Operable Unit

Silver Bow Creek/Butte Area NPL Site

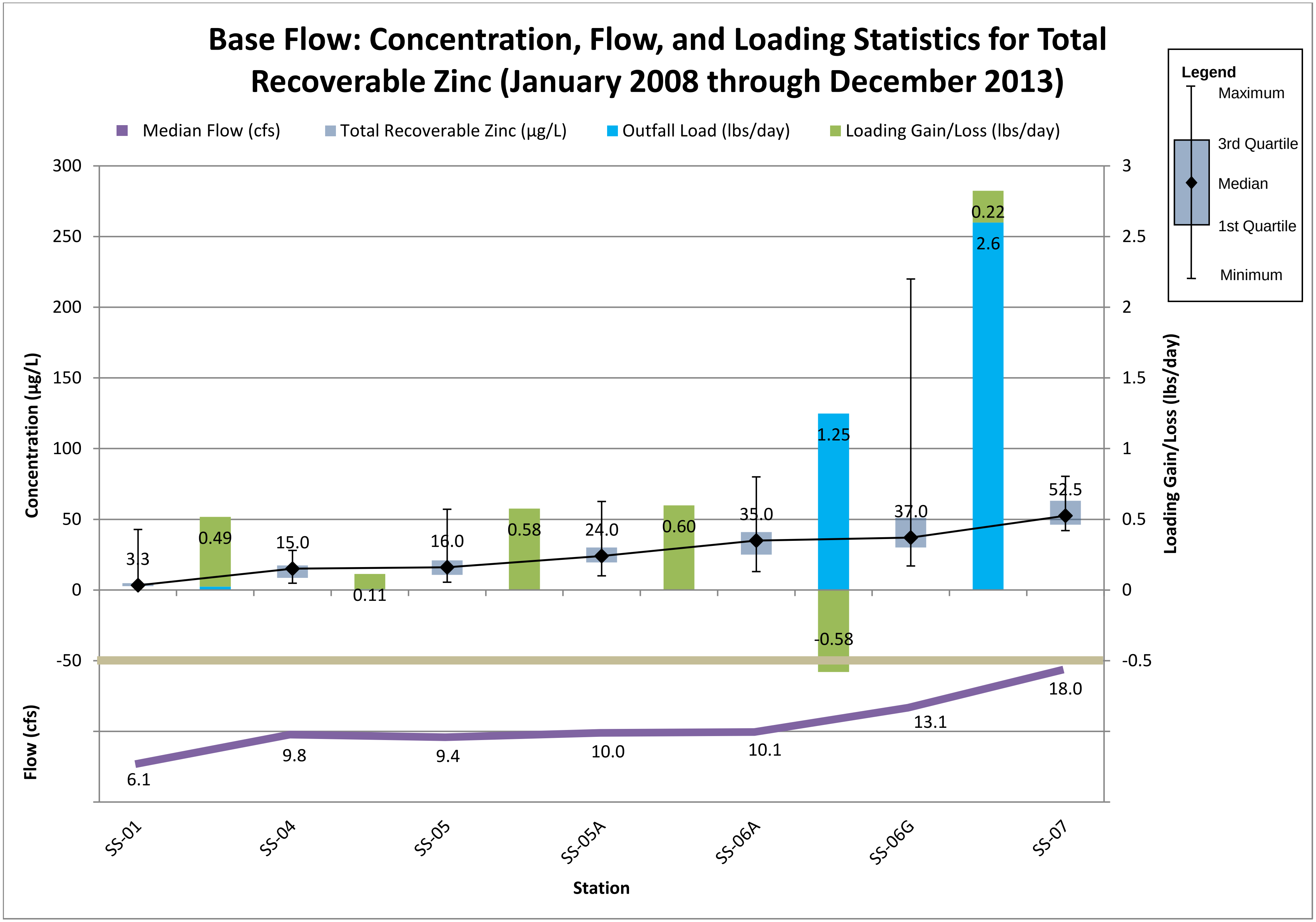

Figure 7-22
Total Recoverable Zinc Statistics and Discharge - 2008 to 2013

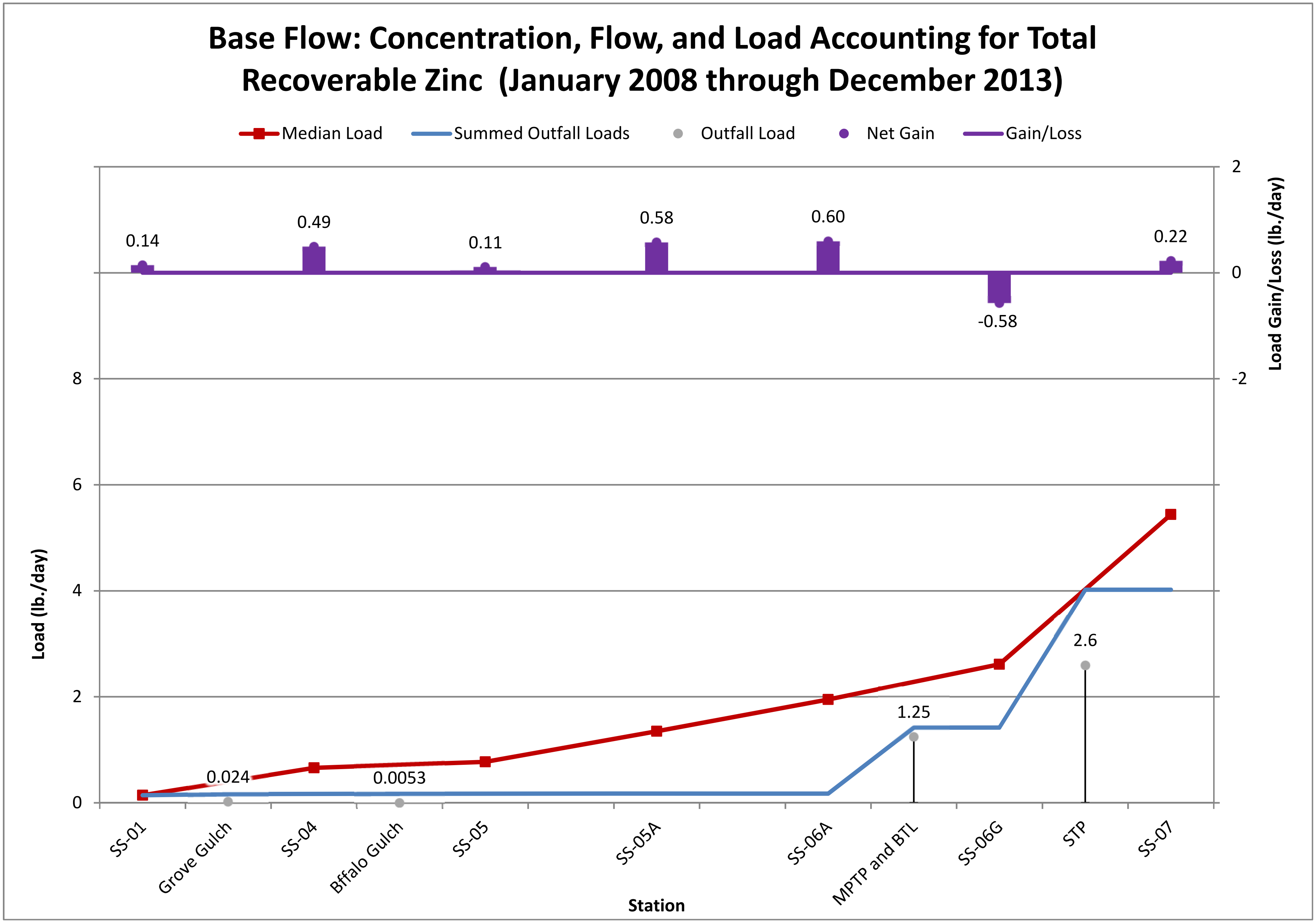

Figure 7-23
Total Recoverable Zinc Load Accounting - 2008 to 2013

Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

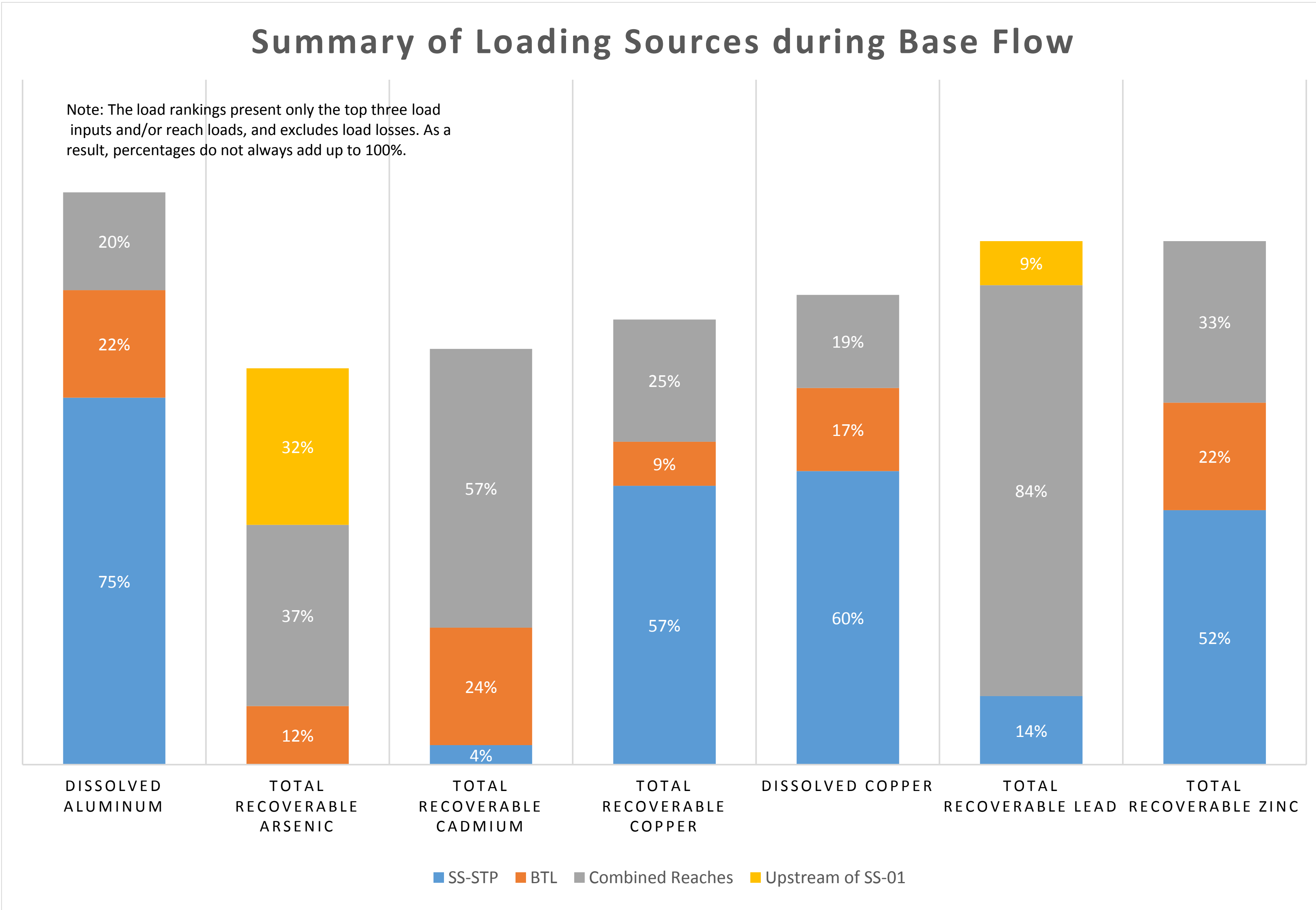

Figure 7-24
Summary of Loading Sources during Base Flow

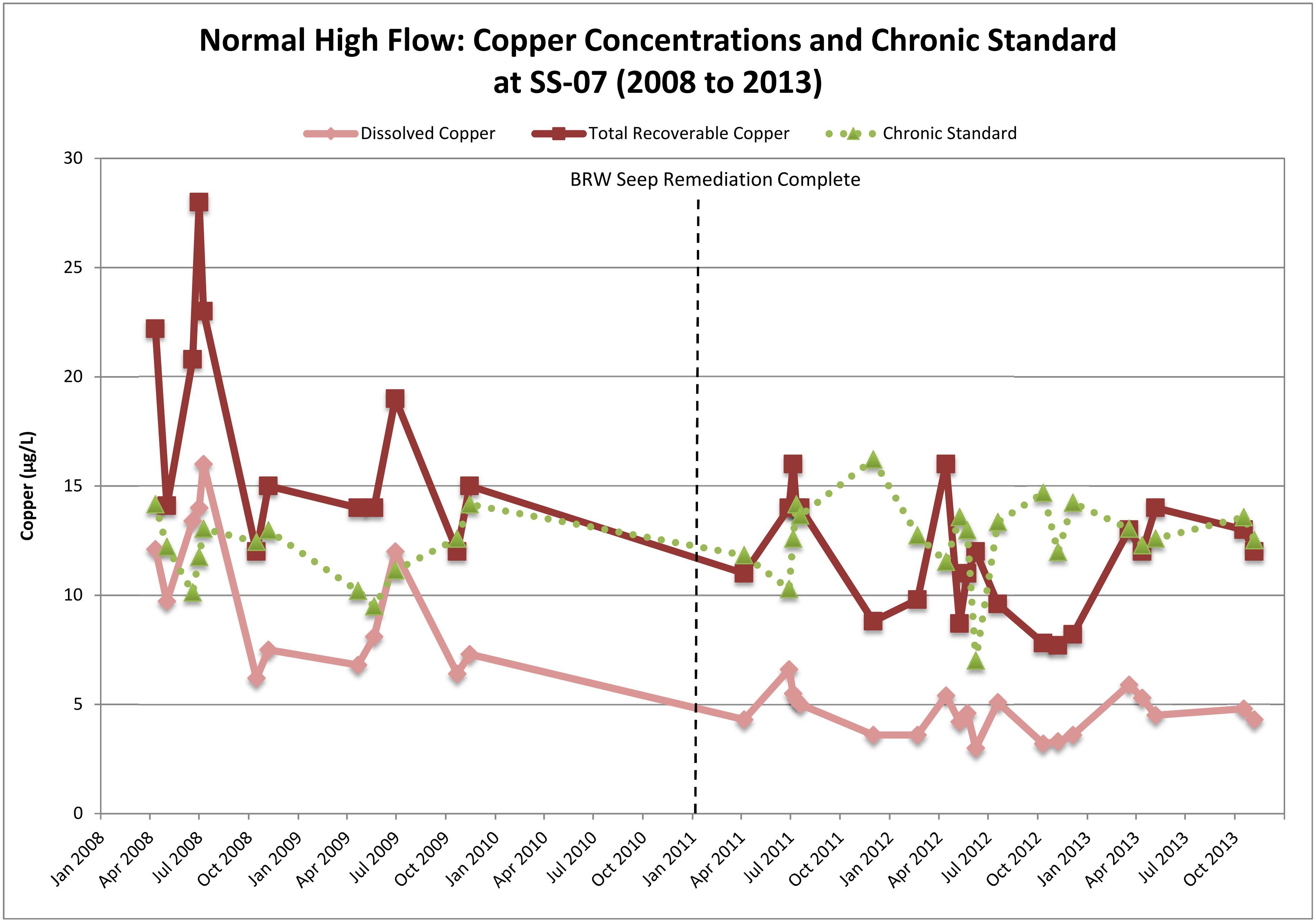

Figure 8-1
High Flow Copper Concentrations SS-07 - 2008 to 2013

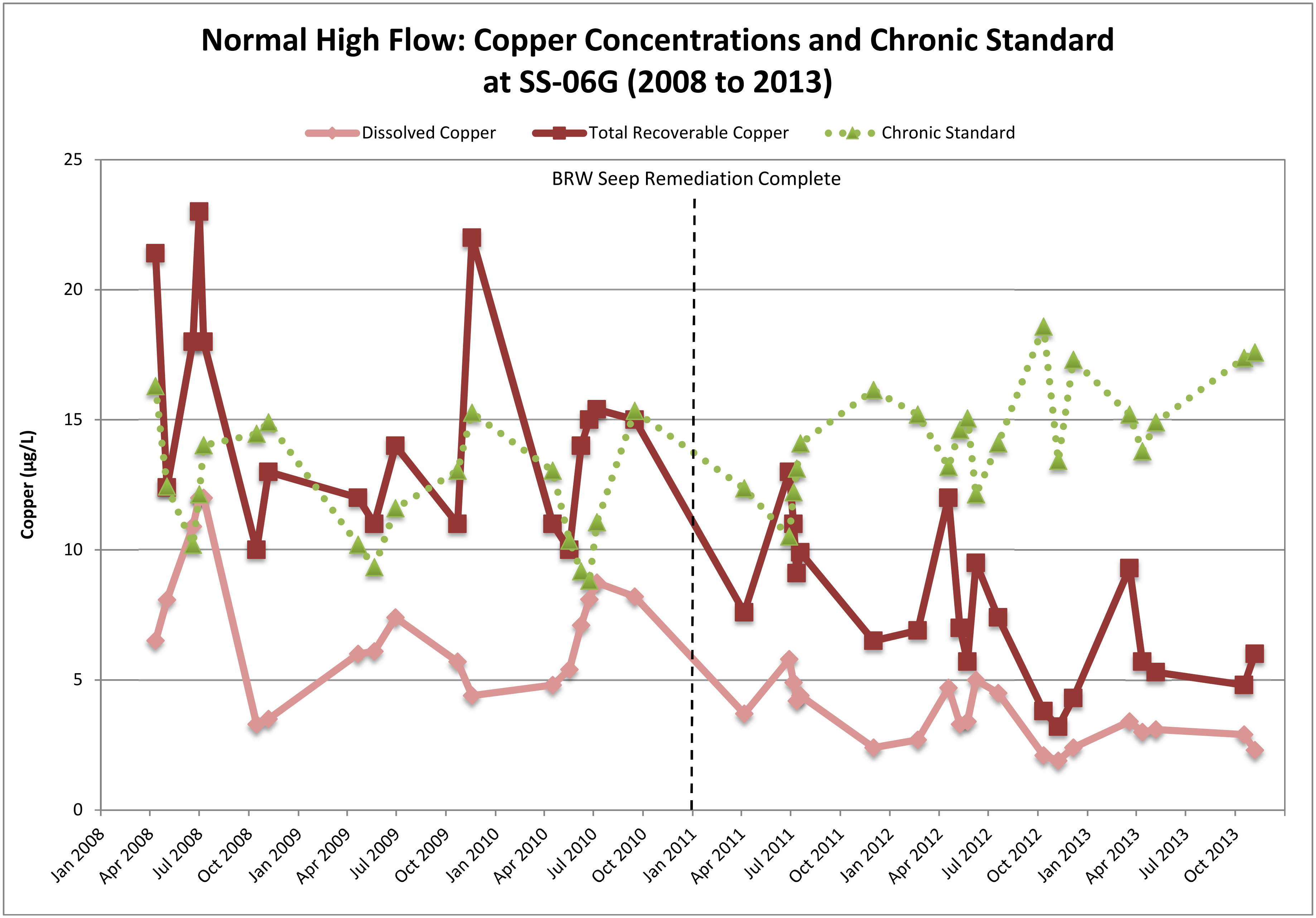

Figure 8-2
High Flow Copper Concentrations SS-06G - 2008 to 2013

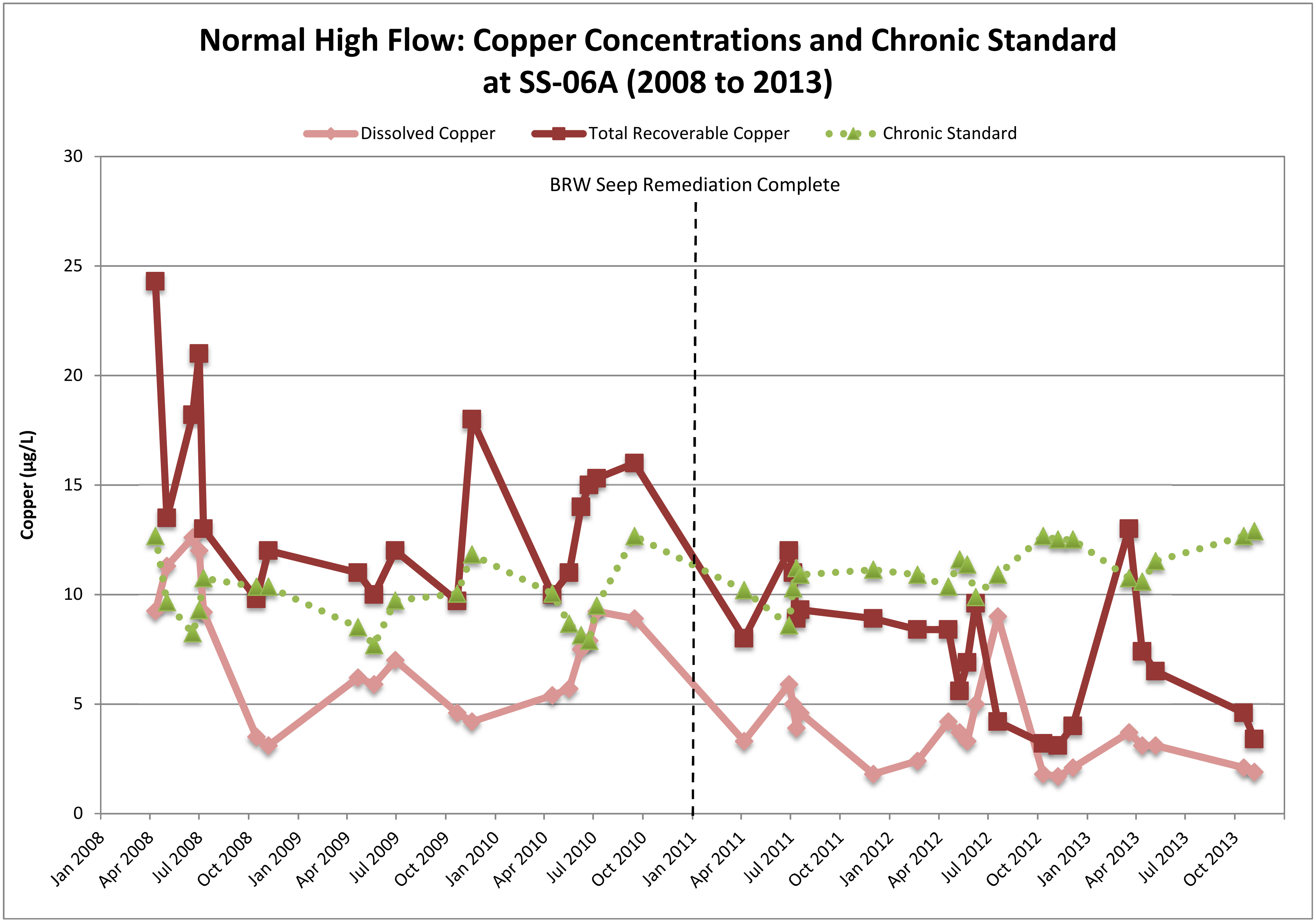

Figure 8-3
High Flow Copper Concentrations SS-06A - 2008 to 2013

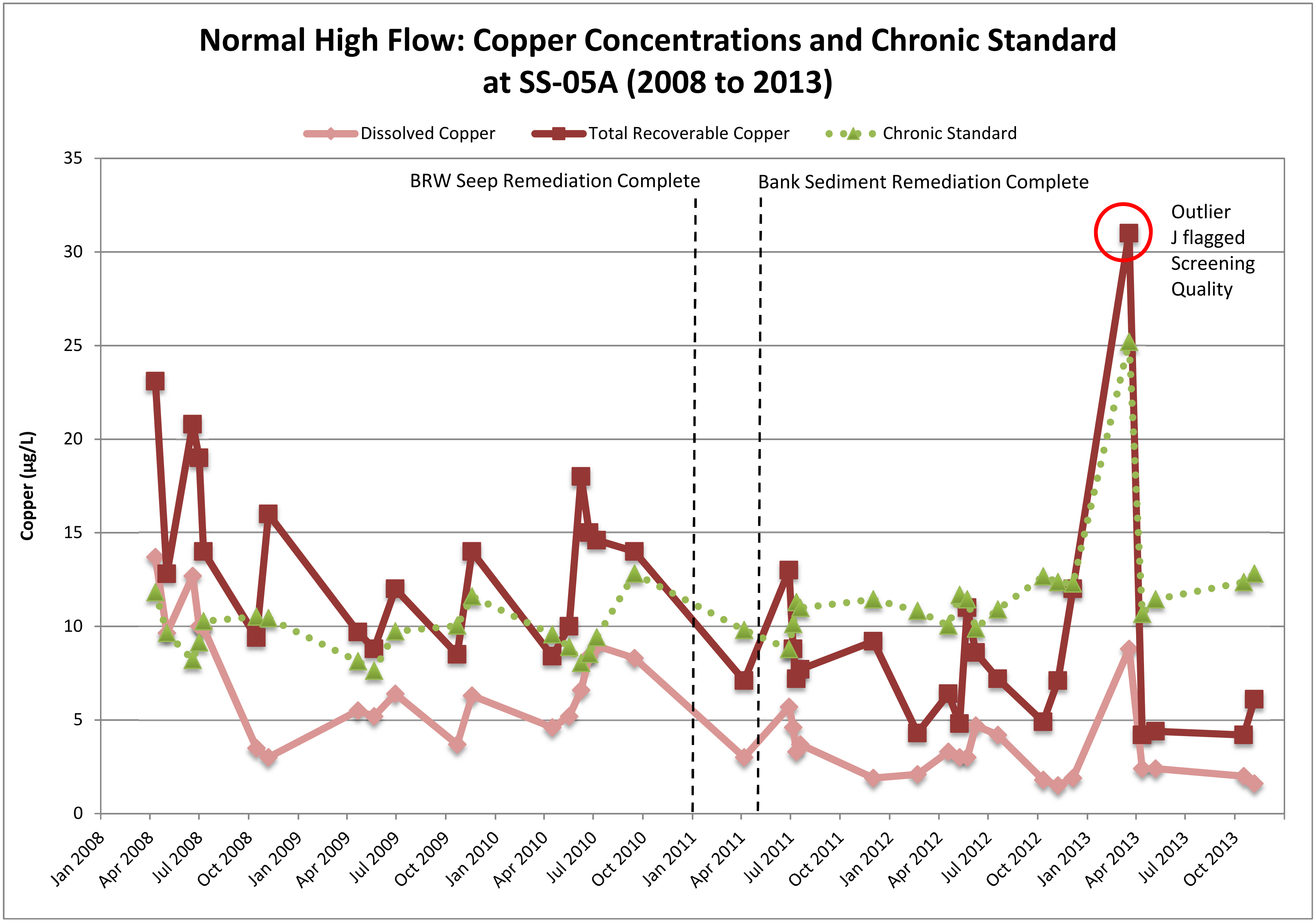

Figure 8-4
High Flow Copper Concentrations SS-05A - 2008 to 2013

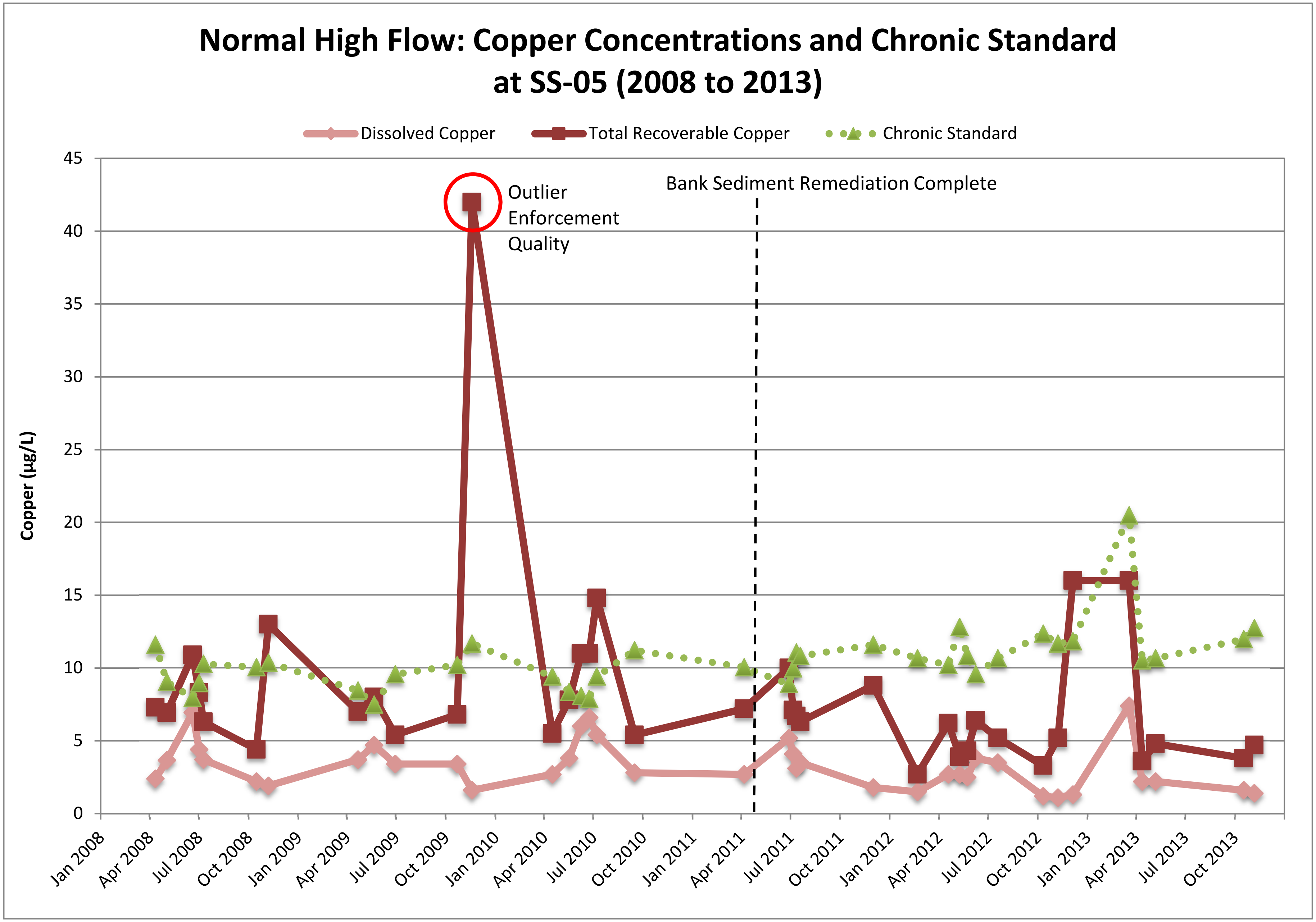

Figure 8-5
High Flow Copper Concentrations SS-05 - 2008 to 2013

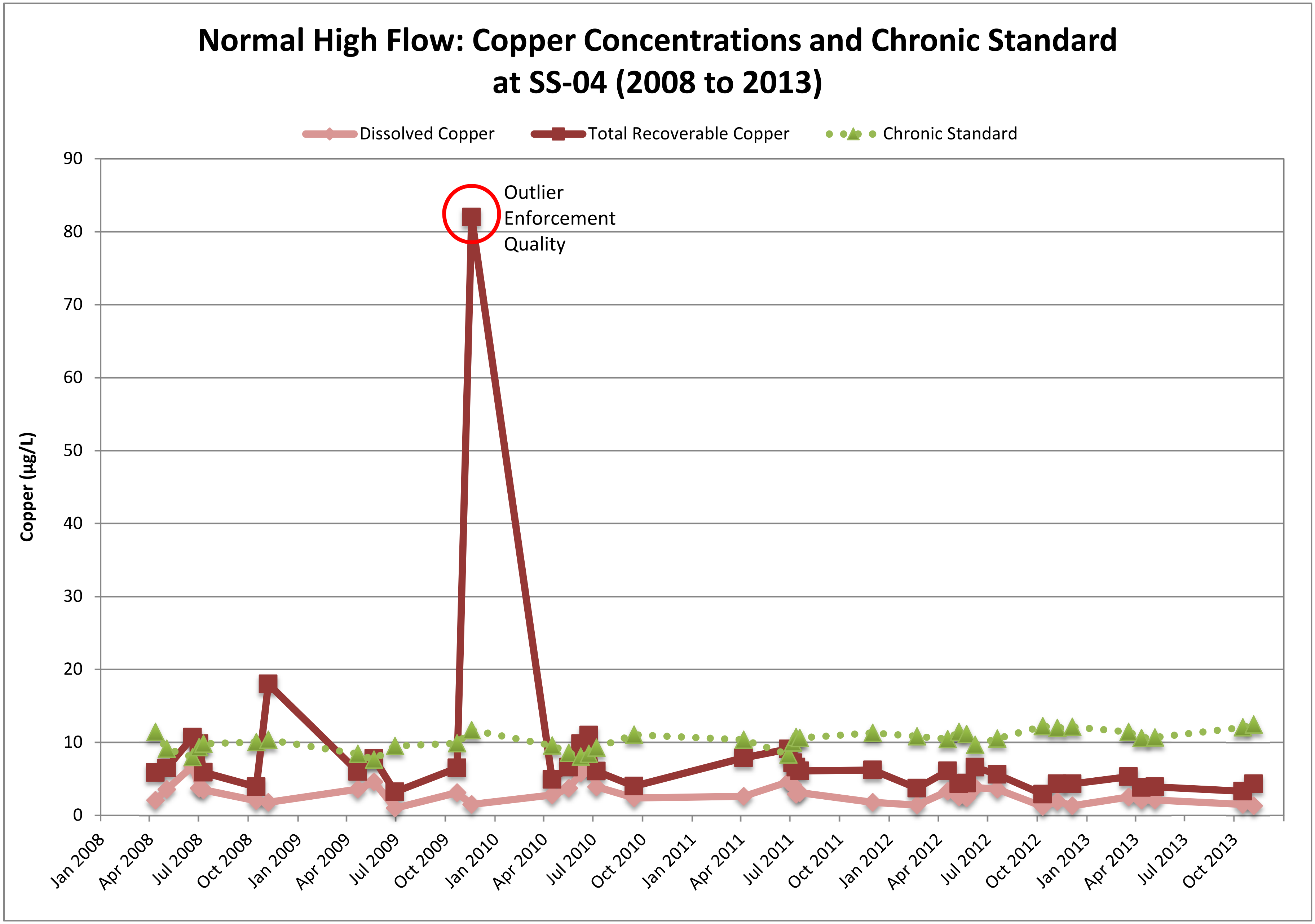

Figure 8-6
High Flow Copper Concentrations SS-04 - 2008 to 2013

Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

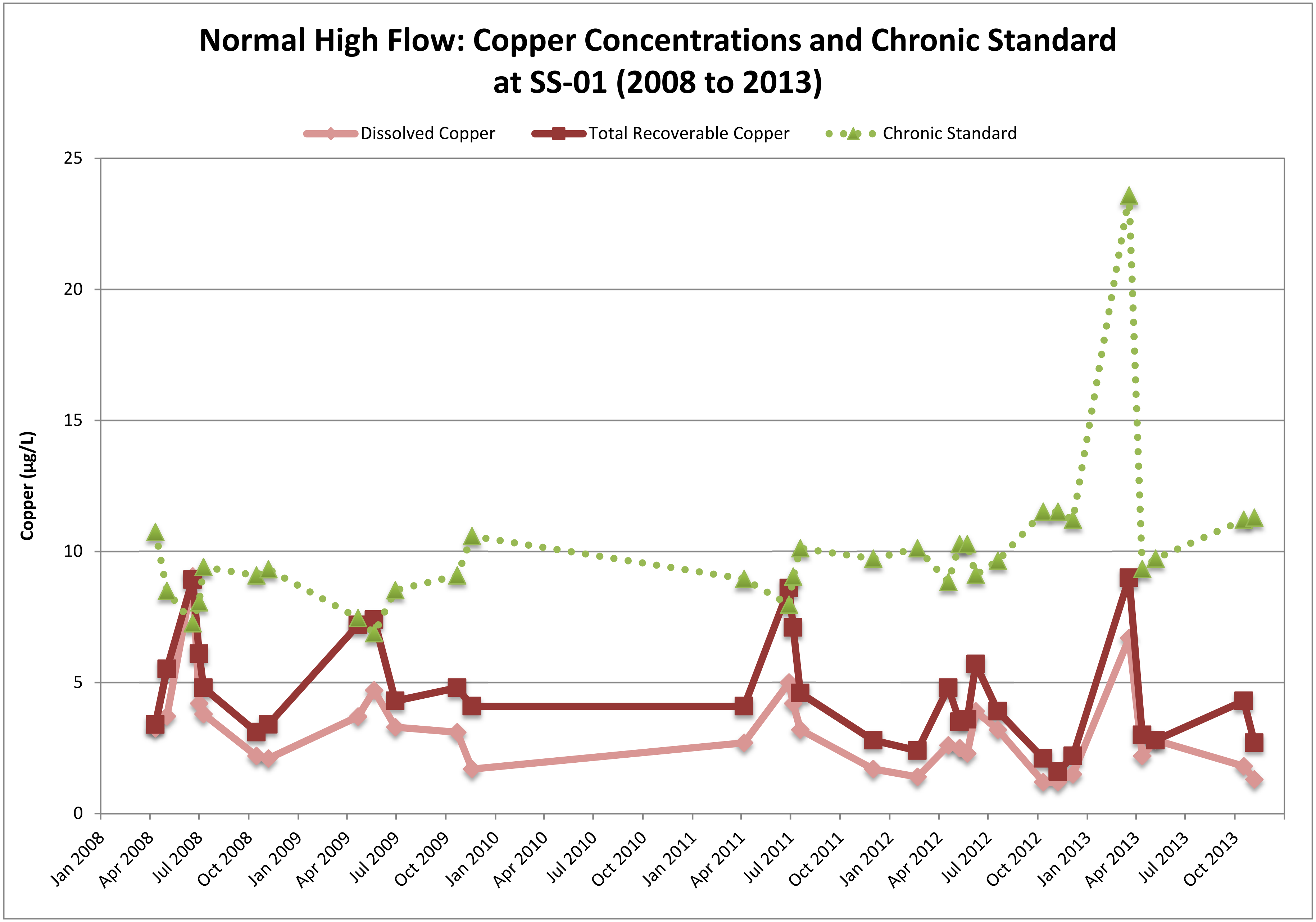

Figure 8-7
High Flow Copper Concentrations SS-01 - 2008 to 2013

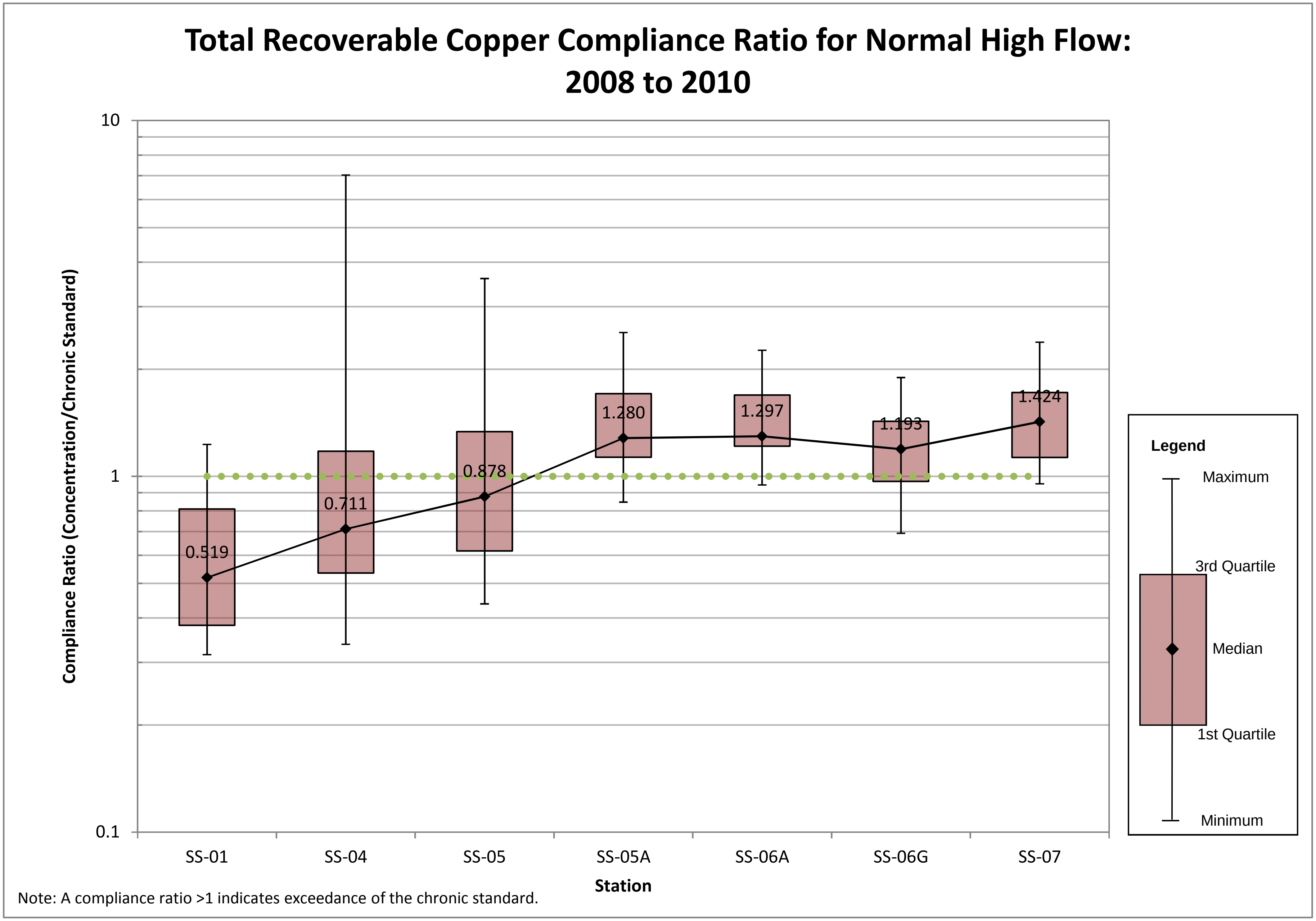

Figure 8-8
High Flow Total Copper Compliance Ratio - 2008 to 2010

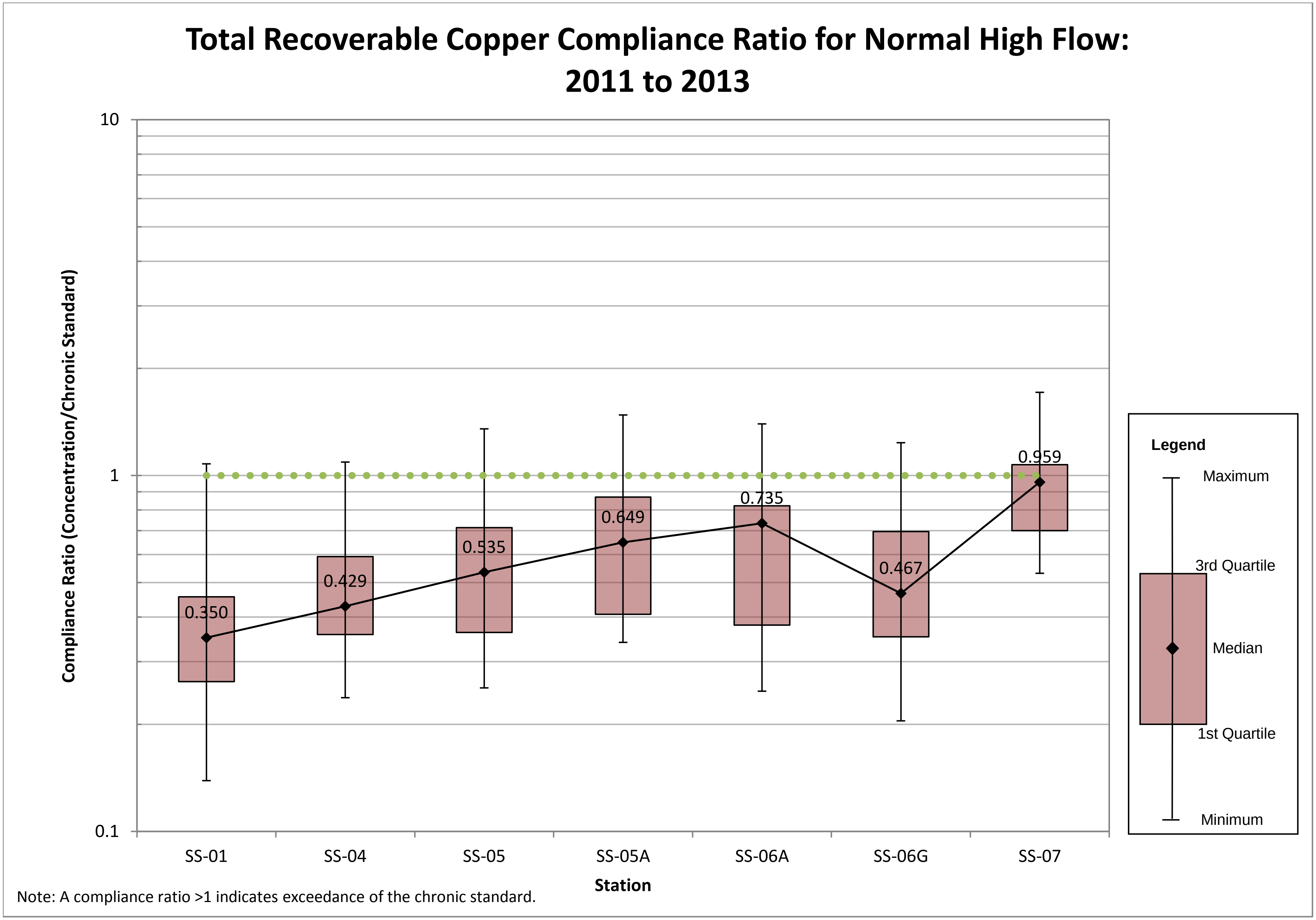

Figure 8-9
High Flow Total Copper Compliance Ratio - 2011 to 2013

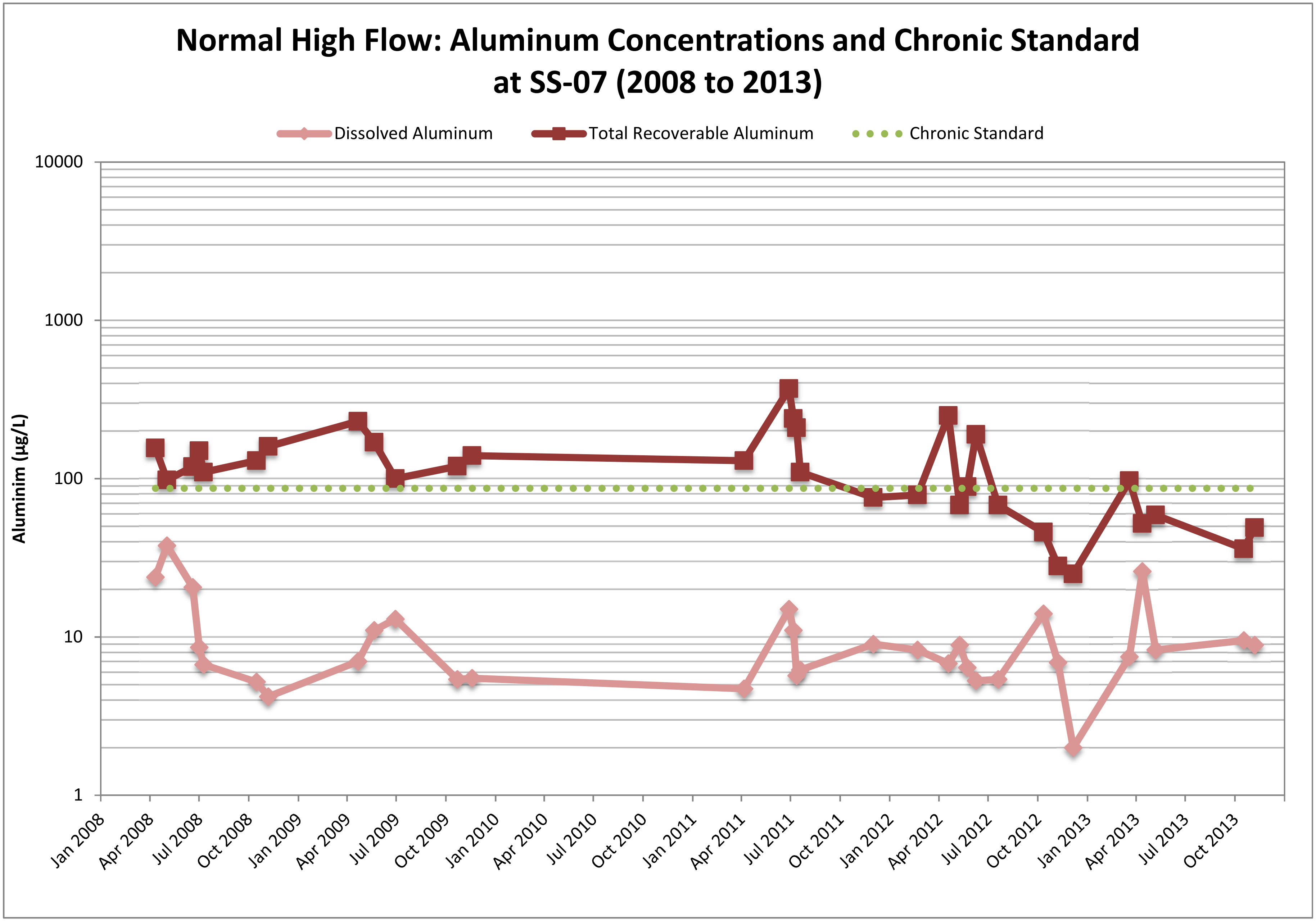

Figure 8-10
High Flow Aluminum Concentrations SS-07 - 2008 to 2013

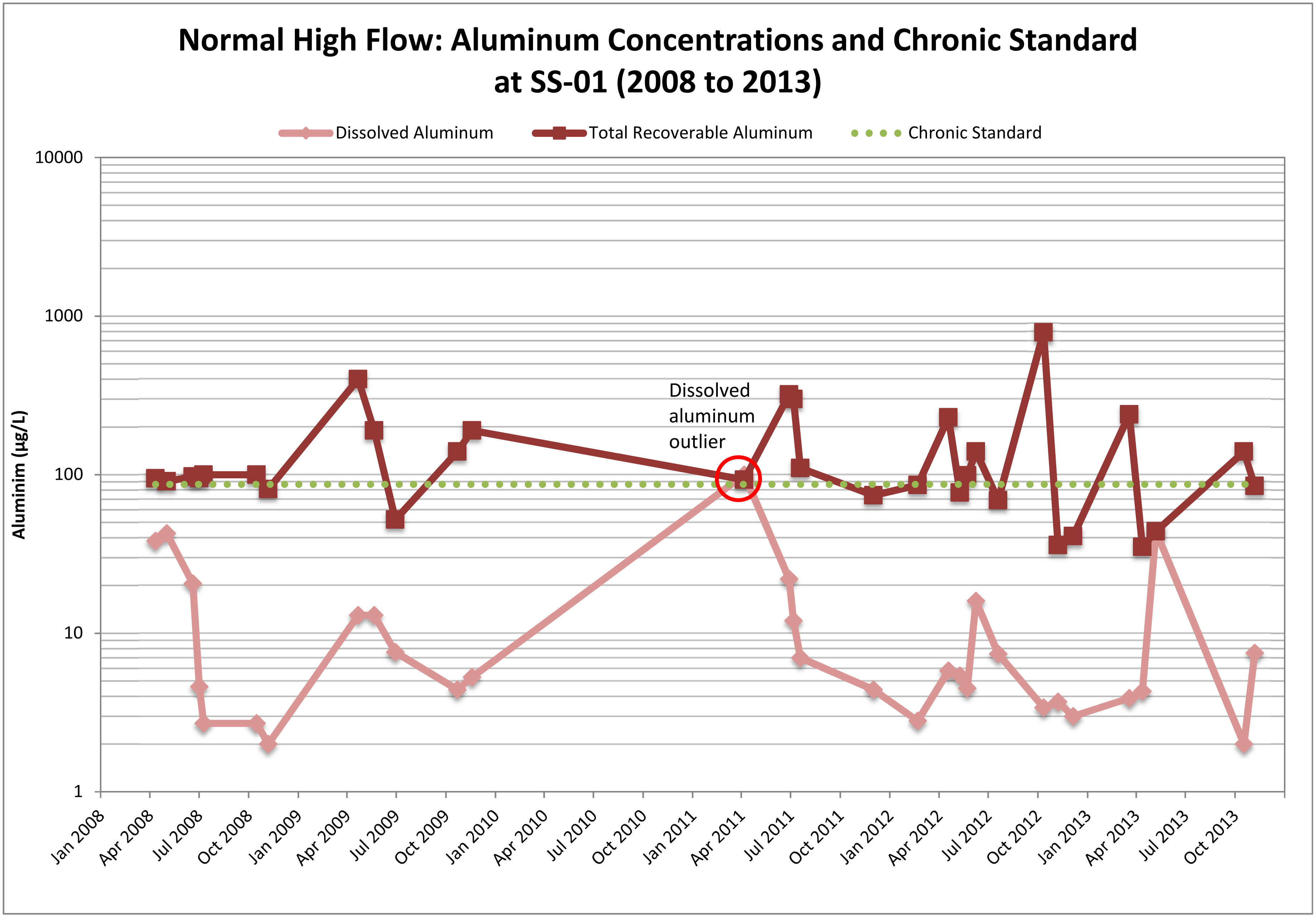

Figure 8-11
High Flow Aluminum Concentrations SS-01 - 2008 to 2013

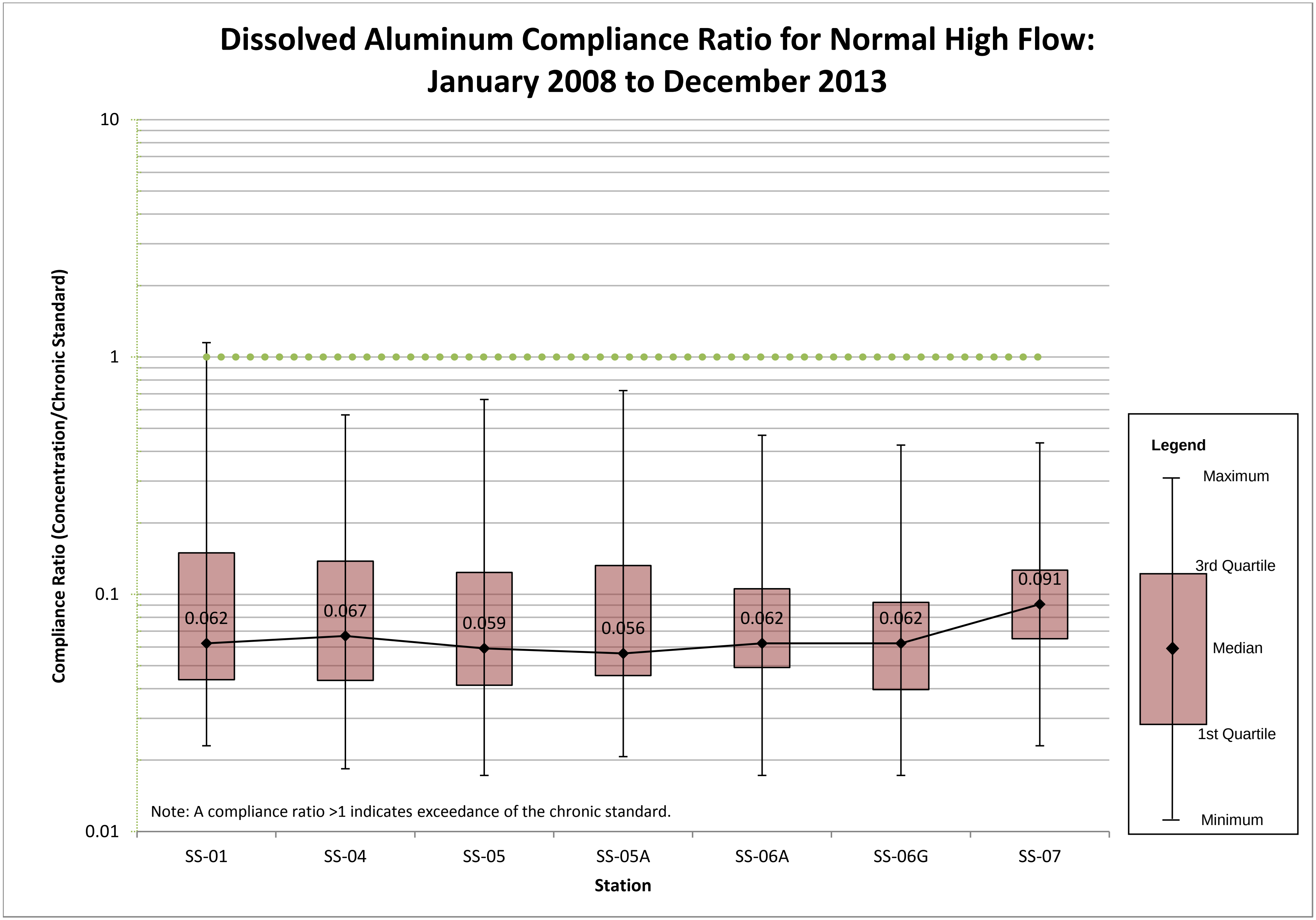

Figure 8-12
High Flow Dissolved Aluminum Compliance Ratio - 2008 to 2013

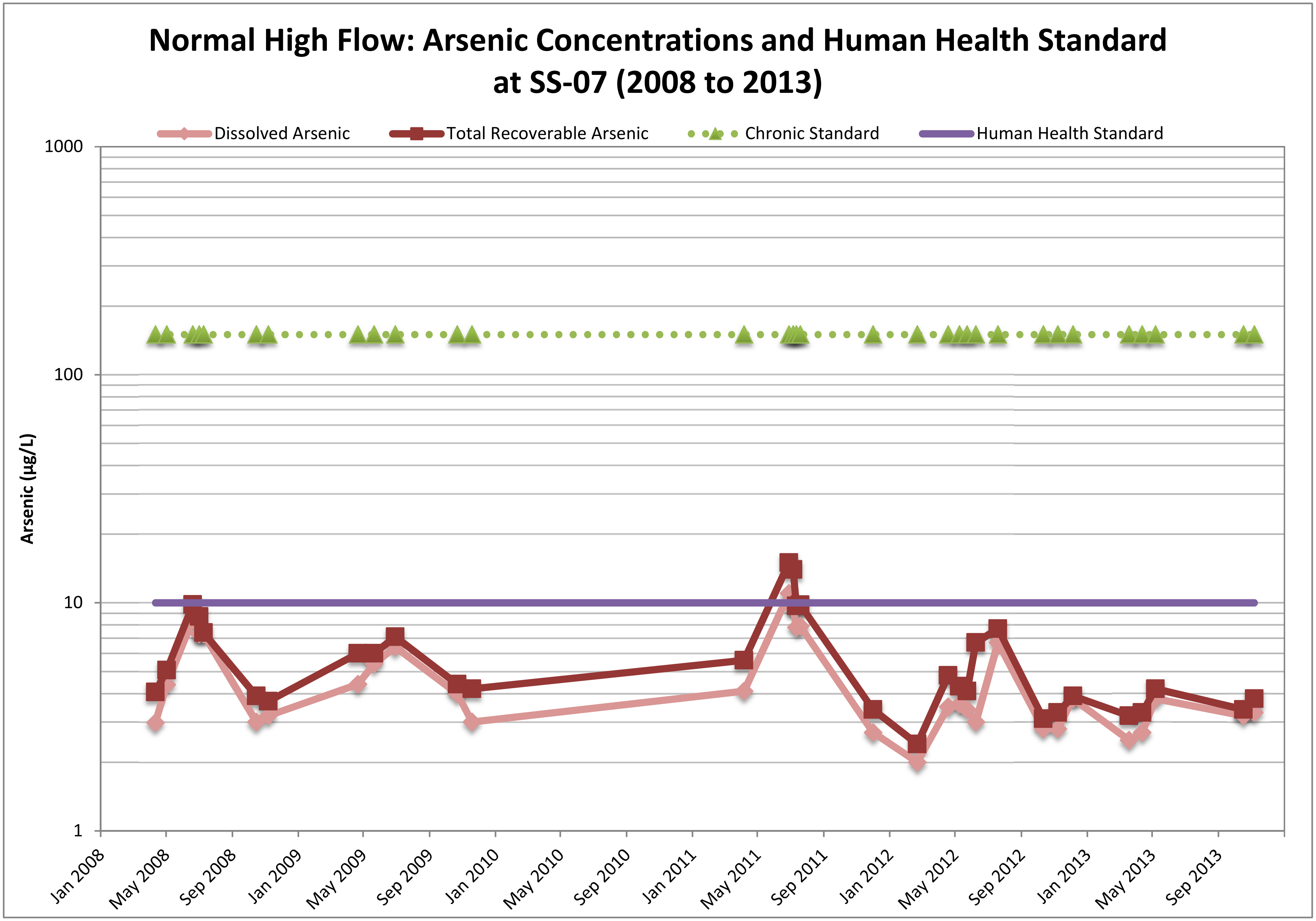

Figure 8-13
High Flow Arsenic Concentrations SS-07 - 2008 to 2013

Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

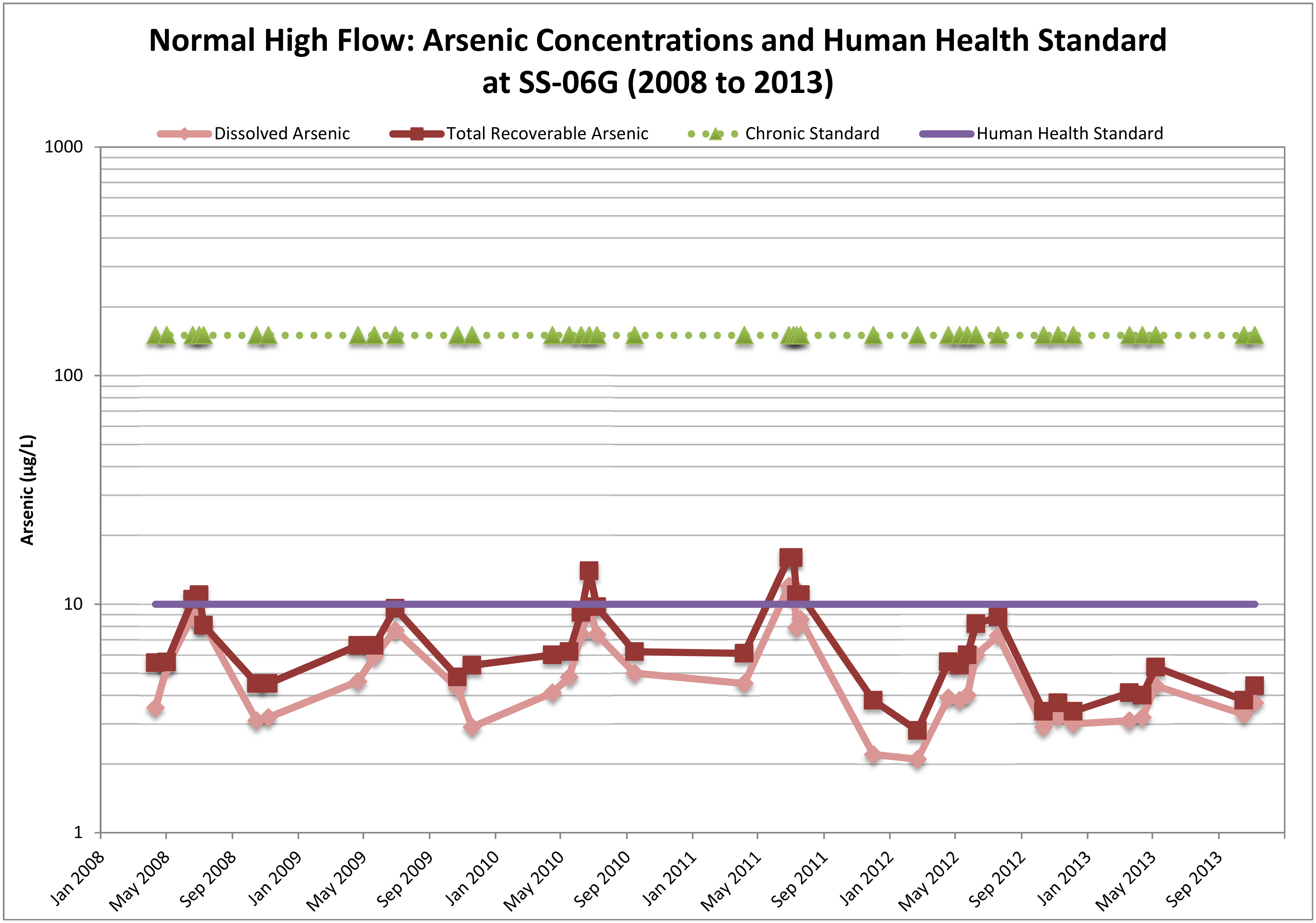

Figure 8-14
High Flow Arsenic Concentrations SS-06G - 2008 to 2013

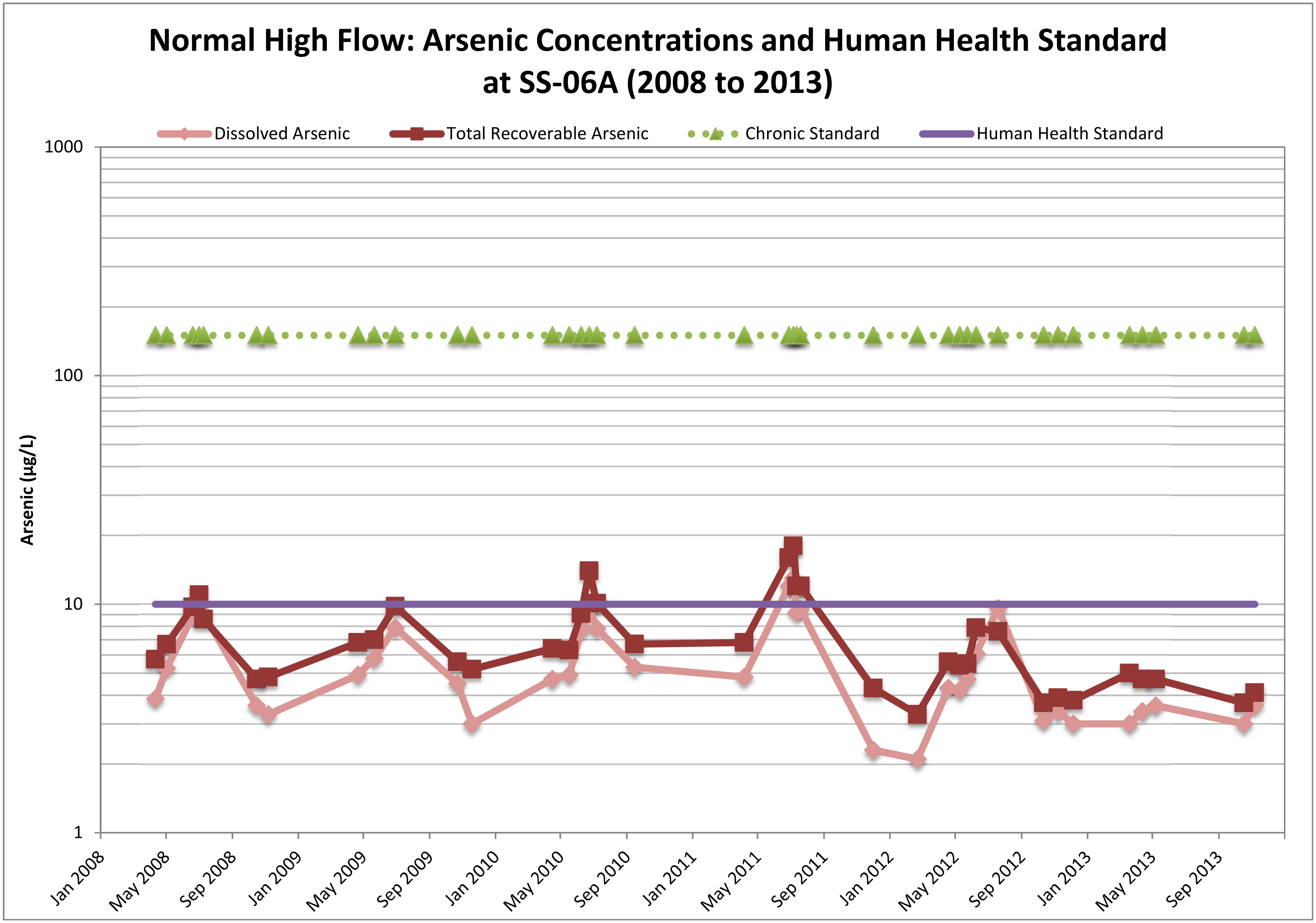

Figure 8-15
High Flow Arsenic Concentrations SS-06A - 2008 to 2013

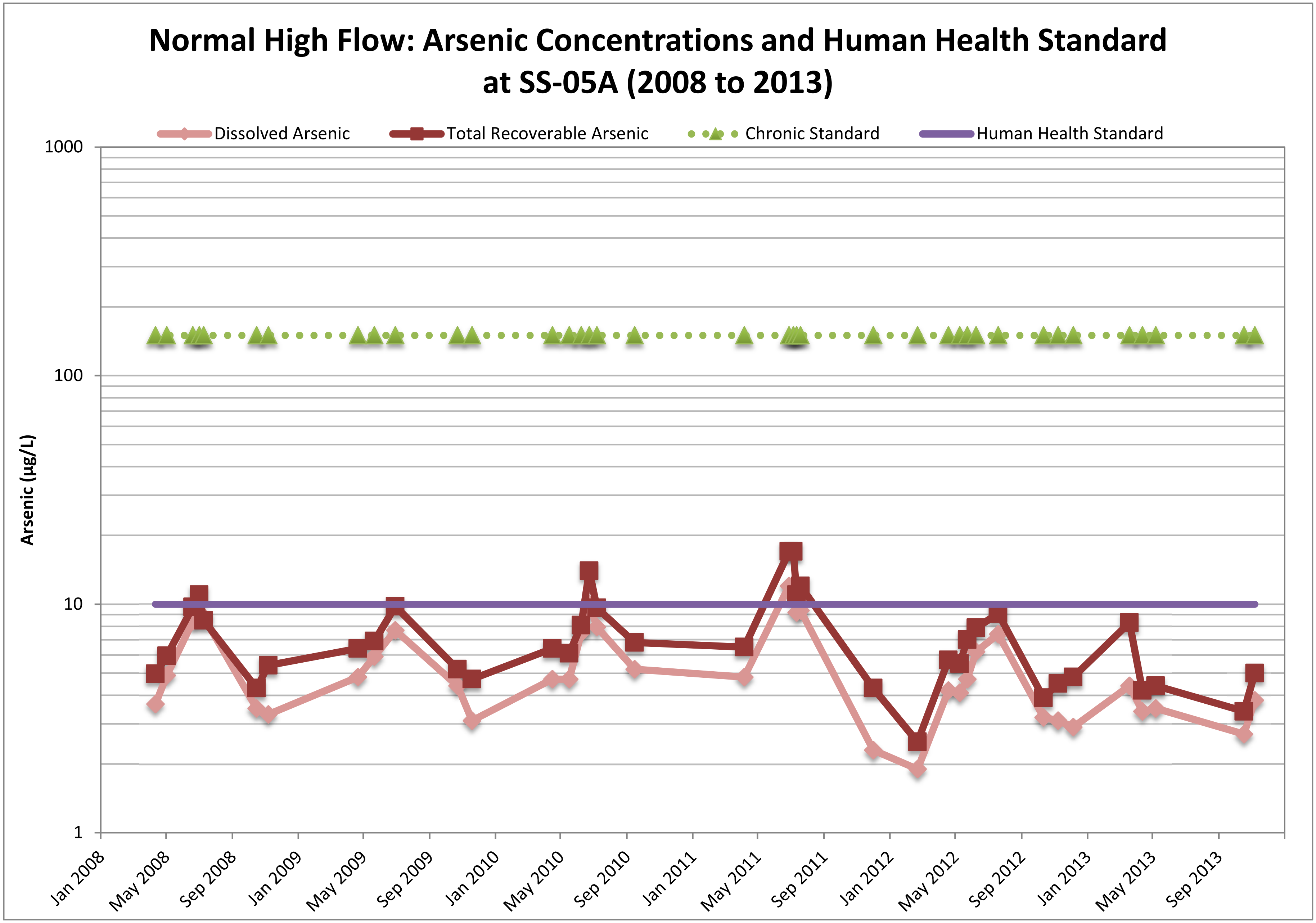

Figure 8-16
High Flow Arsenic Concentrations SS-05A - 2008 to 2013

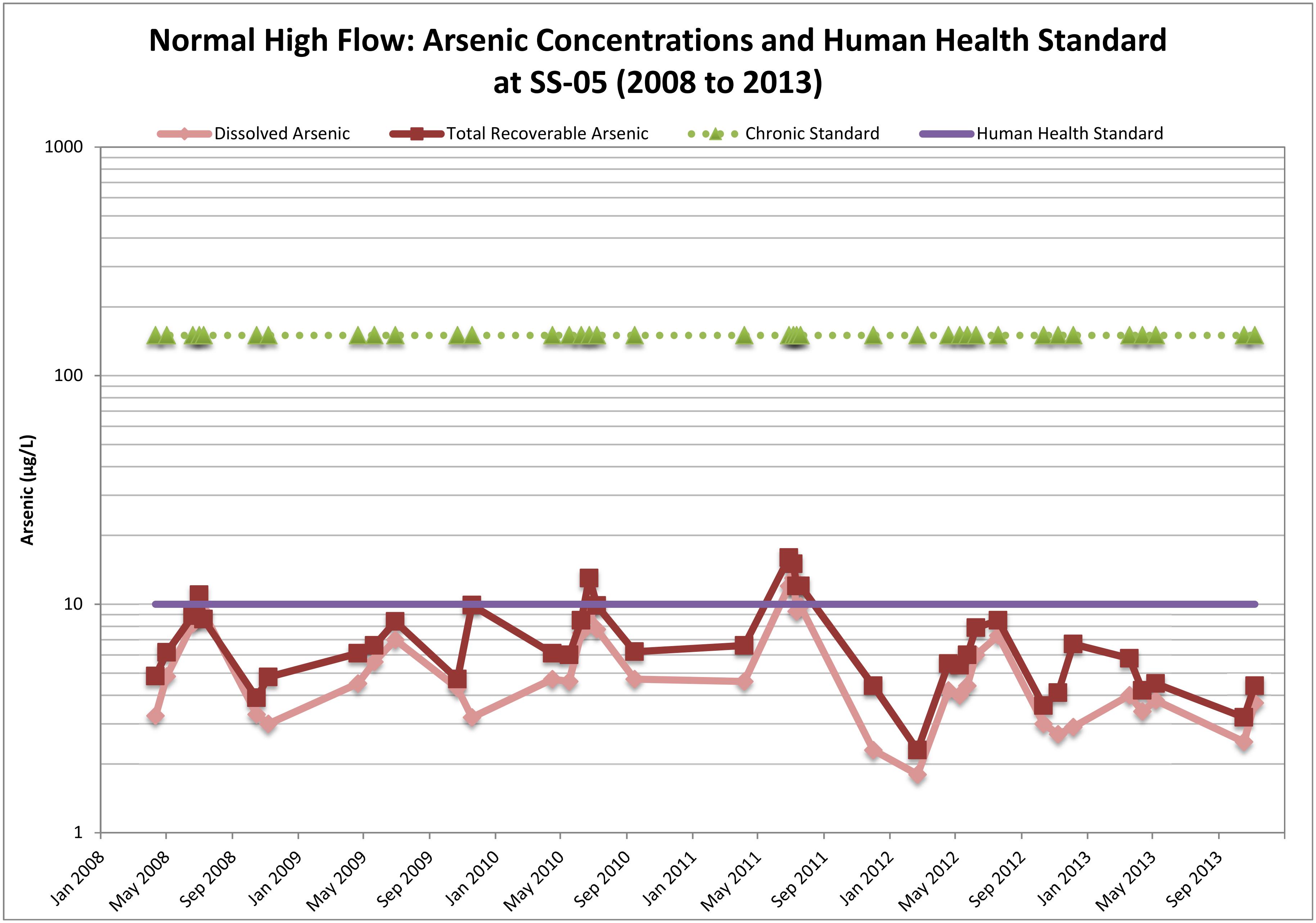

Figure 8-17
High Flow Arsenic Concentrations SS-05 - 2008 to 2013

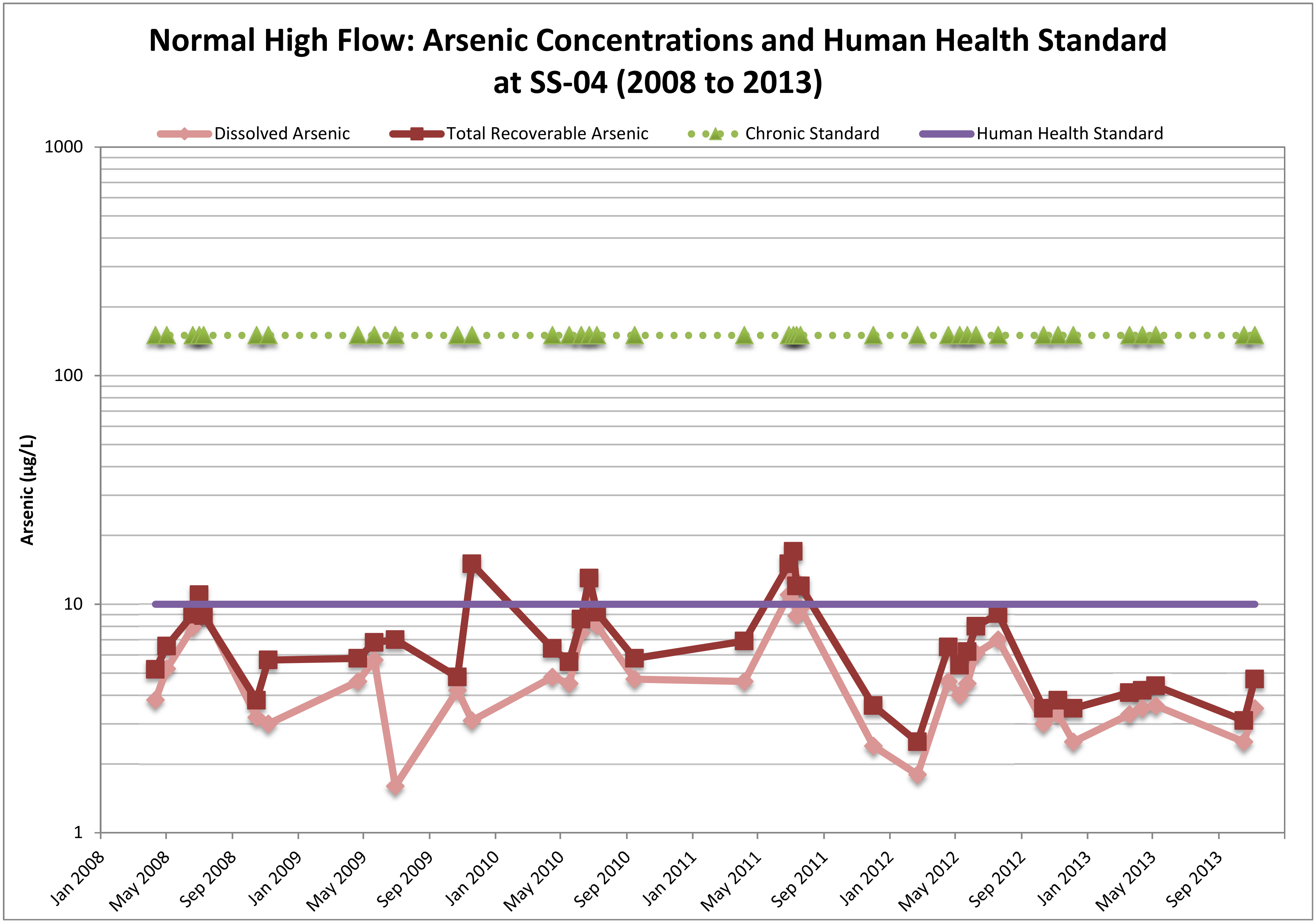

Figure 8-18
High Flow Arsenic Concentrations SS-04 - 2008 to 2013

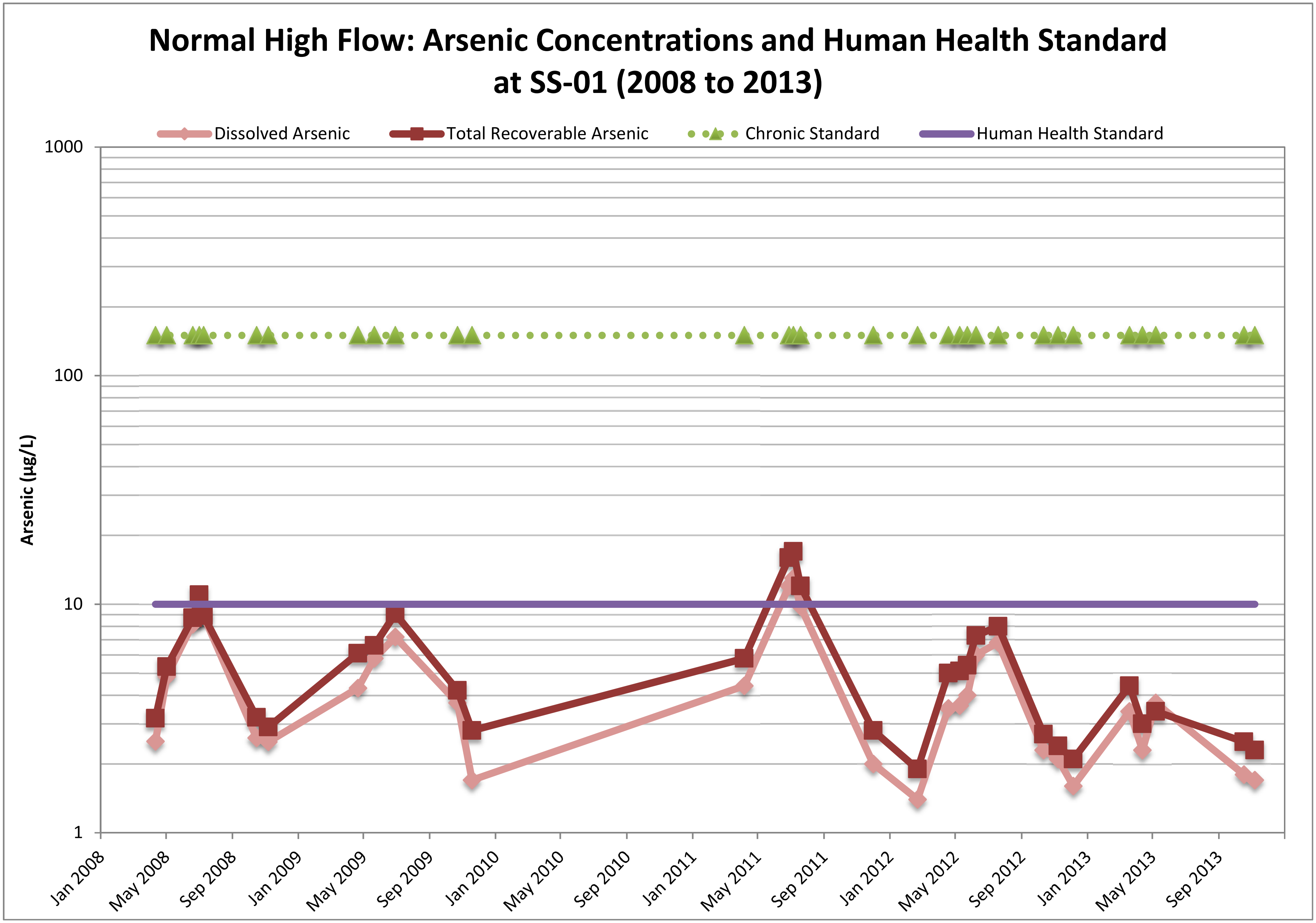

Figure 8-19
High Flow Arsenic Concentrations SS-01 - 2008 to 2013

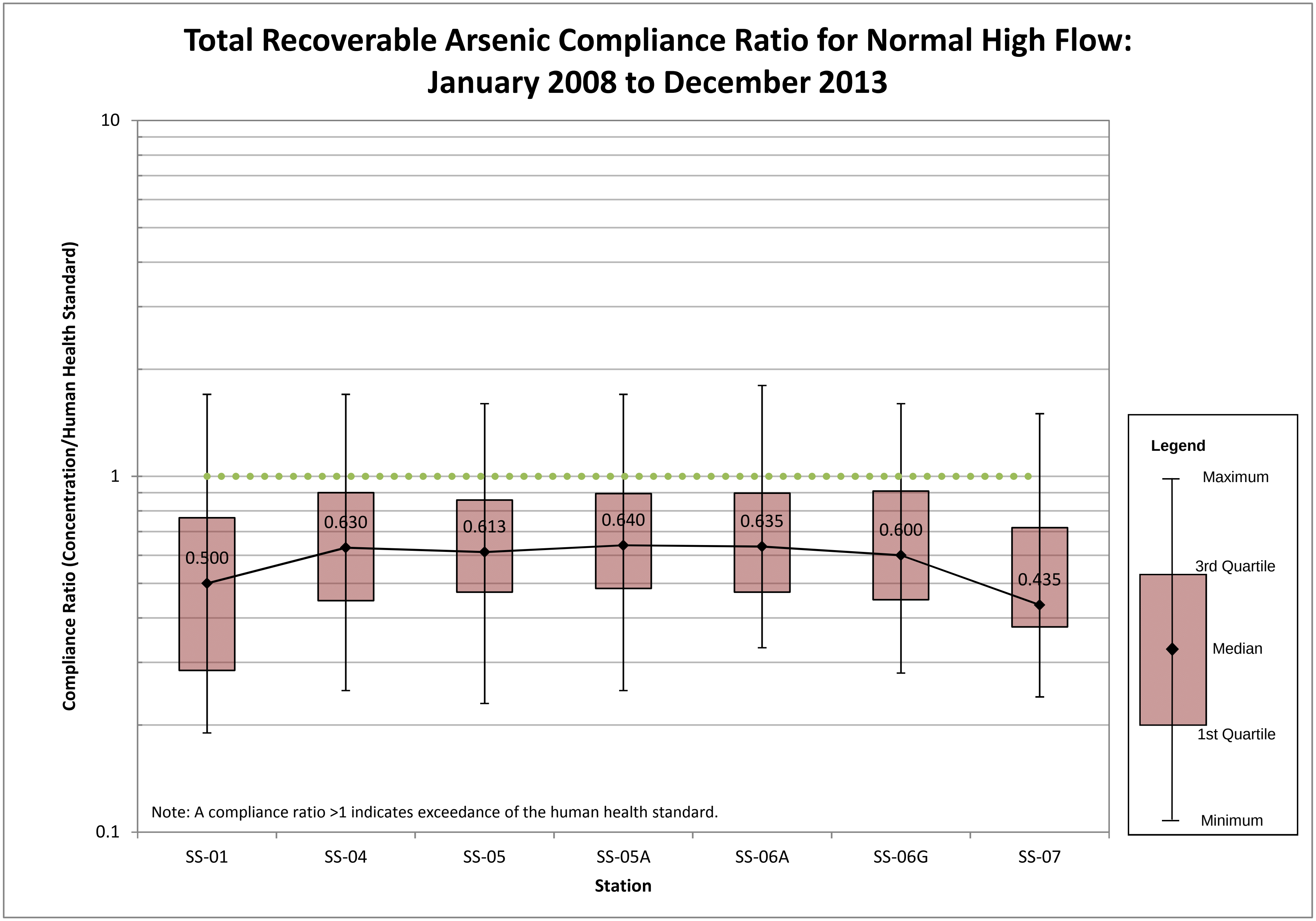

Figure 8-20
High Flow Total Recoverable Arsenic Compliance - 2008 to 2013

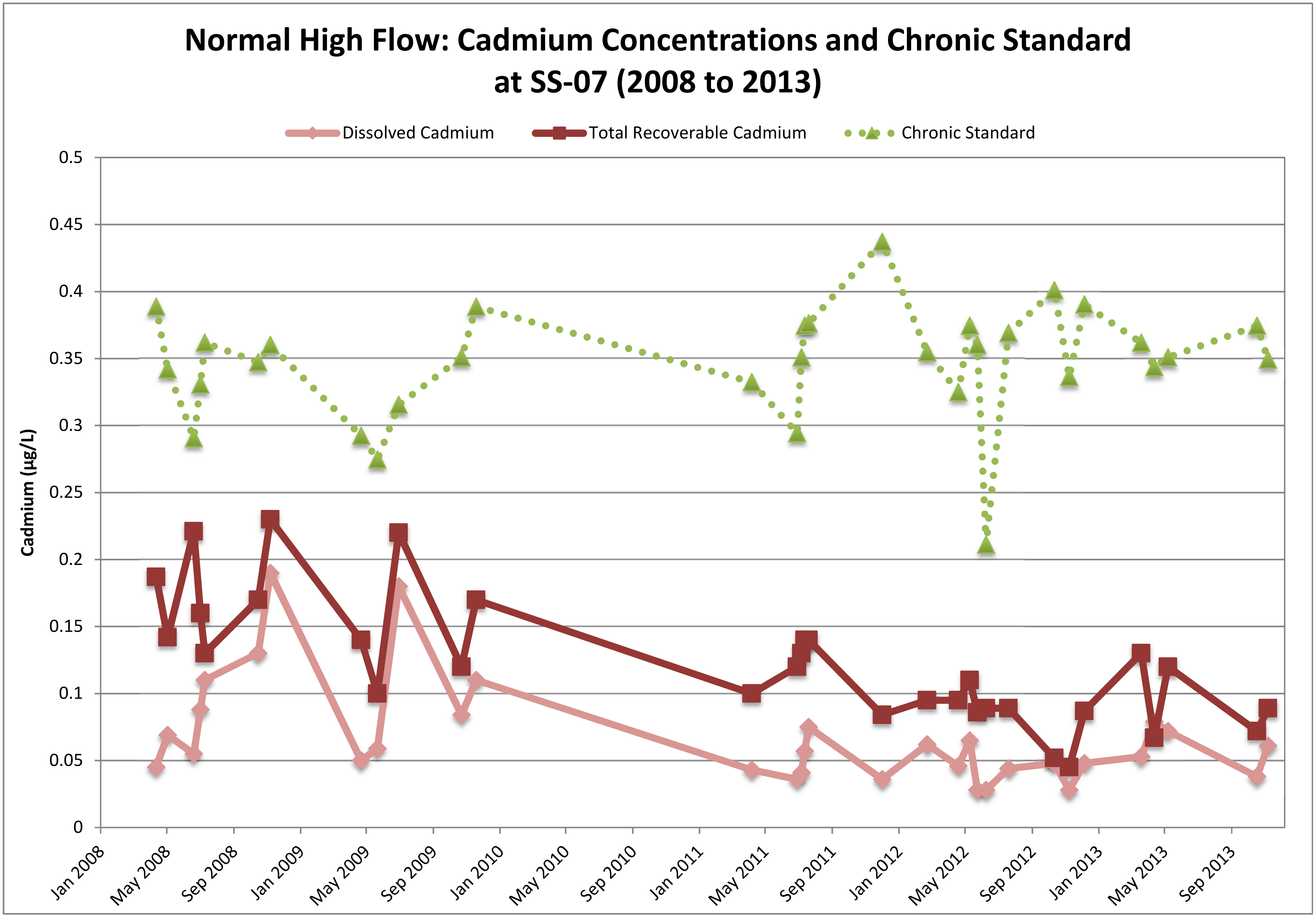

Figure 8-21
High Flow Cadmium Concentrations SS-07 - 2008 to 2013

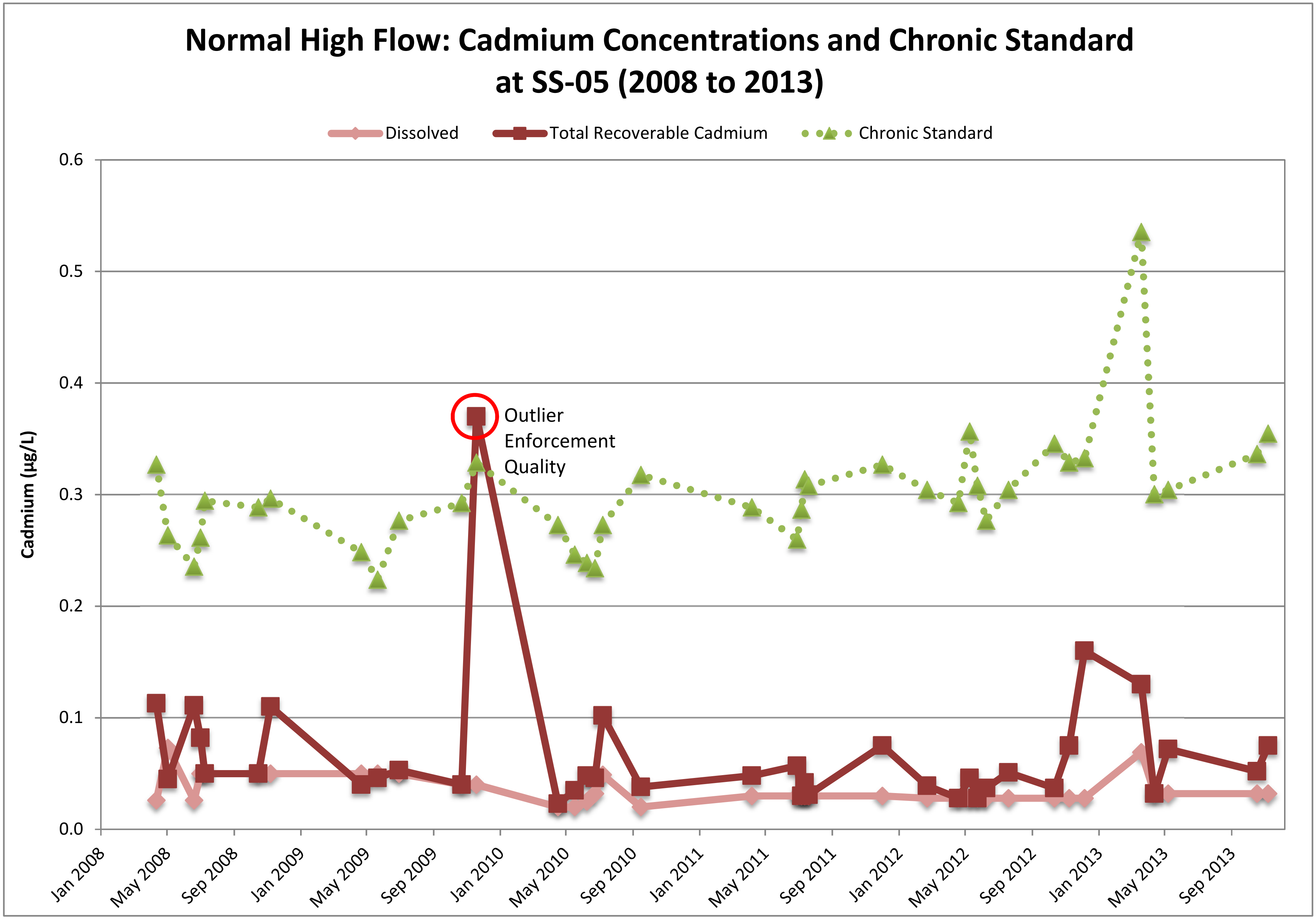

Figure 8-22
High Flow Cadmium Concentrations SS-05 - 2008 to 2013

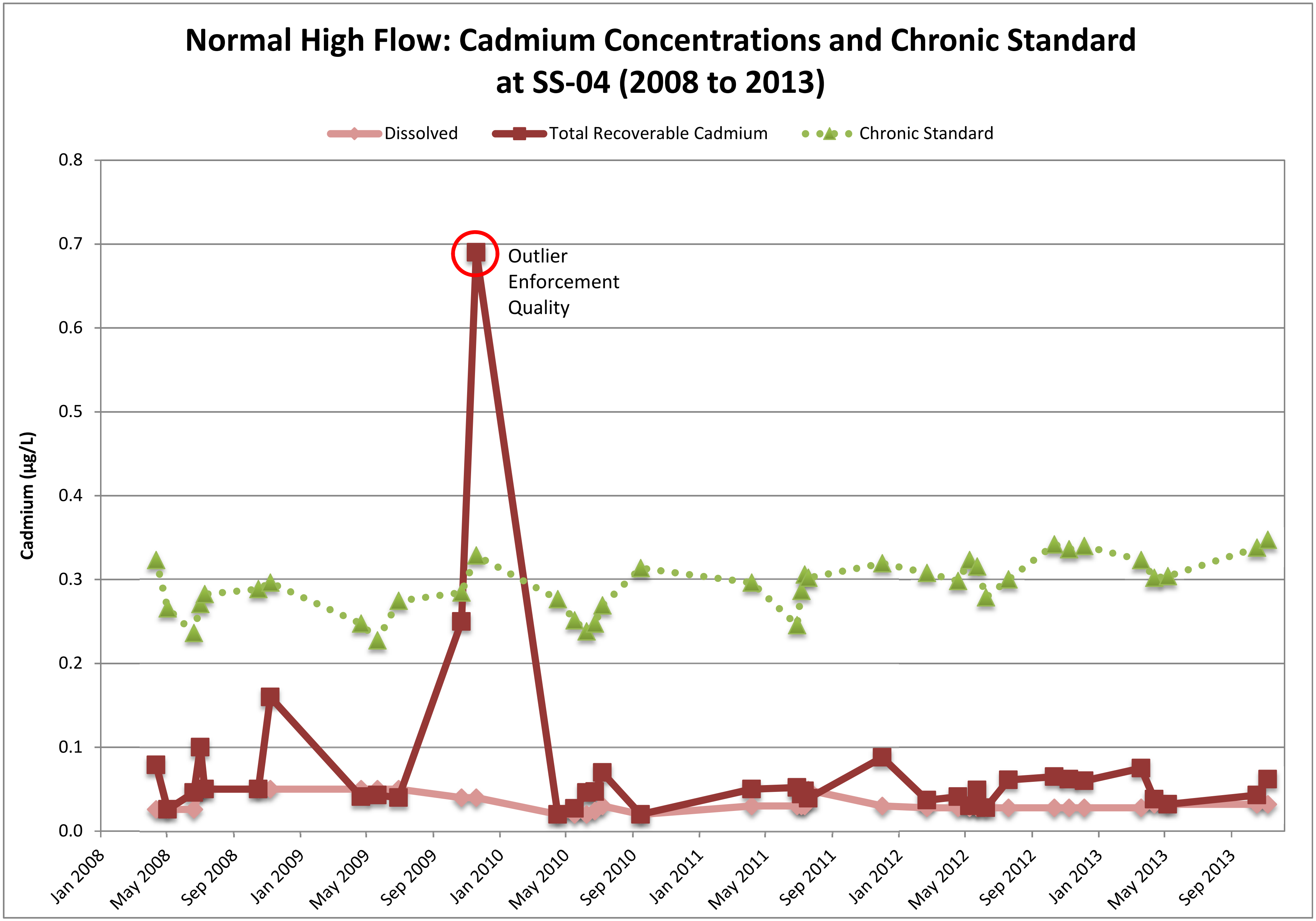

Figure 8-23
High Flow Cadmium Concentrations SS-04 - 2008 to 2013

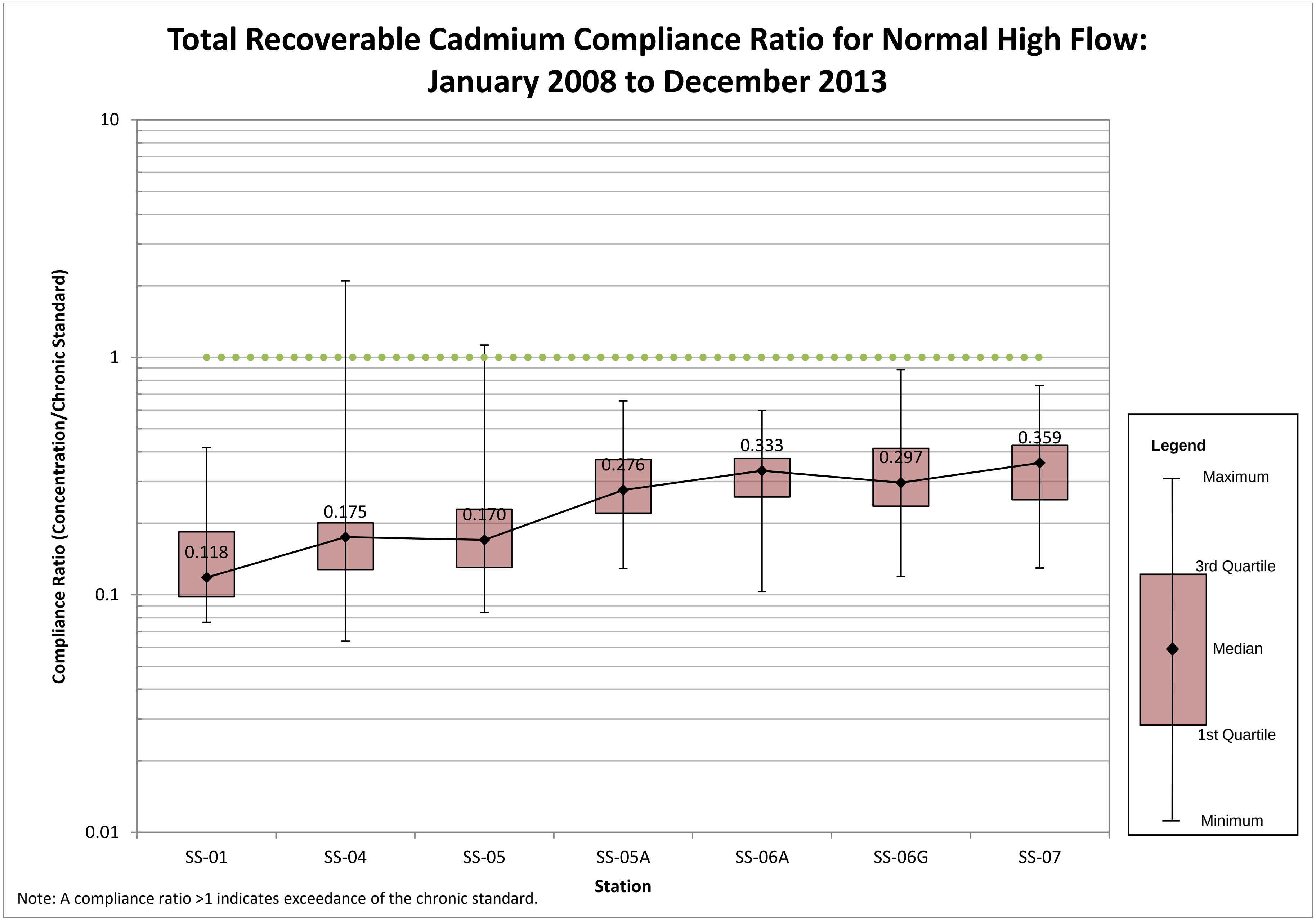

Figure 8-24
High Flow Total Cadmium Compliance Ratio - 2008 to 2013

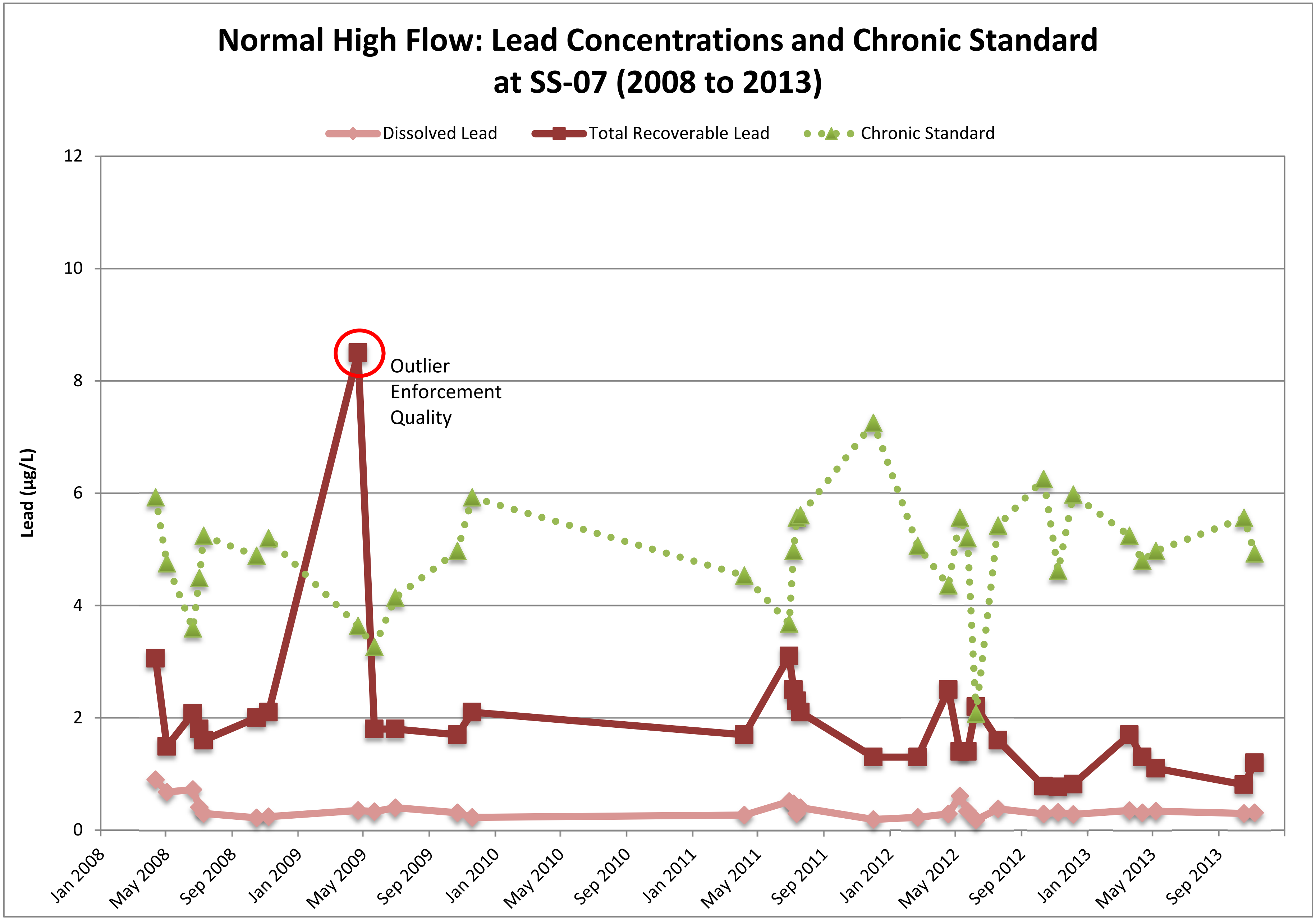

Figure 8-25
High Flow Lead Concentrations SS-07 - 2008 to 2013

Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

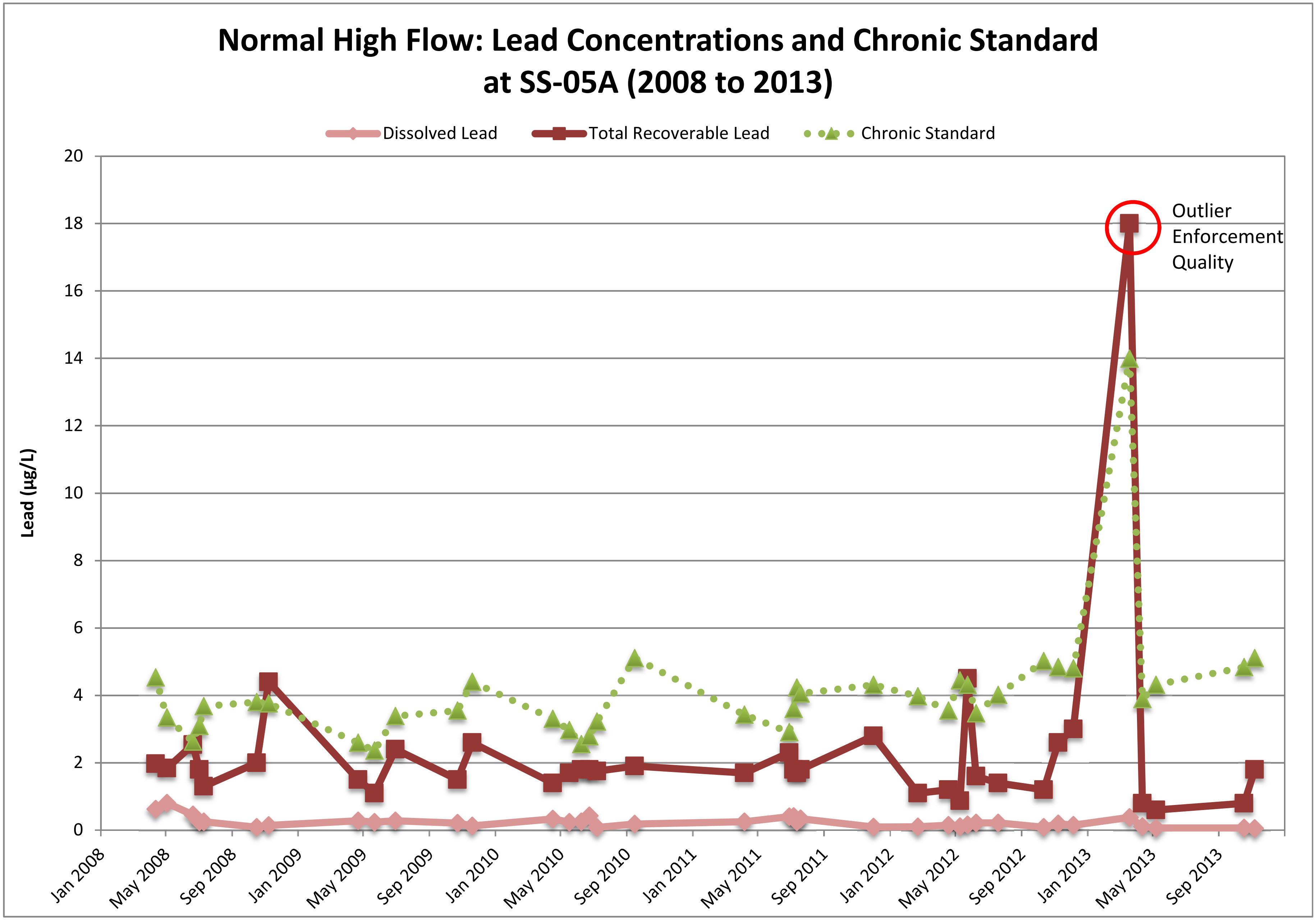

Figure 8-26
High Flow Lead Concentrations SS-05A - 2008 to 2013

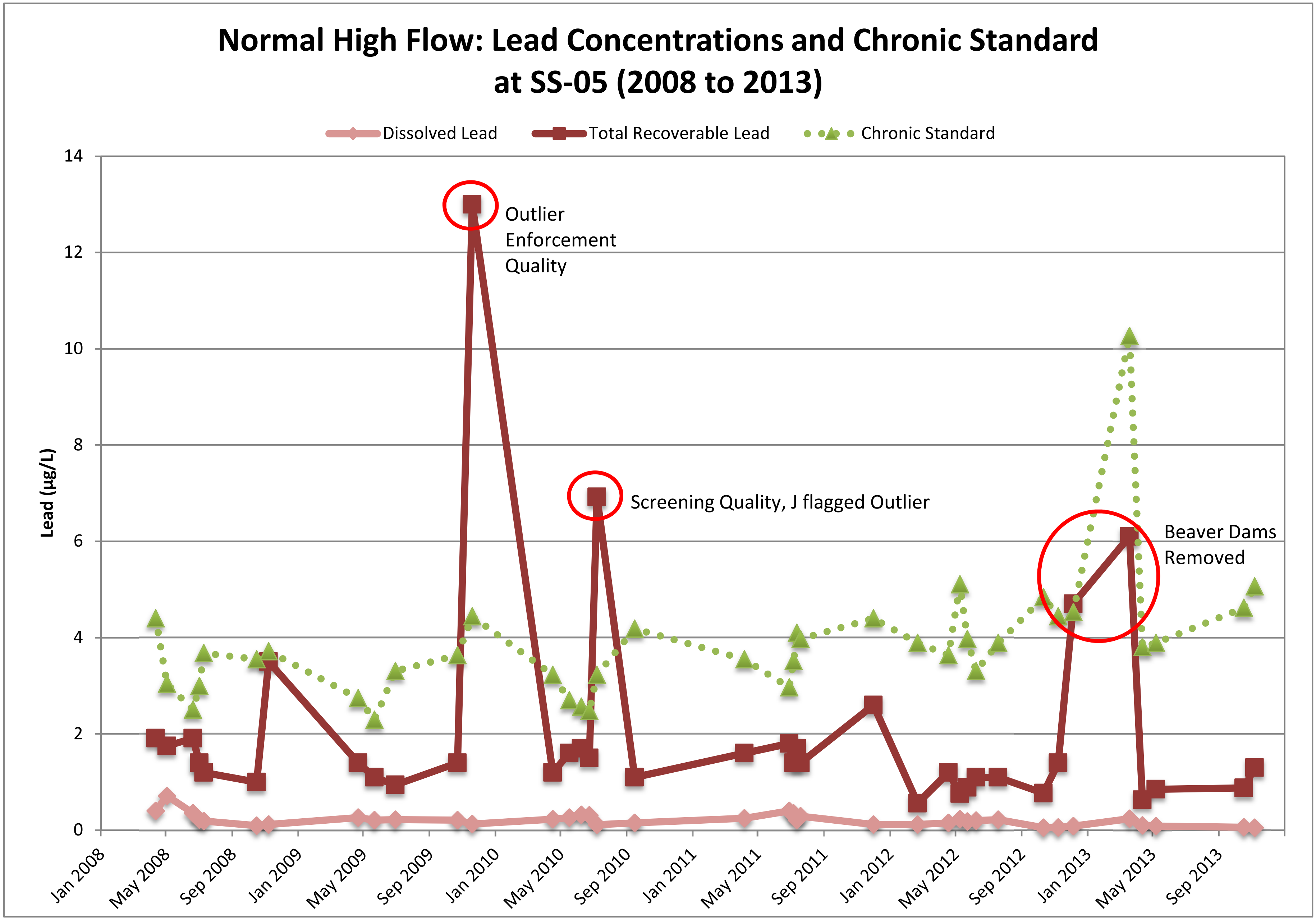

Figure 8-27
High Flow Lead Concentrations SS-05 - 2008 to 2013

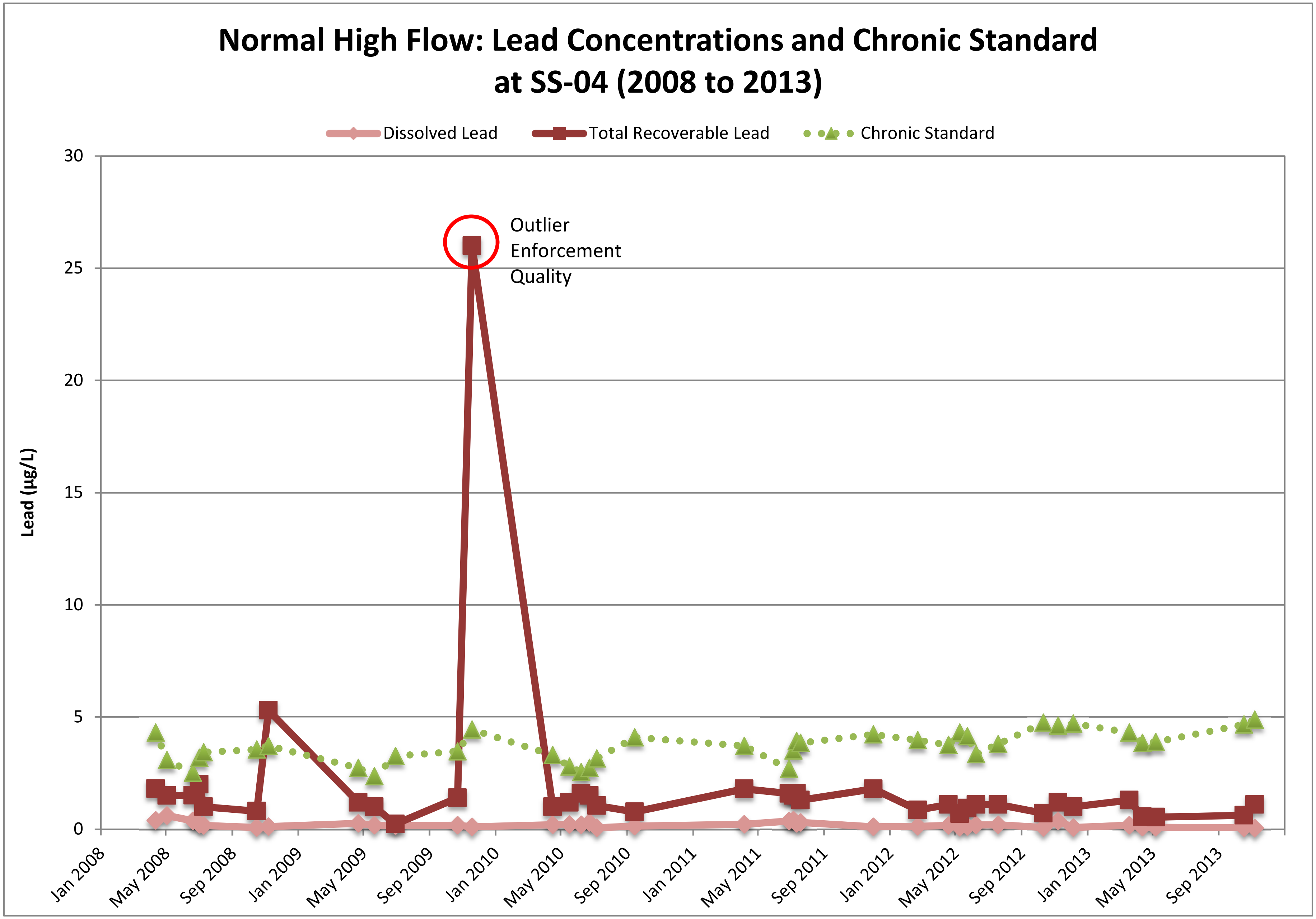

Figure 8-28
High Flow Lead Concentrations SS-04 - 2008 to 2013

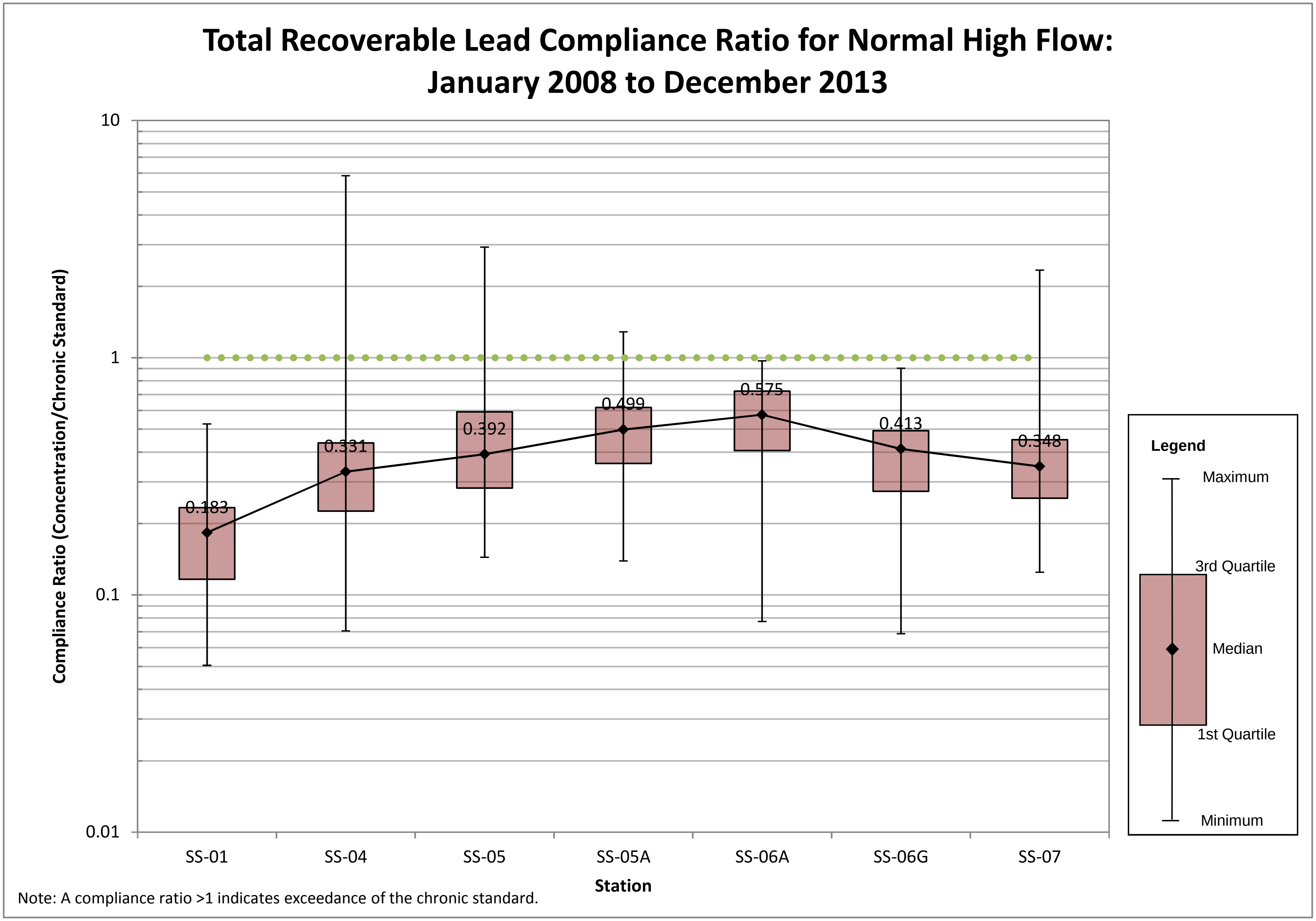

Figure 8-29
High Flow Total Recoverable Lead Compliance Ratio - 2008 to 2013

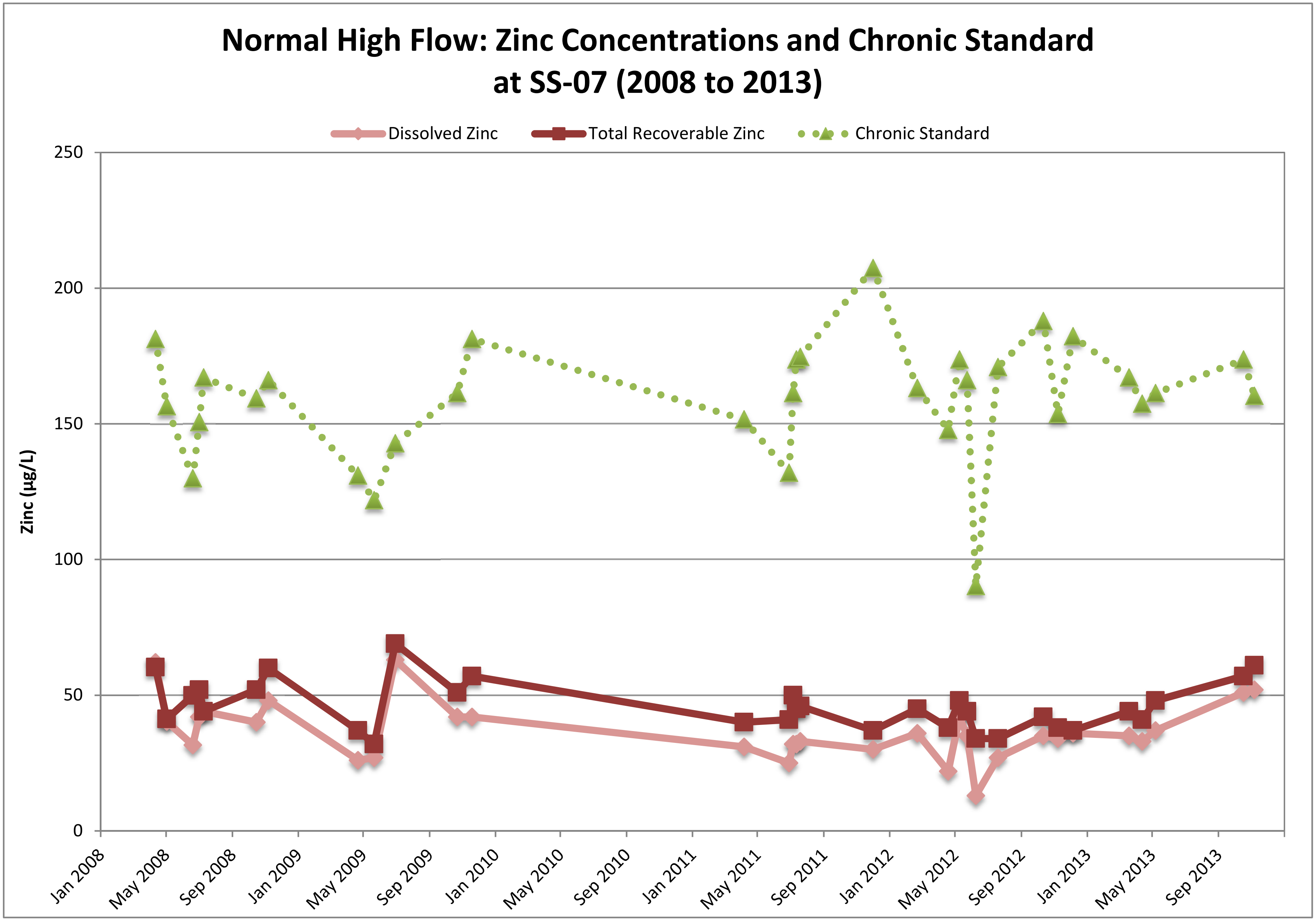

Figure 8-30
High Flow Zinc Concentrations SS-07 - 2008 to 2013

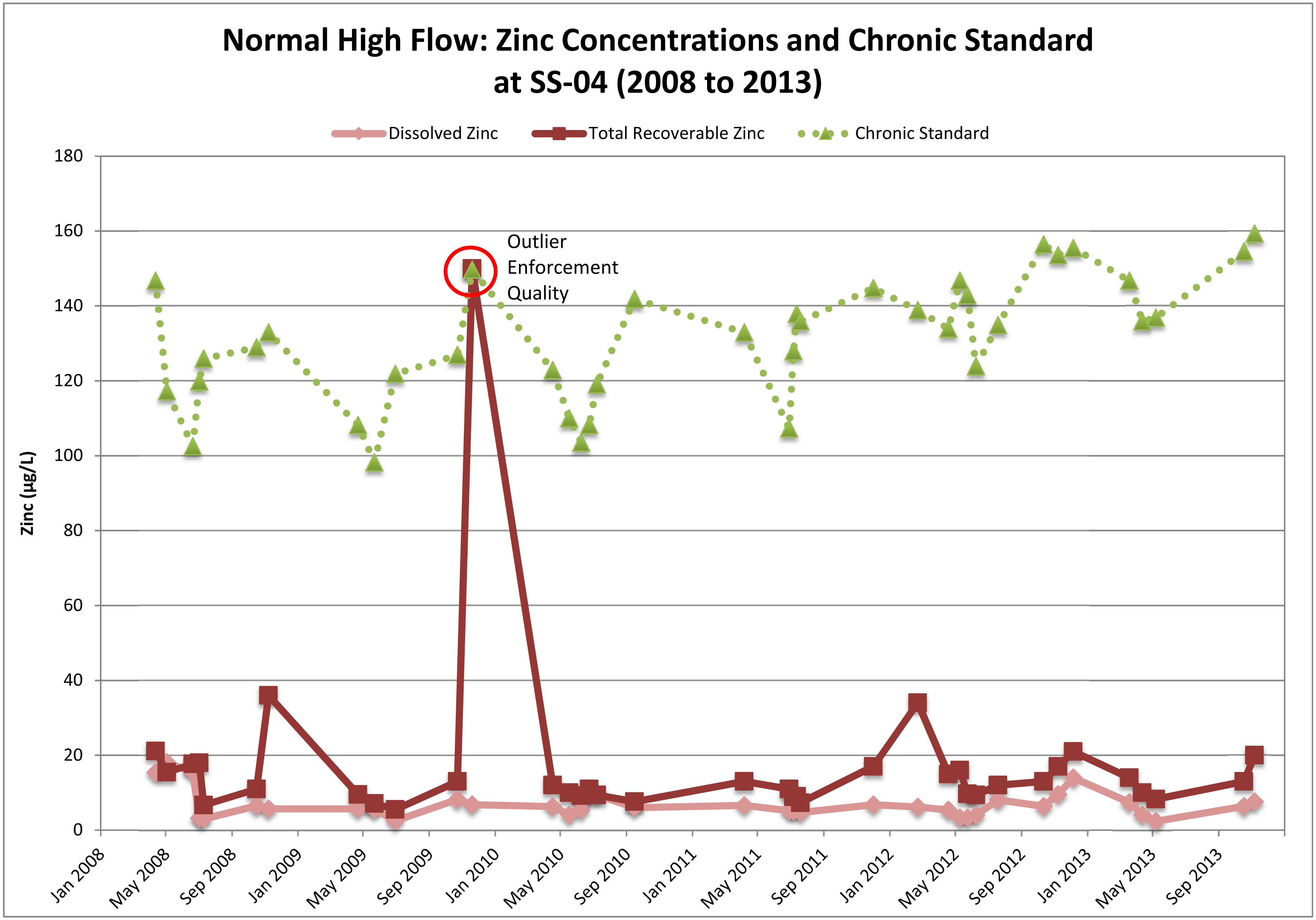

Figure 8-31
High Flow Zinc Concentrations SS-04 - 2008 to 2013

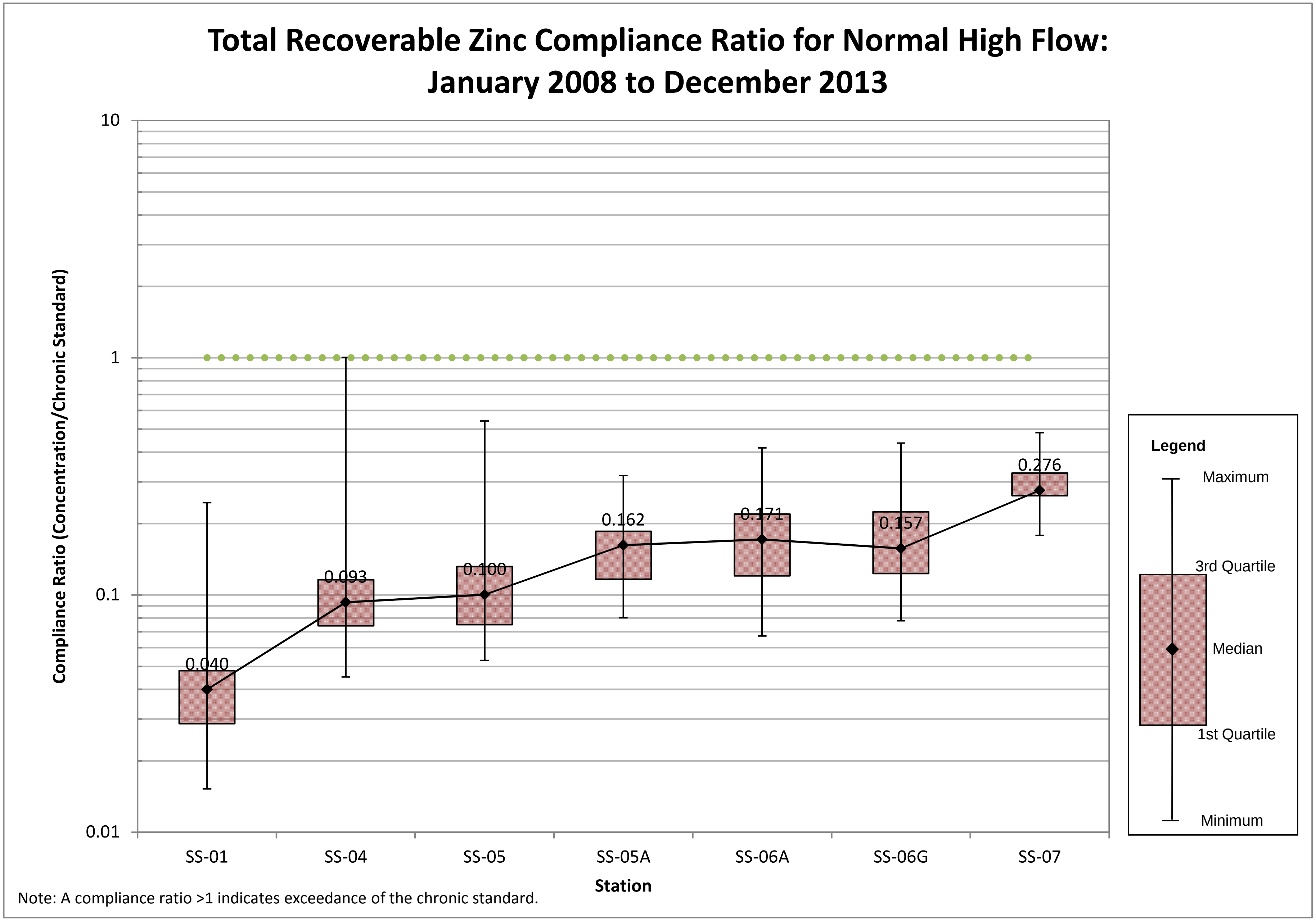

Figure 8-32
High Flow Total Recoverable Zinc Compliance Ratio - 2008 to 2013

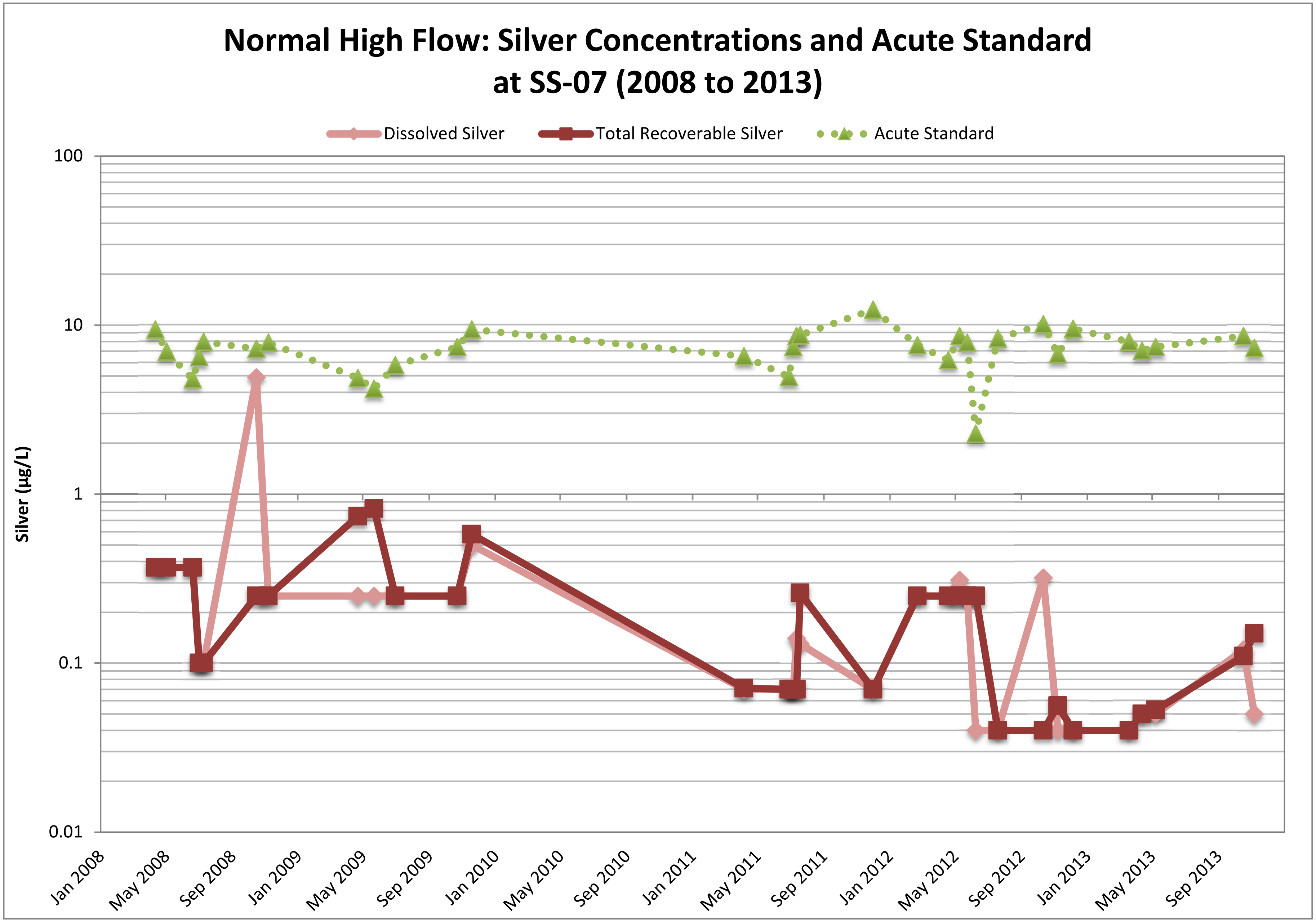

Figure 8-33
High Flow Silver Concentrations SS-07 - 2008 to 2013

Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

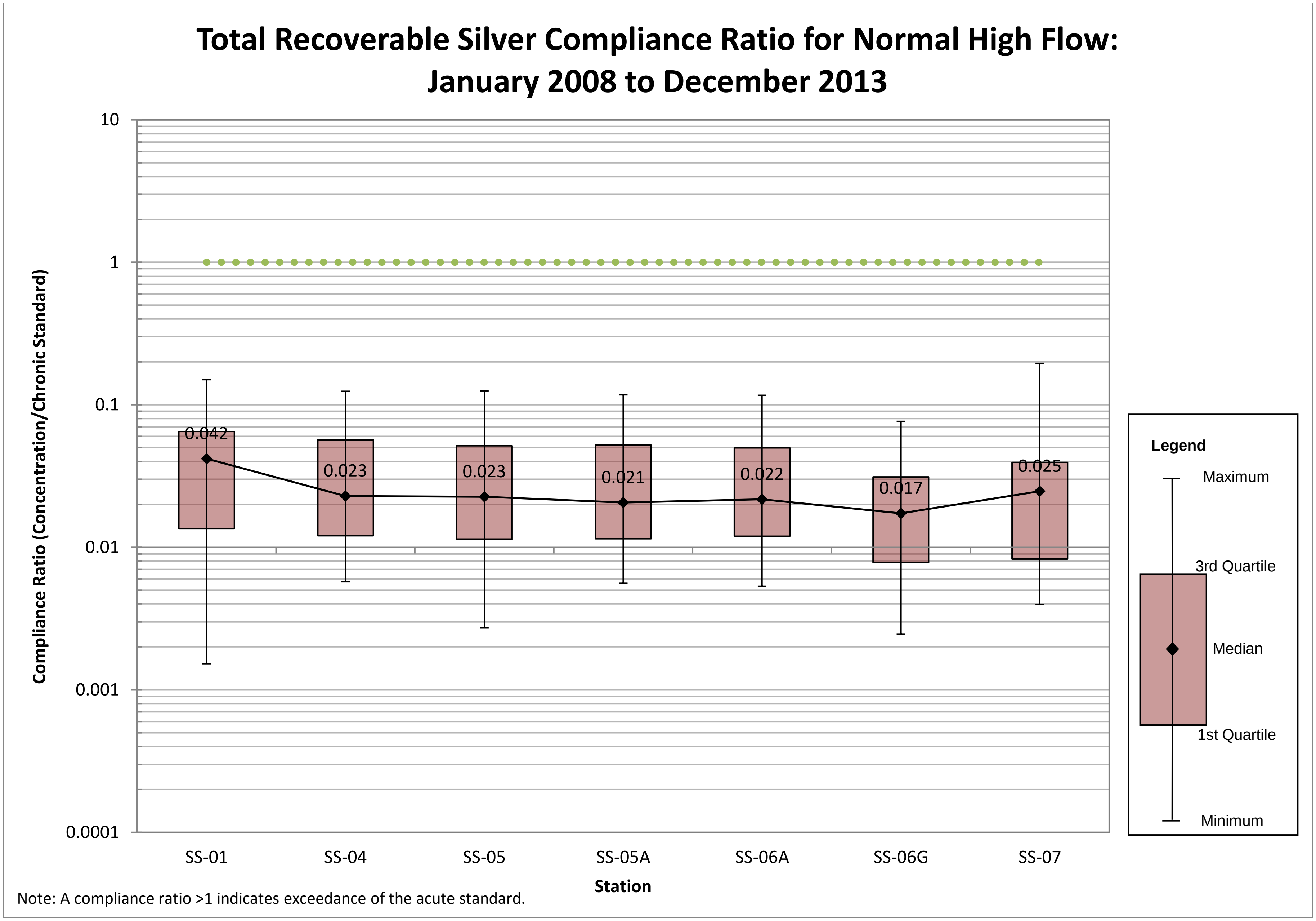

Figure 8-34
High Flow Total Recoverable Silver Compliance Ratio - 2008 to 2013

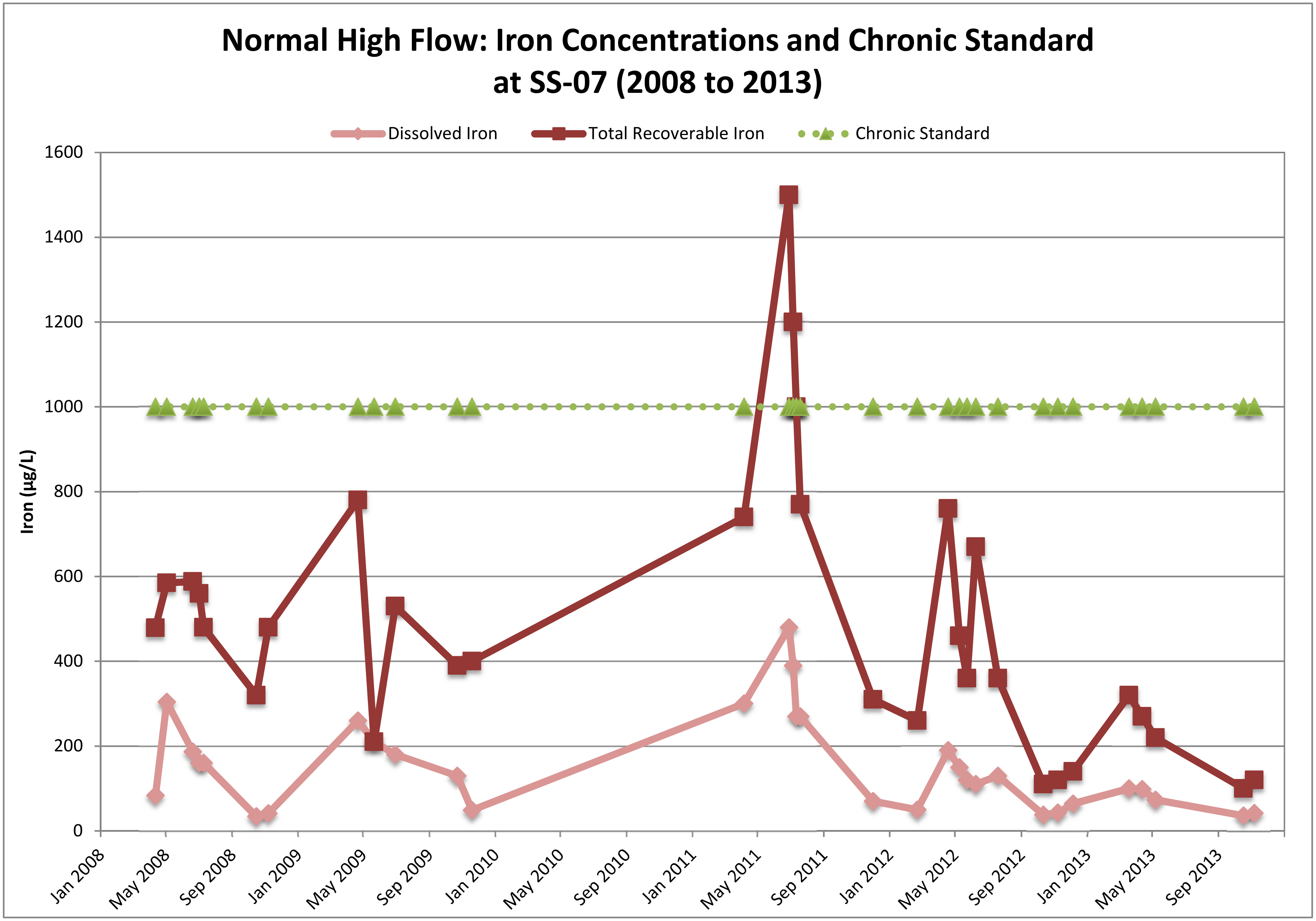

Figure 8-35
High Flow Iron Concentrations SS-07 - 2008 to 2013

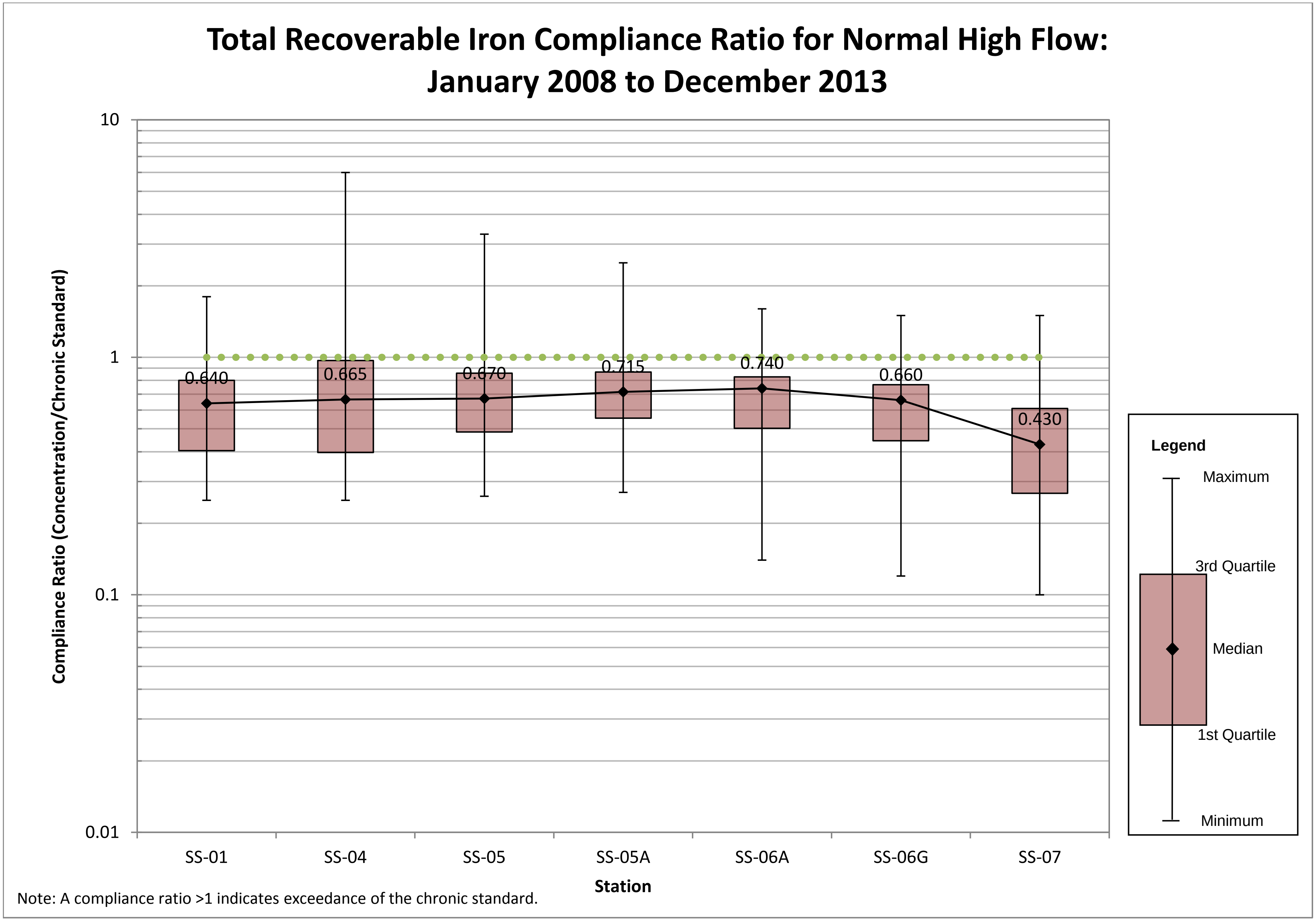

Figure 8-36
High Flow Total Recoverable Iron Compliance Ratio - 2008 to 2013

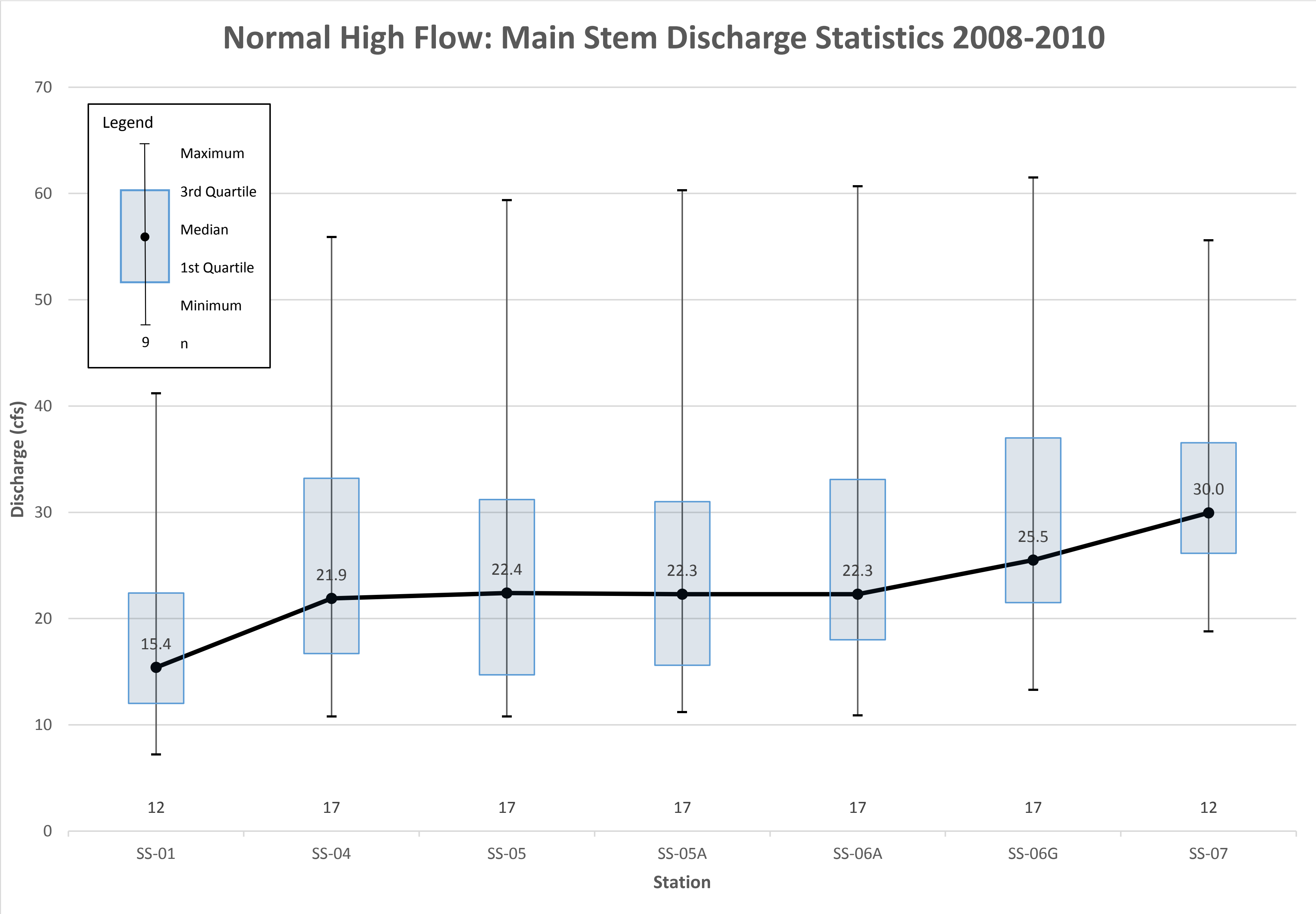

Figure 9-1
Normal High Flow: Main Stem Discharge Statistics 2008-2010

Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

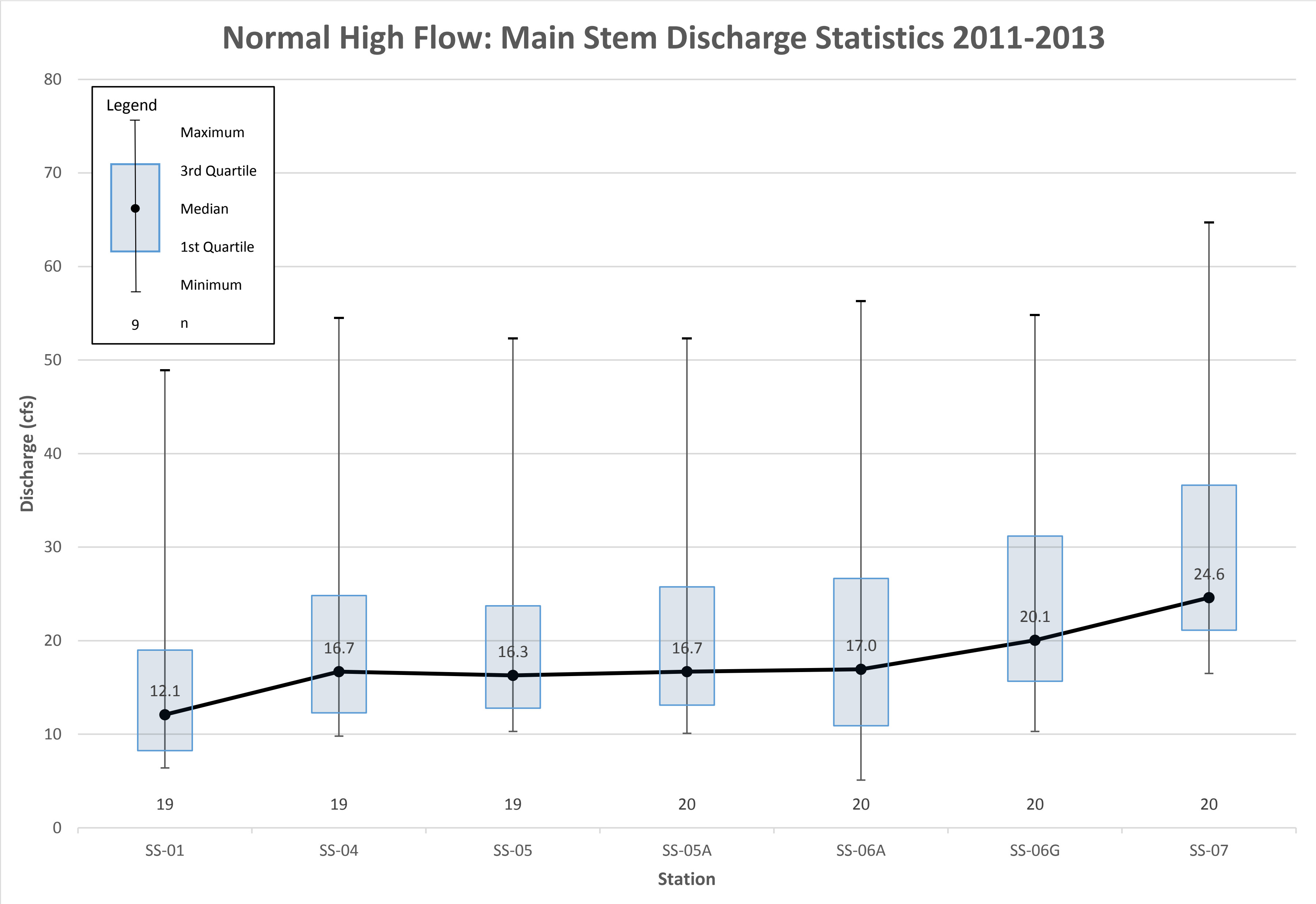

Figure 9-2
Normal High Flow: Main Stem Discharge Statistics 2011-2013

Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

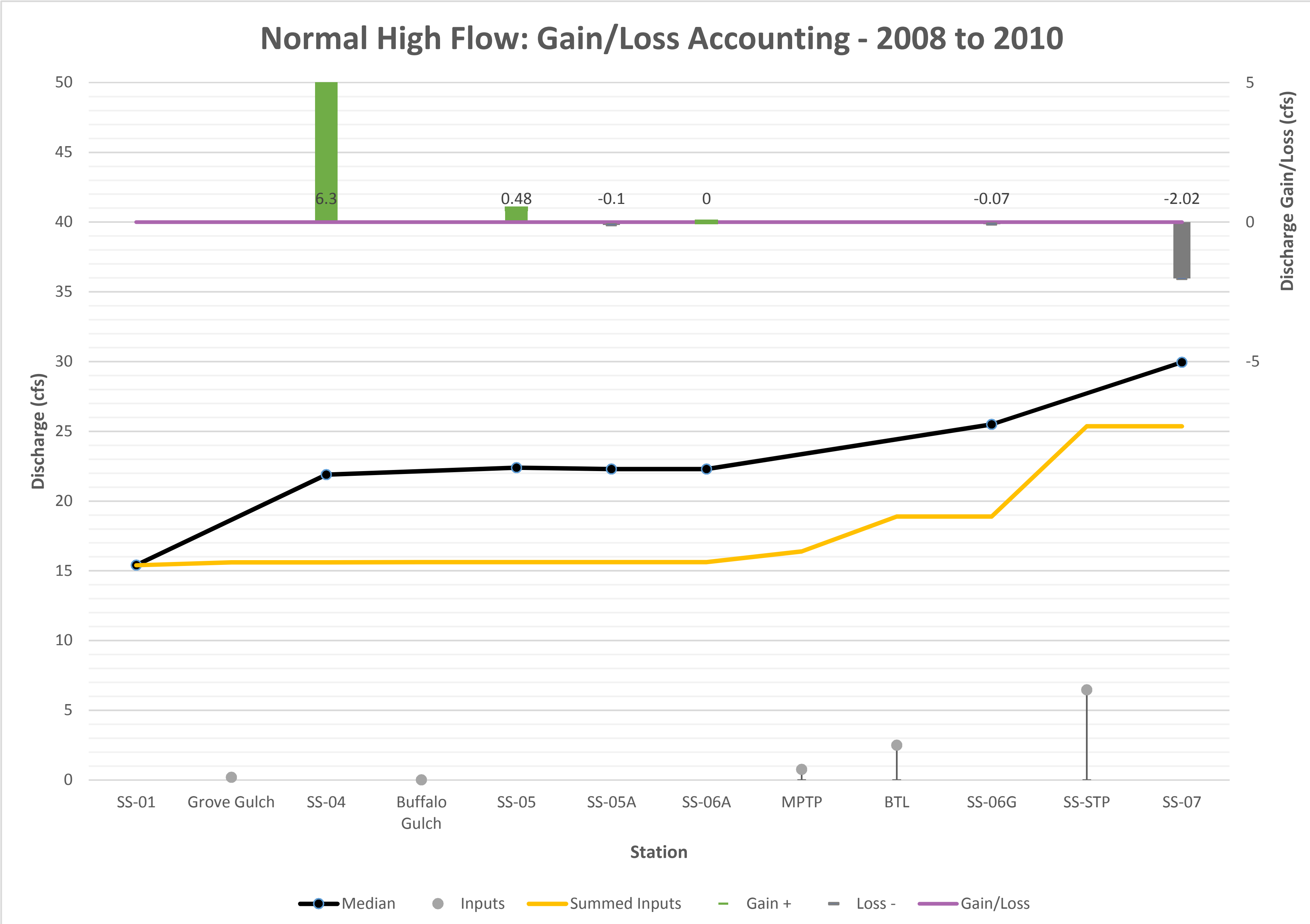

Figure 9-3
Normal High Flow: Gain/Loss Accounting 2008-2010

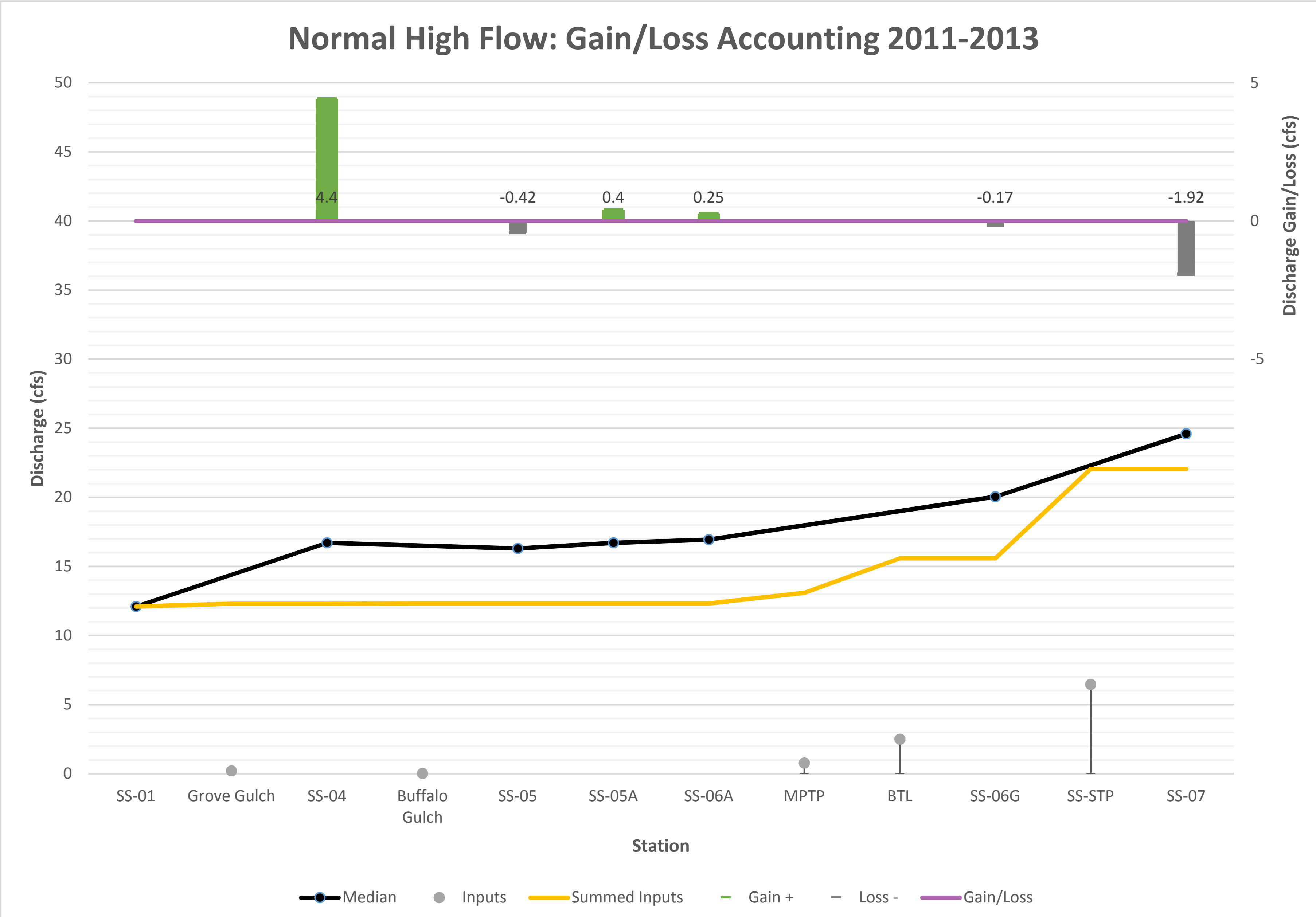

Figure 9-4
Normal High Flow: Gain/Loss Accounting 2011-2013

Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL SIte

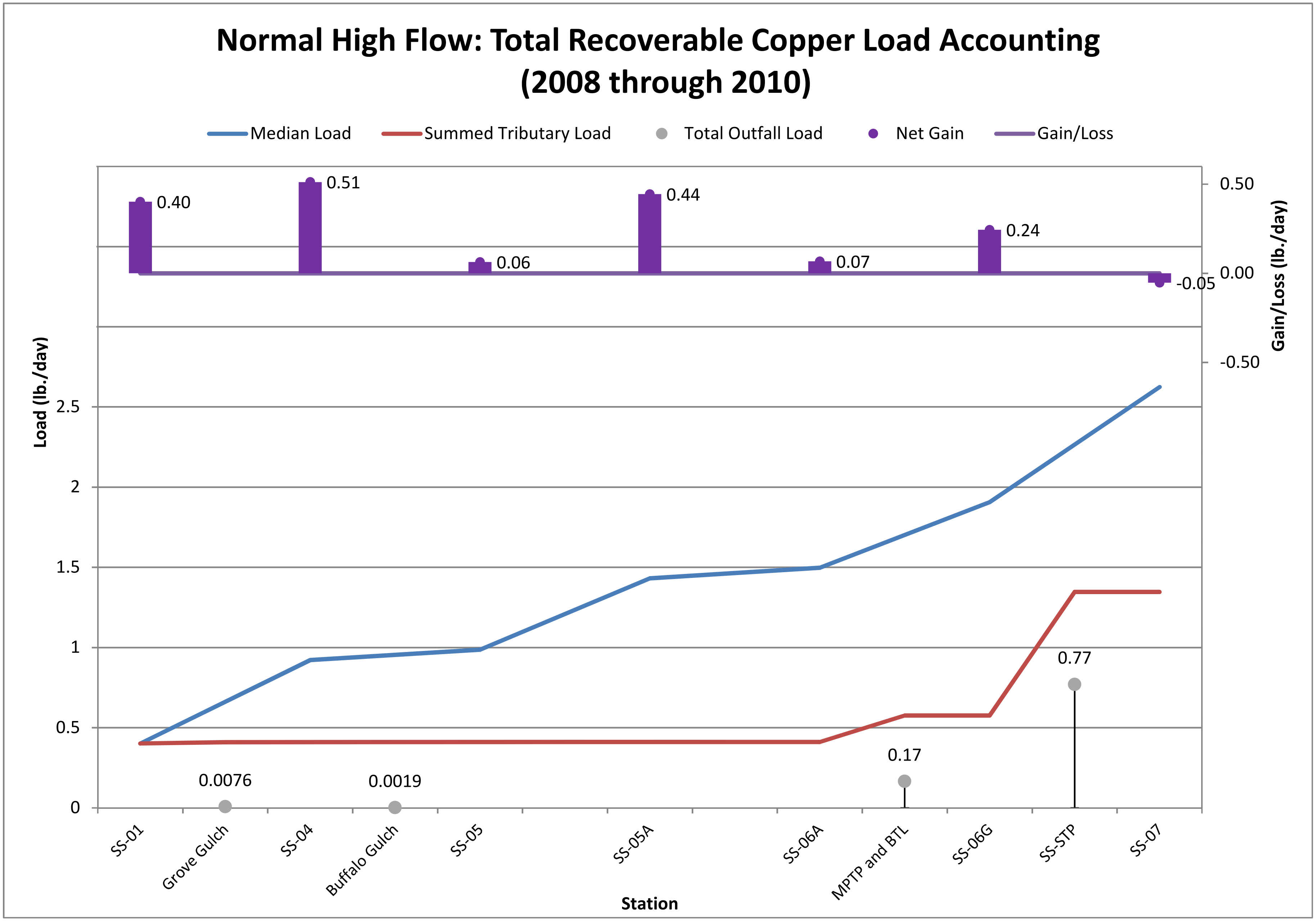

Figure 9-5
Normal High Flow Total Copper Load Accounting 2008 - 2010

Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

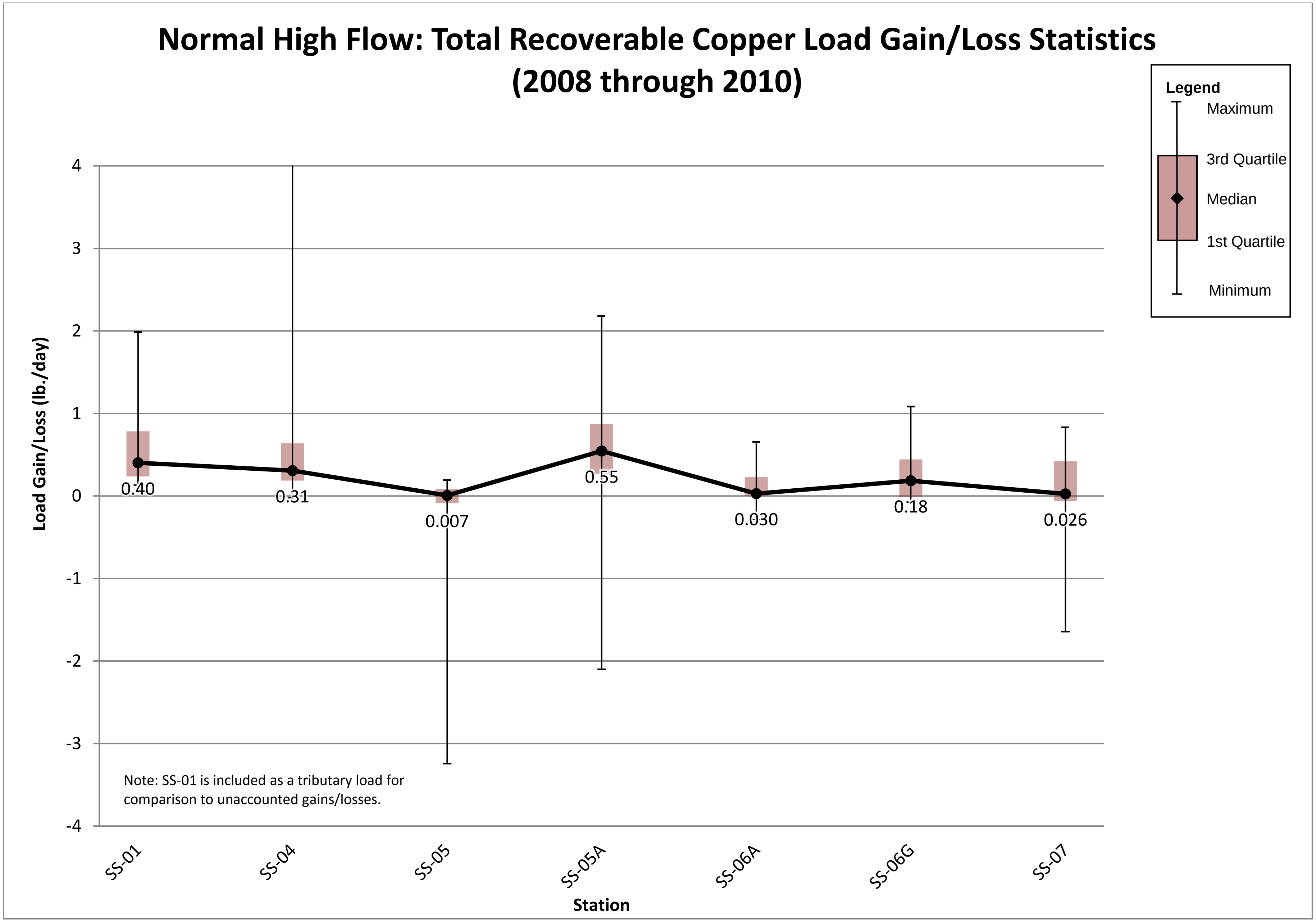

Figure 9-6
Normal High Flow Total Copper Load Statistics 2008 - 2010

Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

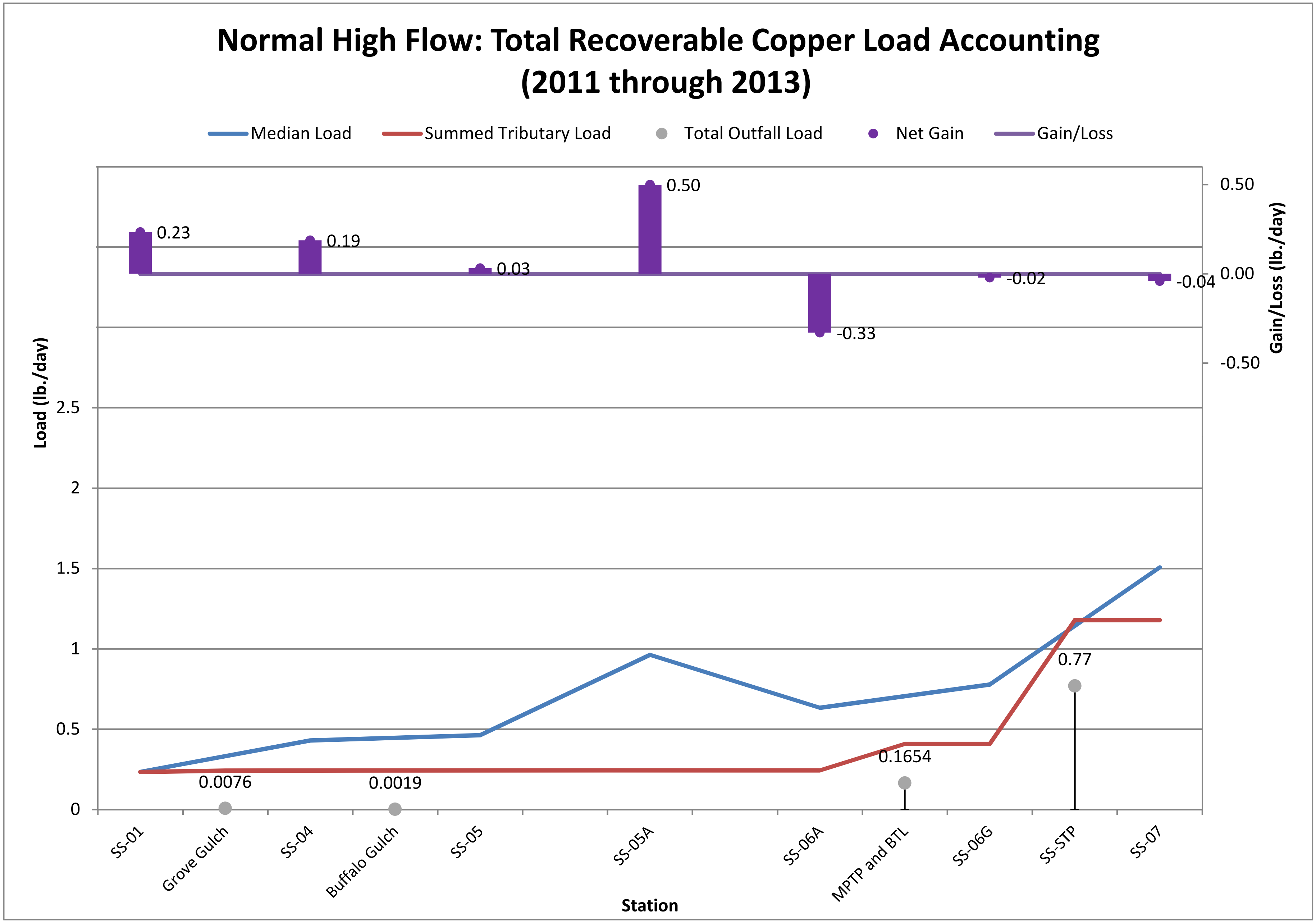

Figure 9-7
Normal High Flow Total Copper Load Accounting 2011 - 2013

Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

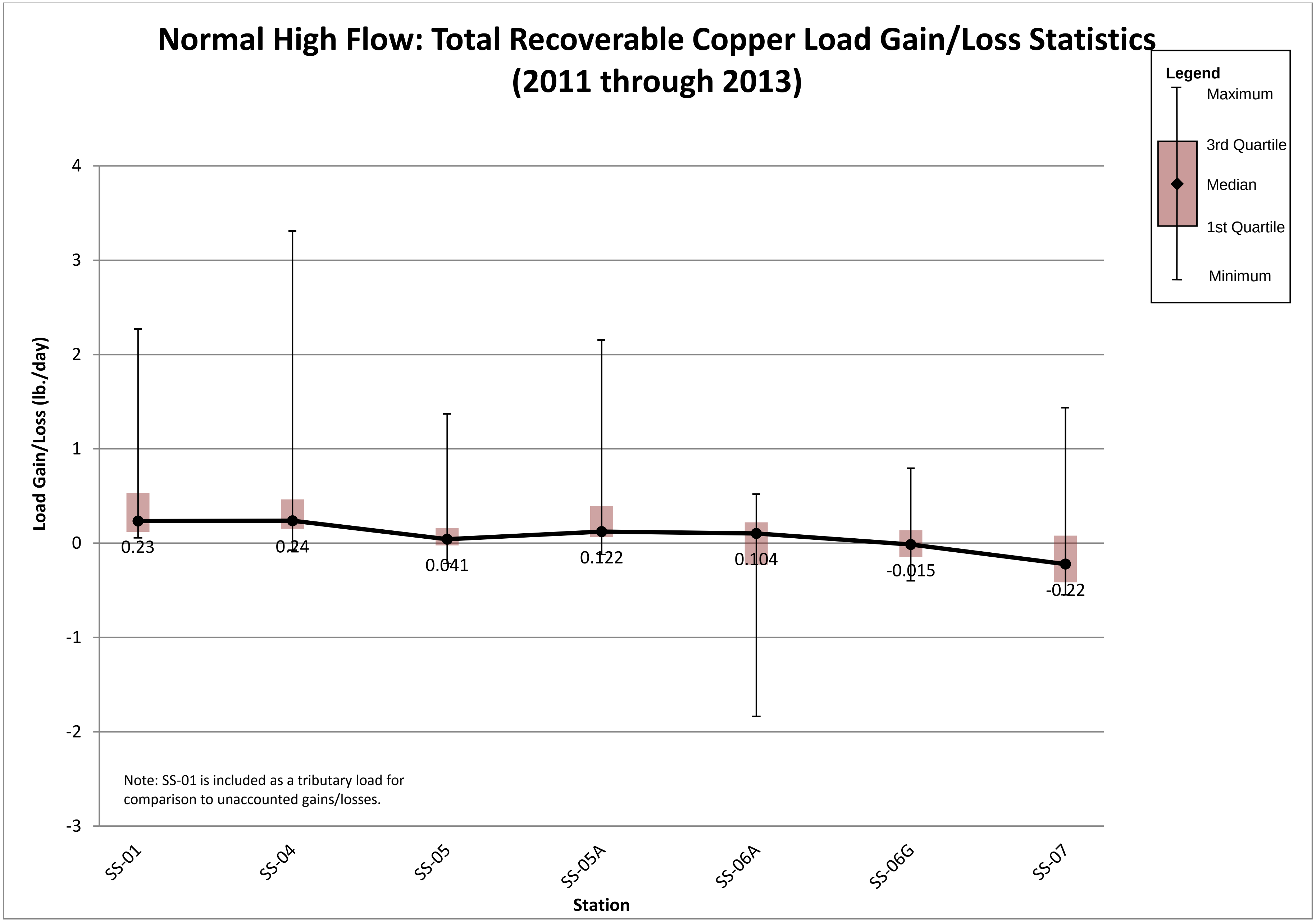

Figure 9-8
Normal High Flow Total Copper Load Statistics 2011 - 2013

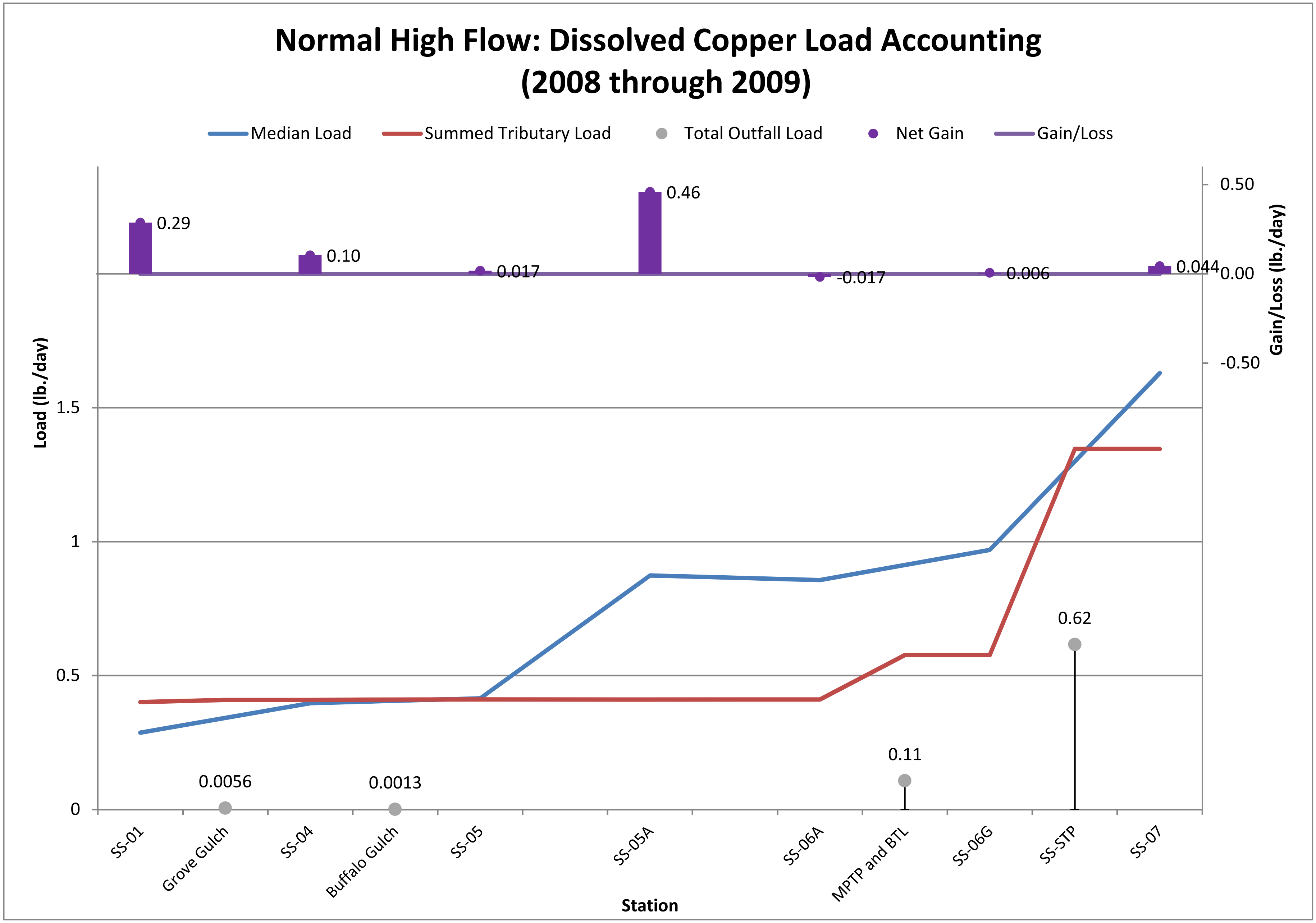

Figure 9-9
High Flow Dissolved Copper Load Accounting 2008 - 2010

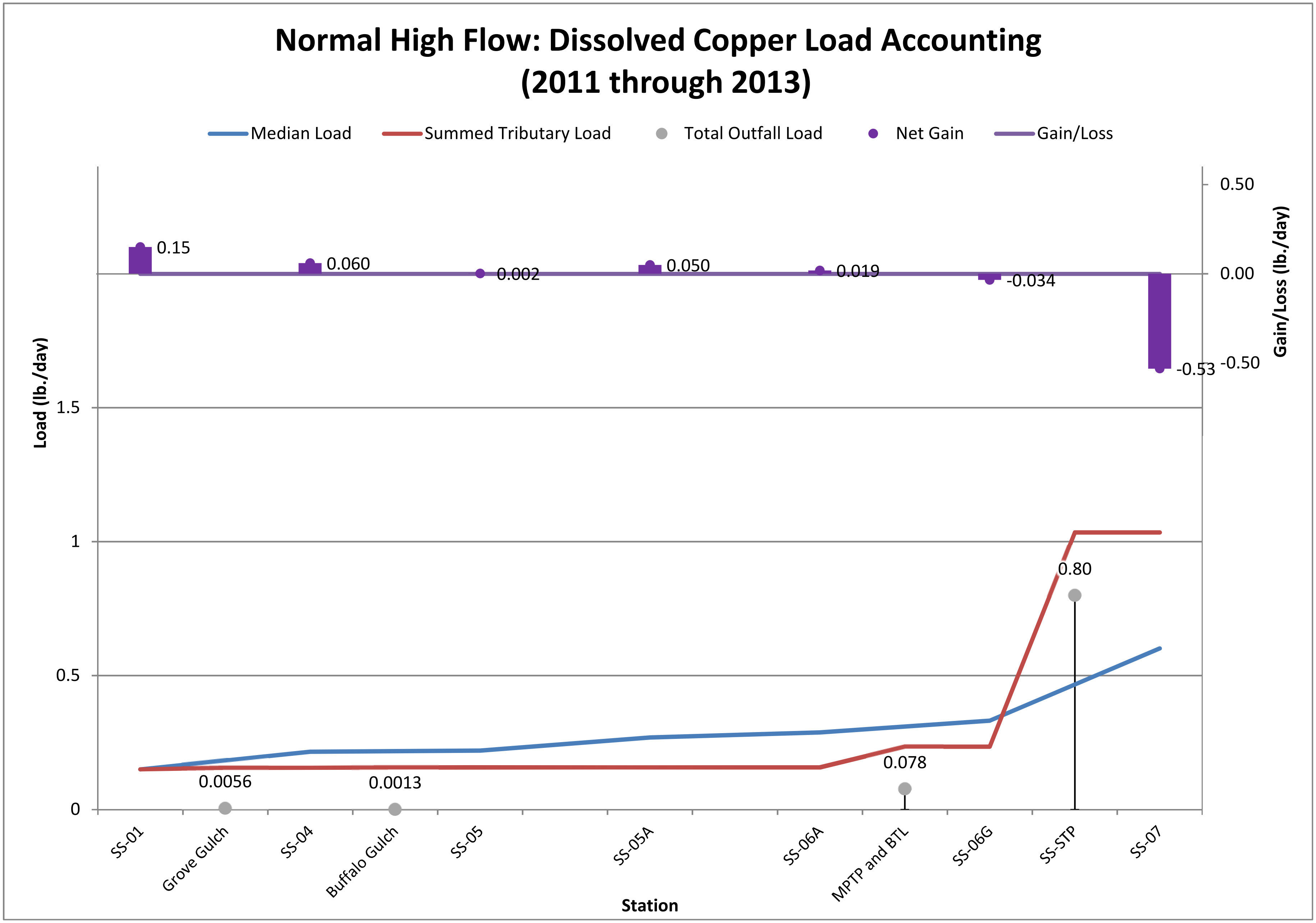

Figure 9-10
High Flow Dissolved Copper Load Accounting 2011 - 2013

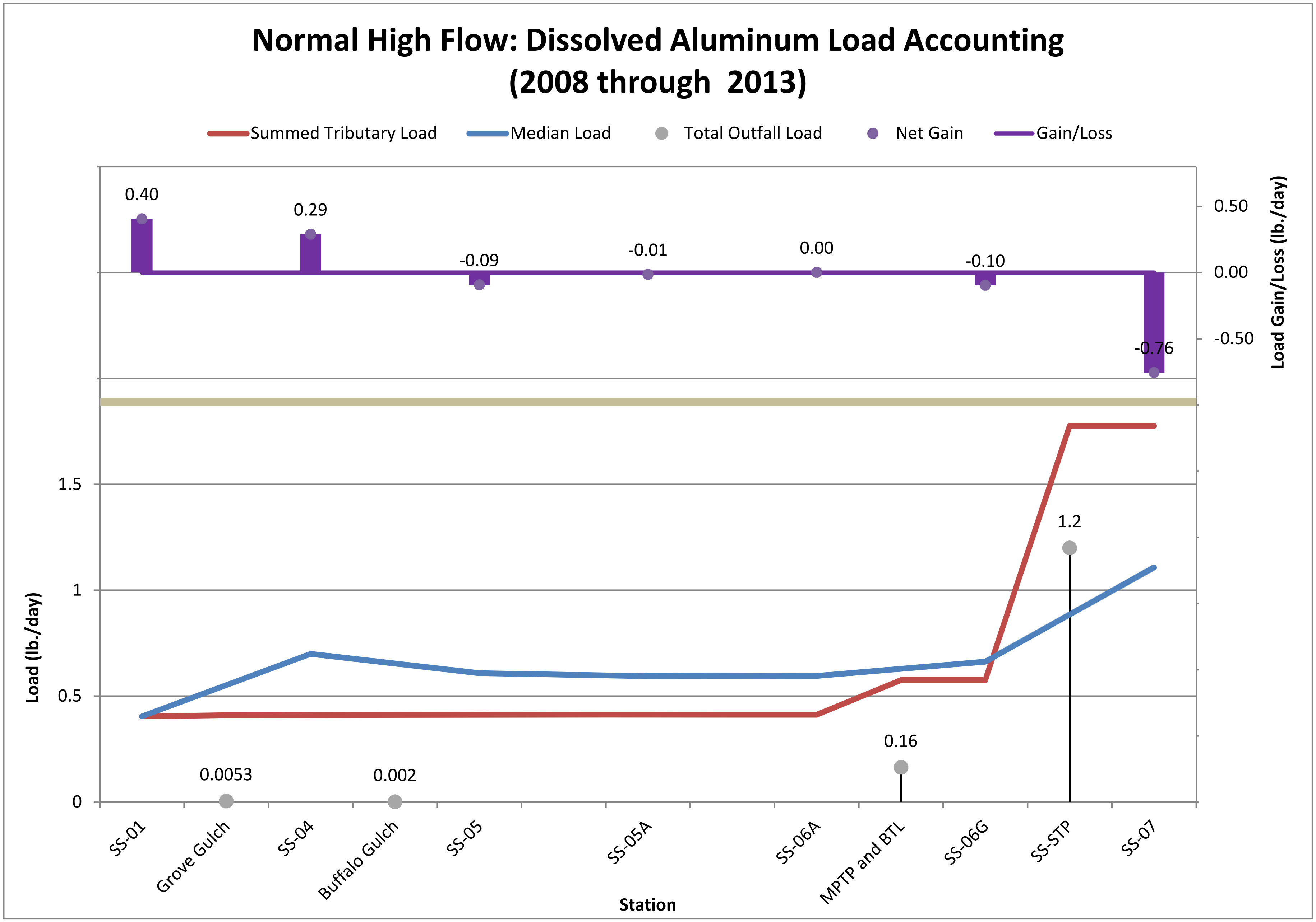

Figure 9-11
Normal High Flow Dissolved Aluminum Load Accounting - 2008 to 2013

Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

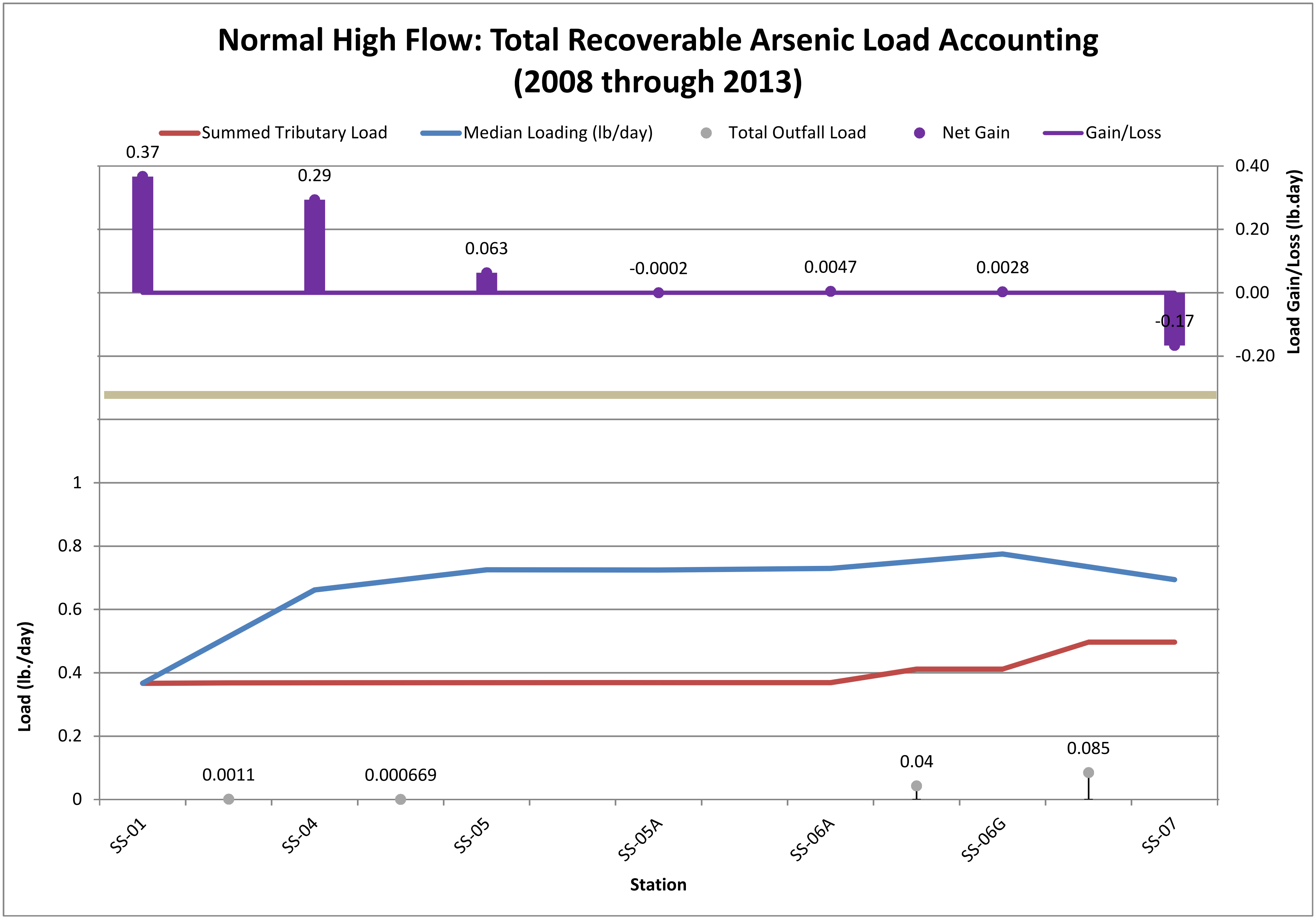

Figure 9-12
High Flow Total Recoverable Arsenic Load Accounting - 2008 to 2013

Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

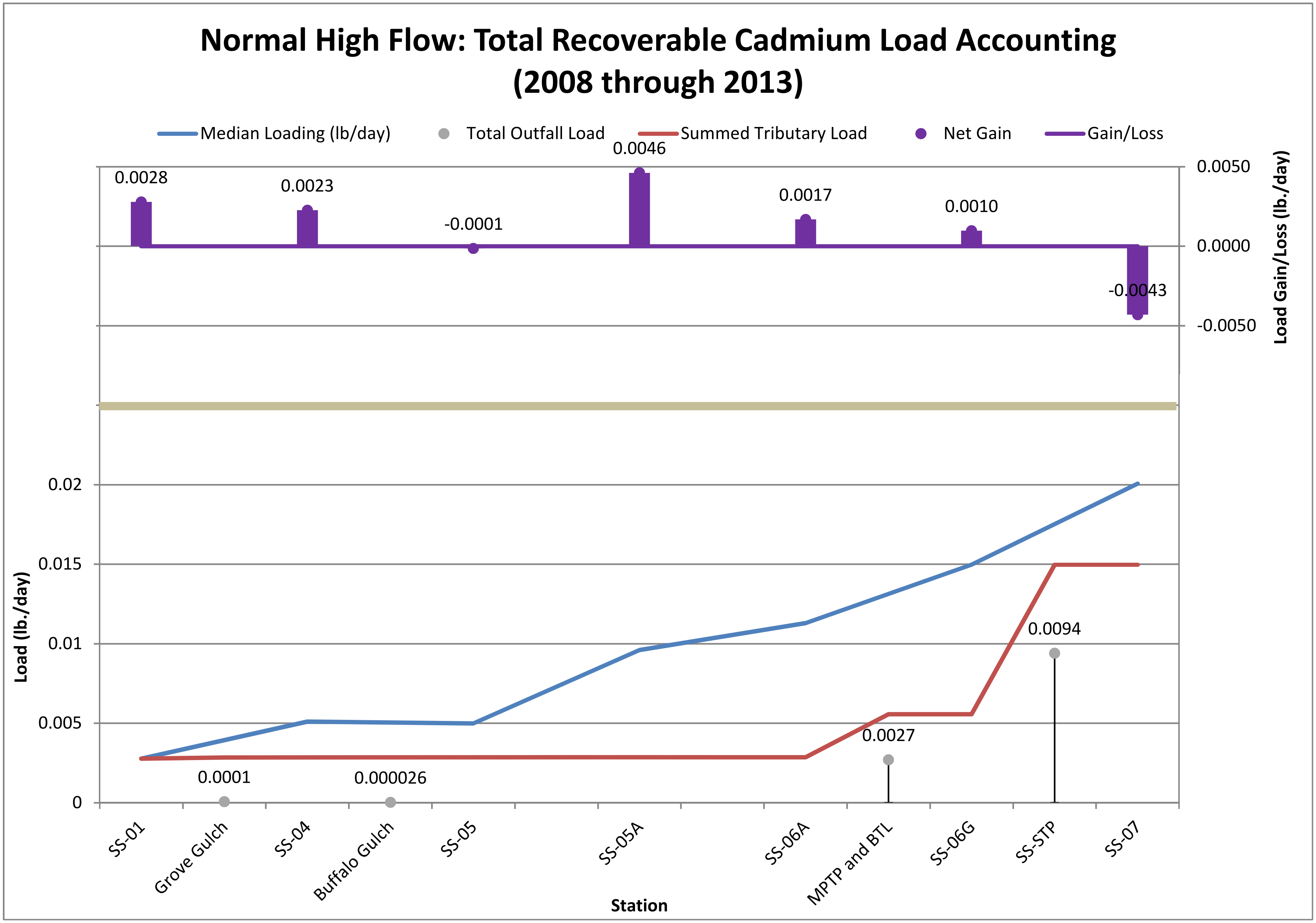

Figure 9-13
High Flow Total Recoverable Cadmium Load Accounting - 2008 to 2013

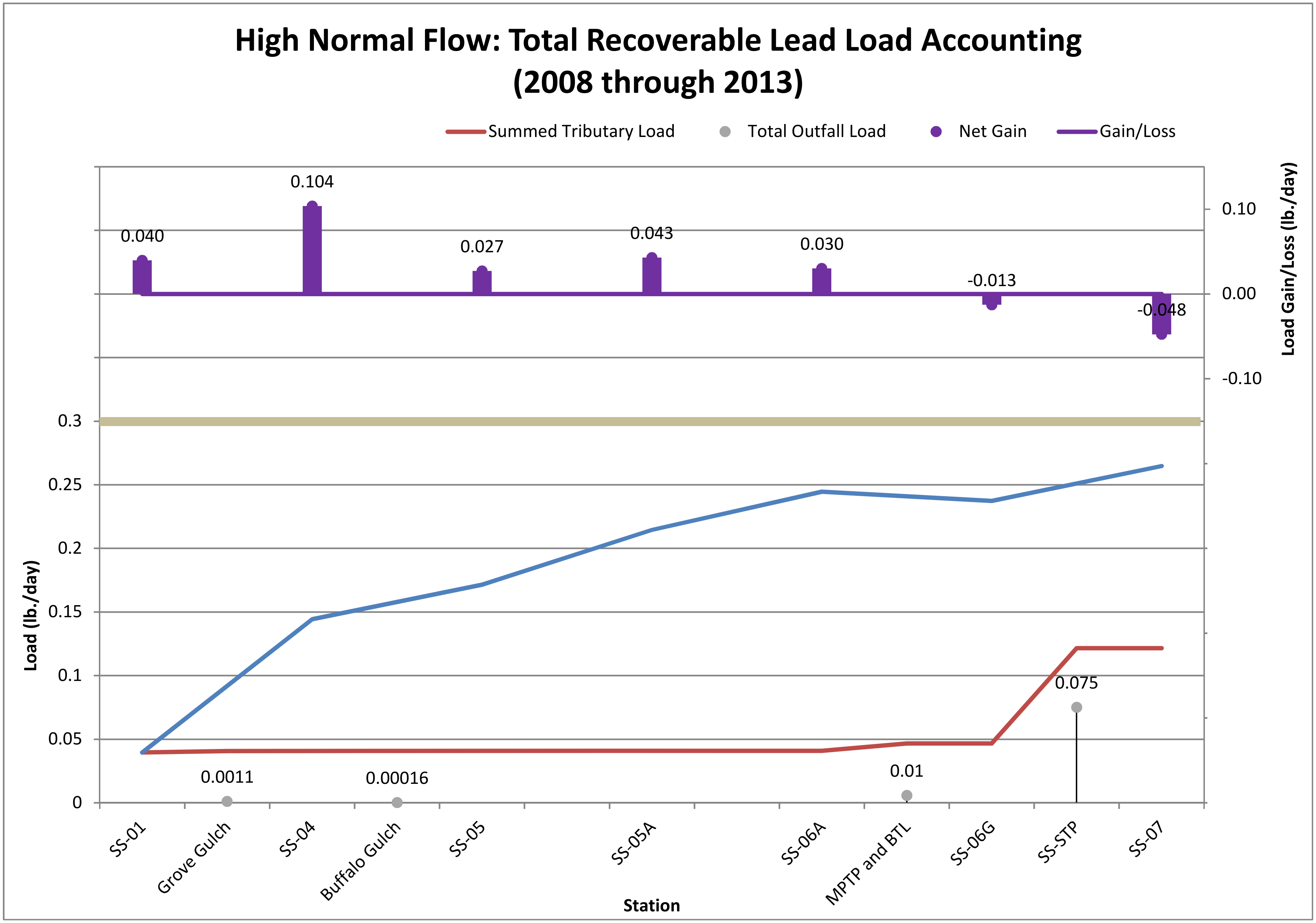

Figure 9-14
High Flow Total Recoverable Lead Load Accounting - 2008 to 2013

Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

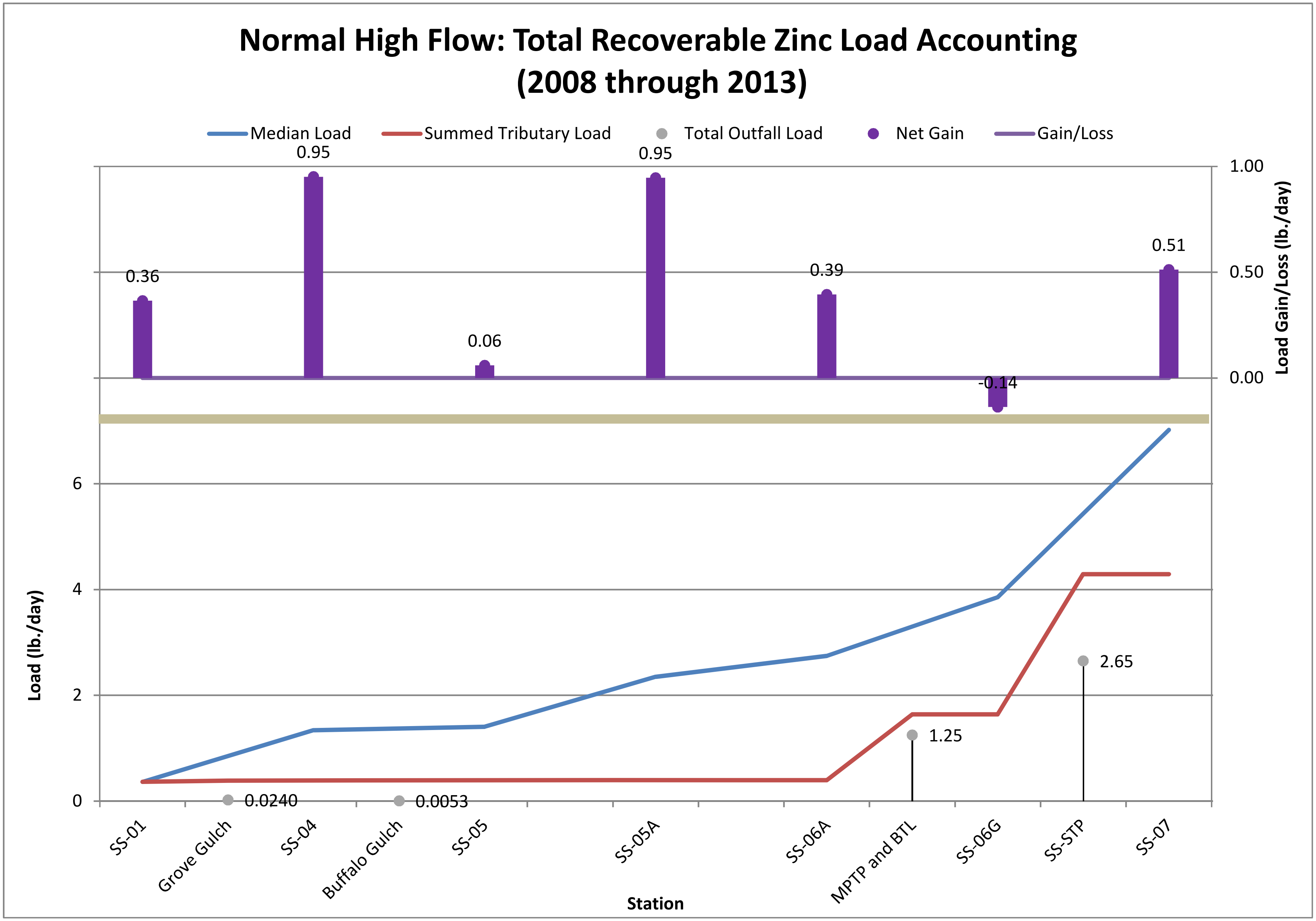

Figure 9-15
High Flow Total Recoverable Zinc Load Accounting - 2008 to 2013

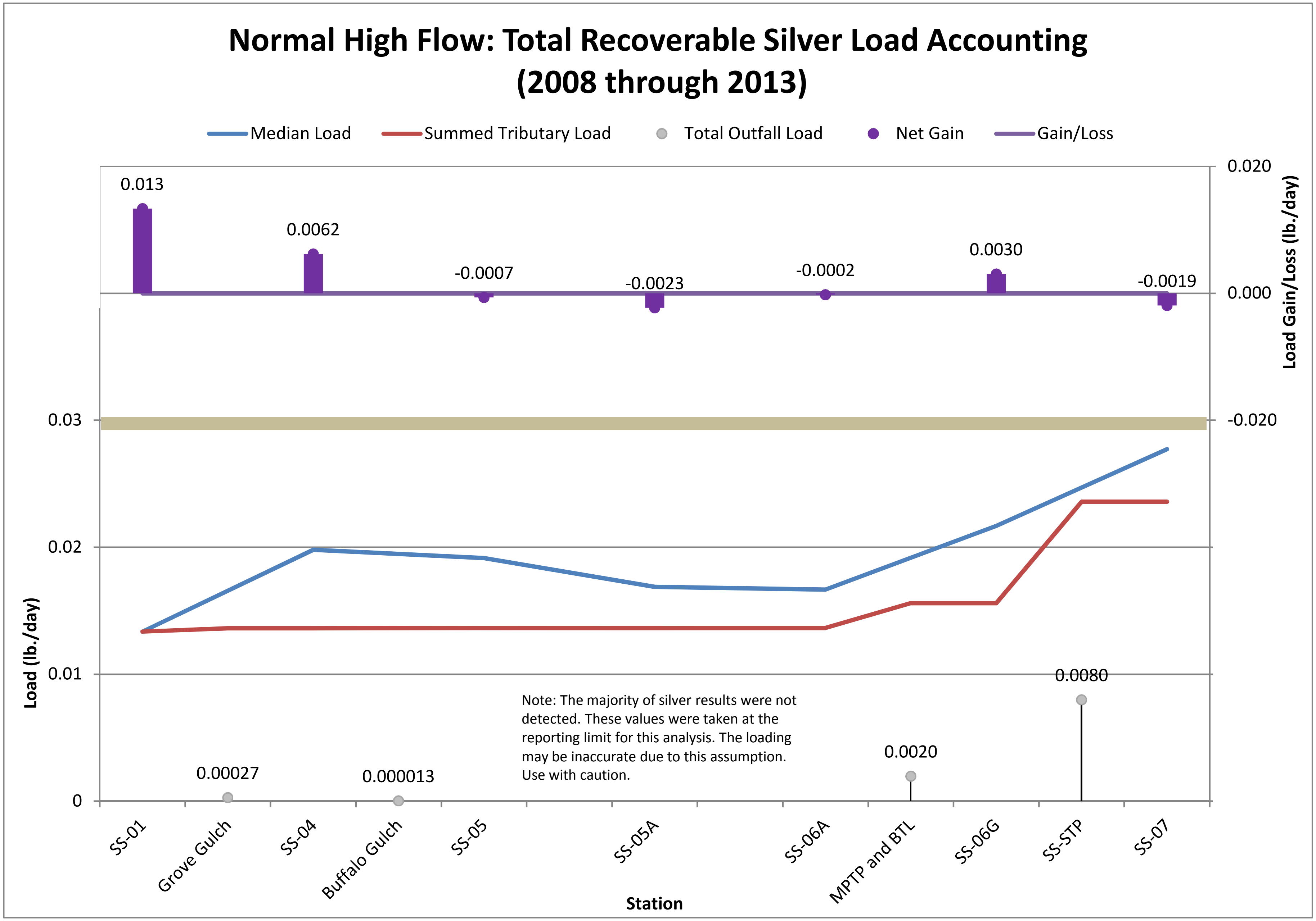

Figure 9-16
High Flow Total Recoverable Silver Load Accounting - 2008 to 2013

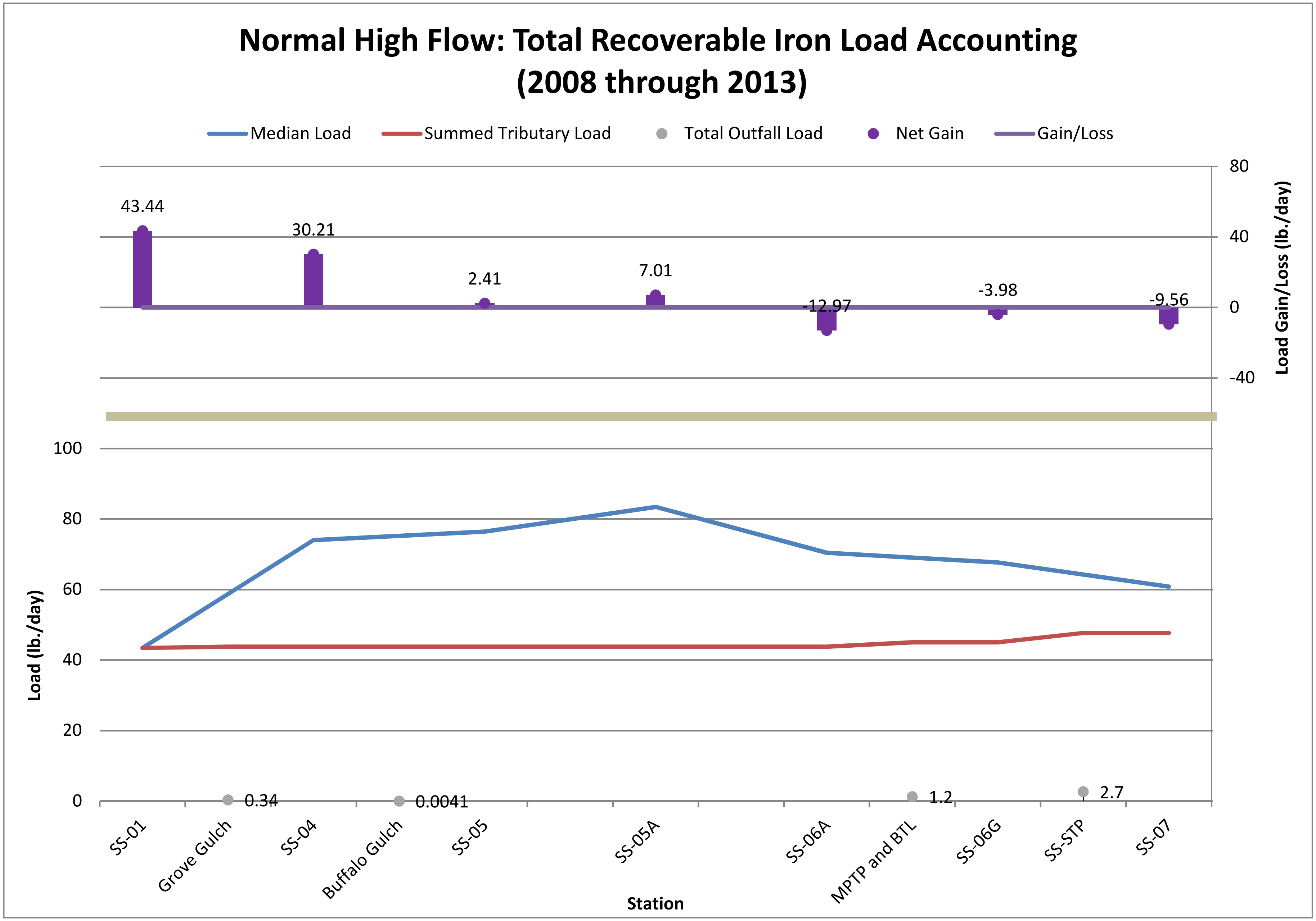

Figure 9-17
High Flow Total Recoverable Iron Load Accounting - 2008 to 2013

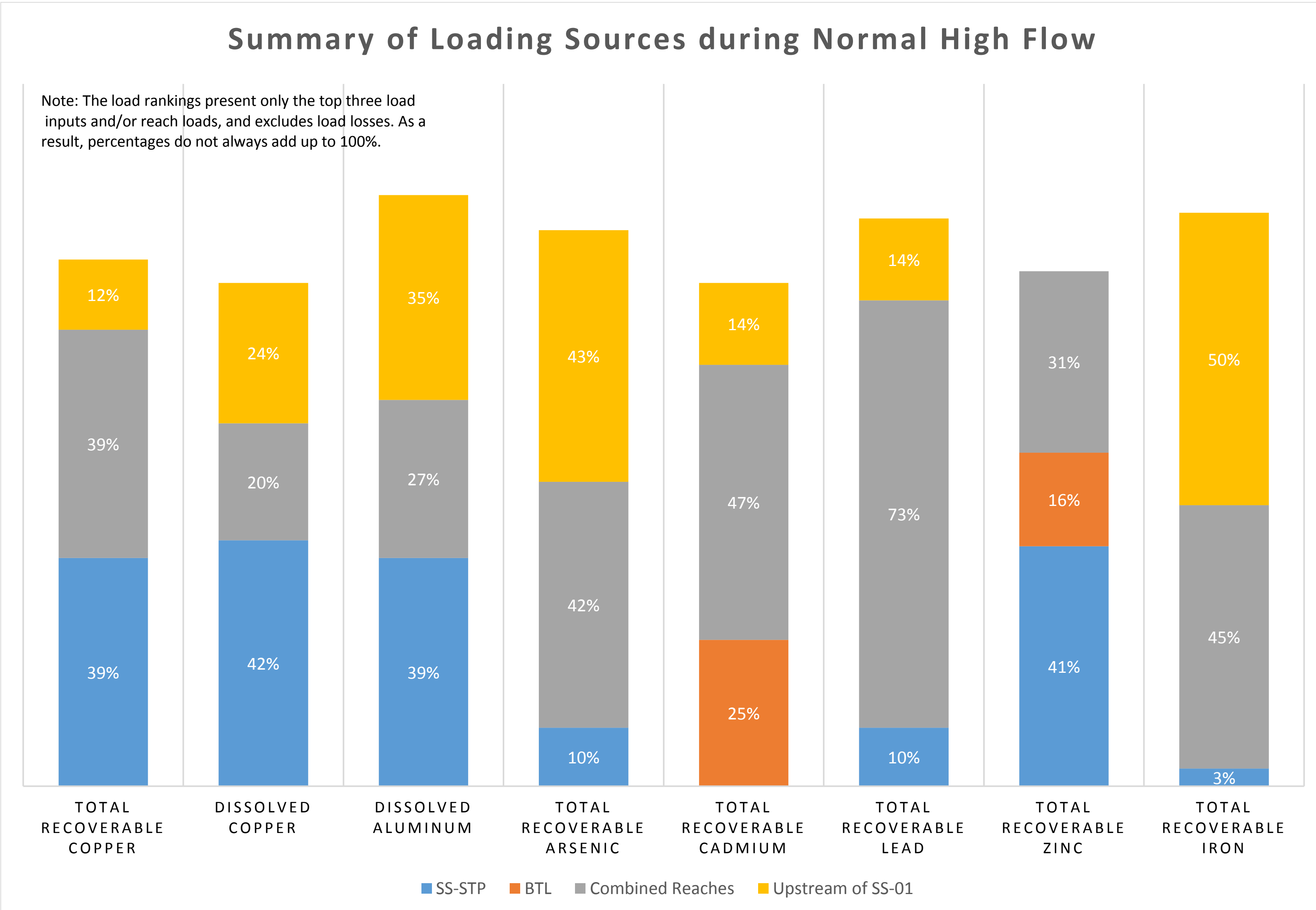

Figure 9-18
Summary of Loading Sources during Normal High Flow

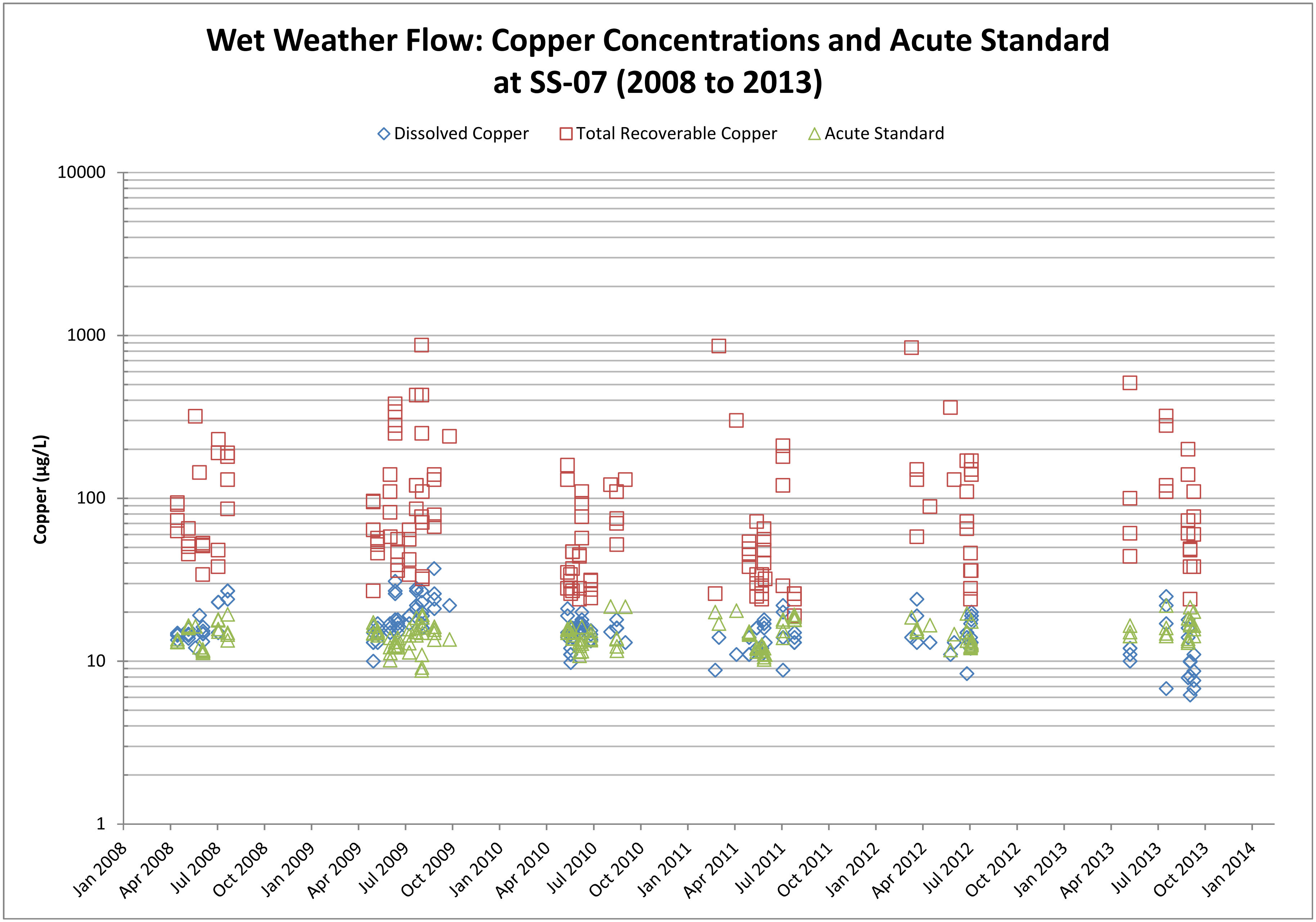

Figure 10-1
Wet Weather Flow Copper Concentrations at SS-07 - 2008 to 2013

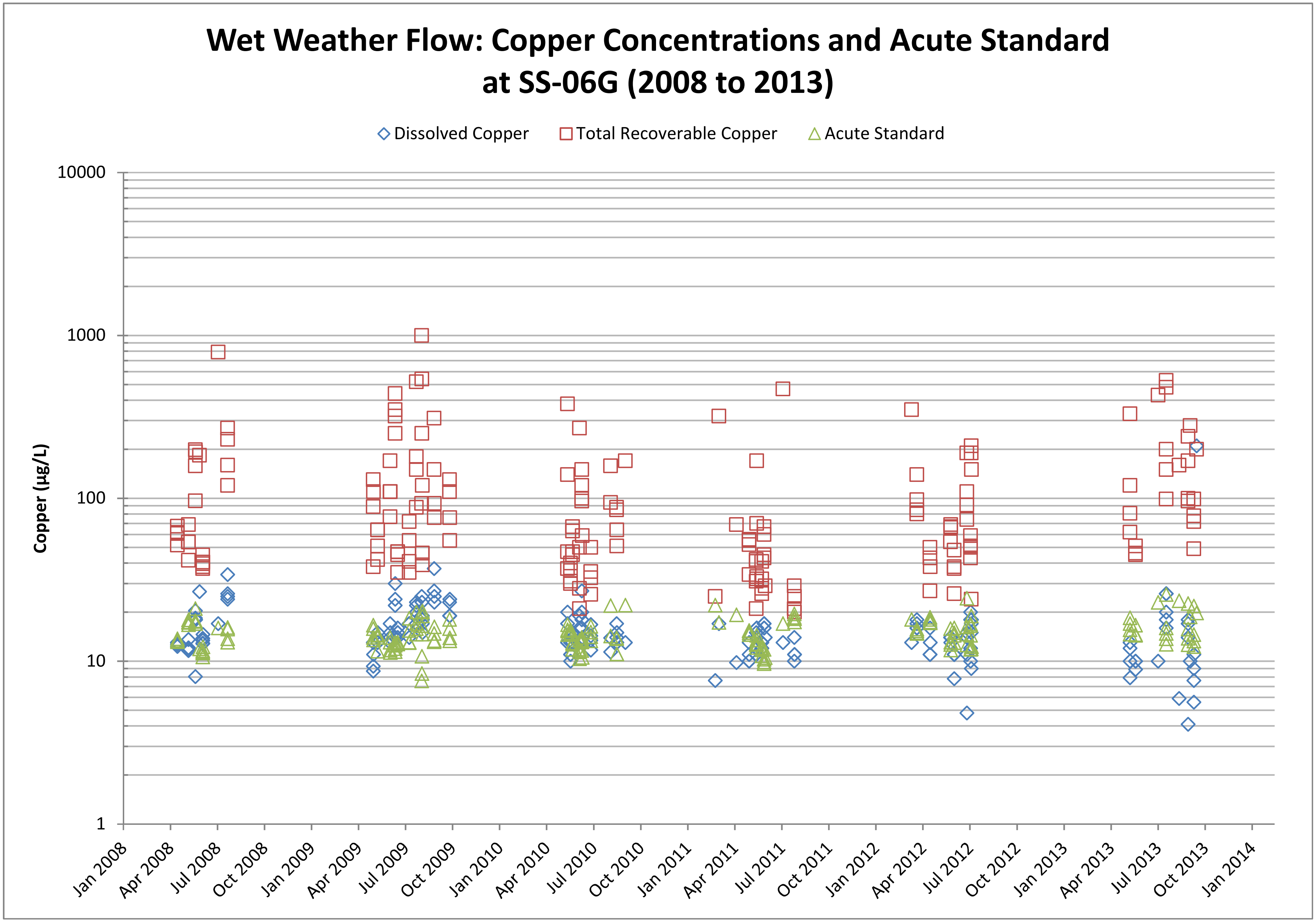

Figure 10-2
Wet Weather Flow Copper Concentrations at SS-06G - 2008 to 2013

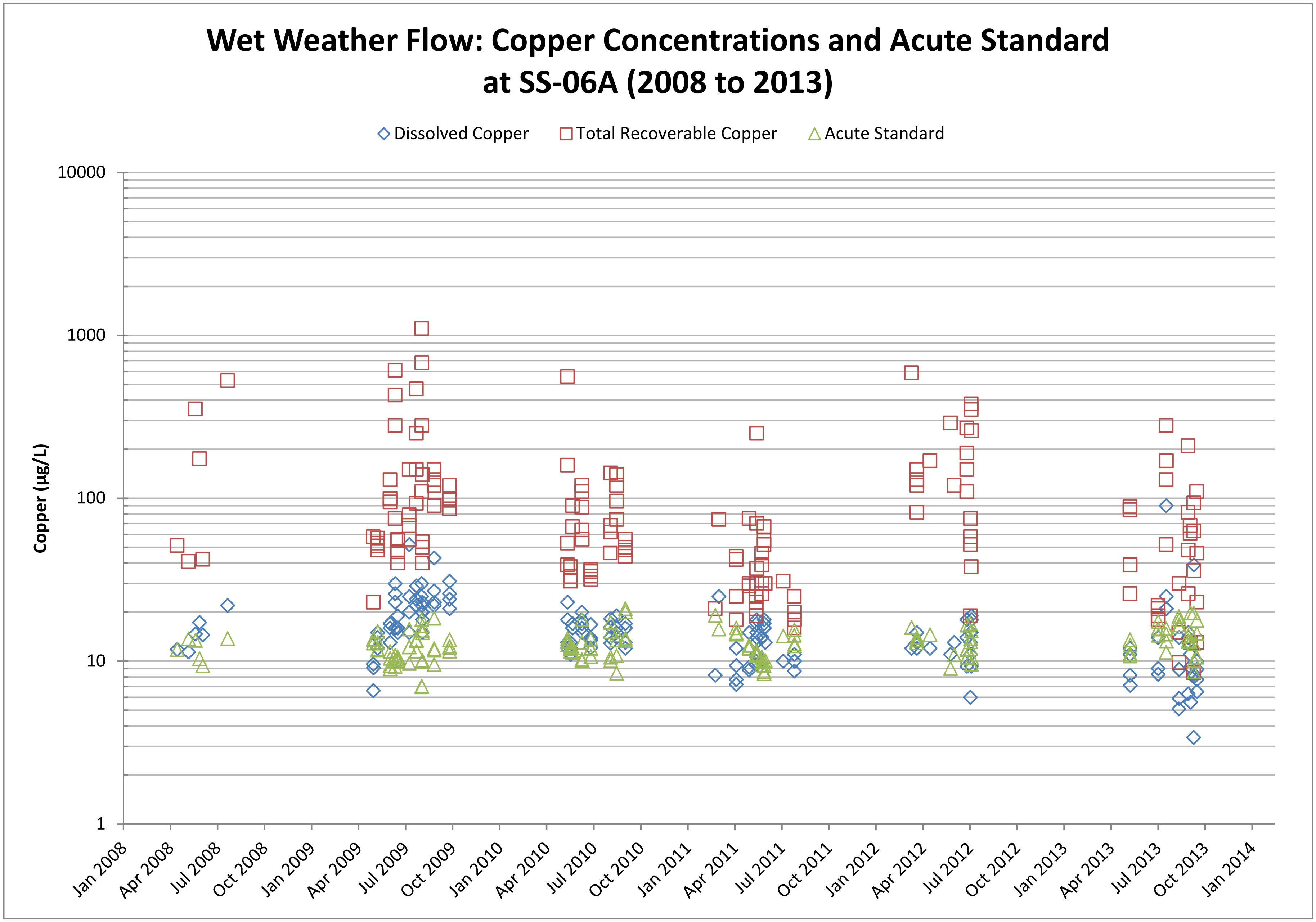

Figure 10-3
Wet Weather Flow Copper Concentrations at SS-06A - 2008 to 2013

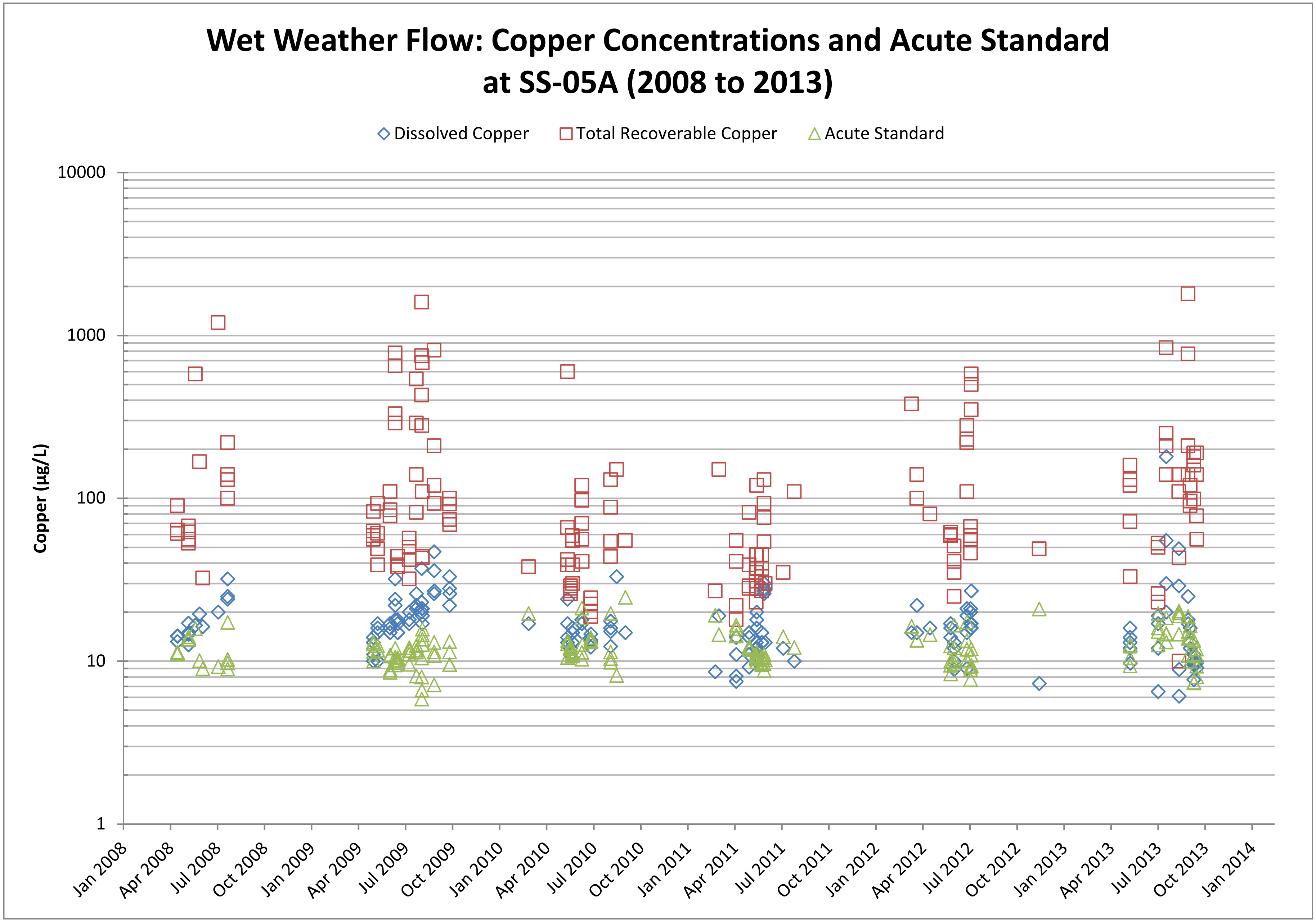

Figure 10-4
Wet Weather Flow Copper Concentrations at SS-05A - 2008 to 2013

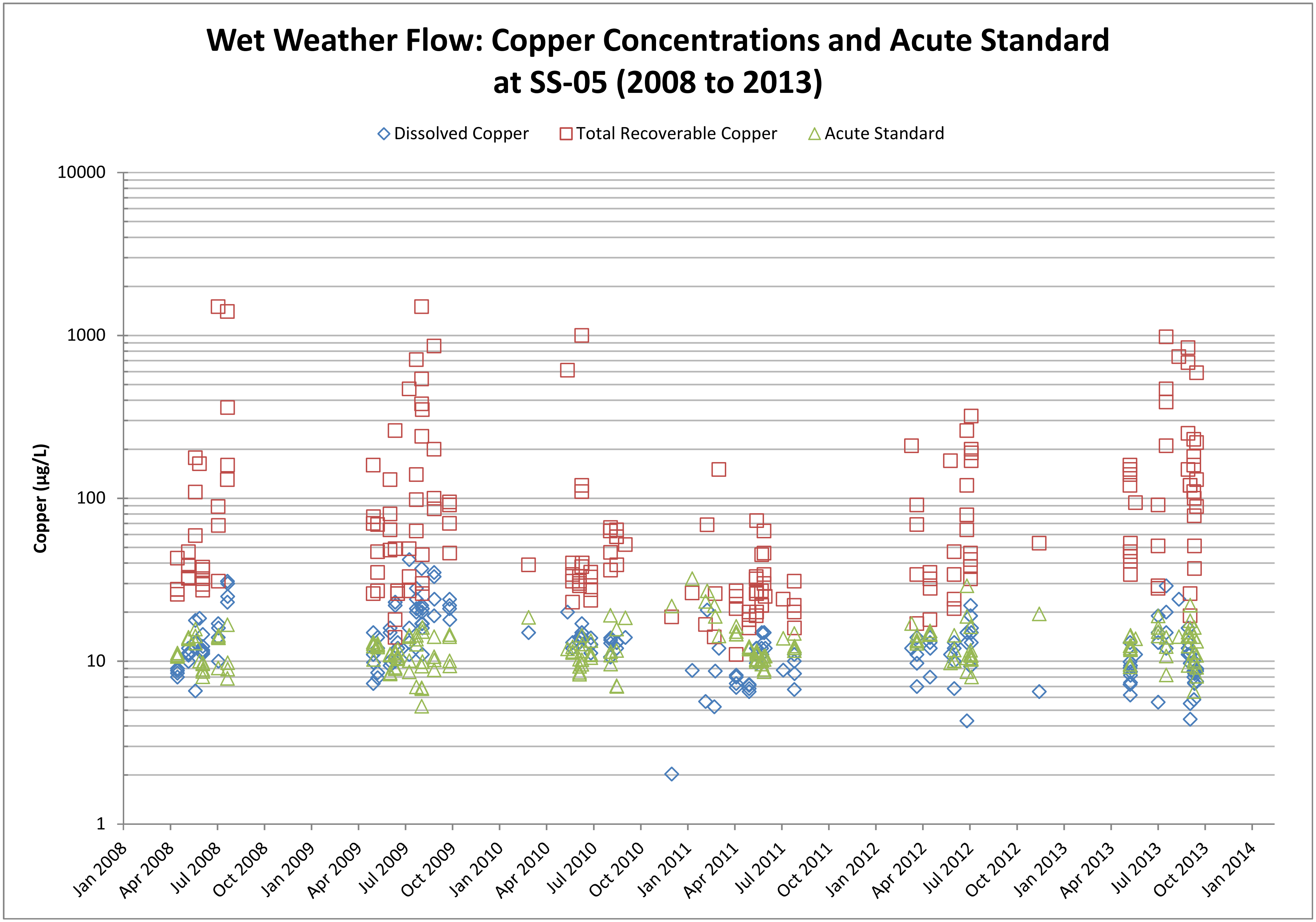

Figure 10-5
Wet Weather Flow Copper Concentrations at SS-05 - 2008 to 2013

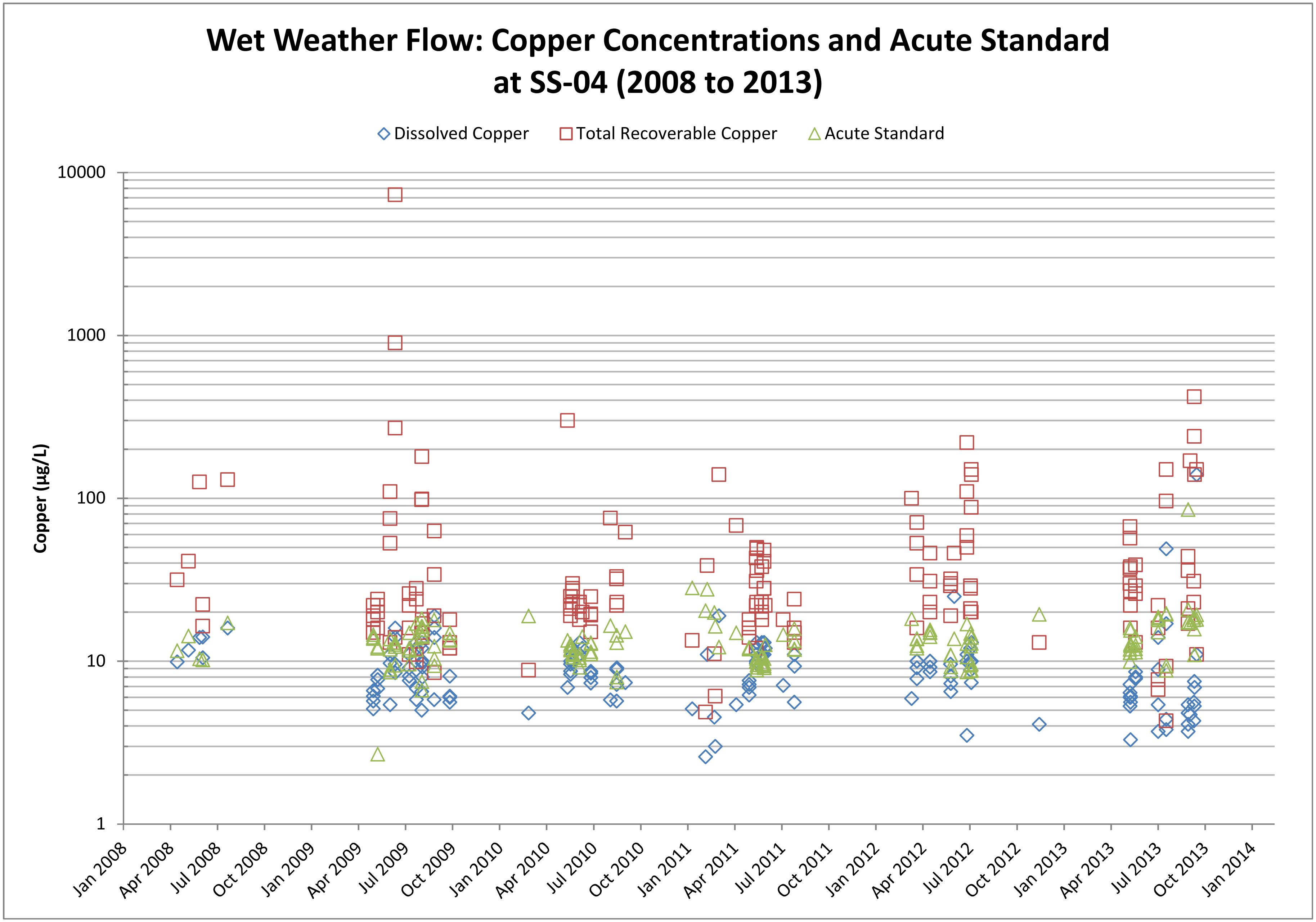

Figure 10-6
Wet Weather Flow Copper Concentrations at SS-04 - 2008 to 2013

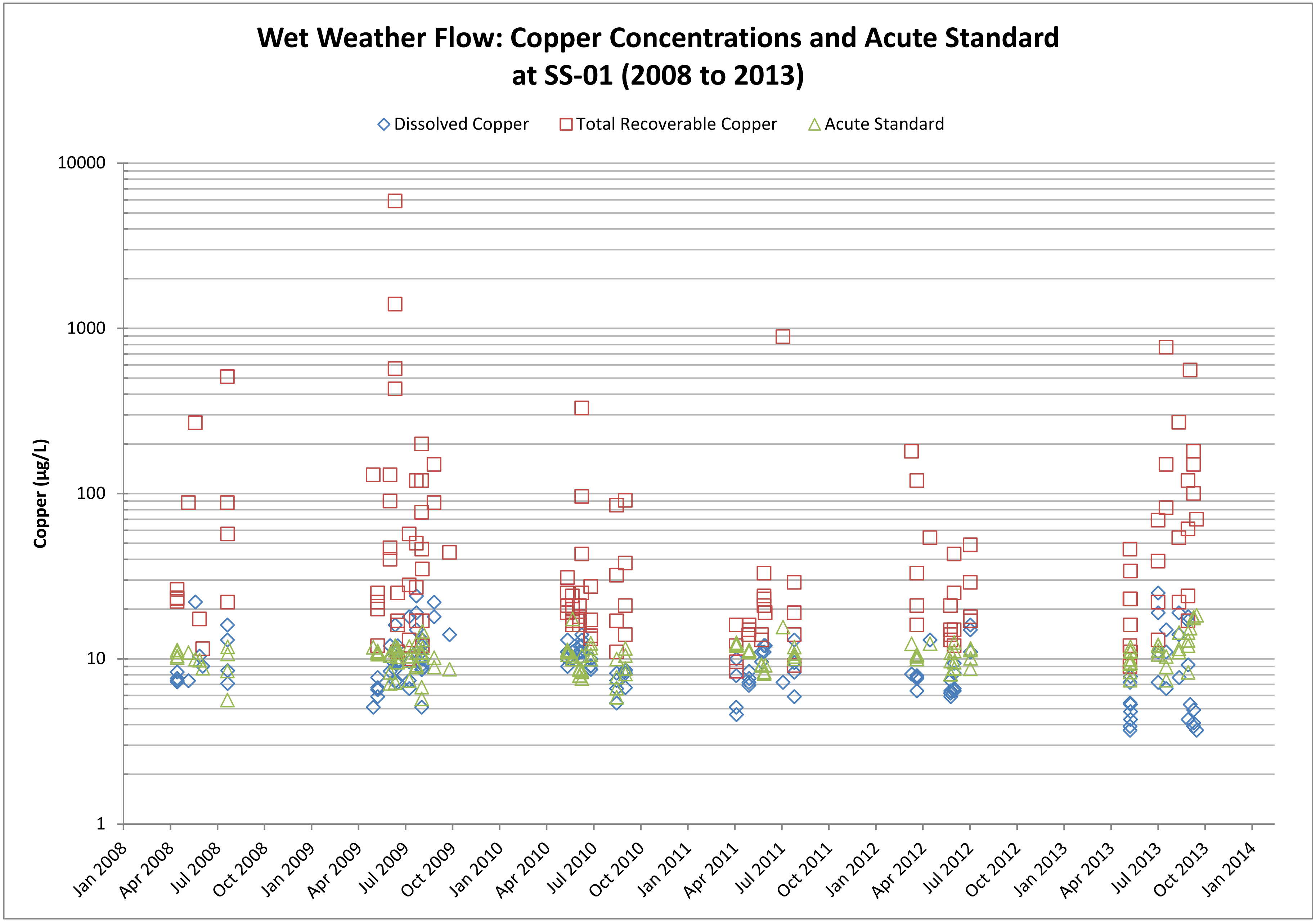

Figure 10-7
Wet Weather Flow Copper Concentrations at SS-01 - 2008 to 2013

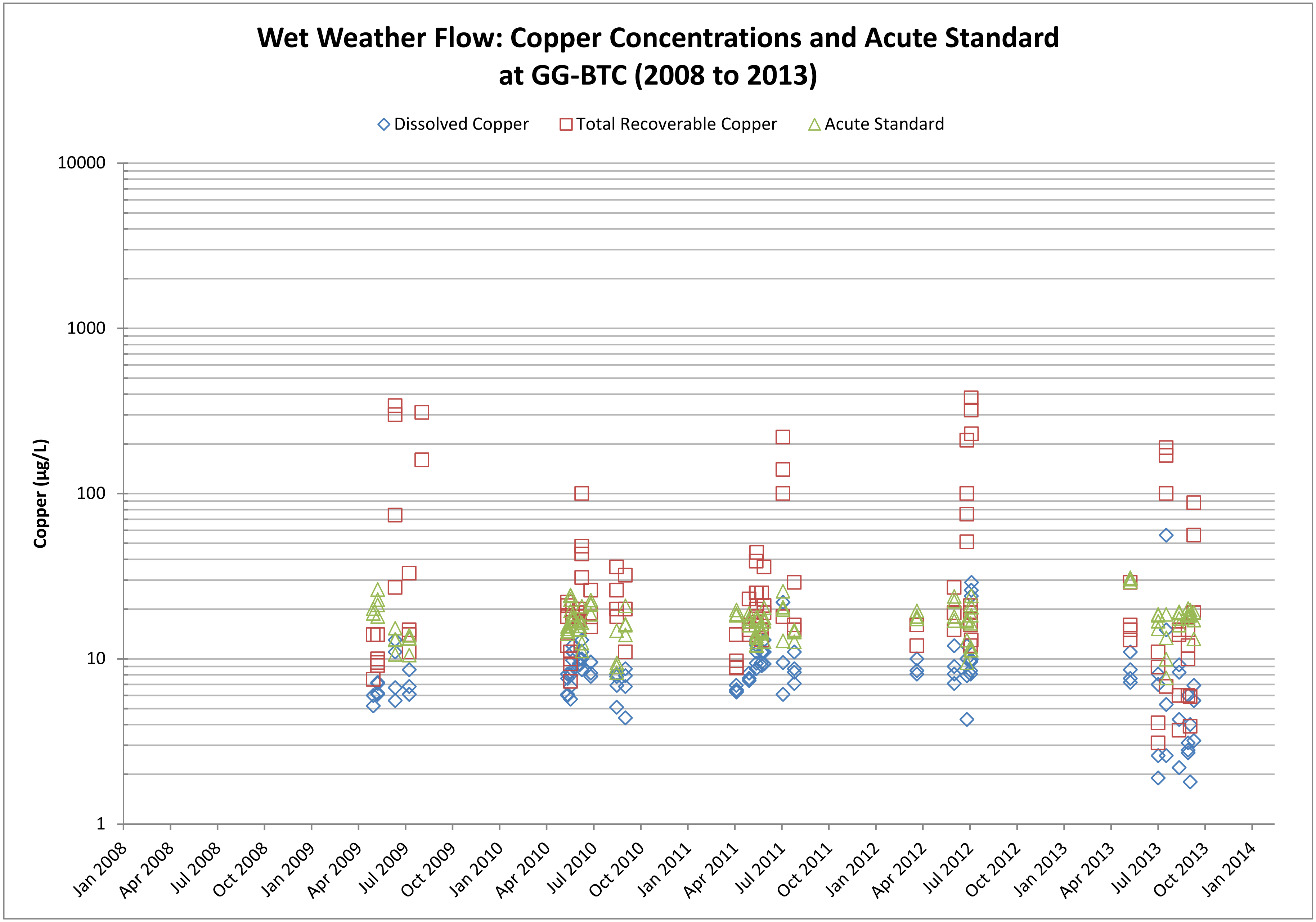

Figure 10-8
Wet Weather Flow Copper Concentrations at GG-BTC - 2008 to 2013

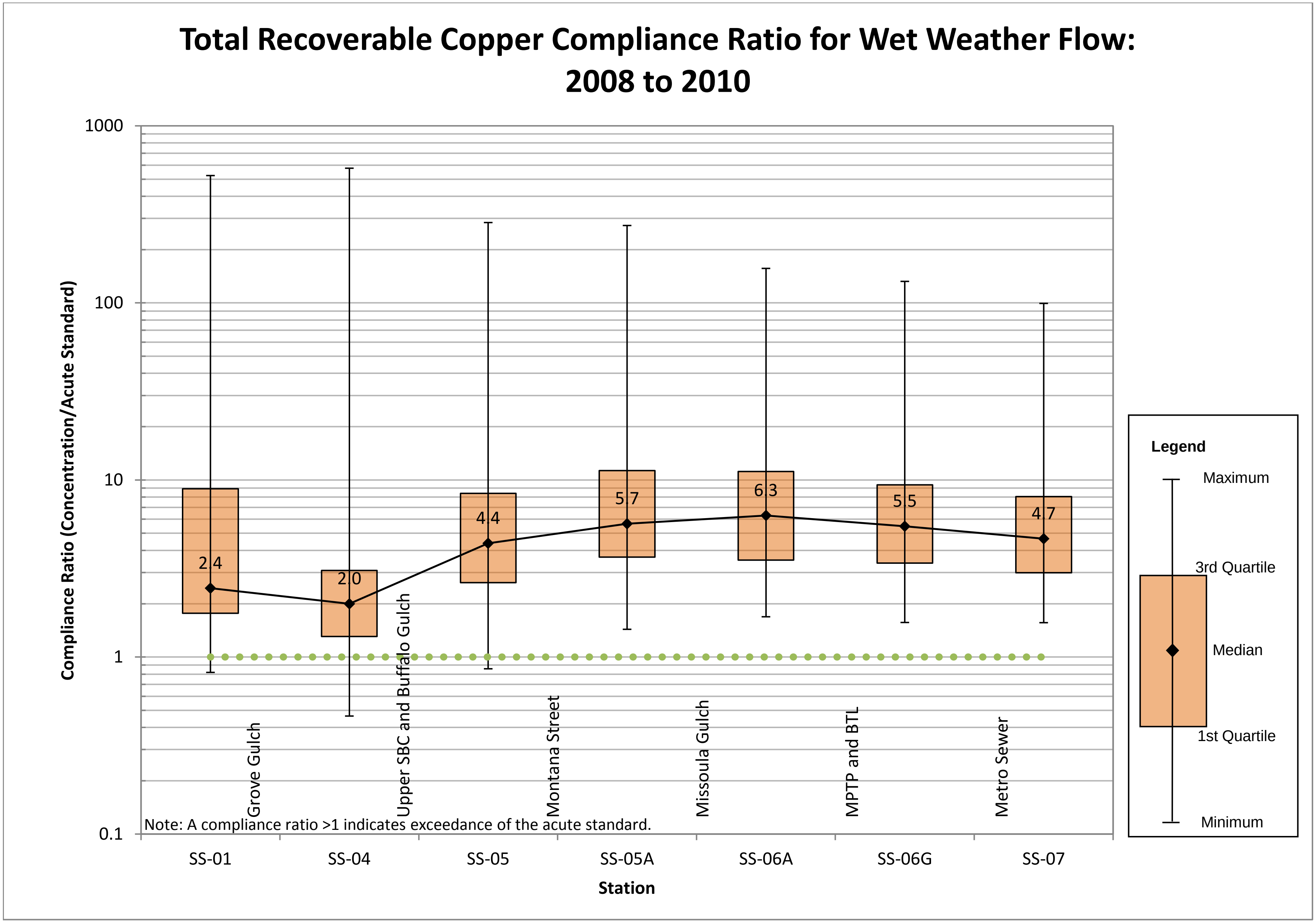

Figure 10-9
Wet Flow Total Recoverable Copper Compliance Ratio - 2008 to 2010

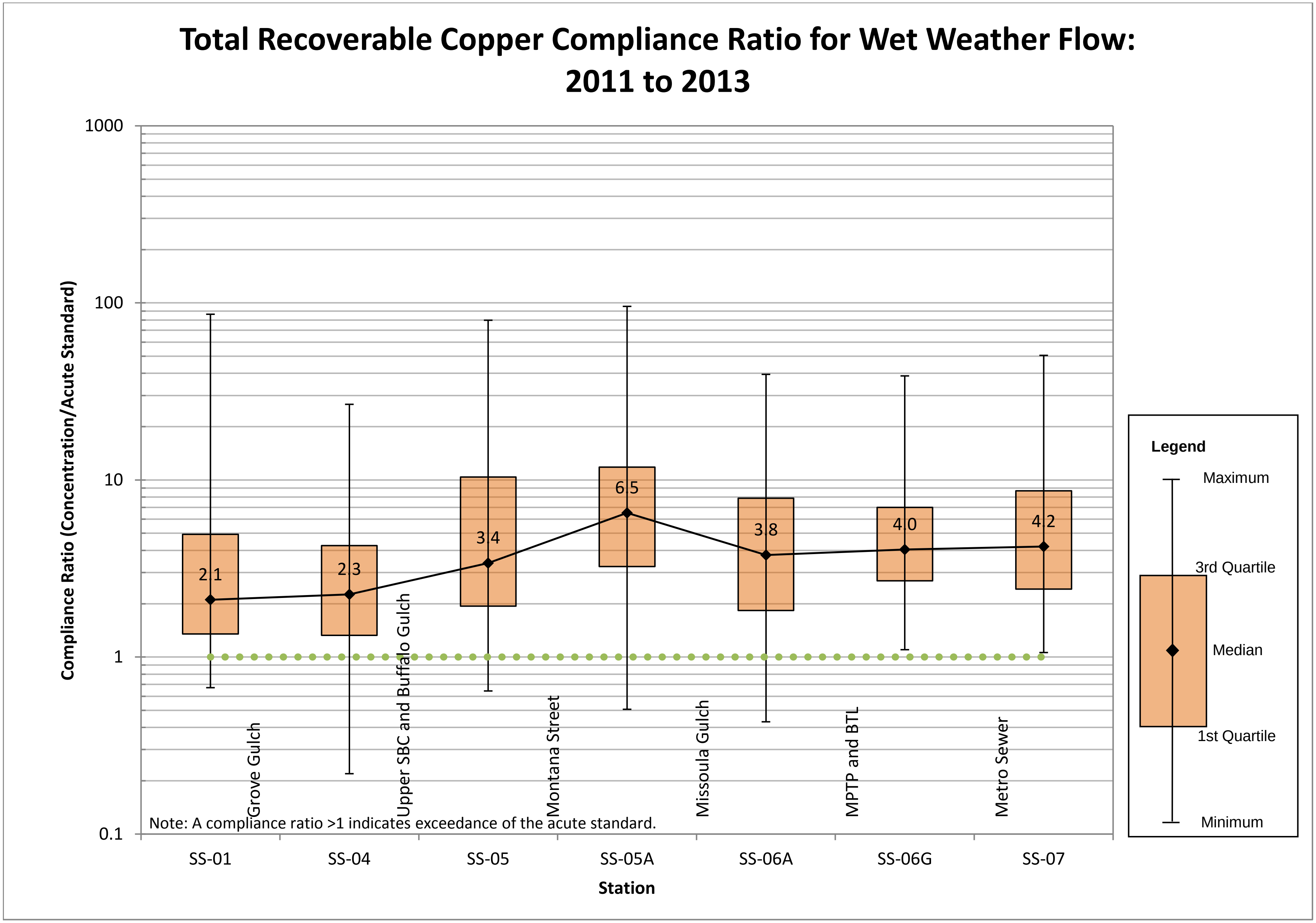

Figure 10-10
Wet Flow Total Recoverable Copper Compliance Ratio - 2011 to 2013

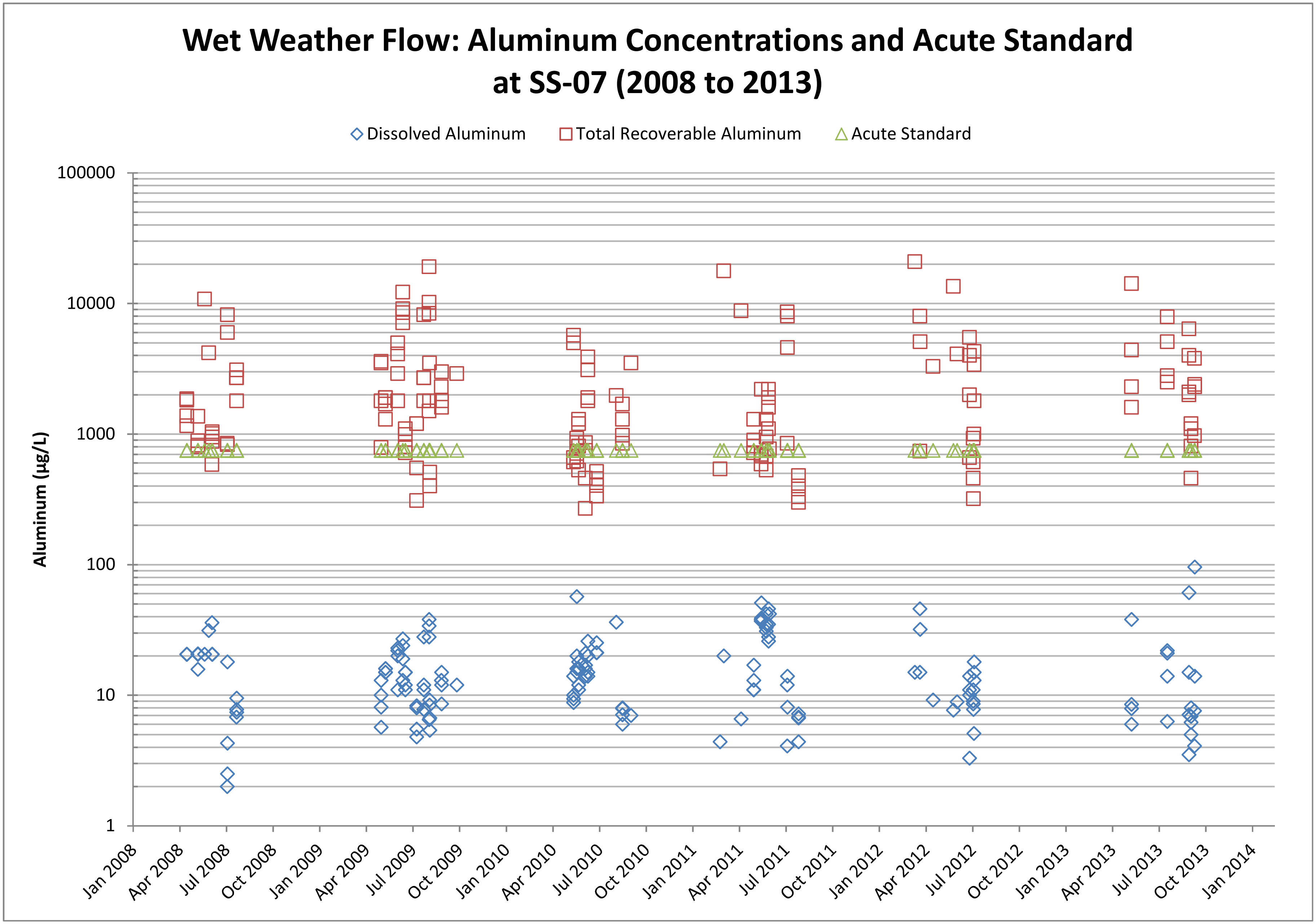

Figure 10-11
Wet Flow Aluminum Concentrations at SS-07 - 2008 to 2013

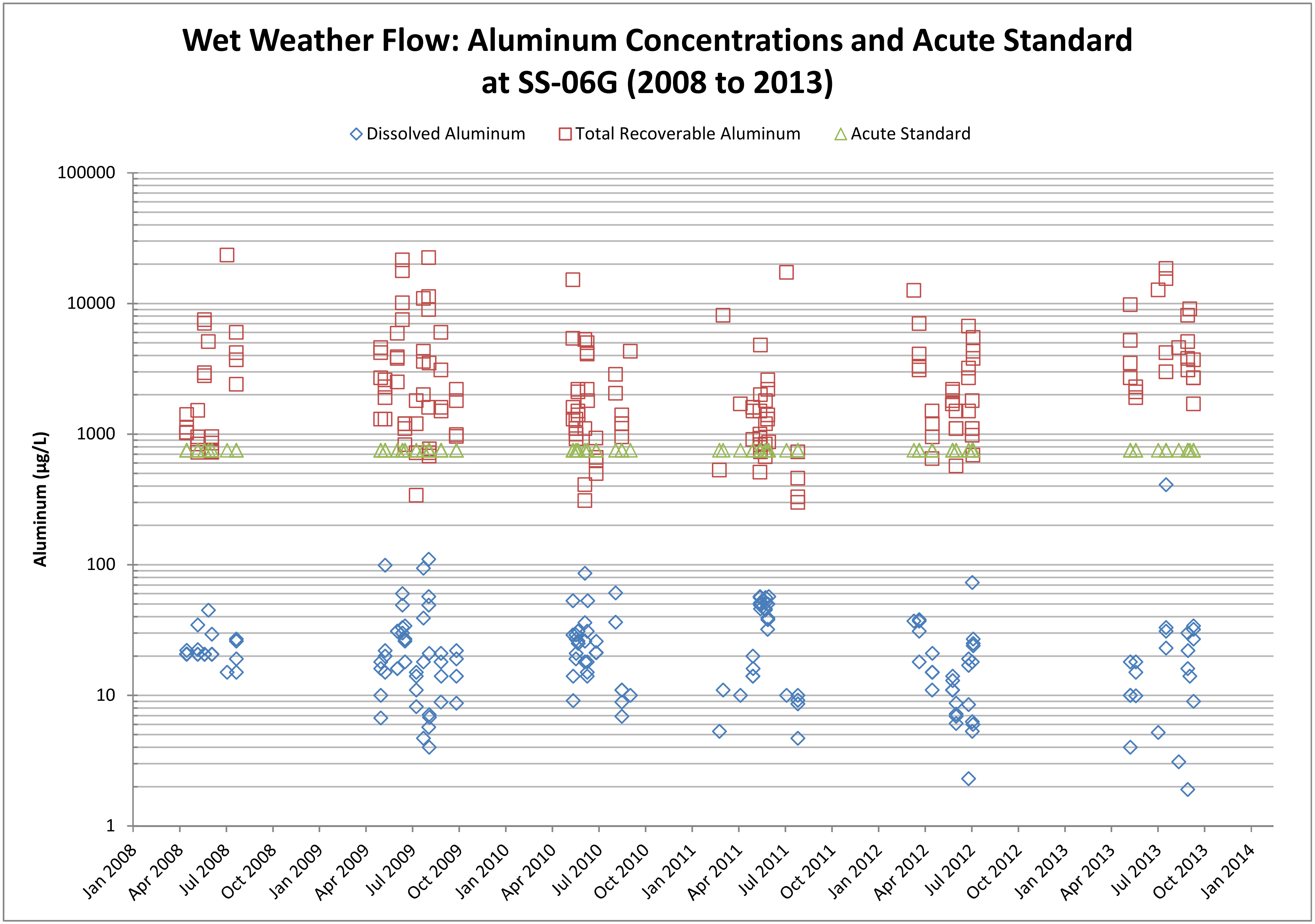

Figure 10-12
Wet Flow Aluminum Concentrations at SS-06G - 2008 to 2013

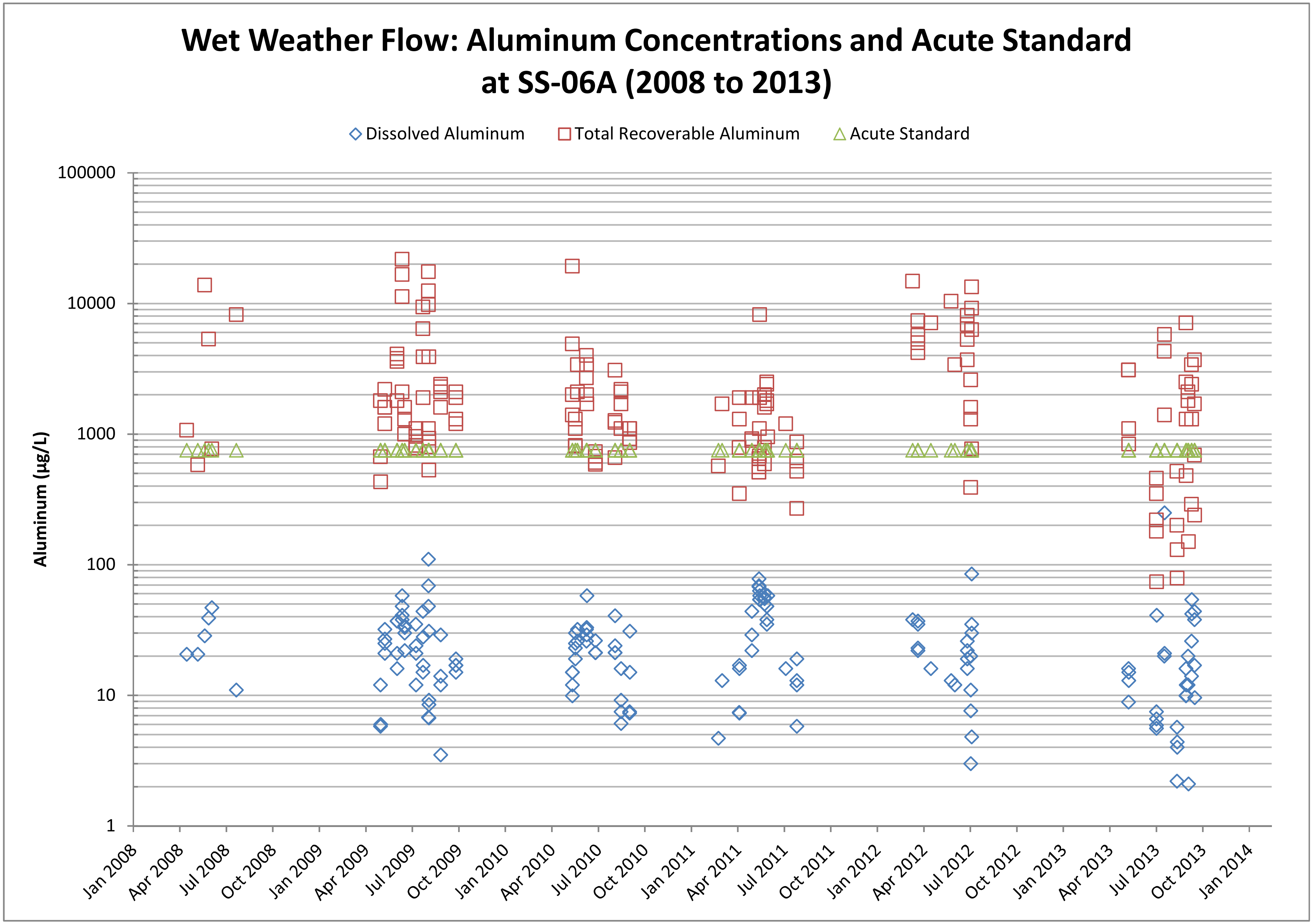

Figure 10-13
Wet Flow Aluminum Concentrations at SS-06A - 2008 to 2013

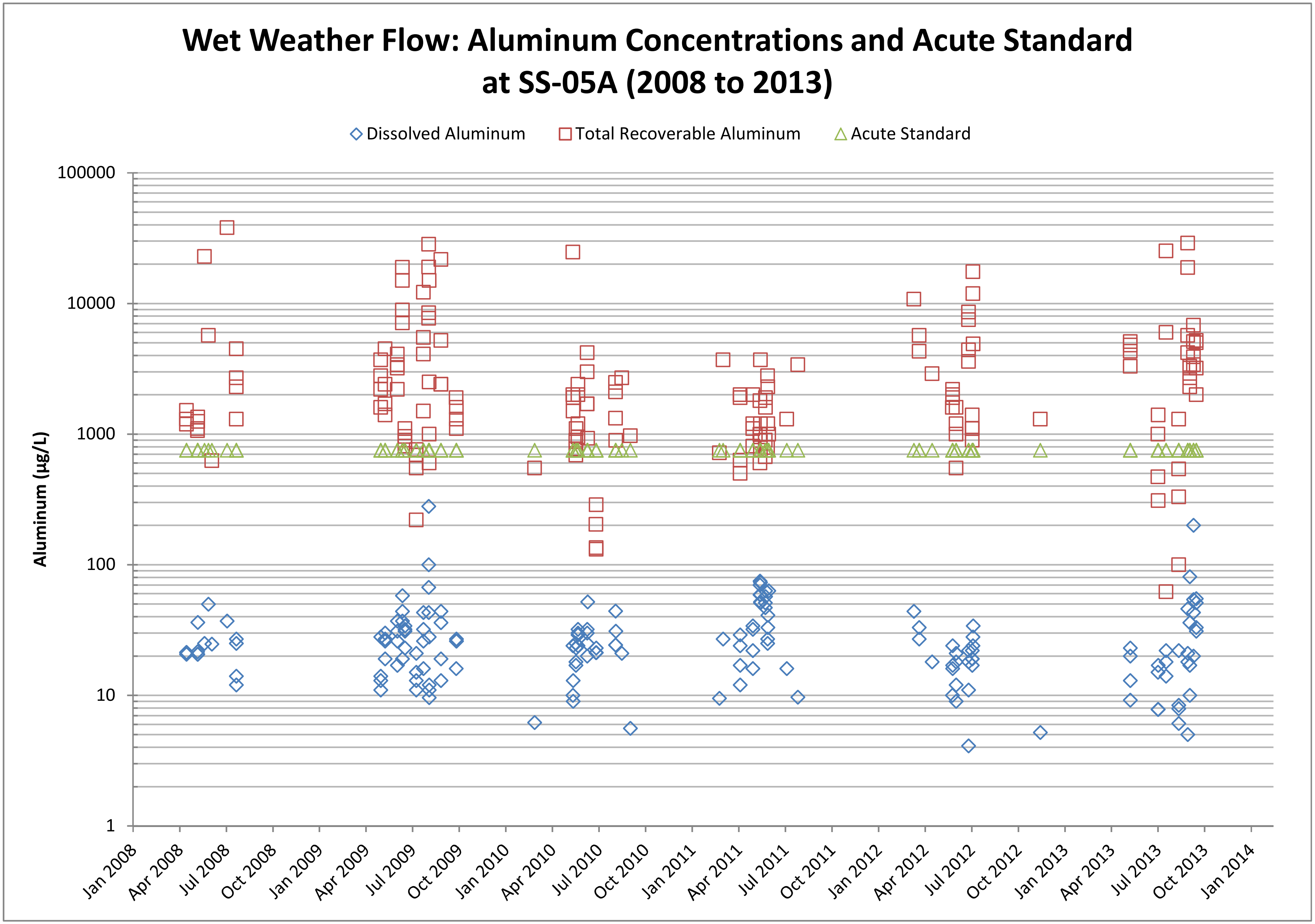

Figure 10-14
Wet Flow Aluminum Concentrations at SS-05A - 2008 to 2013

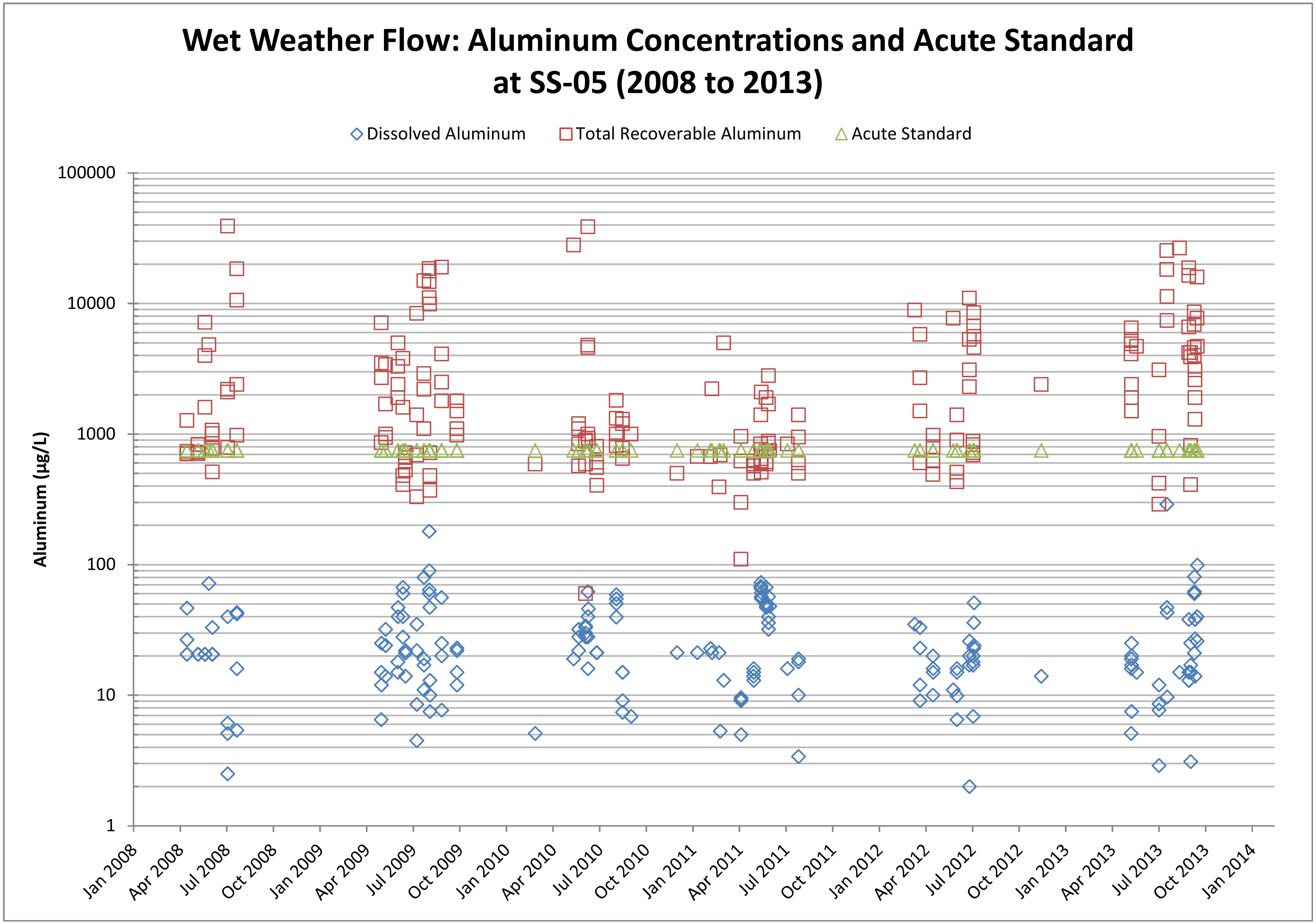

Figure 10-15
Wet Flow Aluminum Concentrations at SS-05 - 2008 to 2013

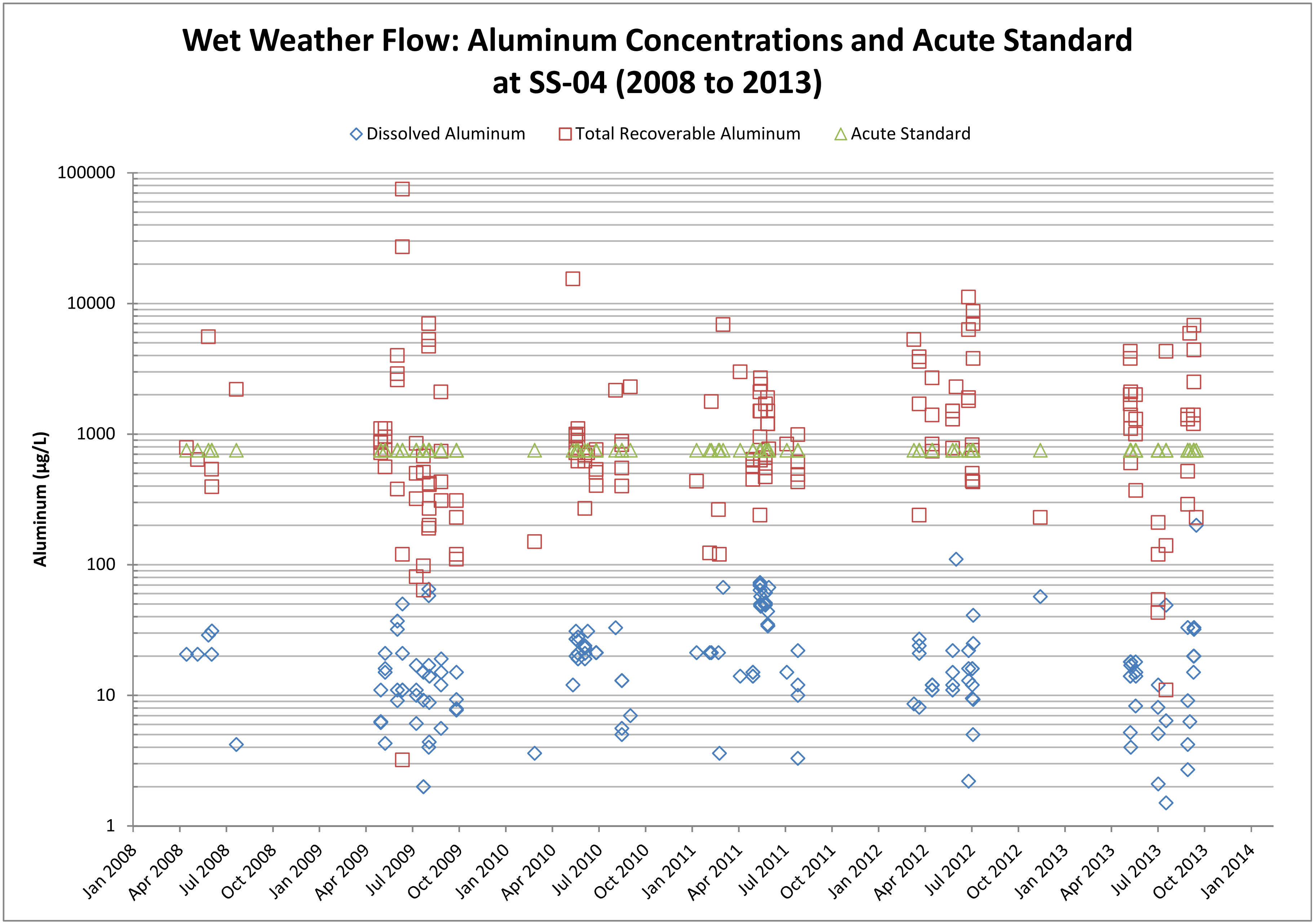

Figure 10-16
Wet Flow Aluminum Concentrations at SS-04 - 2008 to 2013

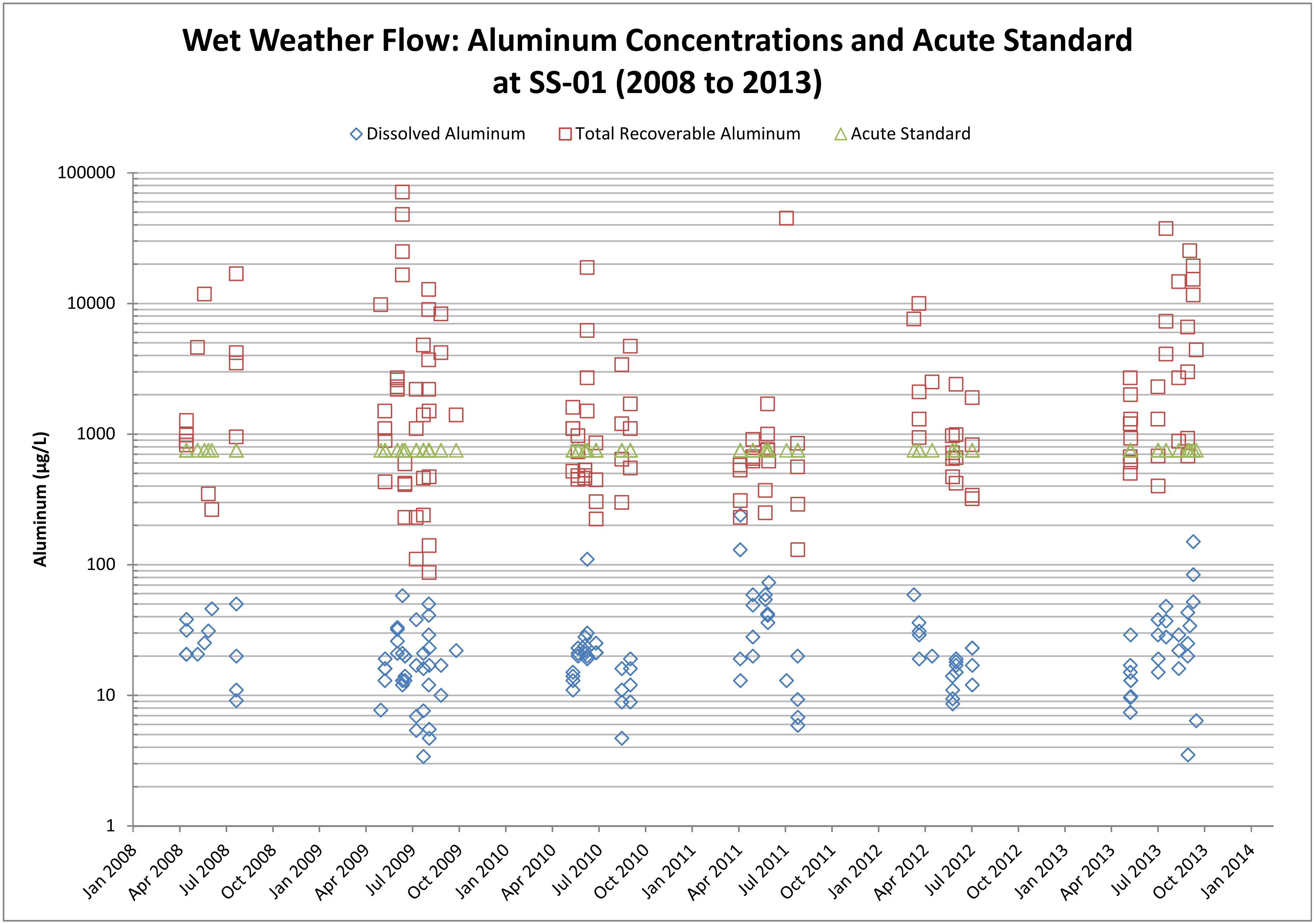

Figure 10-17
Wet Flow Aluminum Concentrations at SS-01 - 2008 to 2013

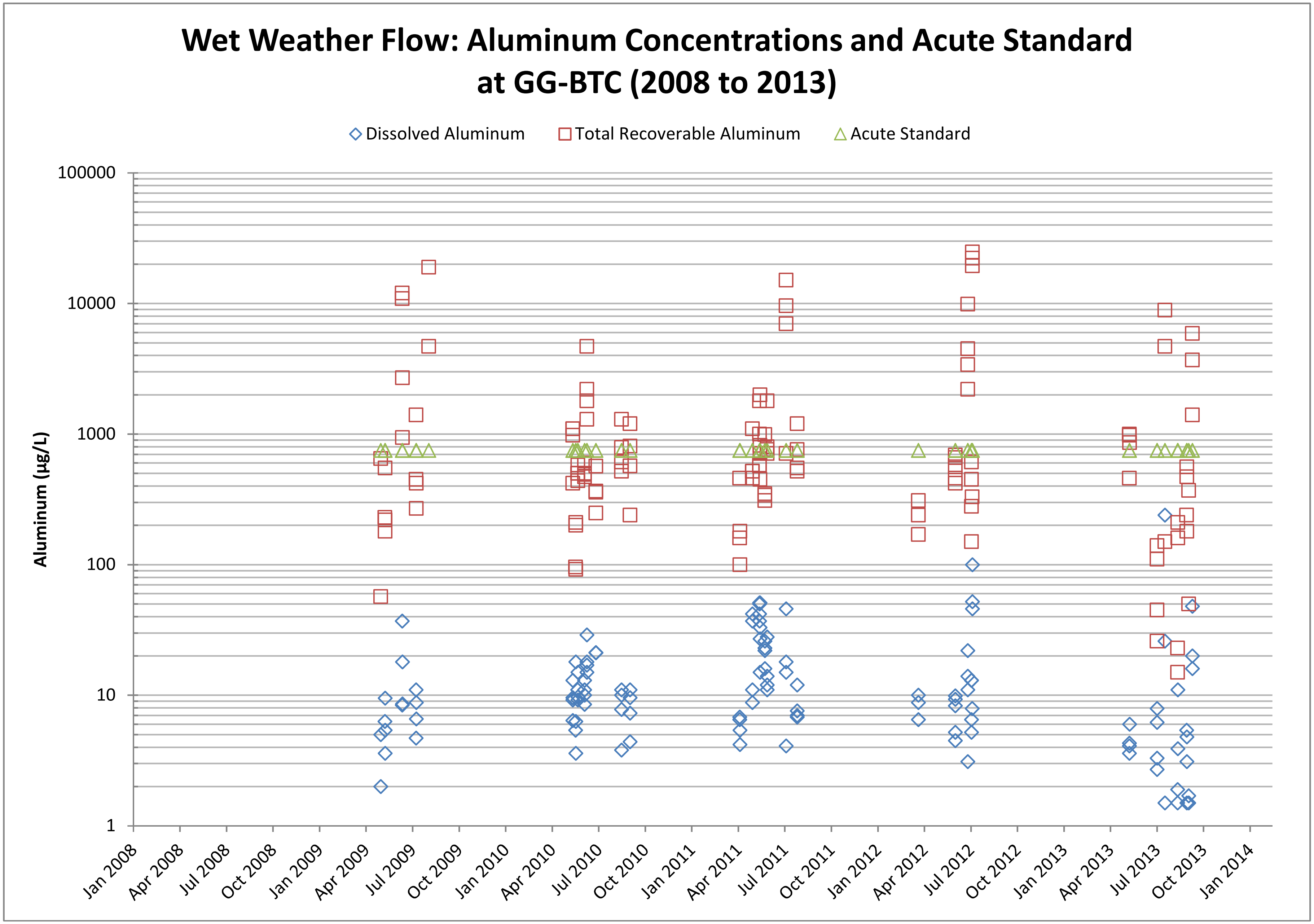

Figure 10-18
Wet Flow Aluminum Concentrations at GG-BTC - 2008 to 2013

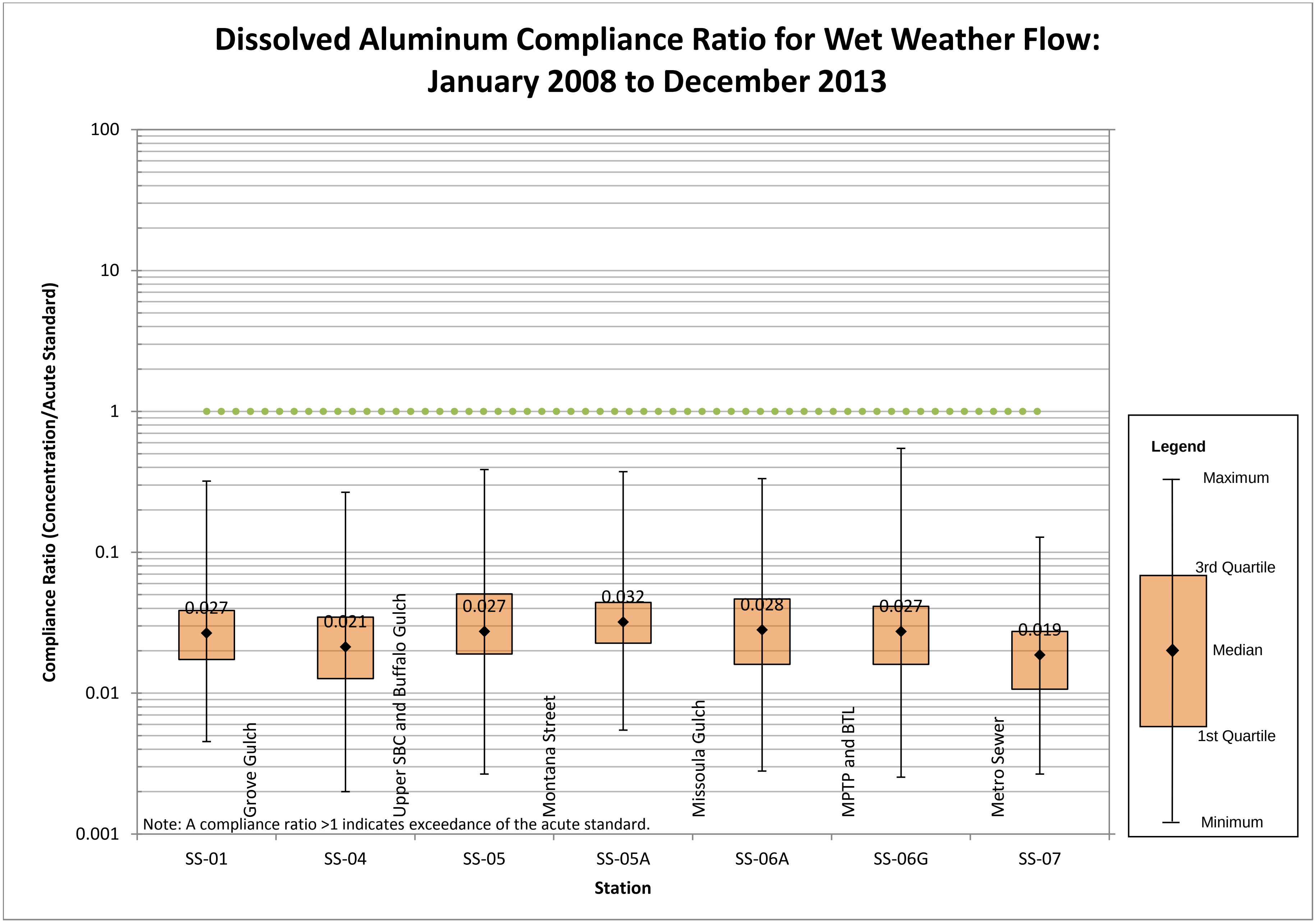

Figure 10-19
Wet Flow Dissolved Aluminum Compliance Ratio - 2008 to 2013

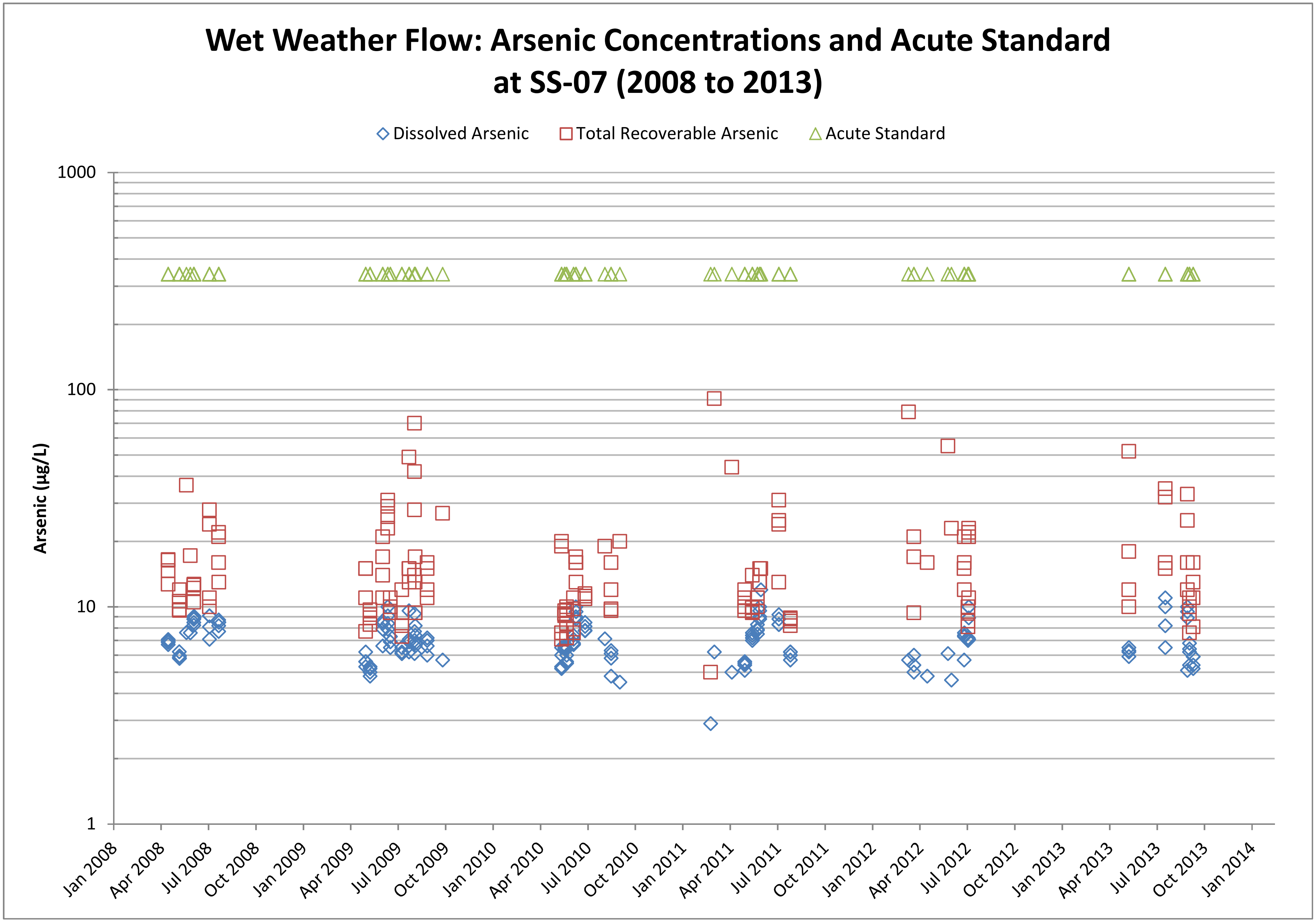

Figure 10-20
Wet Weather Flow Arsenic Concentrations at SS-07 - 2008 to 2013

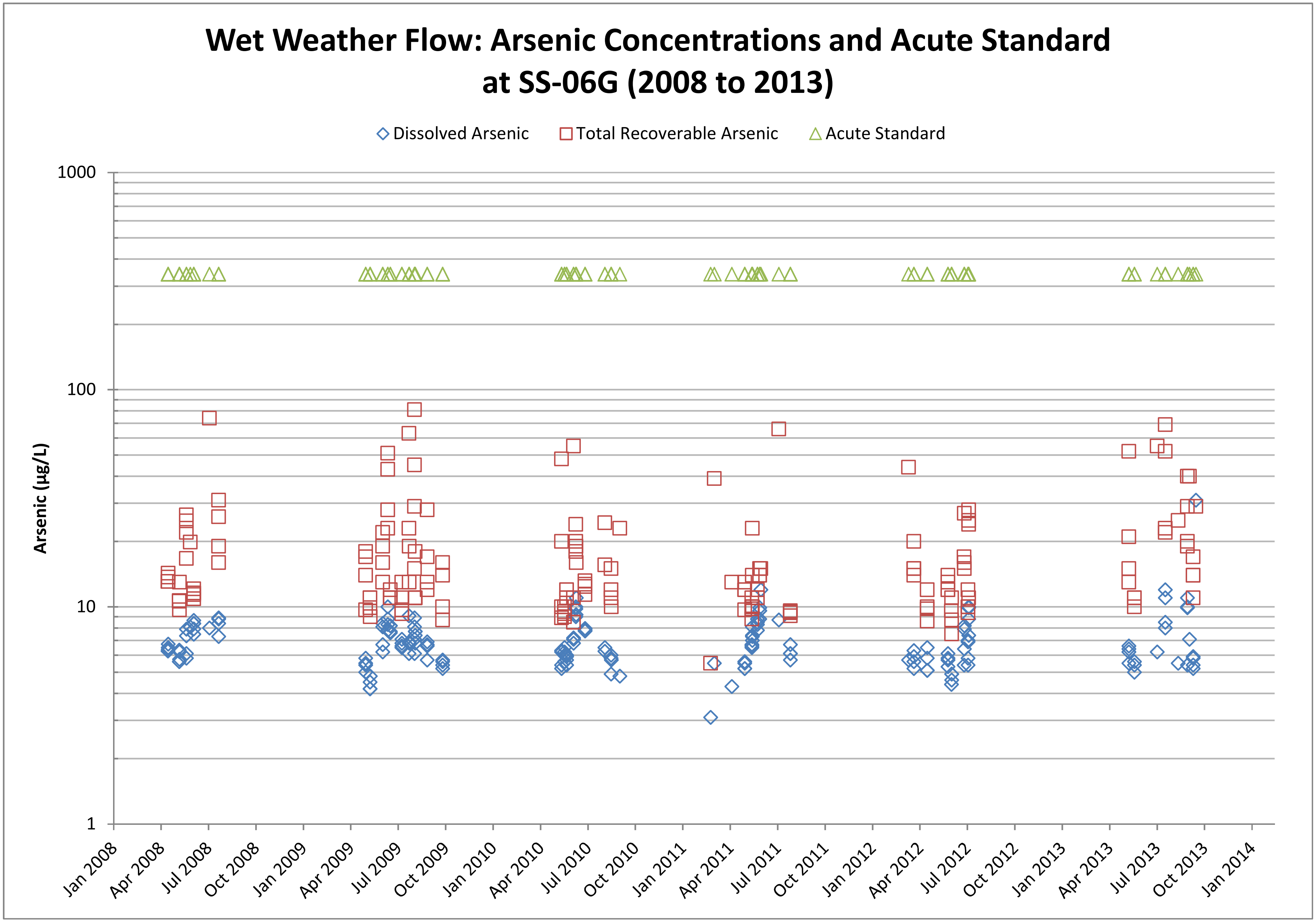

Figure 10-21
Wet Weather Flow Arsenic Concentrations at SS-06G - 2008 to 2013

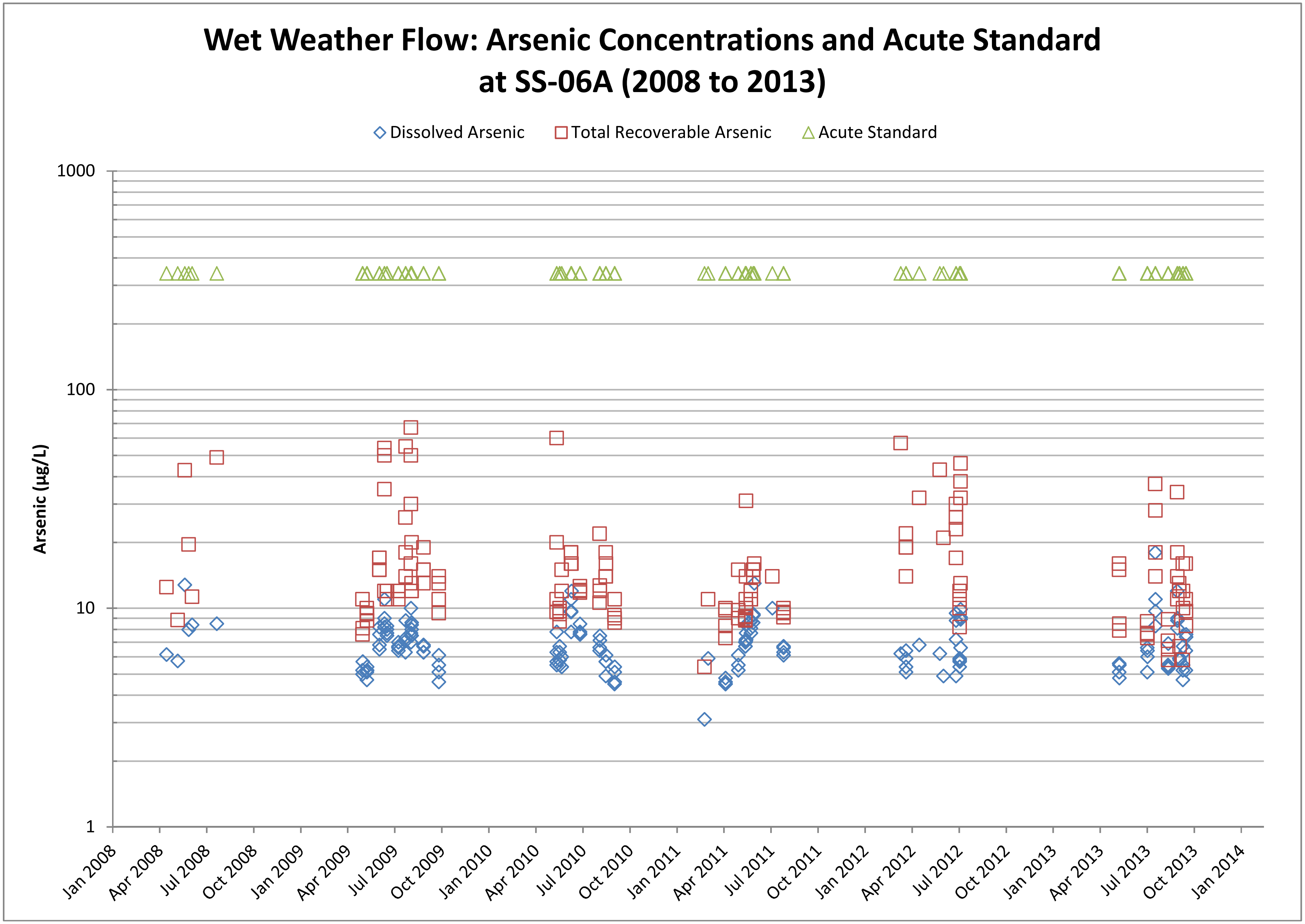

Figure 10-22
Wet Weather Flow Arsenic Concentrations at SS-06A - 2008 to 2013

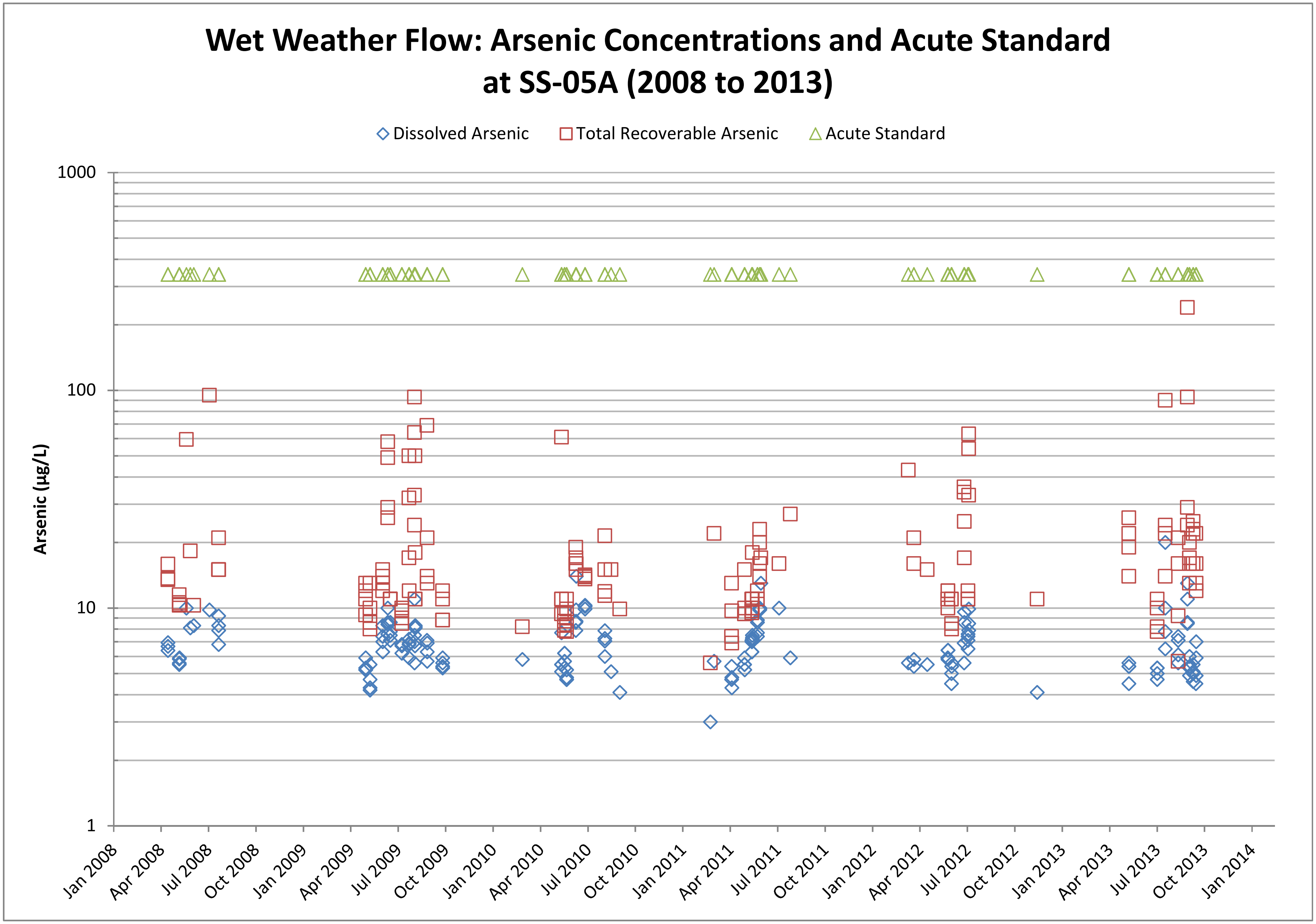

Figure 10-23
Wet Weather Flow Arsenic Concentrations at SS-05A - 2008 to 2013

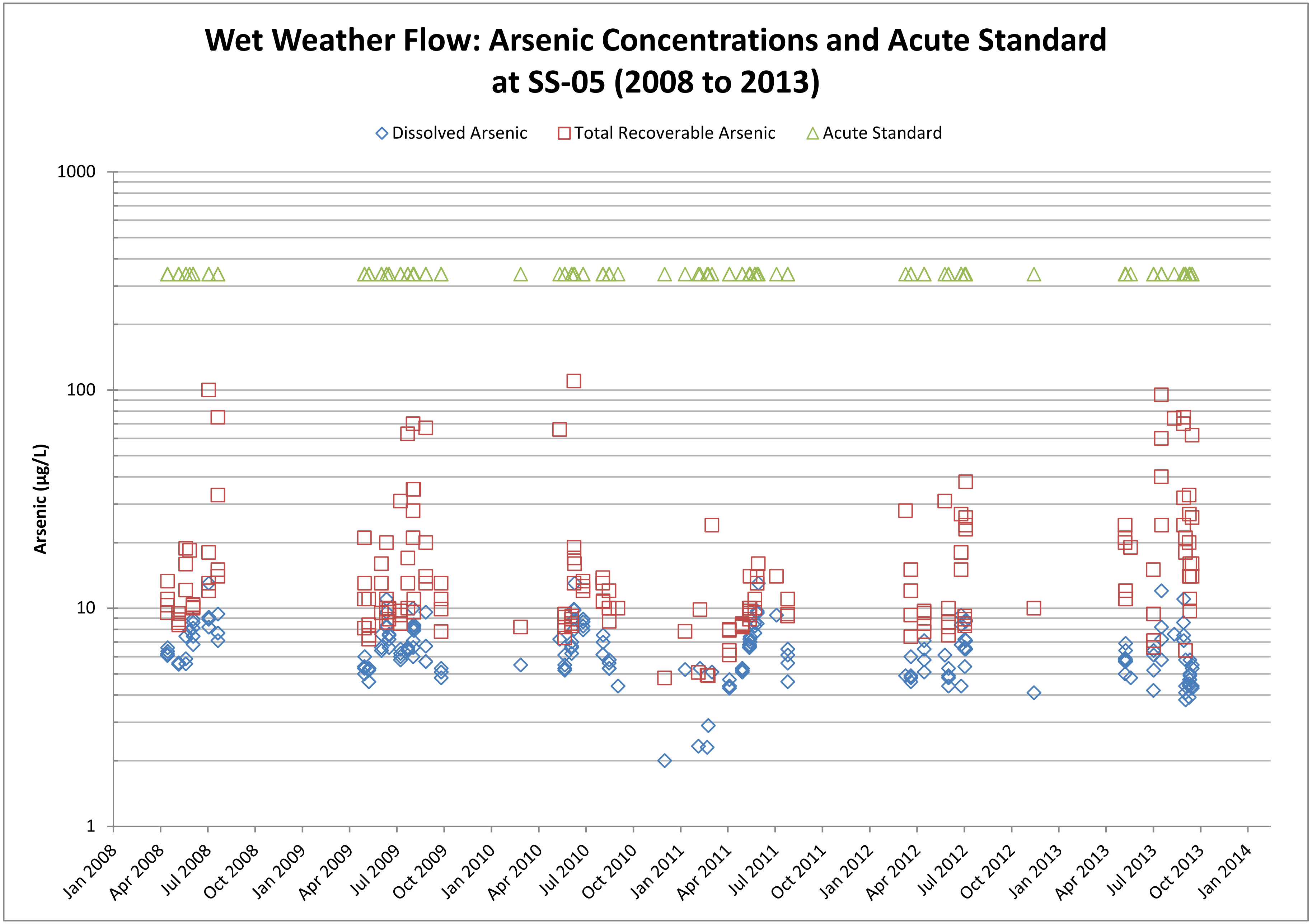

Figure 10-24
Wet Weather Flow Arsenic Concentrations at SS-05 - 2008 to 2013

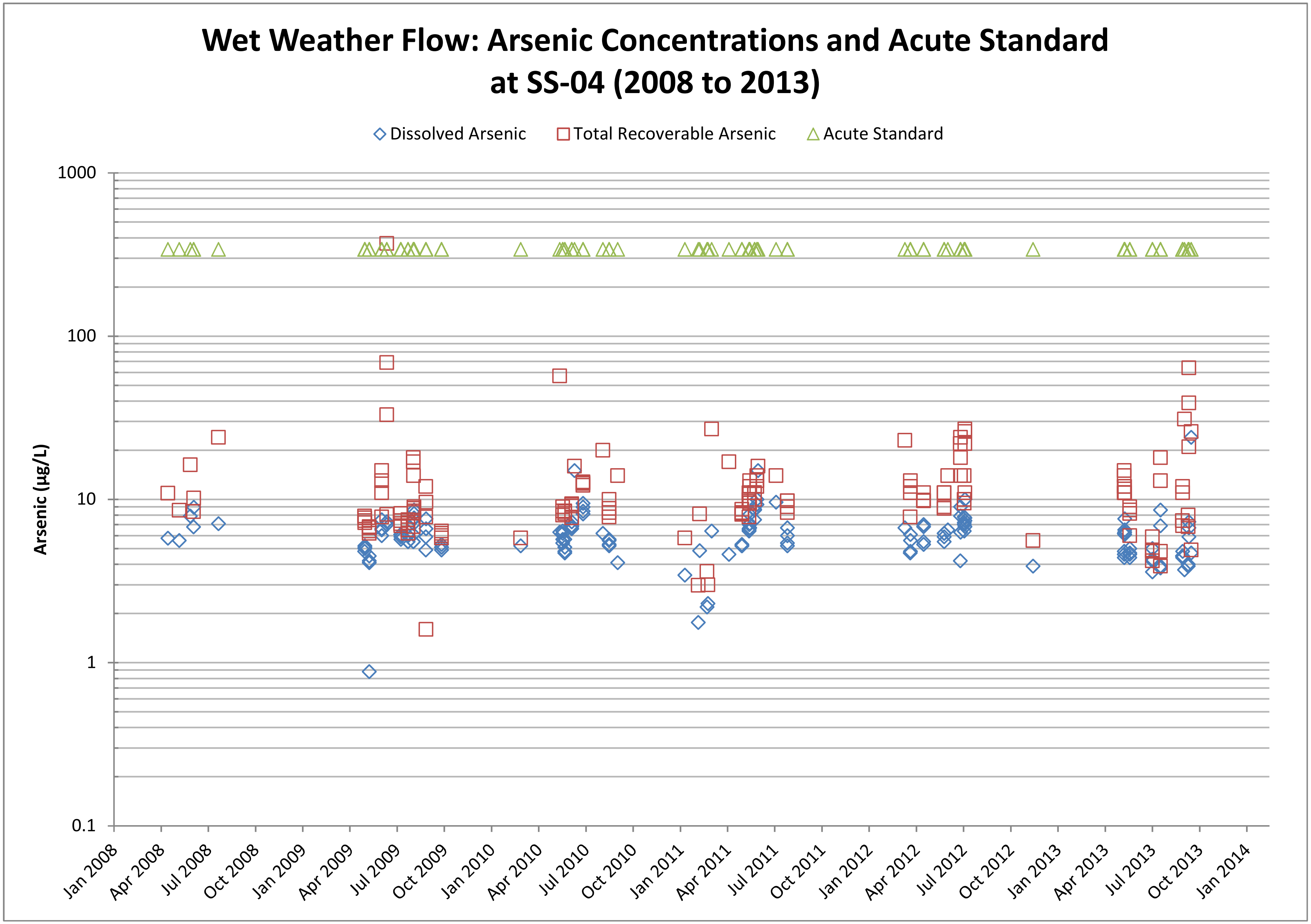

Figure 10-25
Wet Weather Flow Arsenic Concentrations at SS-04 - 2008 to 2013

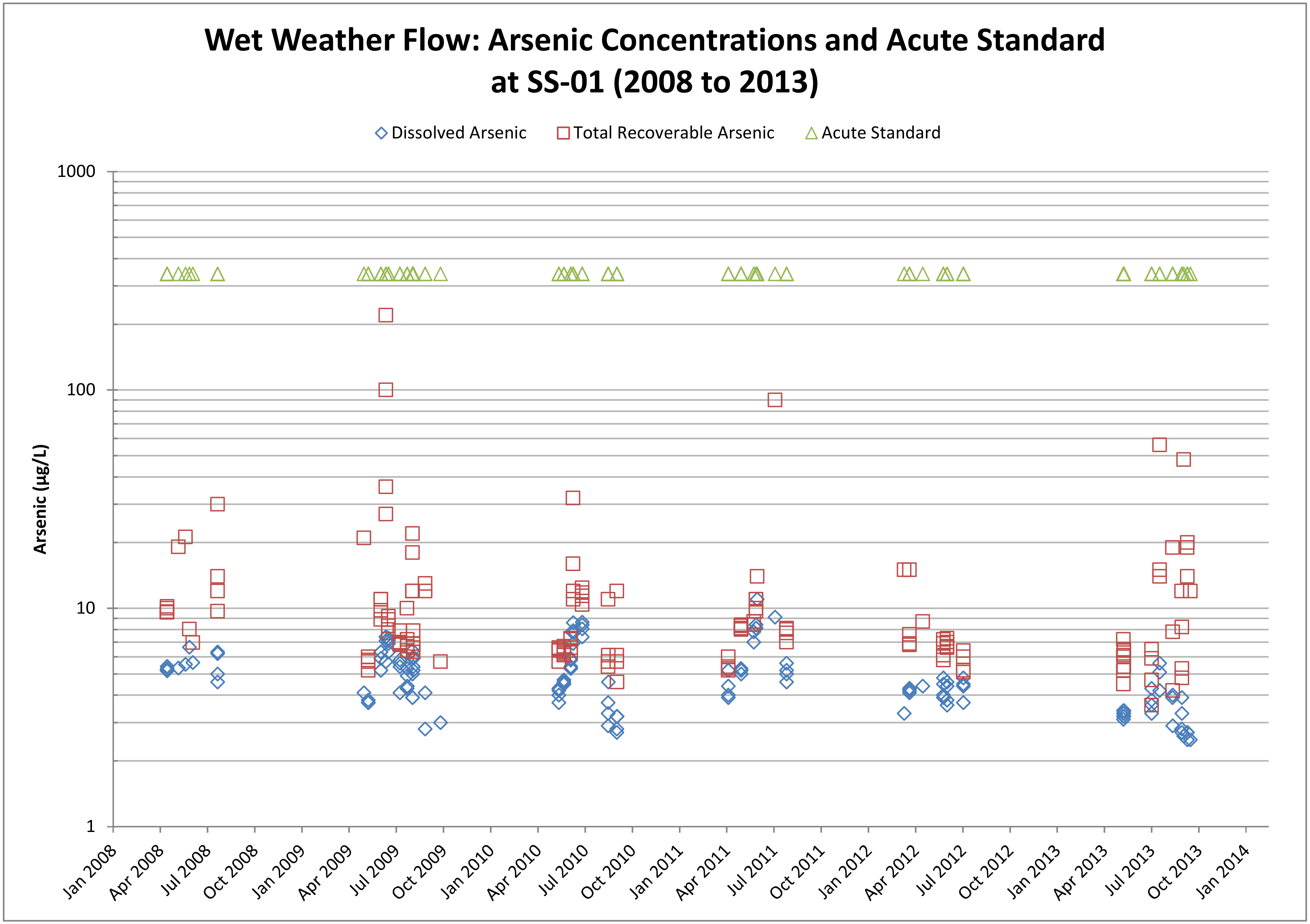

Figure 10-26
Wet Weather Flow Arsenic Concentrations at SS-01 - 2008 to 2013

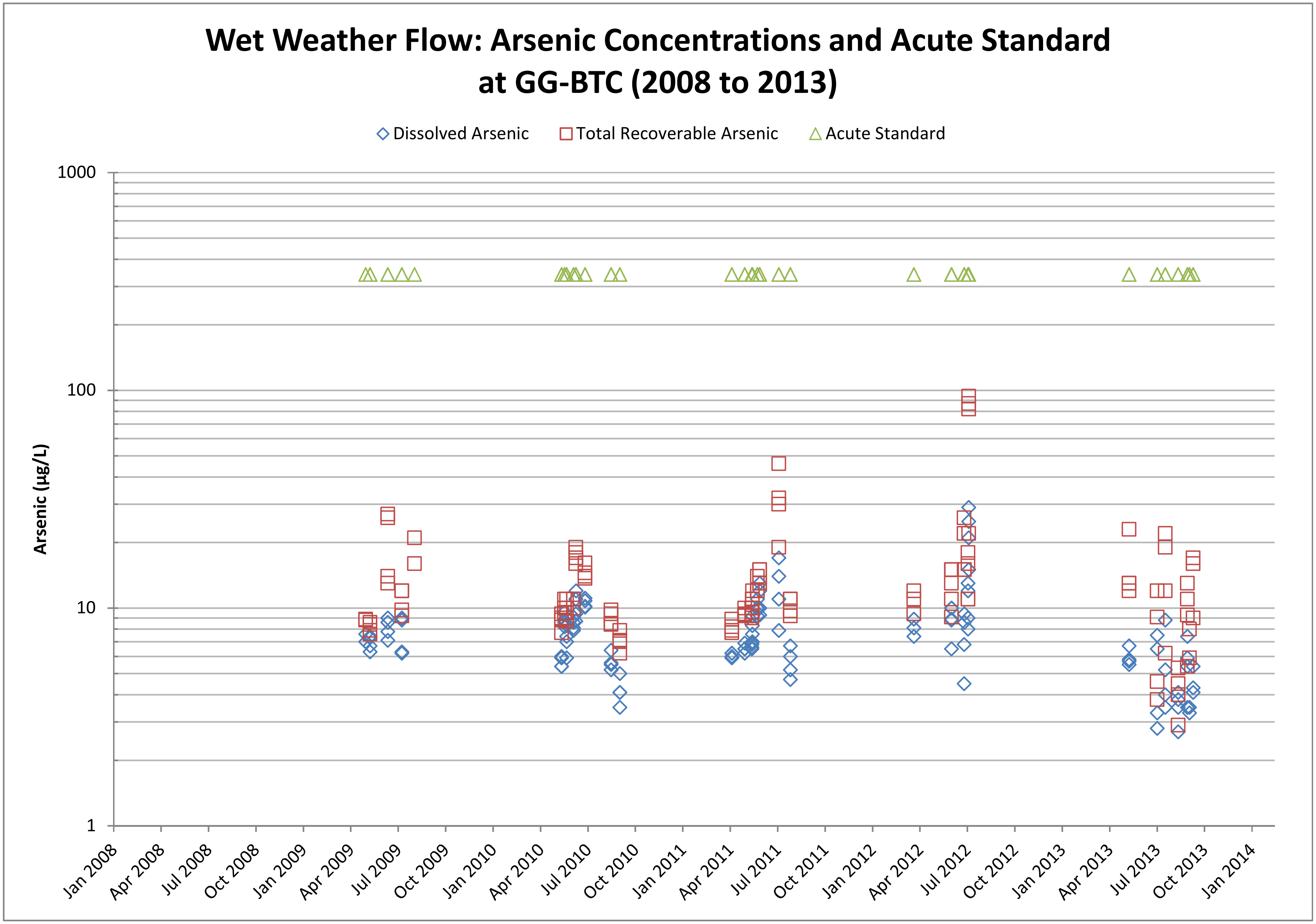

Figure 10-27
Wet Weather Flow Arsenic Concentrations at GG-BTC - 2008 to 2013

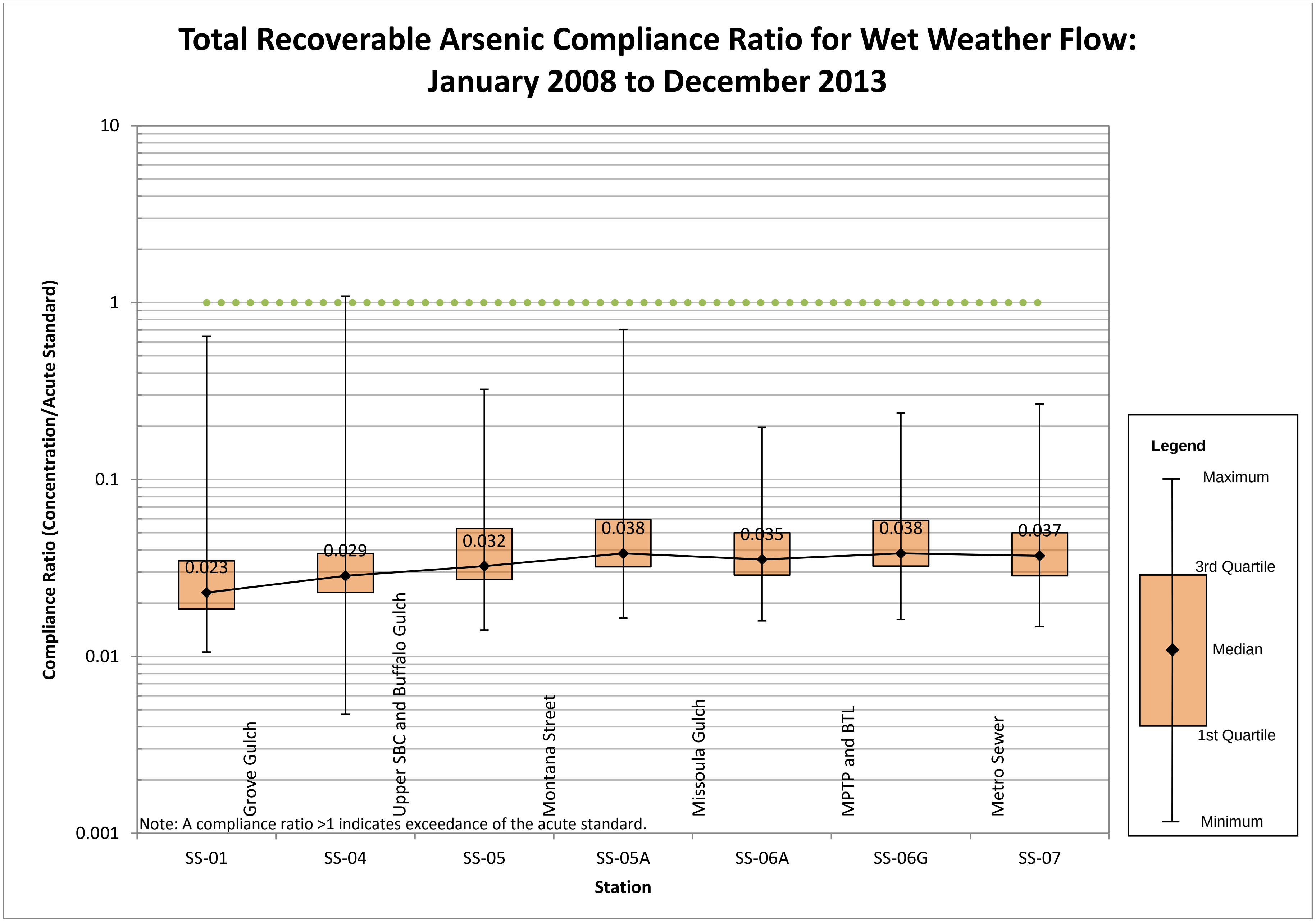

Figure 10-28
Wet Flow Total Arsenic Compliance Ratio - 2008 to 2013

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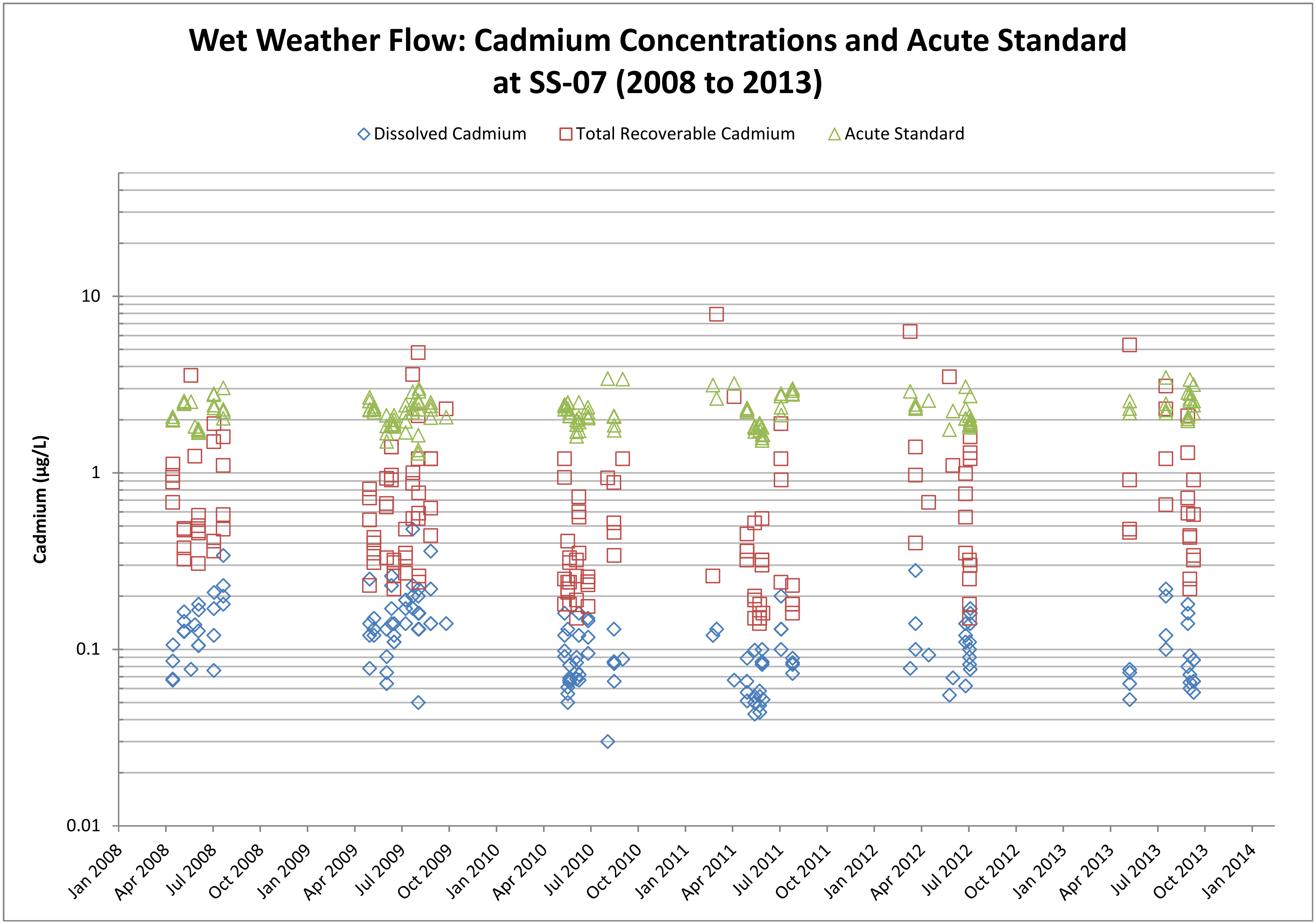

Figure 10-29
Wet Weather Flow Cadmium Concentrations at SS-07 - 2008 to 2013

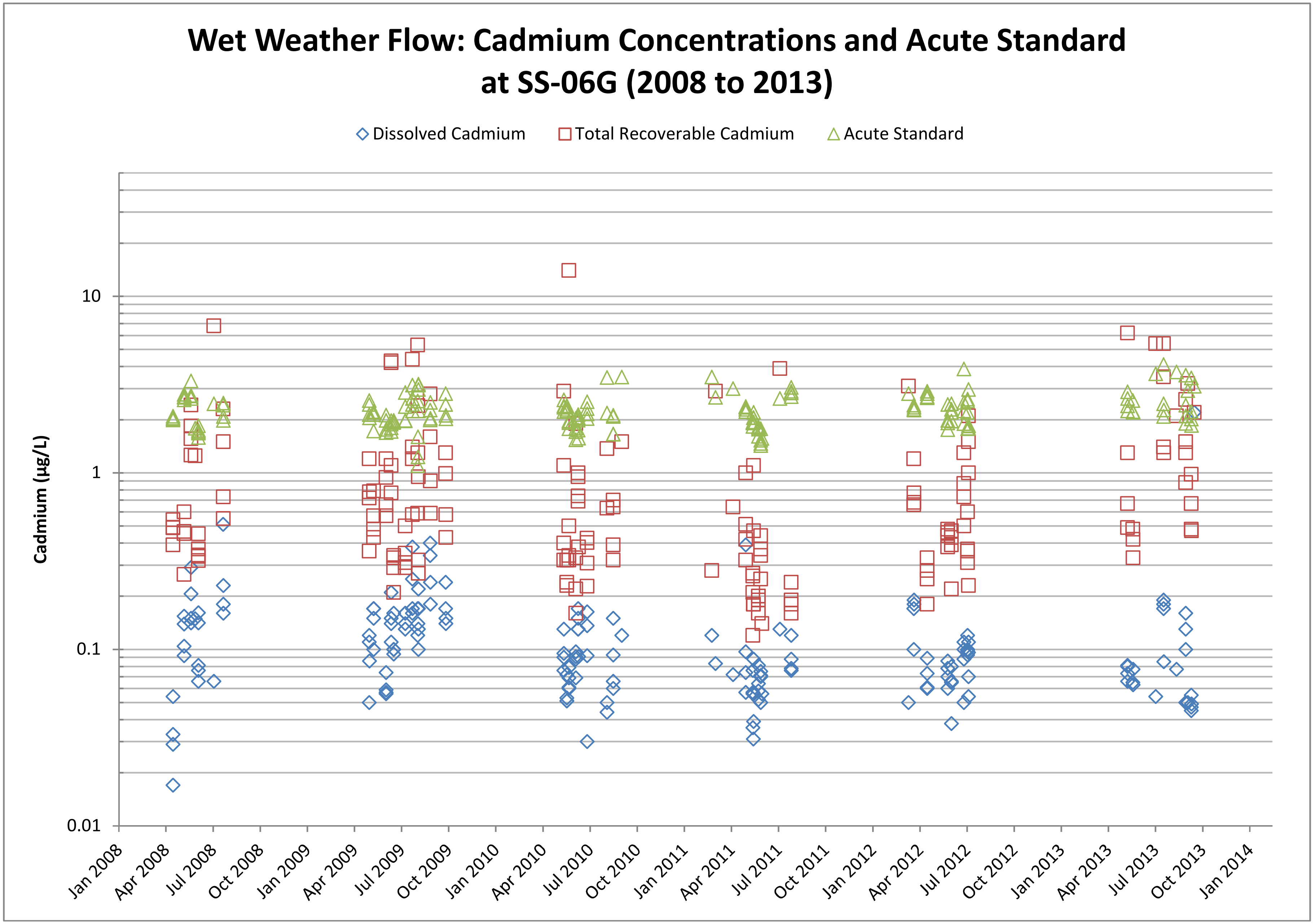

Figure 10-30
Wet Weather Flow Cadmium Concentrations at SS-06G - 2008 to 2013

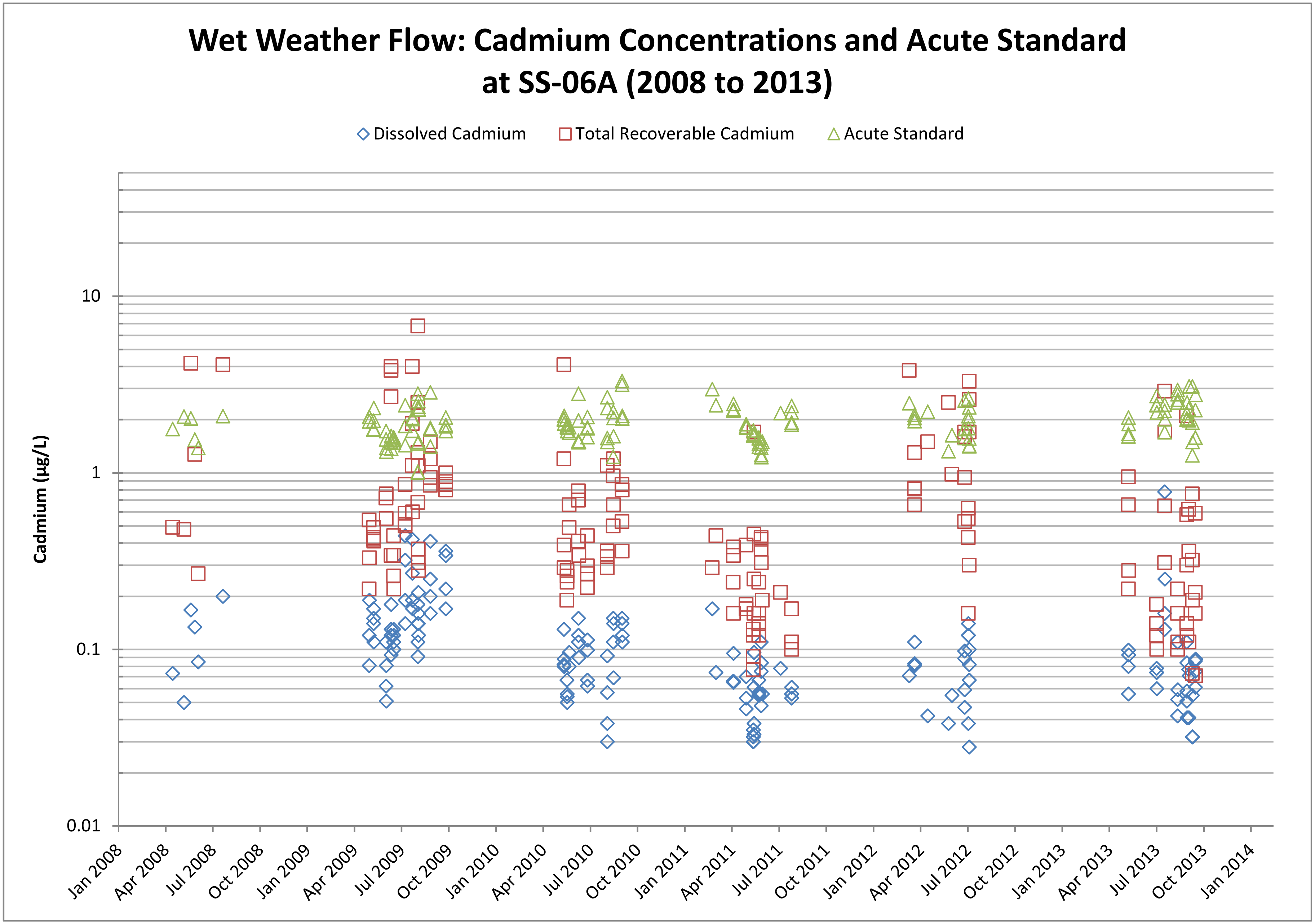

Figure 10-31
Wet Weather Flow Cadmium Concentrations at SS-06A -2008 to 2013

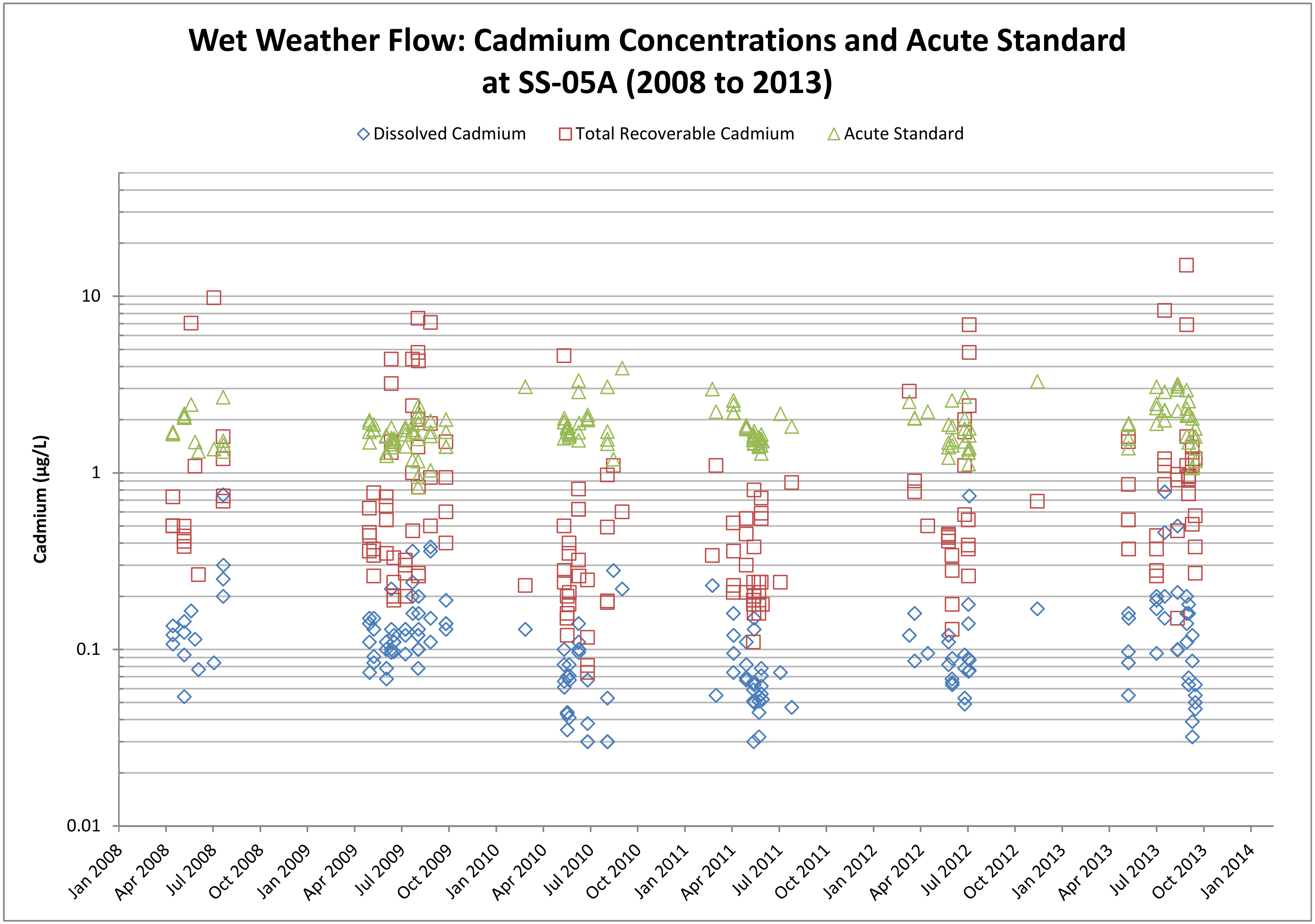

Figure 10-32
Wet Weather Flow Cadmium Concentrations at SS-05A - 2008 to 2013

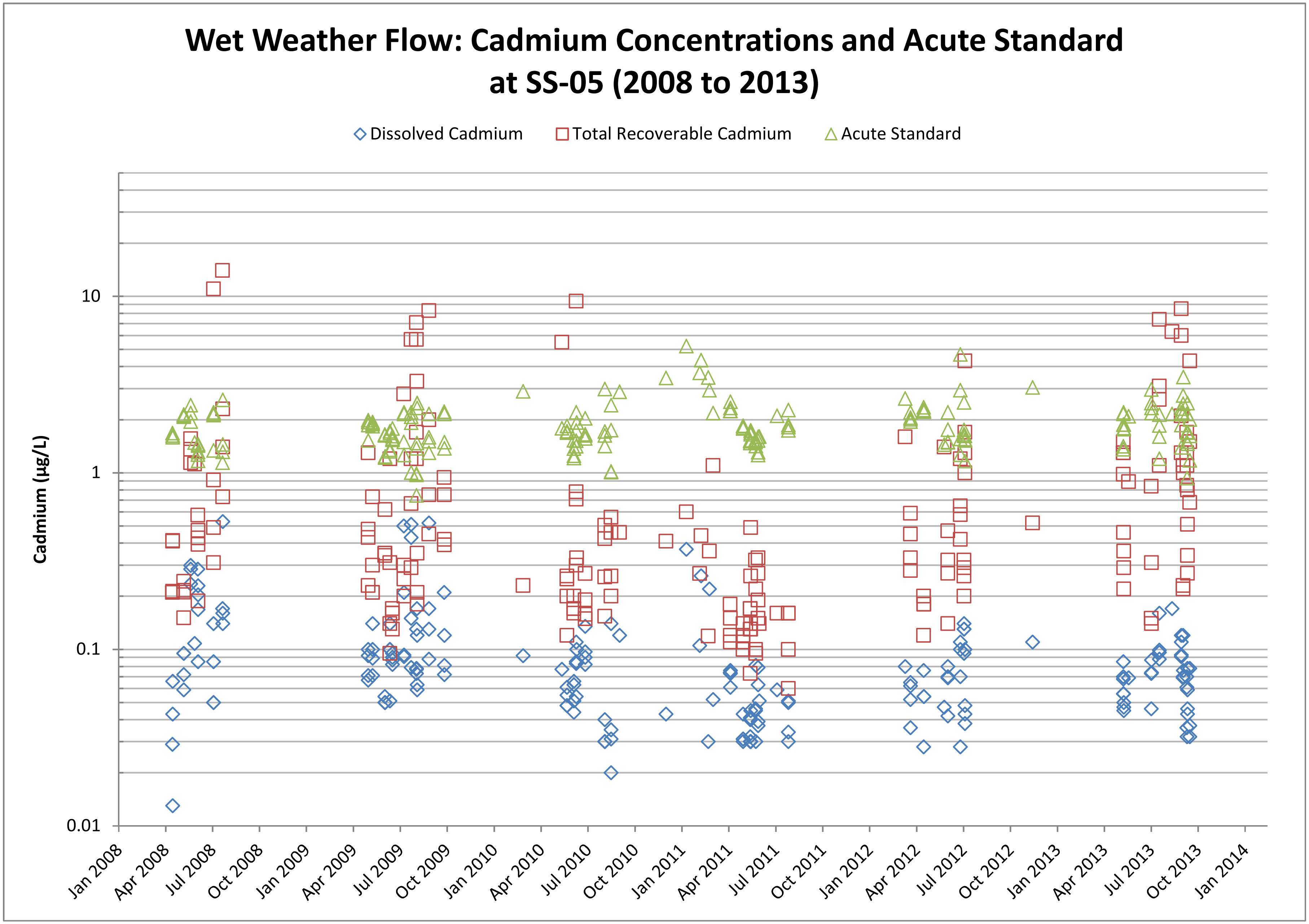

Figure 10-33
Wet Weather Flow Cadmium Concentrations at SS-05 - 2008 to 2013

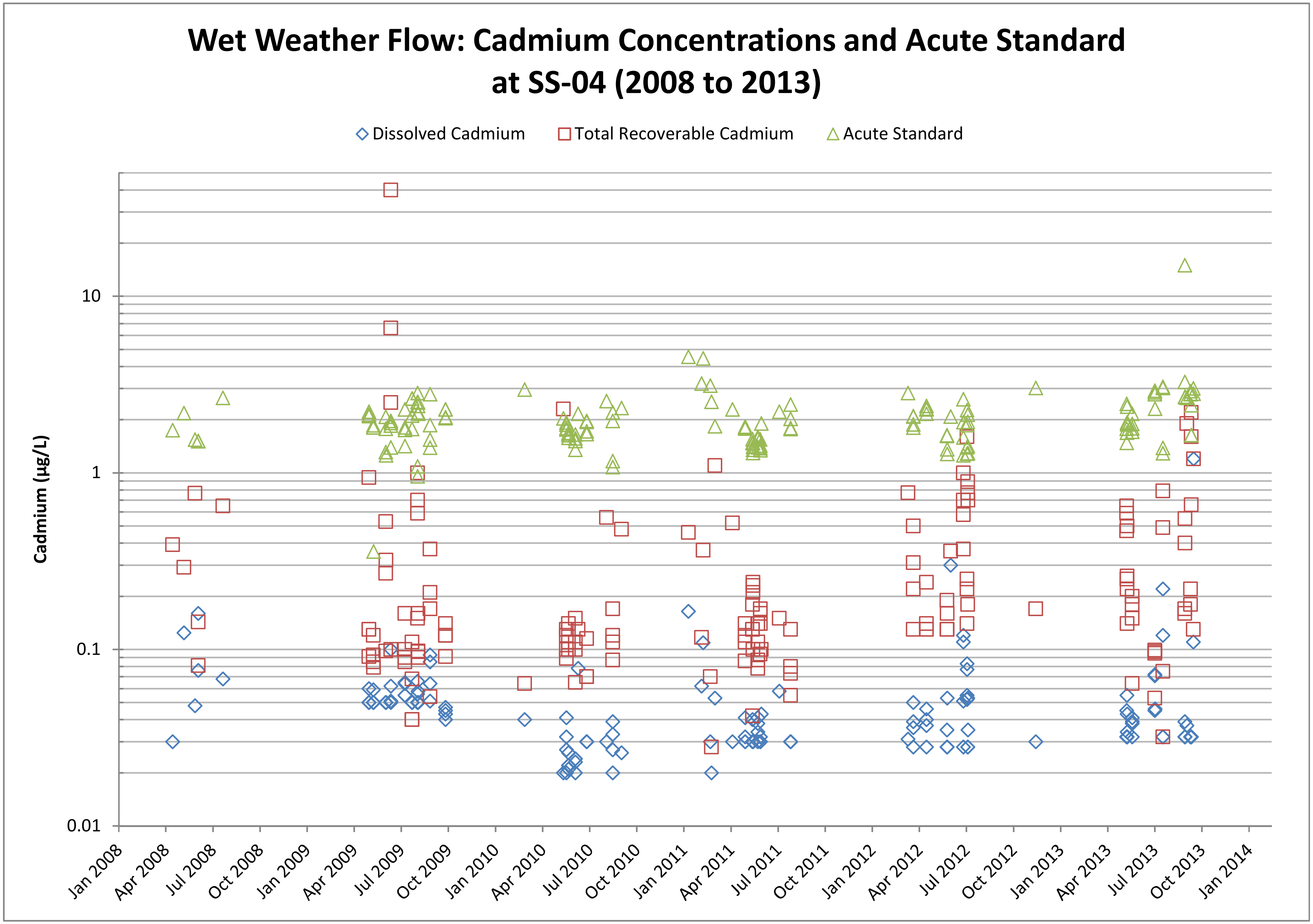

Figure 10-34
Wet Weather Flow Cadmium Concentrations at SS-04 - 2008 to 2013

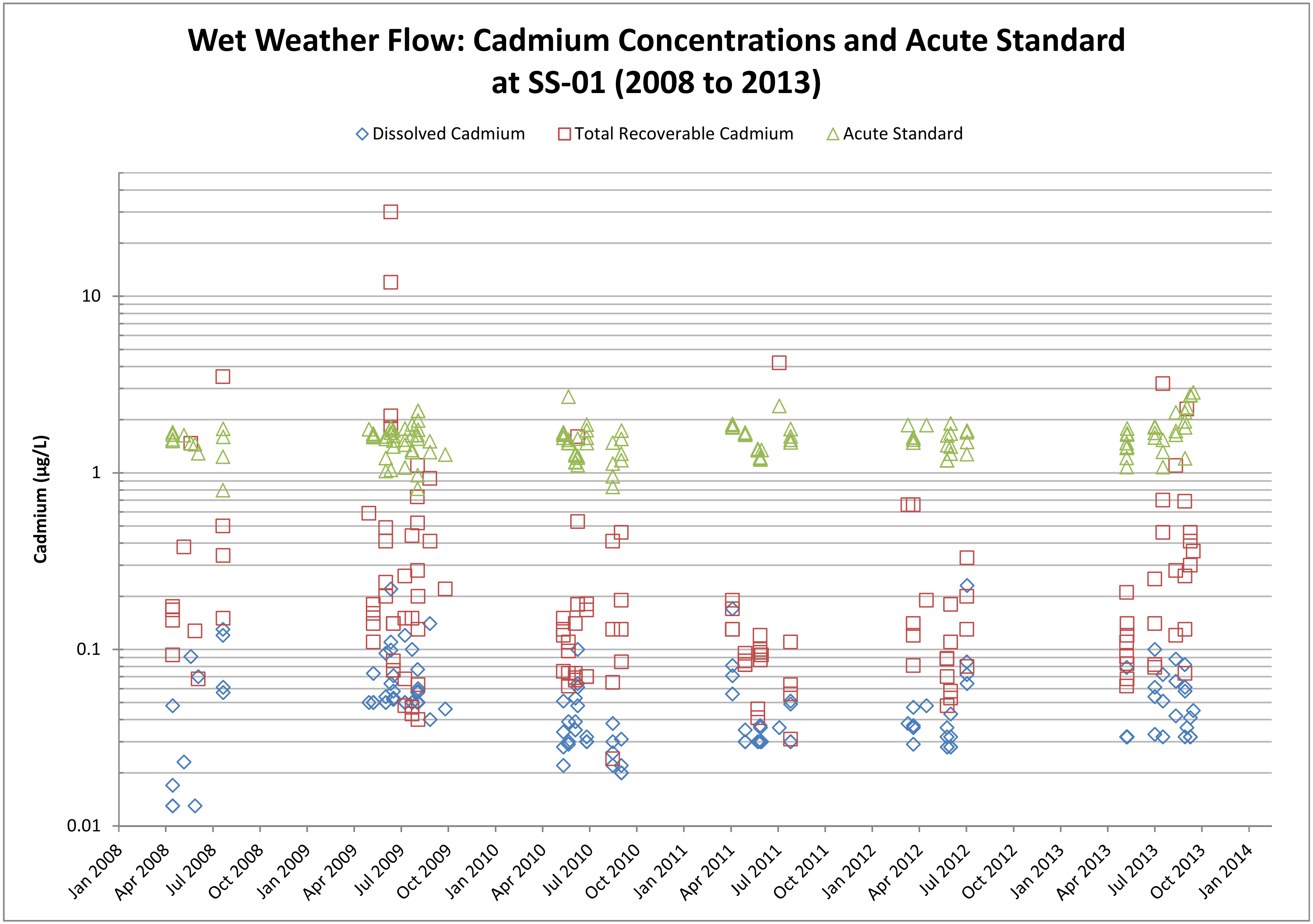

Figure 10-35
Wet Weather Flow Cadmium Concentrations at SS-01 - 2008 to 2013

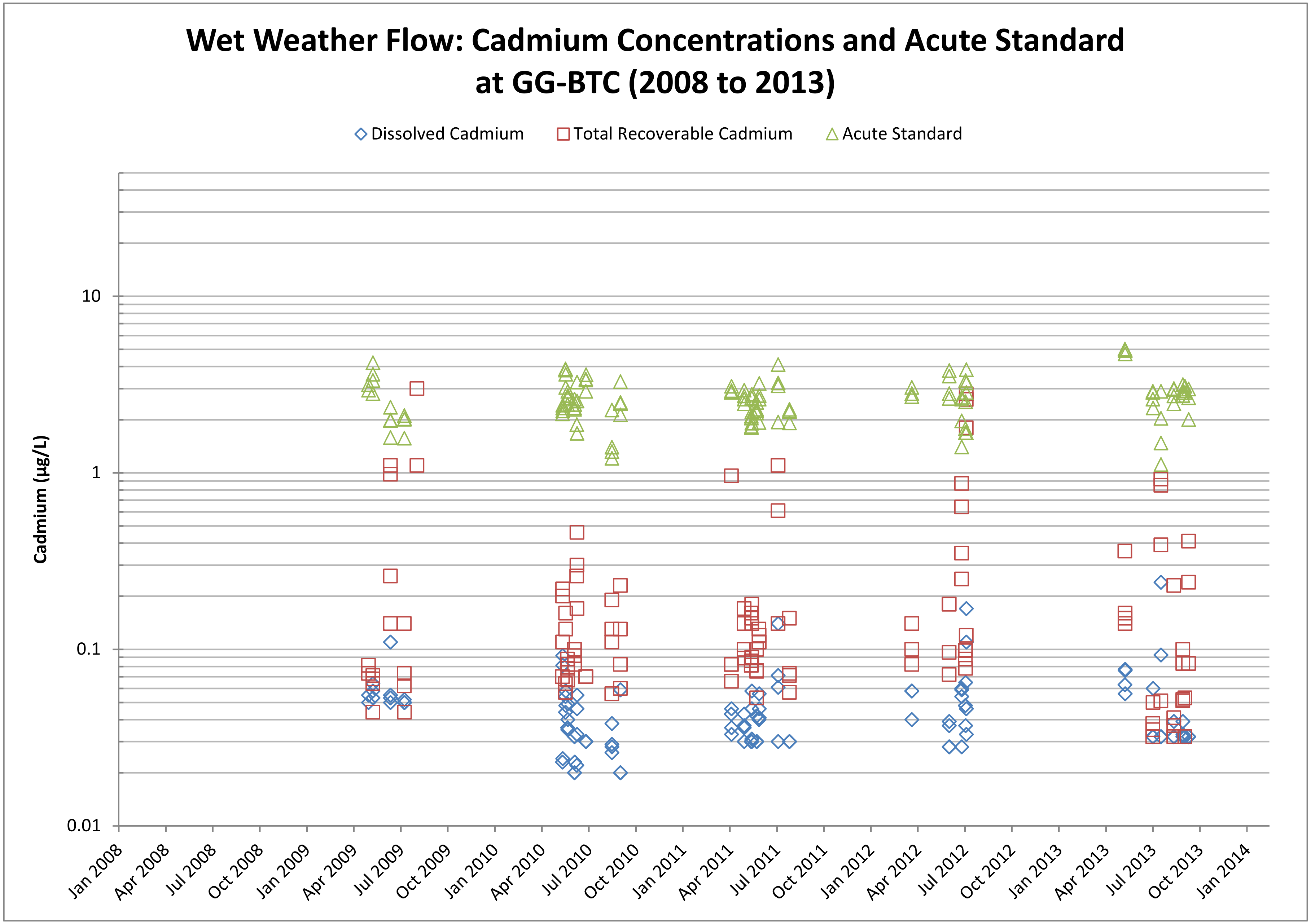

Figure 10-36
Wet Weather Flow Cadmium Concentrations at GG-BTC - 2008 to 2013

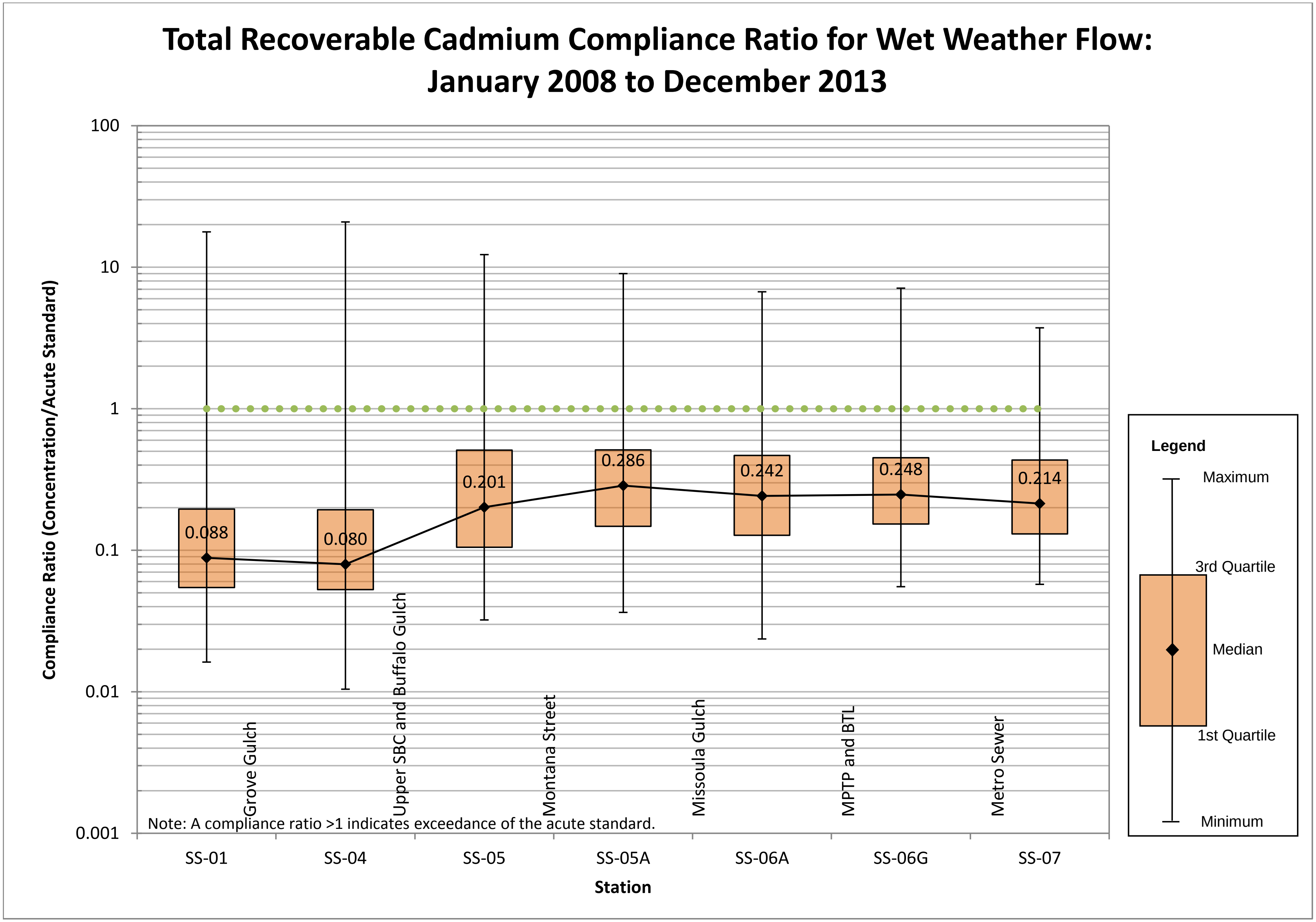

Figure 10-37
Wet Flow Total Cadmium Compliance Ratio - 2008 to 2013

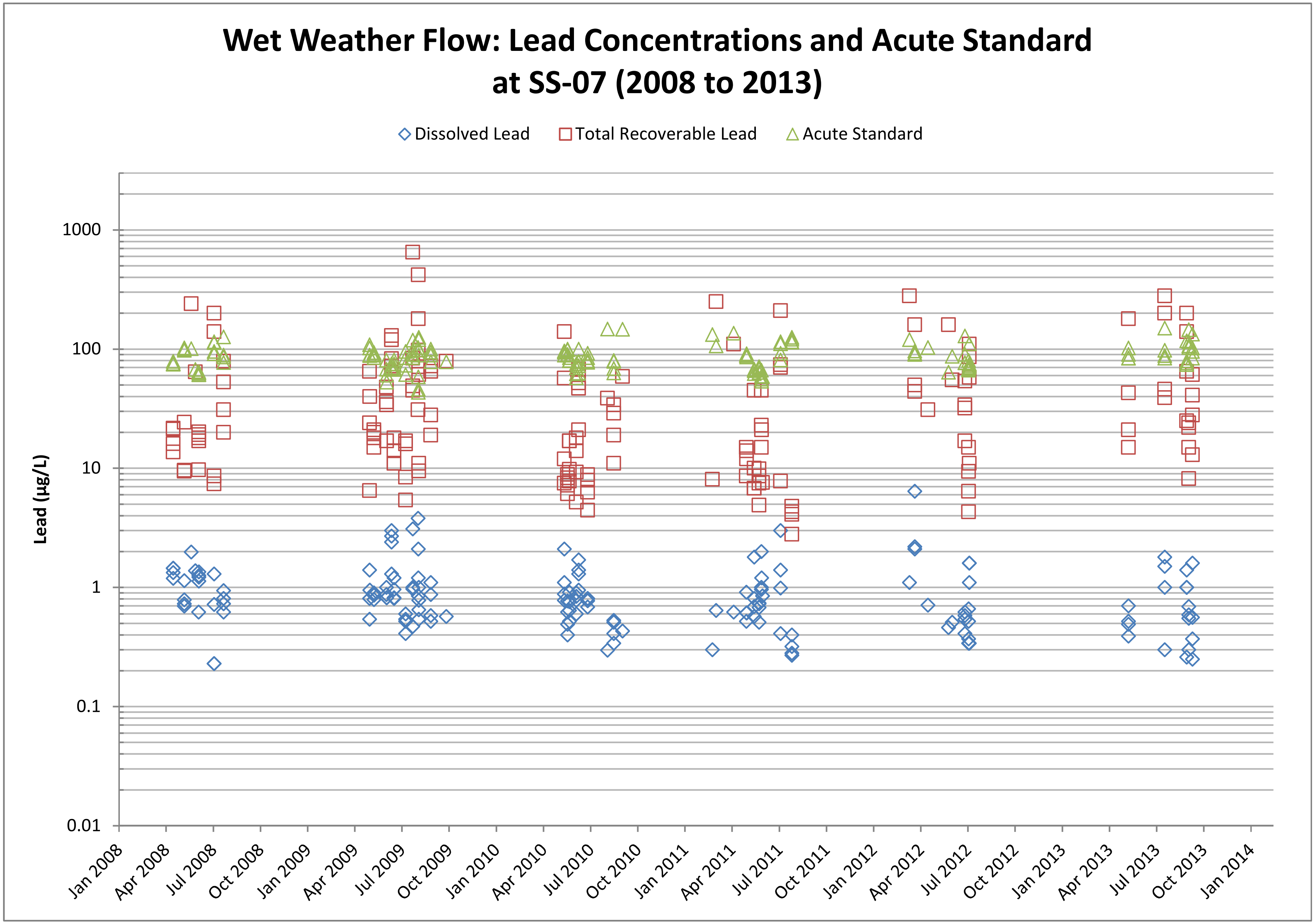

Figure 10-38
Wet Weather Flow Lead Concentrations at SS-07 - 2008 to 2013

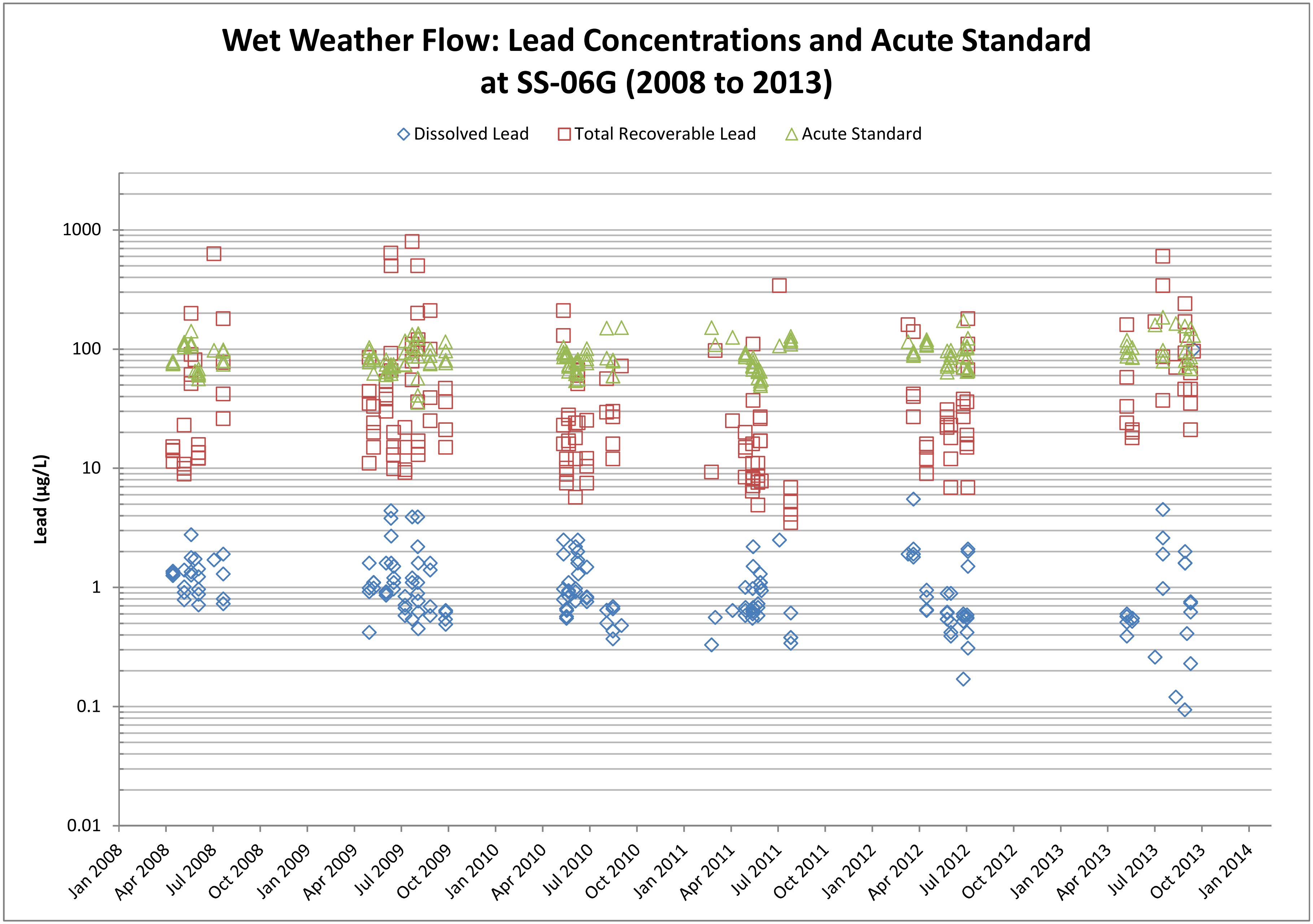

Figure 10-39
Wet Weather Flow Lead Concentrations at SS-06G - 2008 to 2013

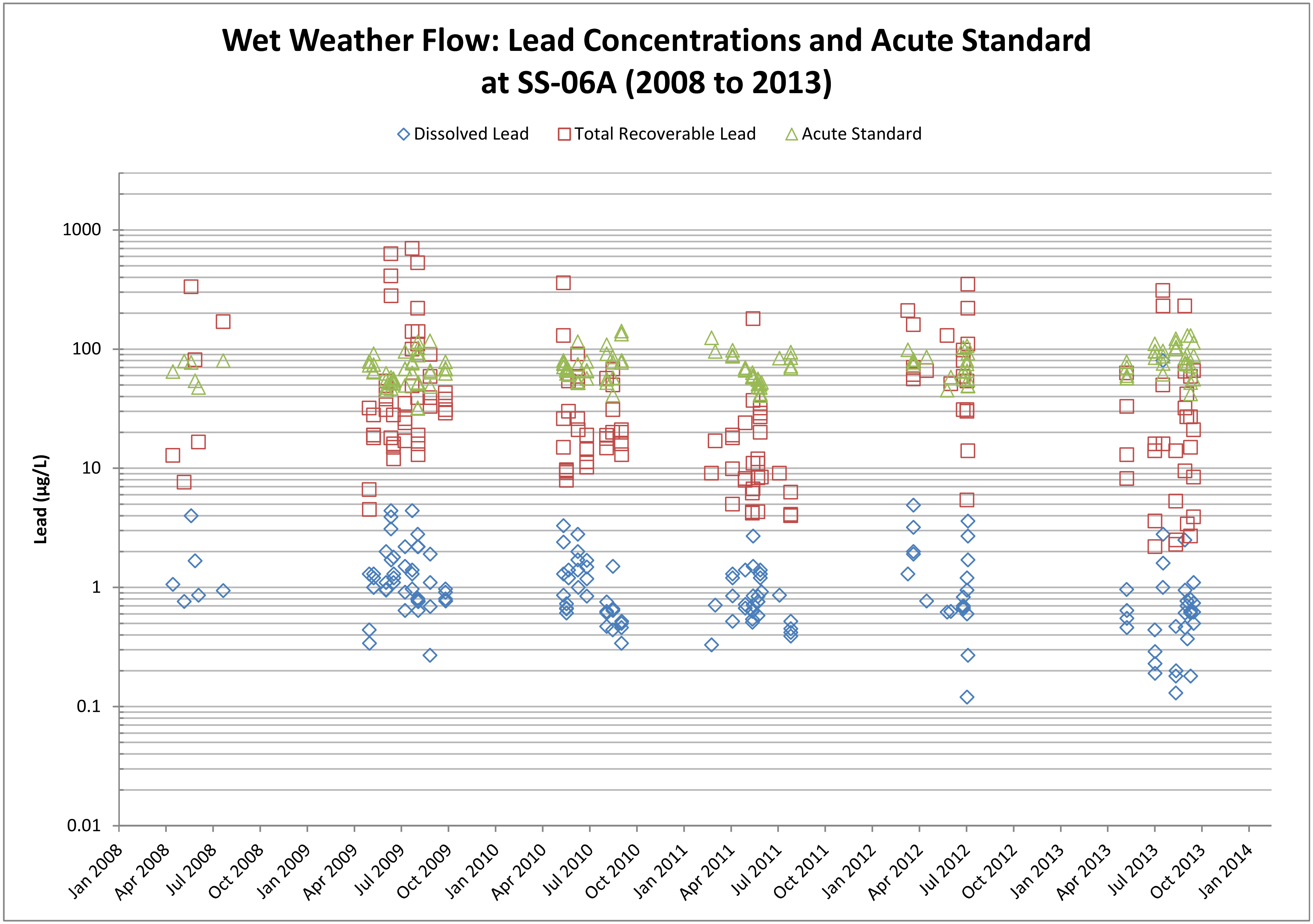

Figure 10-40
Wet Weather Flow Lead Concentrations at SS-06A - 2008 to 2013

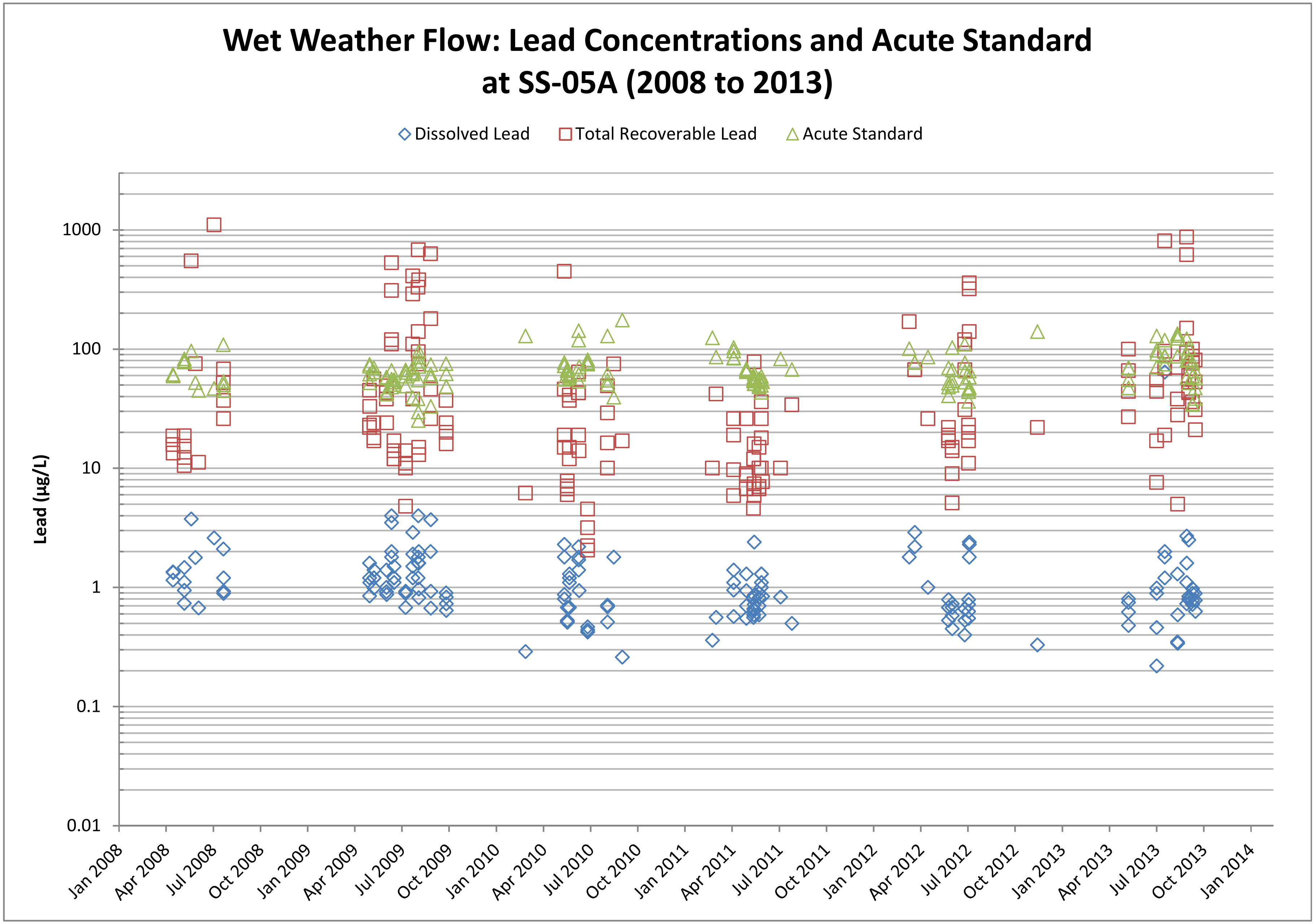

Figure 10-41
Wet Weather Flow Lead Concentrations at SS-05A - 2008 to 2013

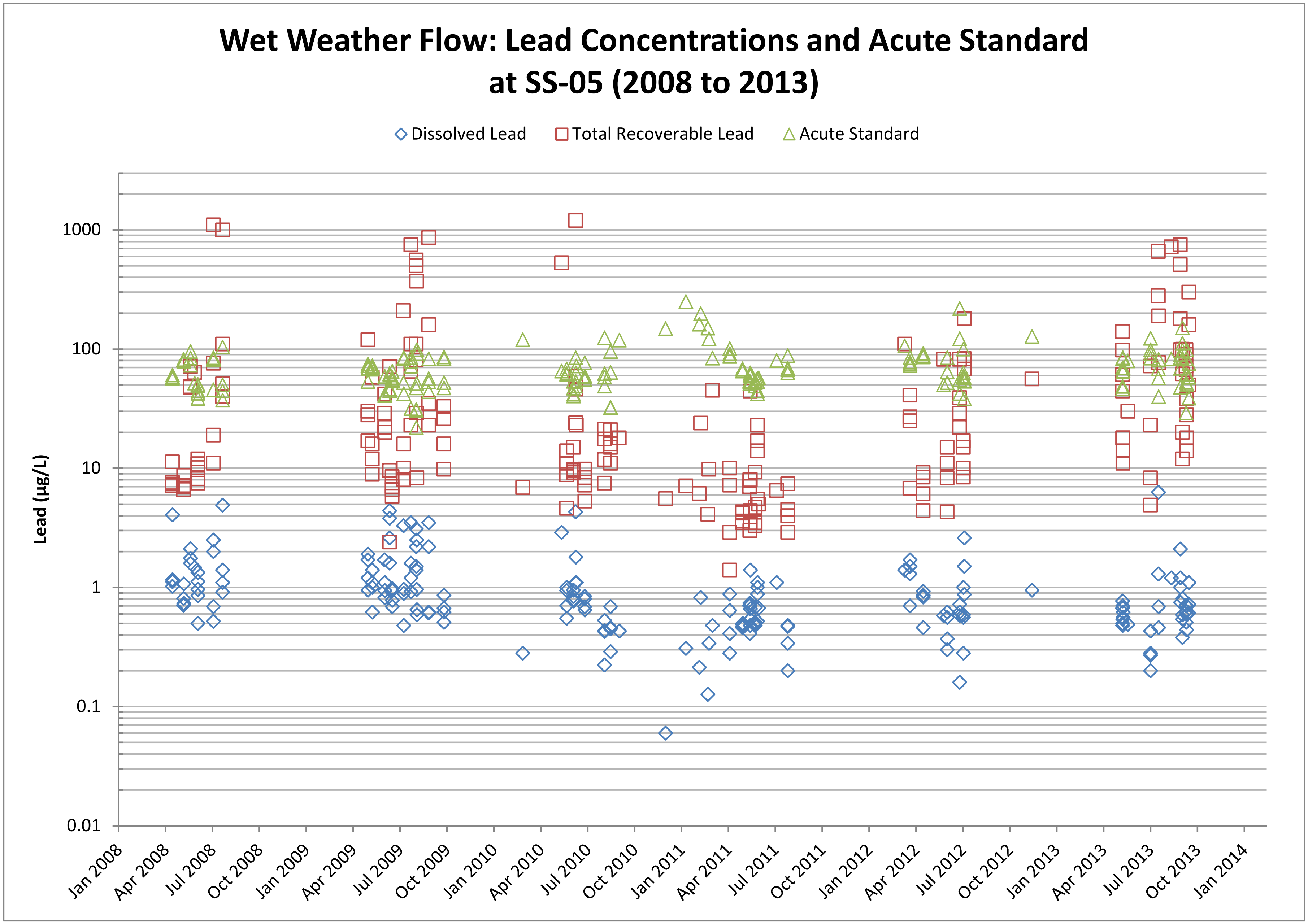

Figure 10-42
Wet Weather Flow Lead Concentrations at SS-05 - 2008 to 2013

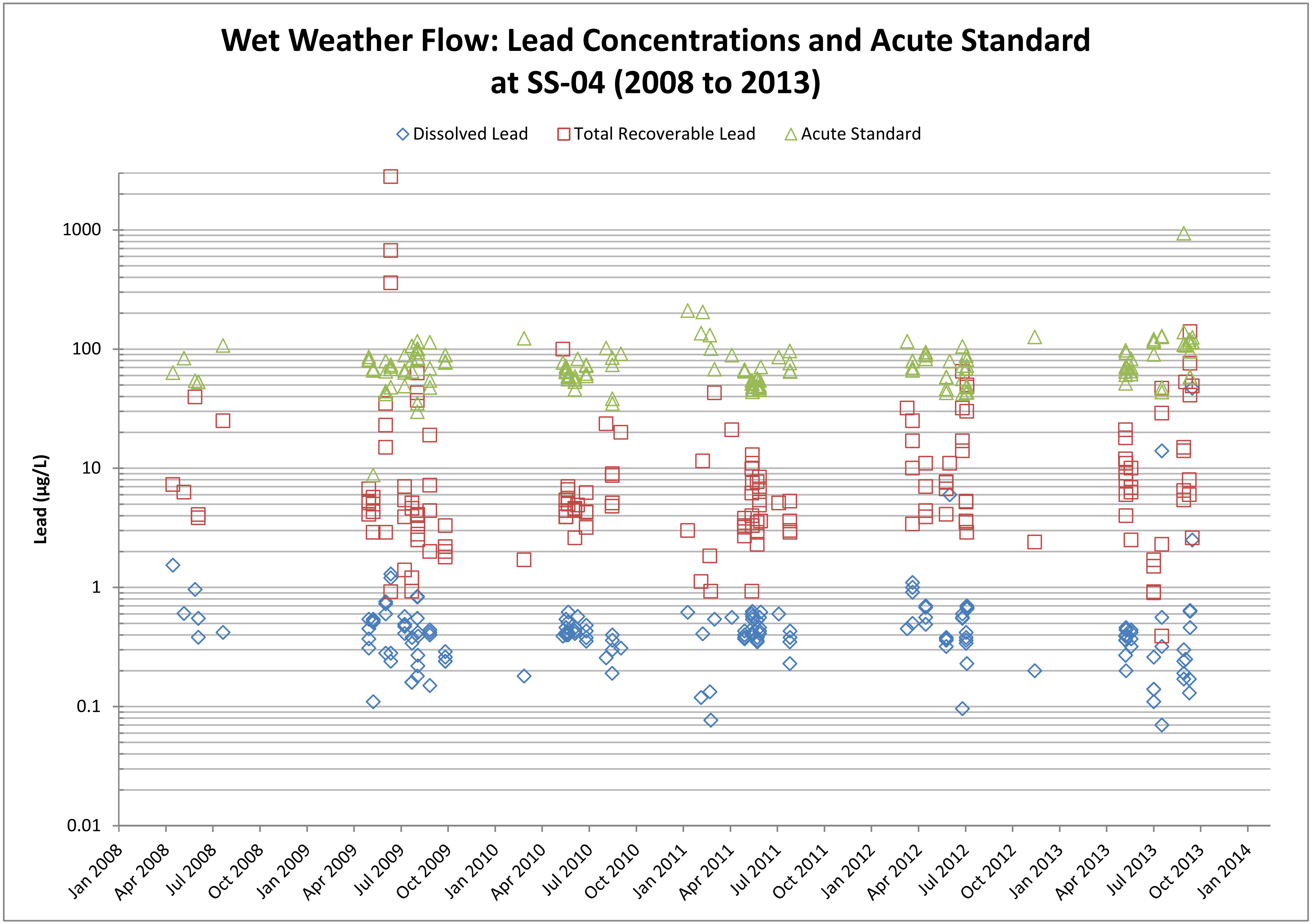

Figure 10-43
Wet Weather Flow Lead Concentrations at SS-04 - 2008 to 2013

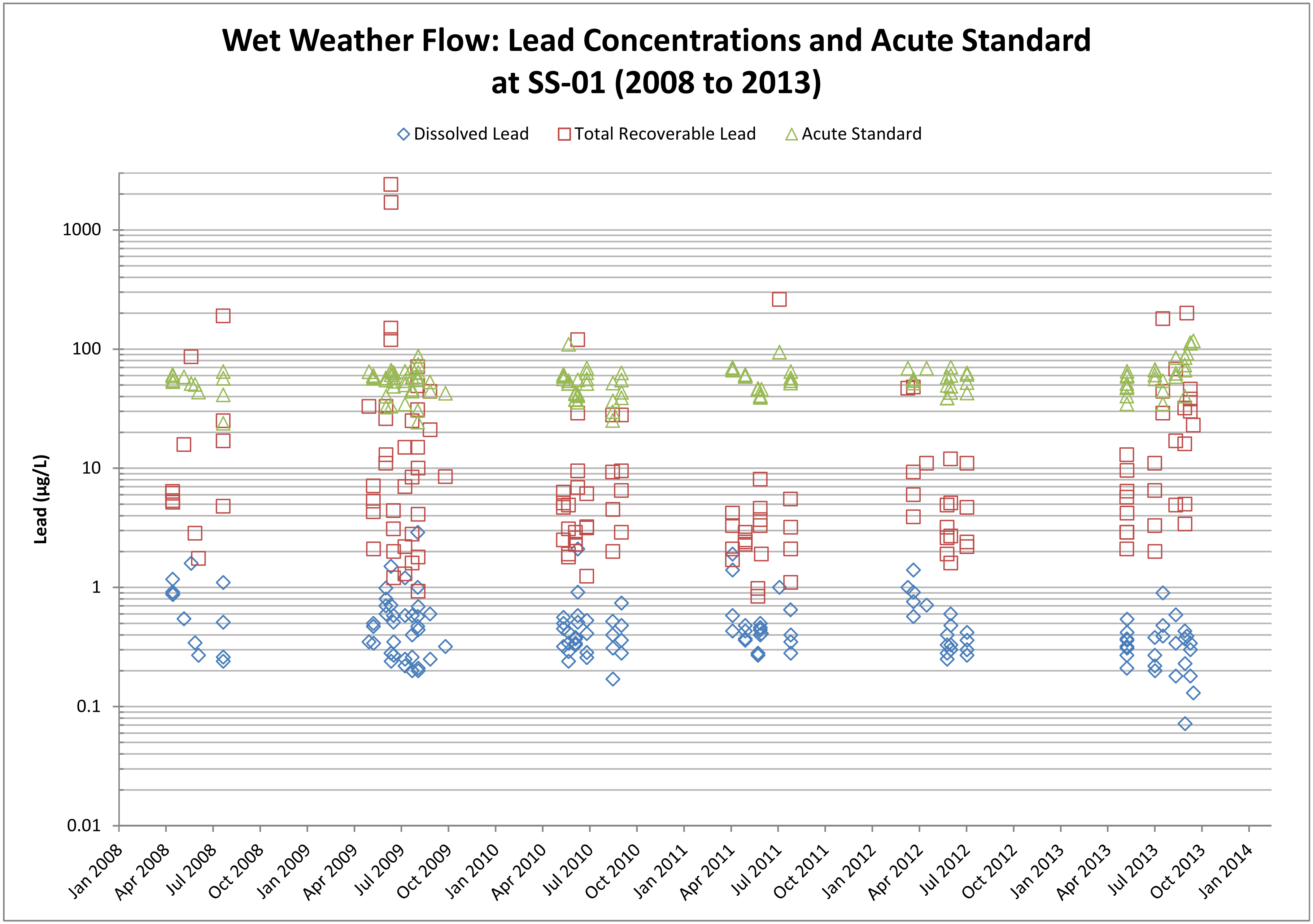

Figure 10-44
Wet Weather Flow Lead Concentrations at SS-01 - 2008 to 2013

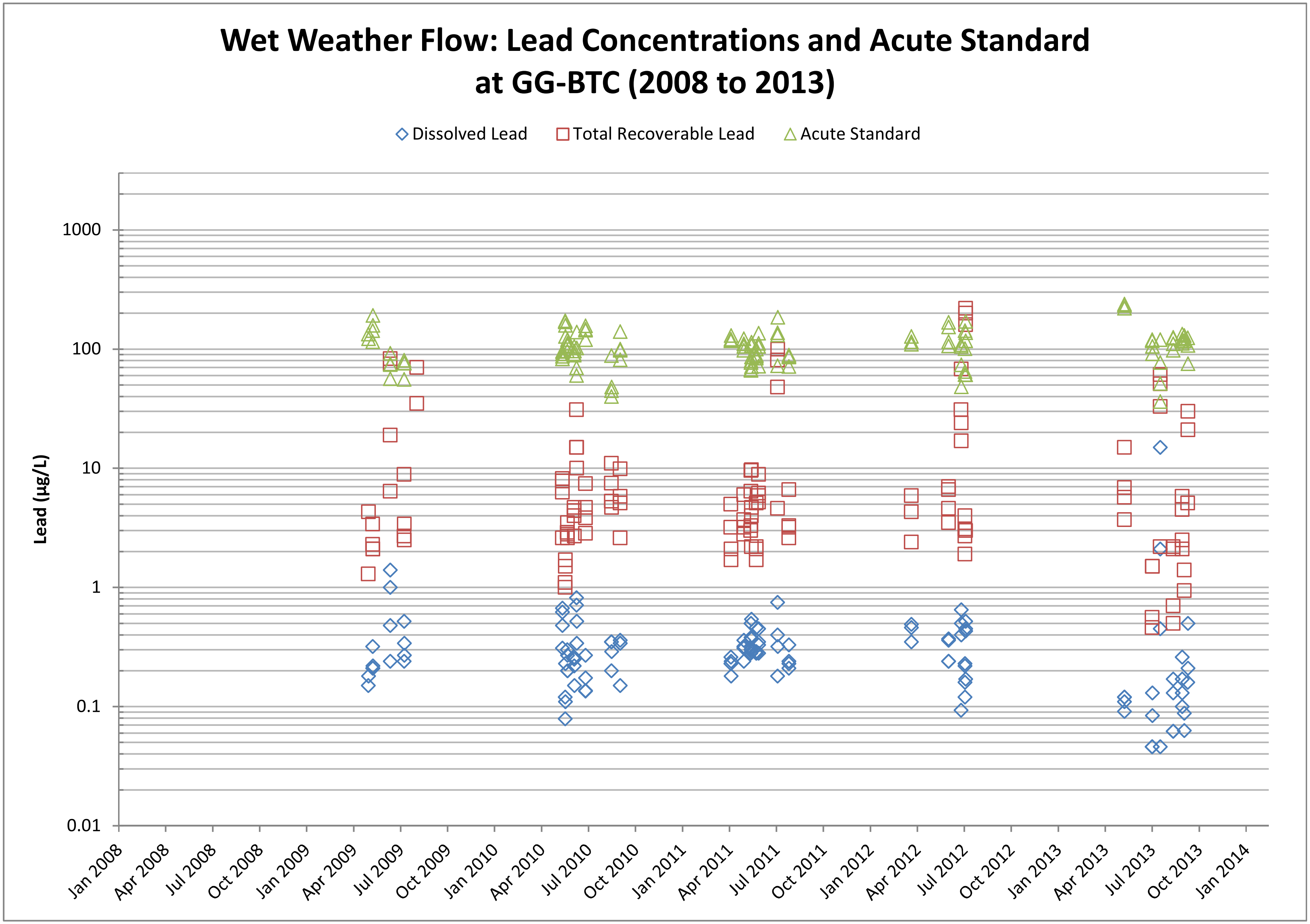

Figure 10-45
Wet Weather Flow Lead Concentrations at GG-BTC - 2008 to 2013

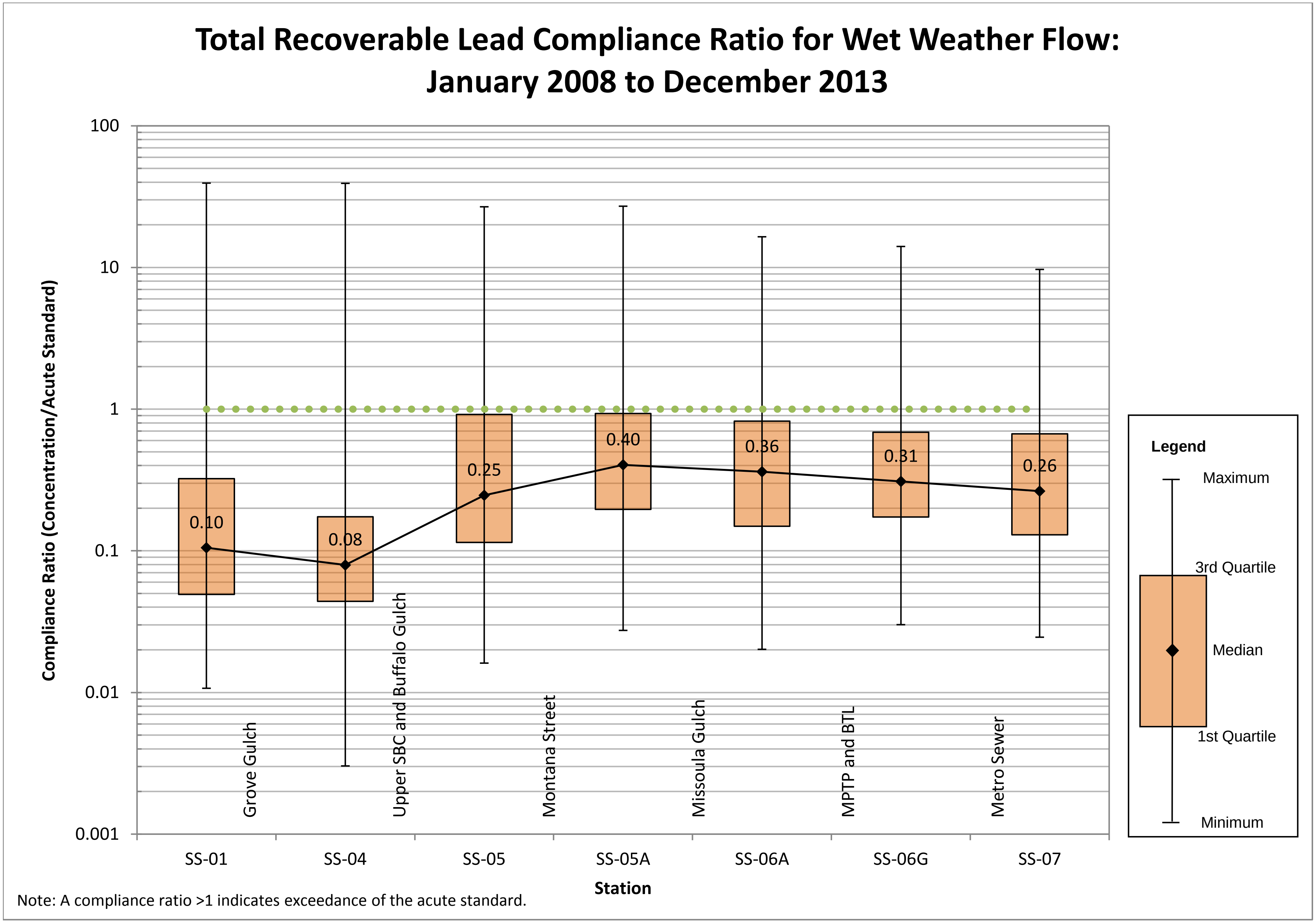

Figure 10-46
Wet Flow Total Lead Compliance Ratio - 2008 to 2013

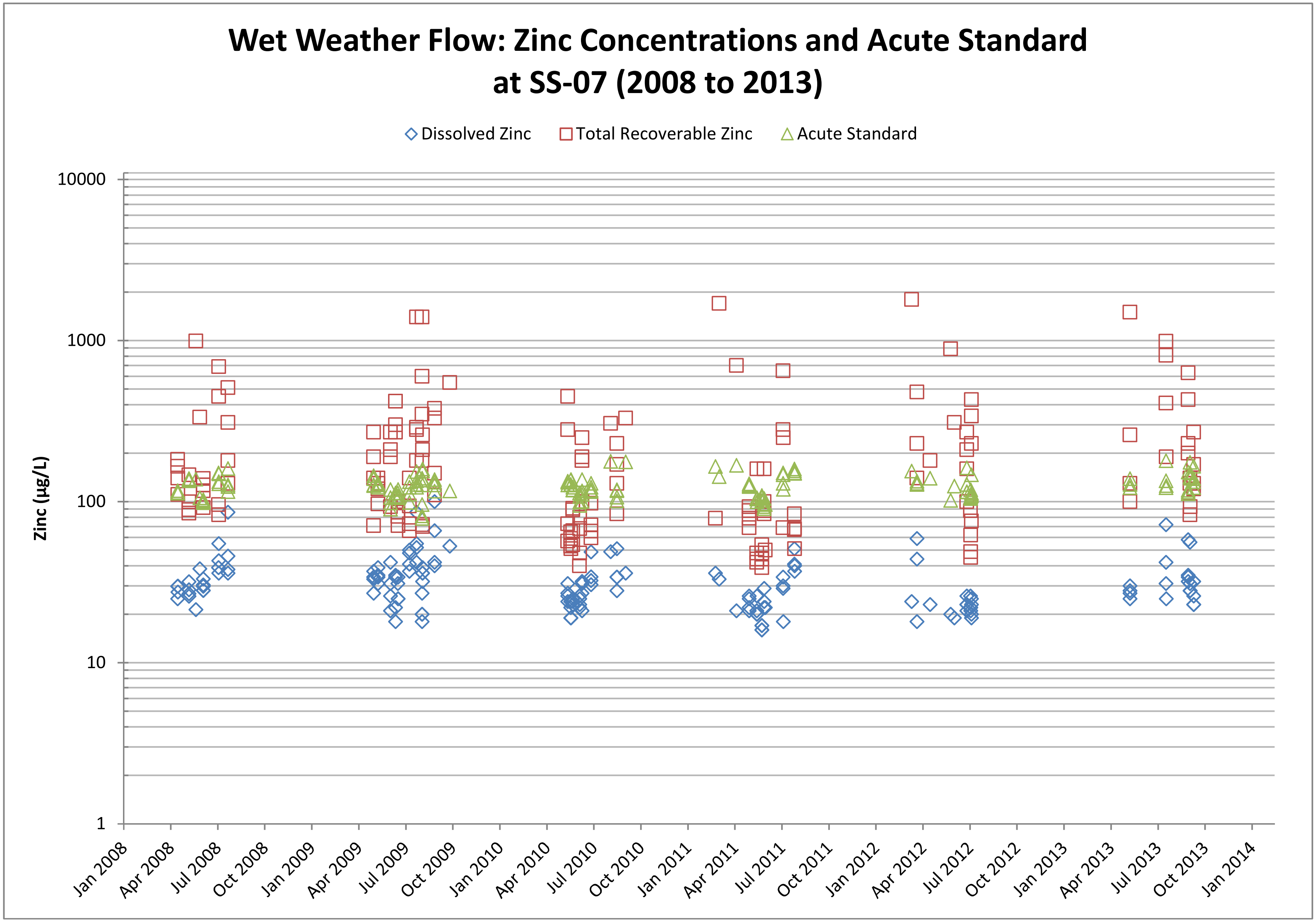

Figure 10-47
Wet Weather Flow Zinc Concentrations at SS-07 - 2008 to 2013

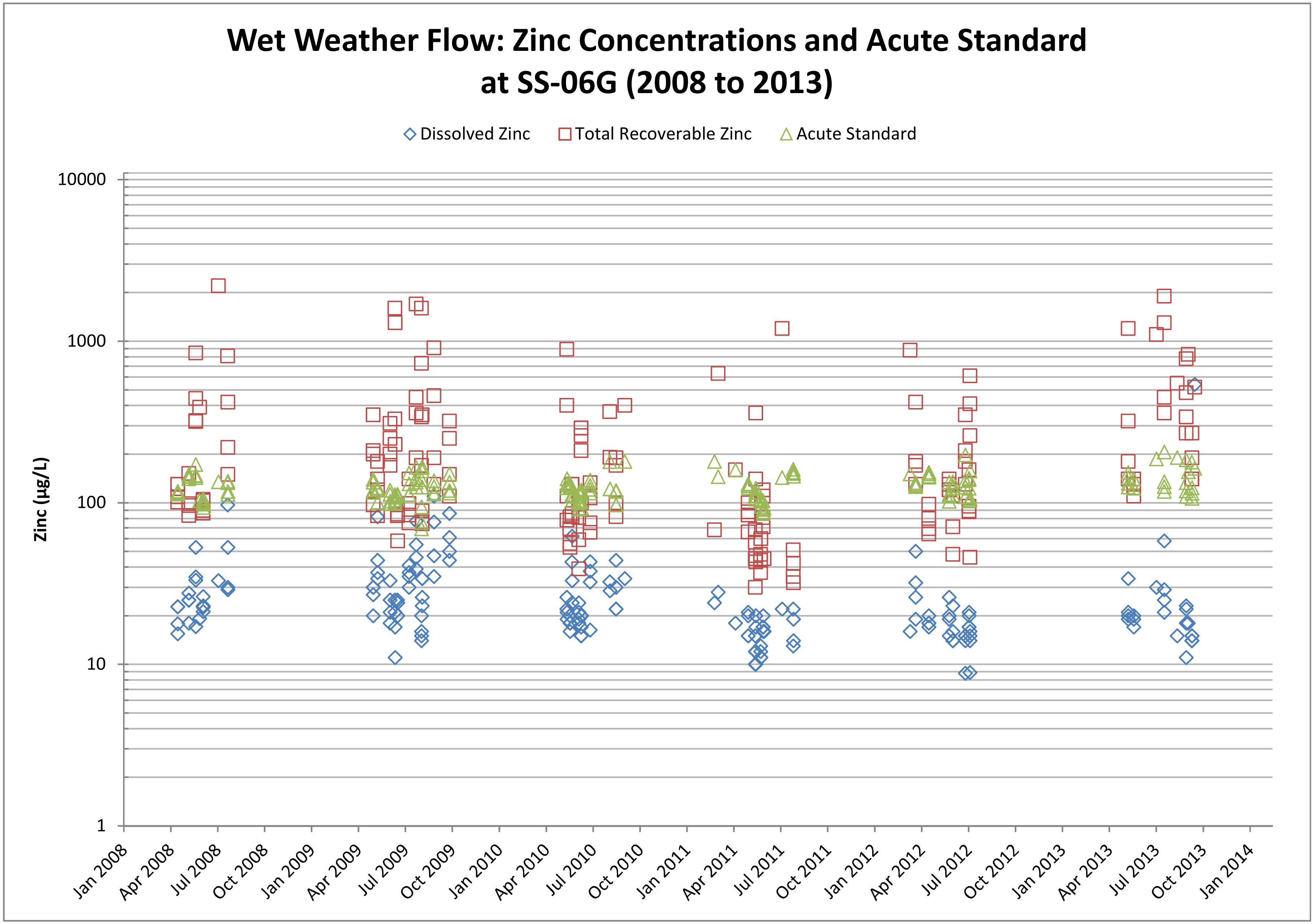

Figure 10-48
Wet Weather Flow Zinc Concentrations at SS-06G - 2008 to 2013

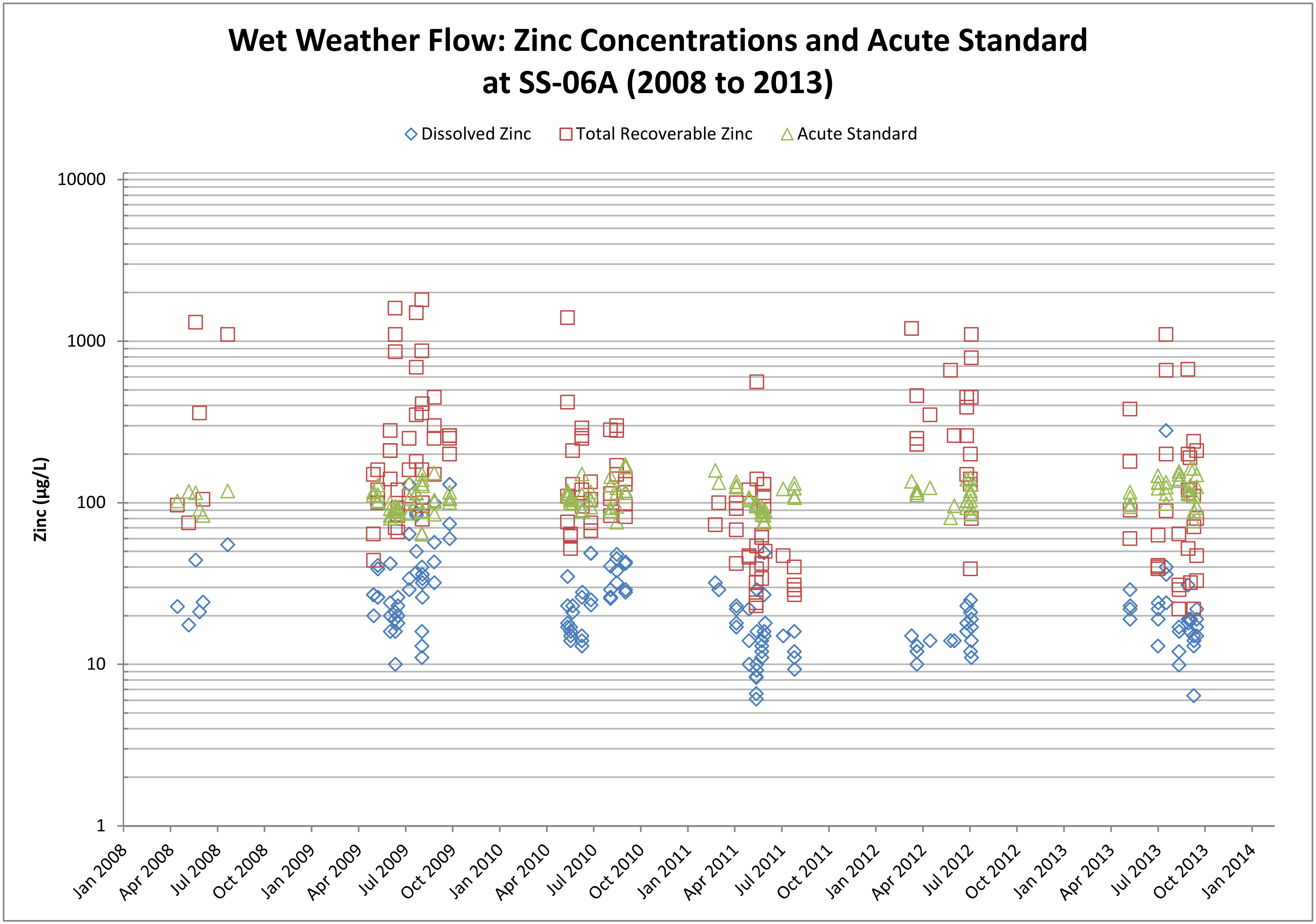

Figure 10-49
Wet Weather Flow Zinc Concentrations at SS-06A - 2008 to 2013

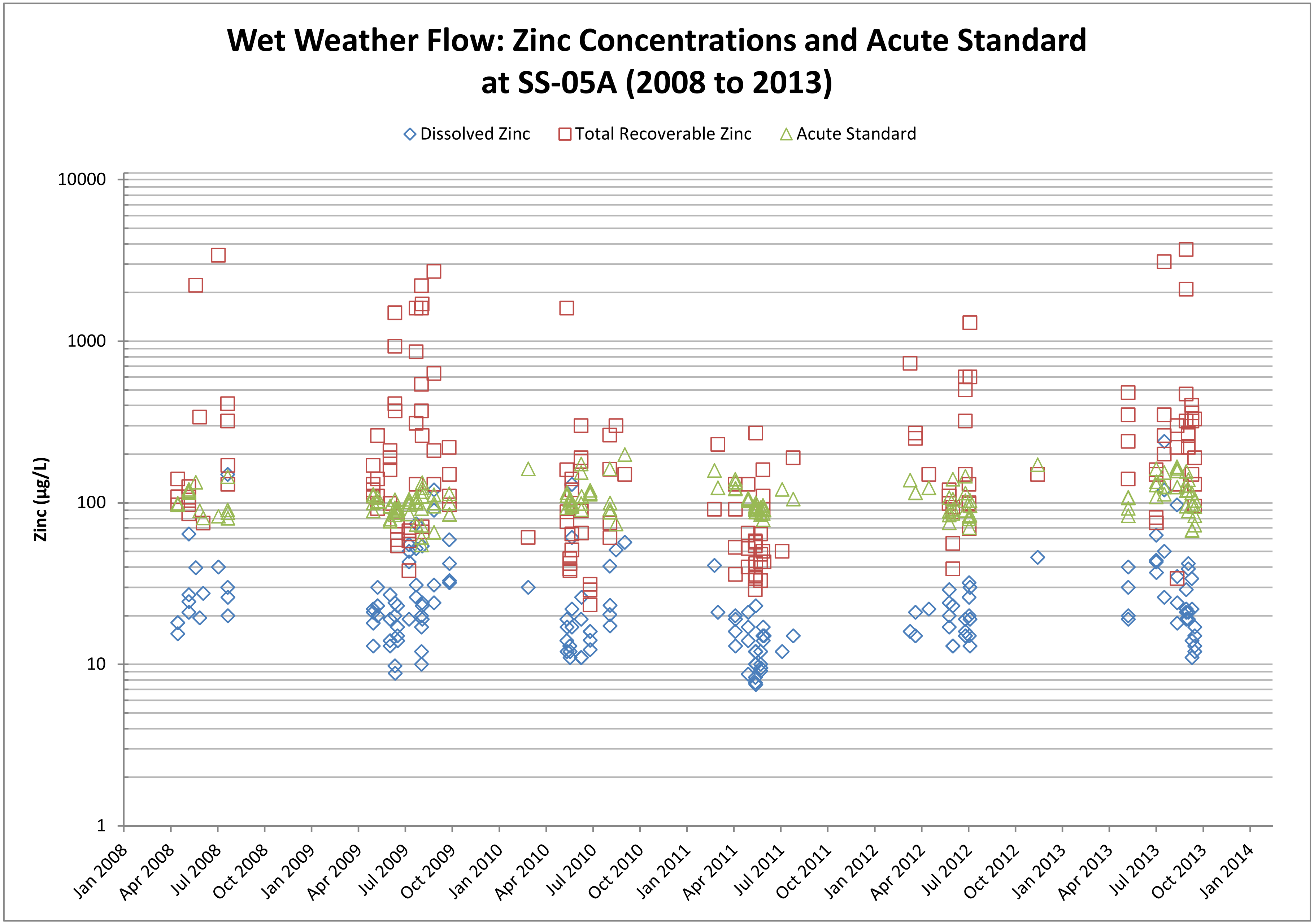

Figure 10-50
Wet Weather Flow Zinc Concentrations at SS-05A - 2008 to 2013

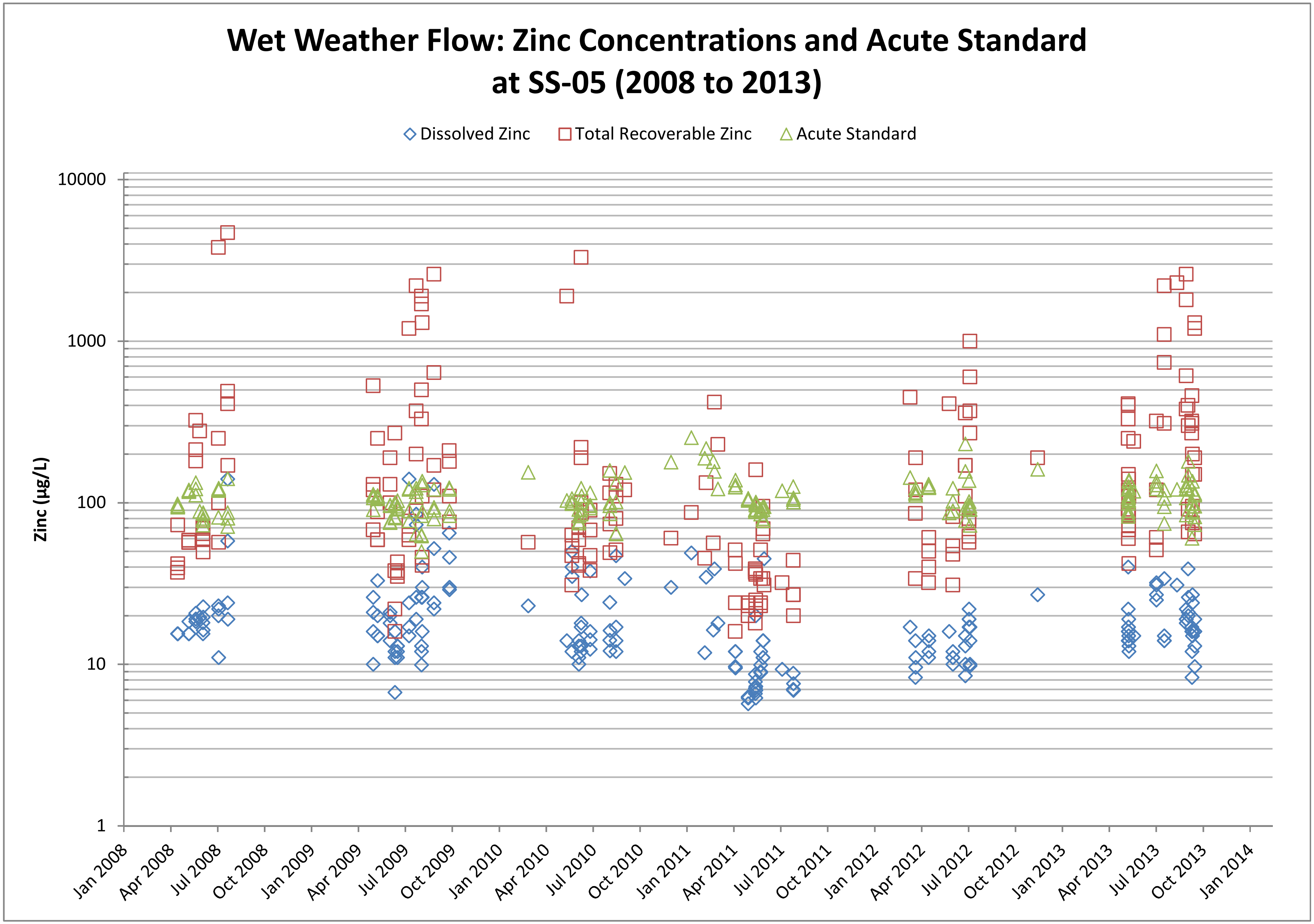

Figure 10-51
Wet Weather Flow Zinc Concentrations at SS-05 - 2008 to 2013

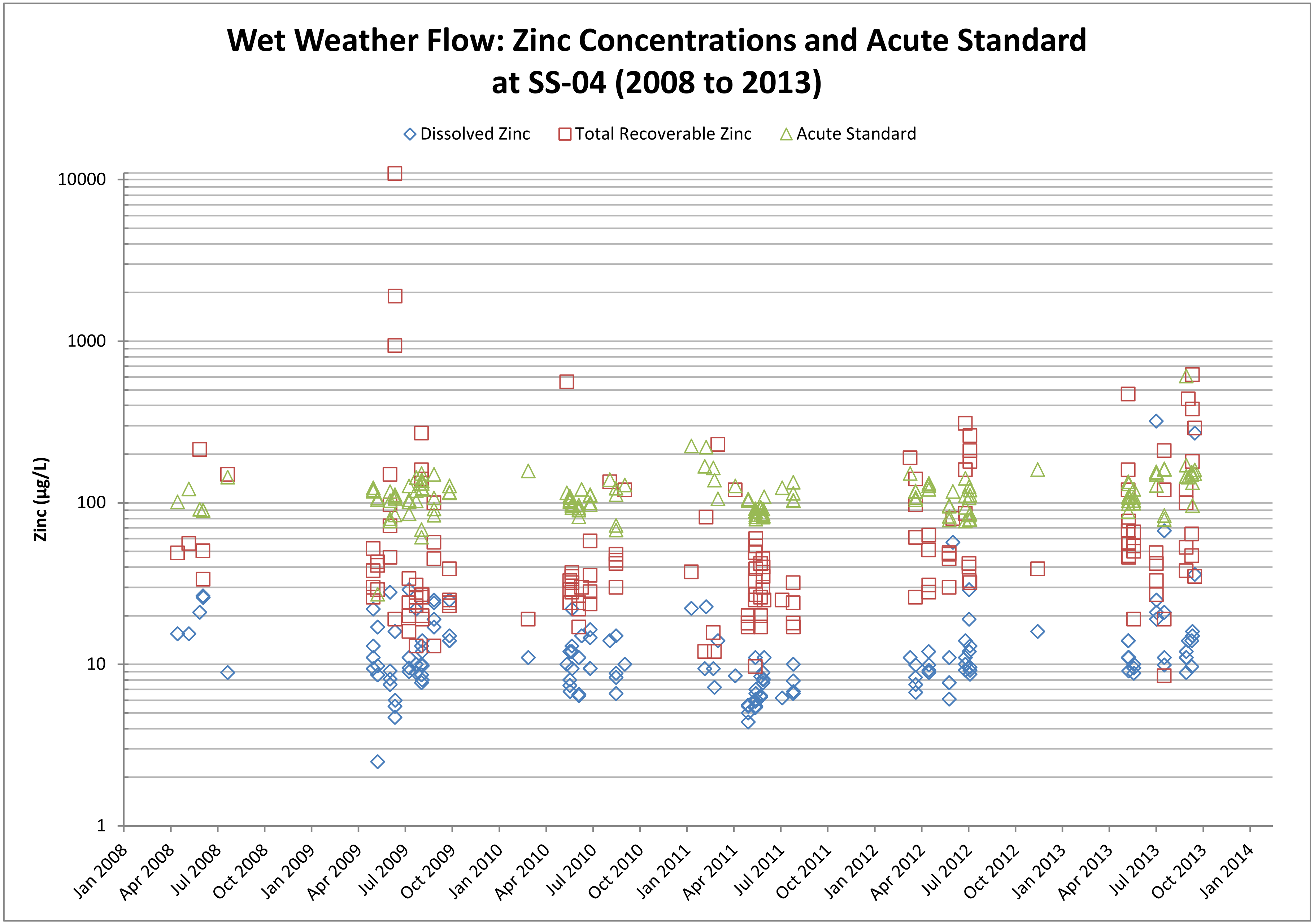

Figure 10-52
Wet Weather Flow Zinc Concentrations at SS-04 - 2008 to 2013

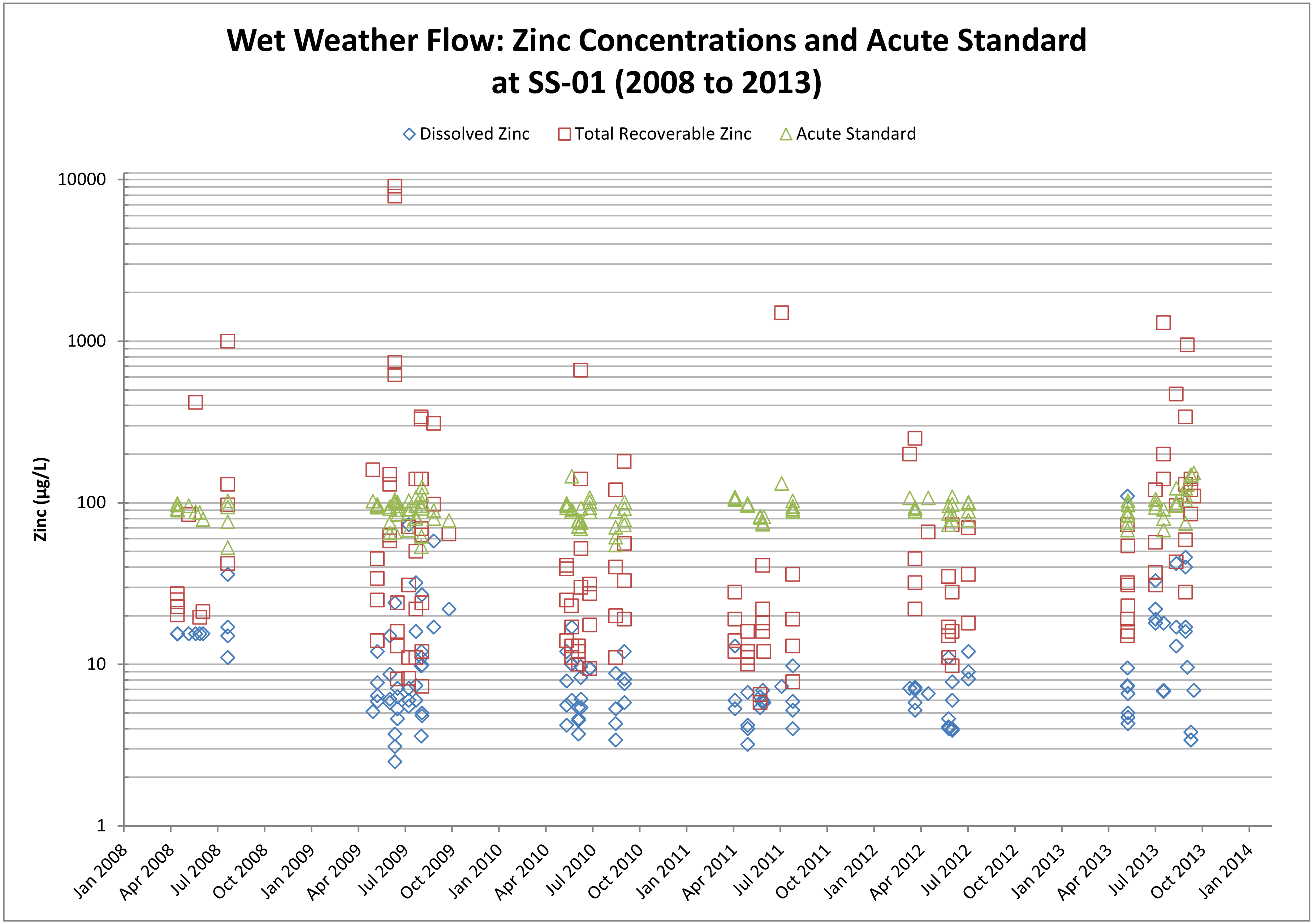

Figure 10-53
Wet Weather Flow Zinc Concentrations at SS-01 - 2008 to 2013

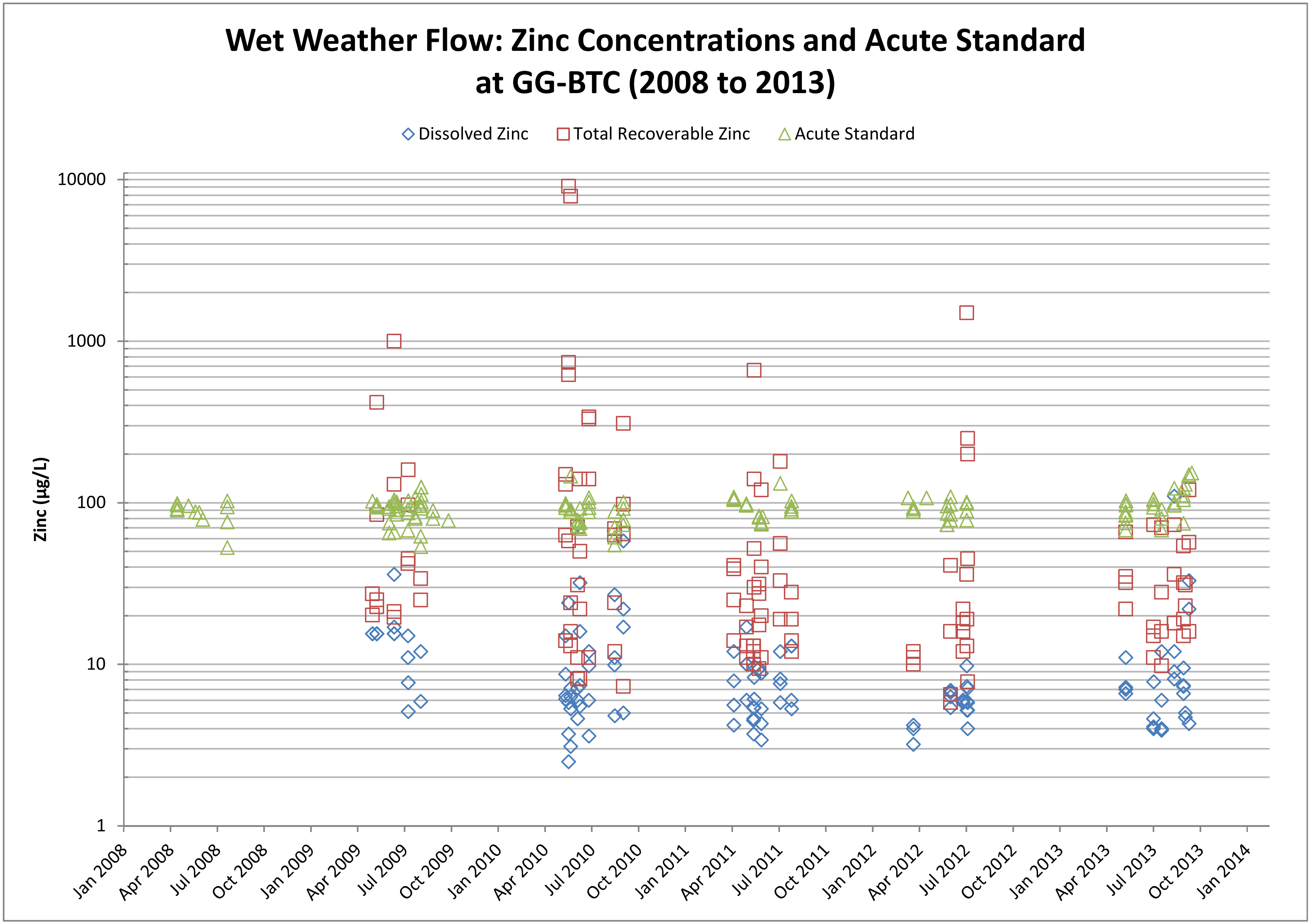

Figure 10-54
Wet Weather Flow Zinc Concentrations at GG-BTC - 2008 to 2013

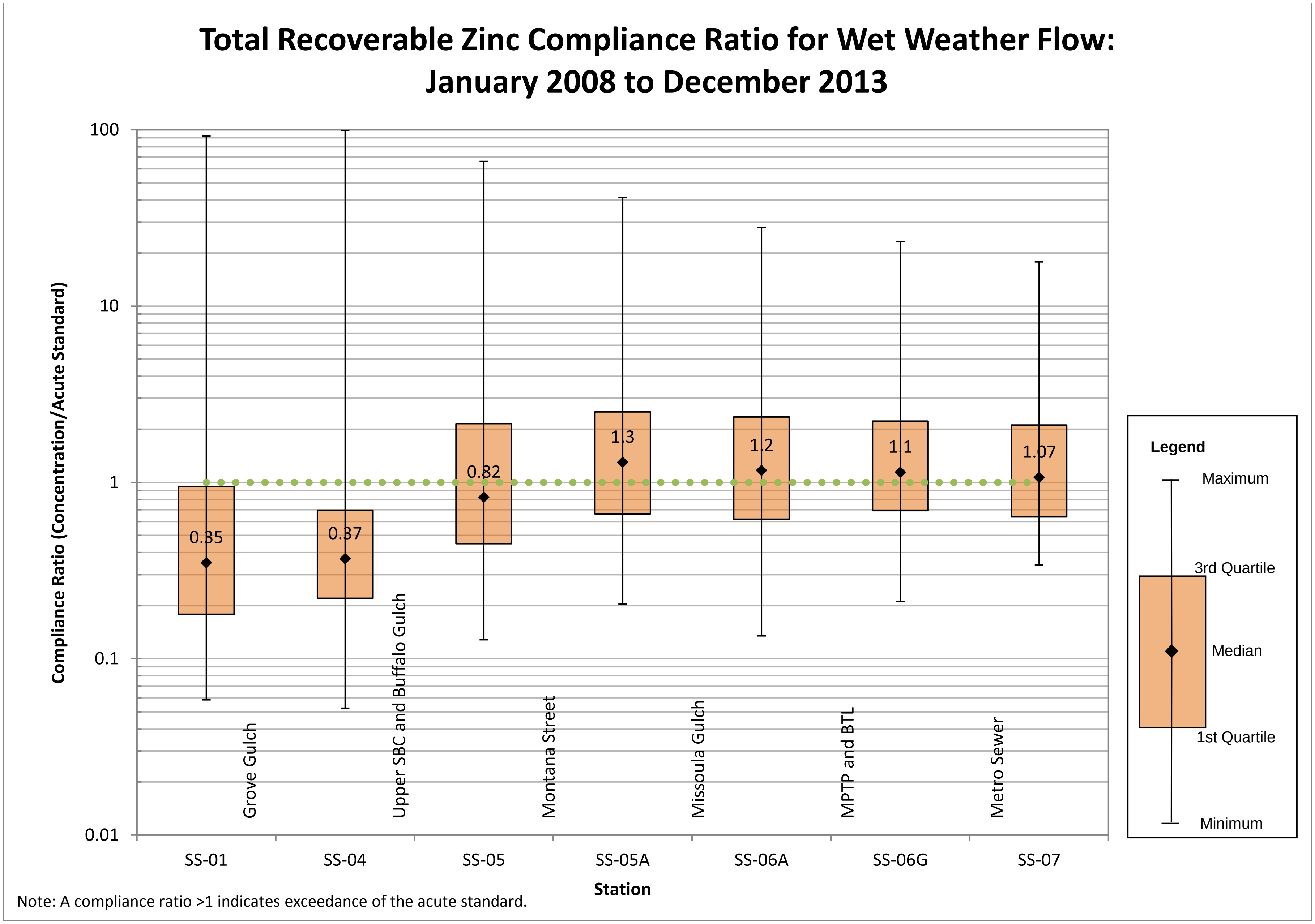

Figure 10-55
Wet Flow Total Zinc Compliance Ratio - 2008 to 2013

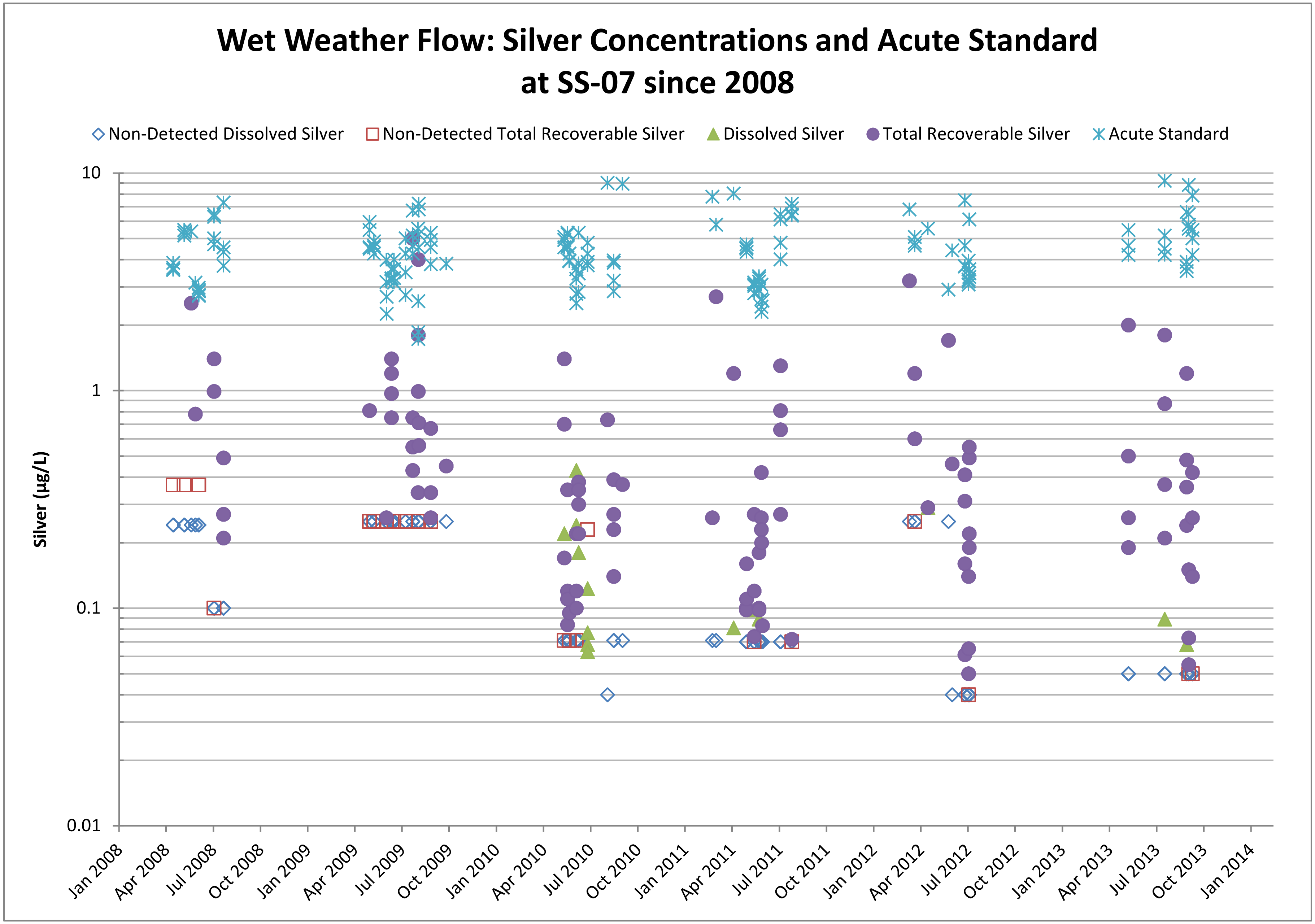

Figure 10-56
Wet Weather Flow Silver Concentrations at SS-07 - 2008 to 2013

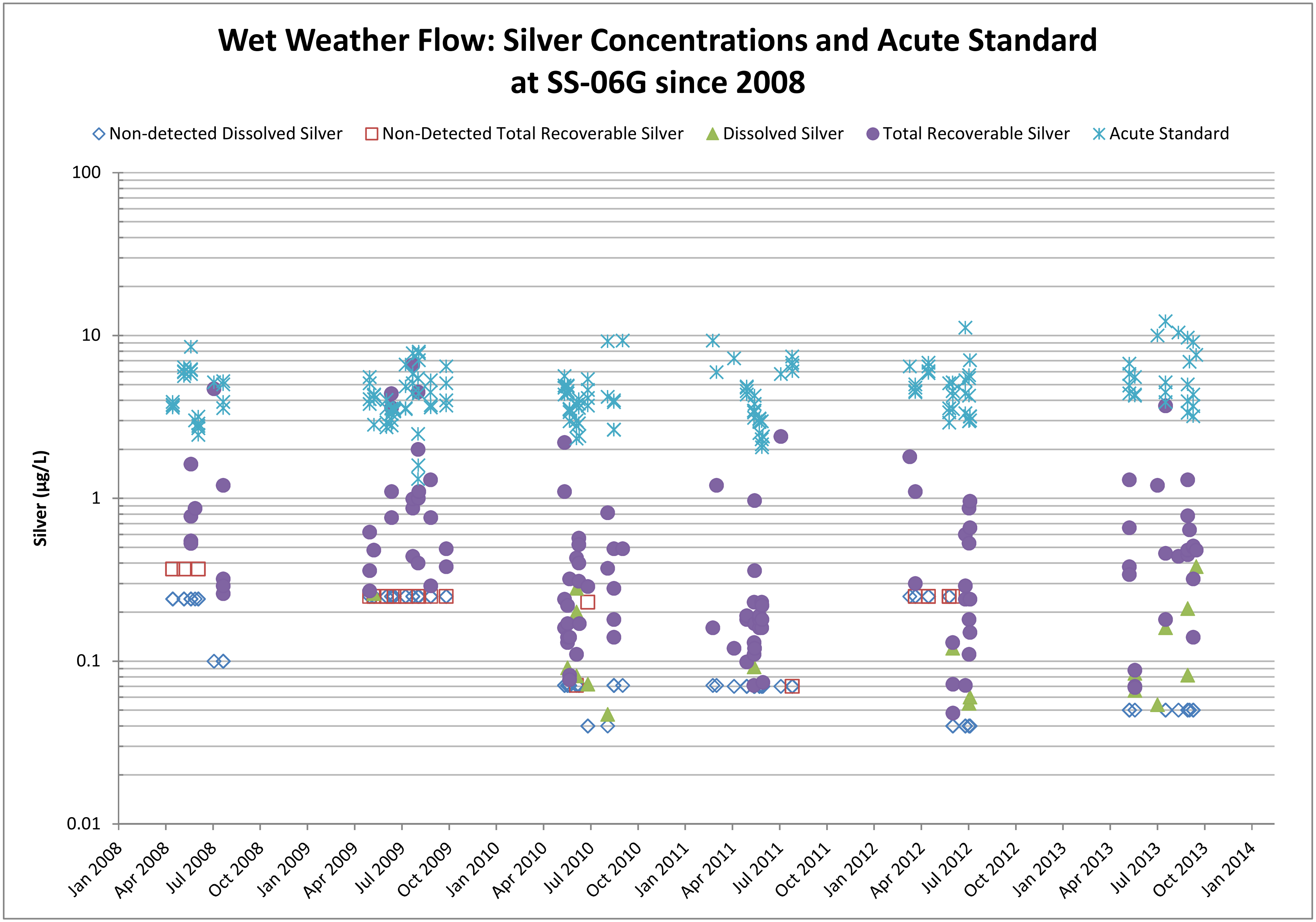

Figure 10-57
Wet Weather Flow Silver Concentrations at SS-06G - 2008 to 2013

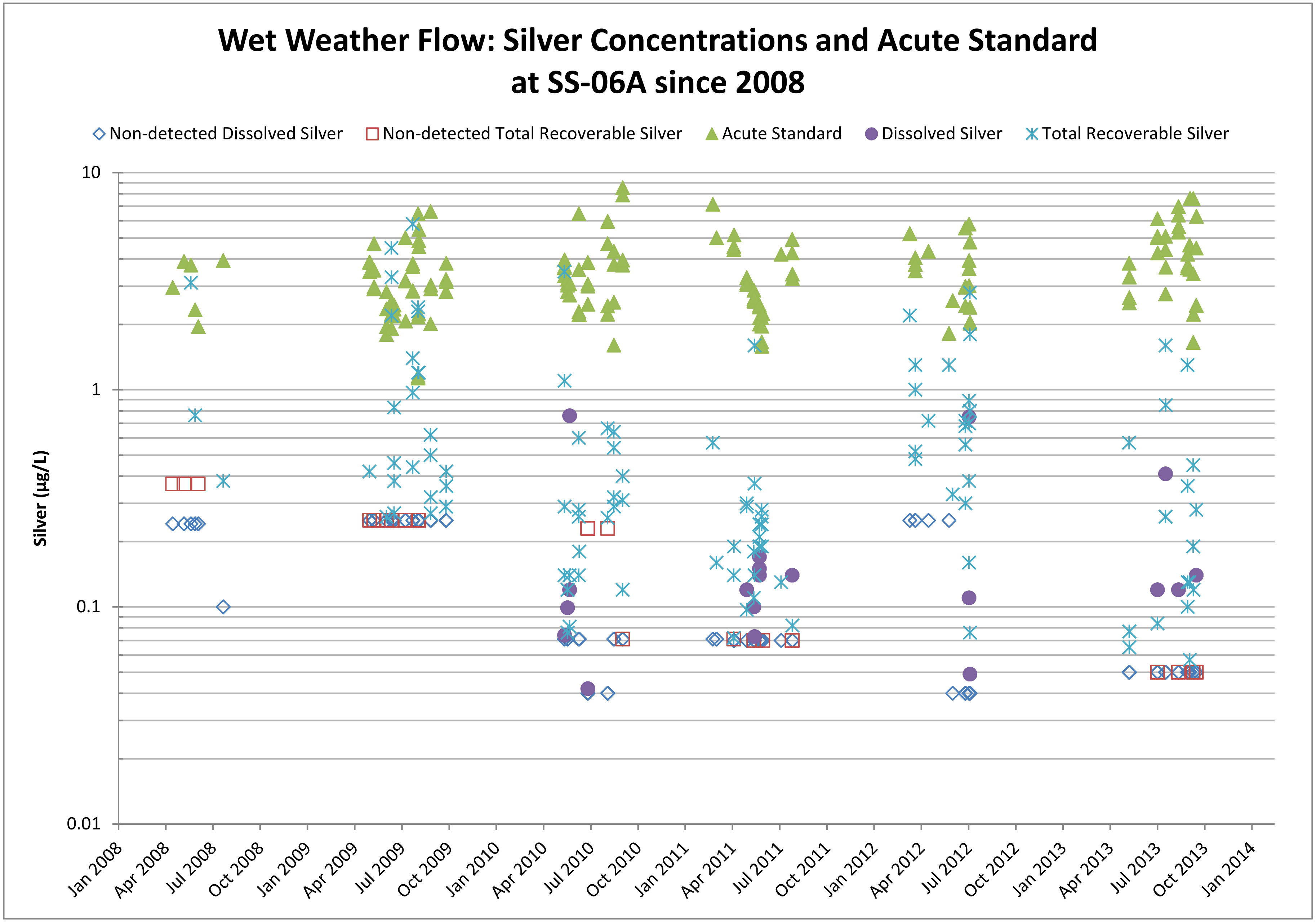

Figure 10-58
Wet Weather Flow Silver Concentrations at SS-06A - 2008 to 2013

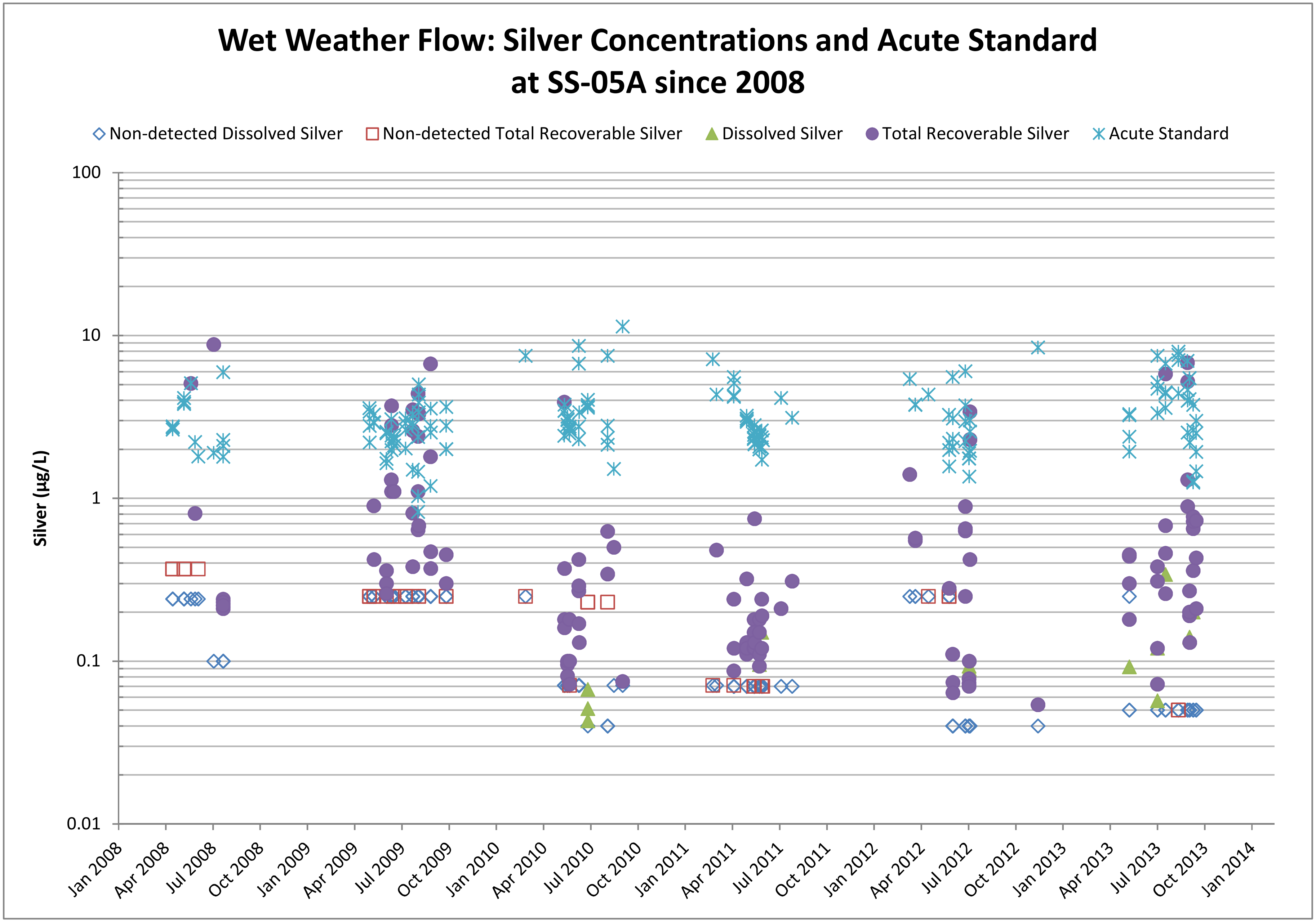

Figure 10-59
Wet Weather Flow Silver Concentrations at SS-05A - 2008 to 2013

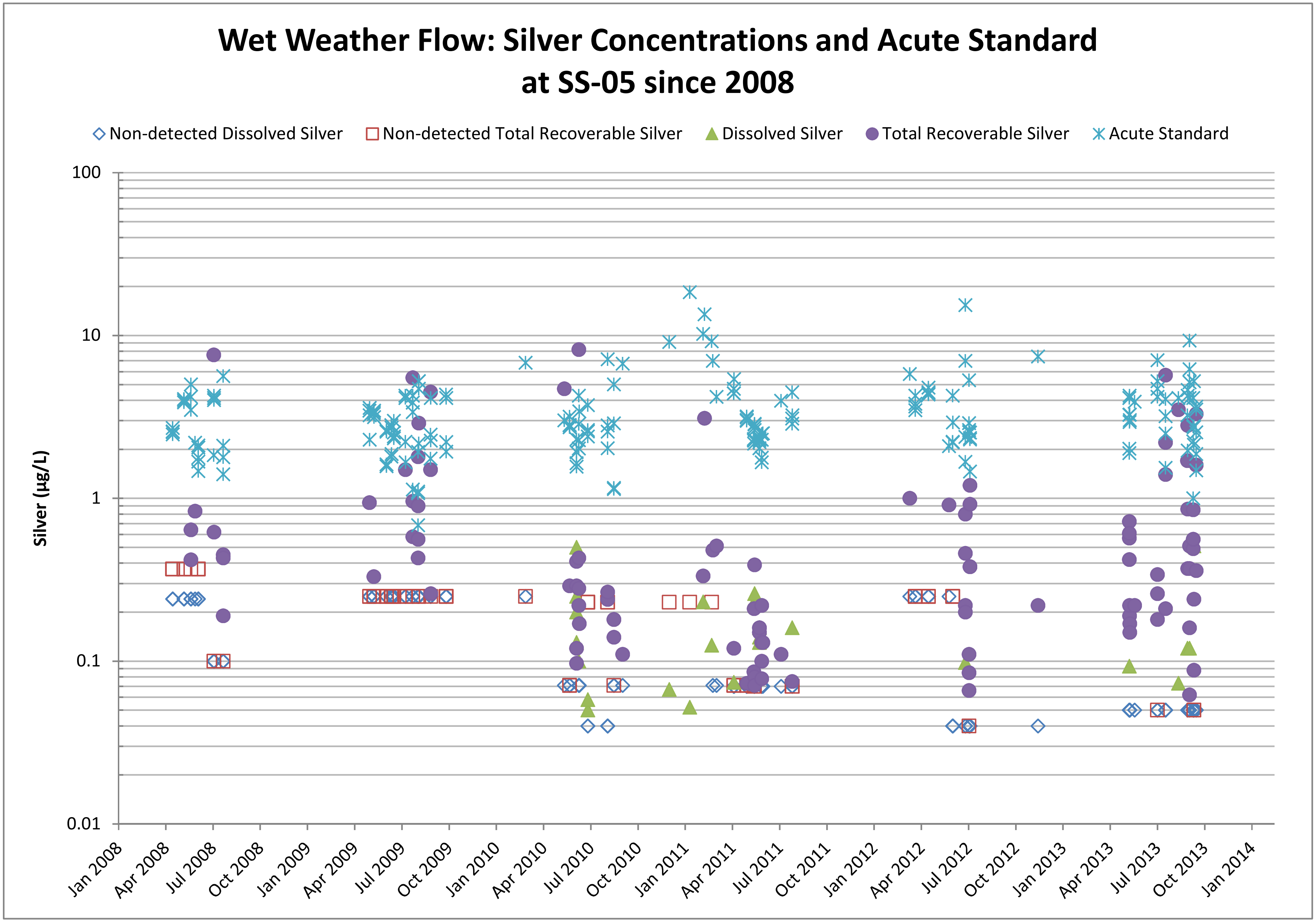

Figure 10-60
Wet Weather Flow Silver Concentrations at SS-05 - 2008 to 2013

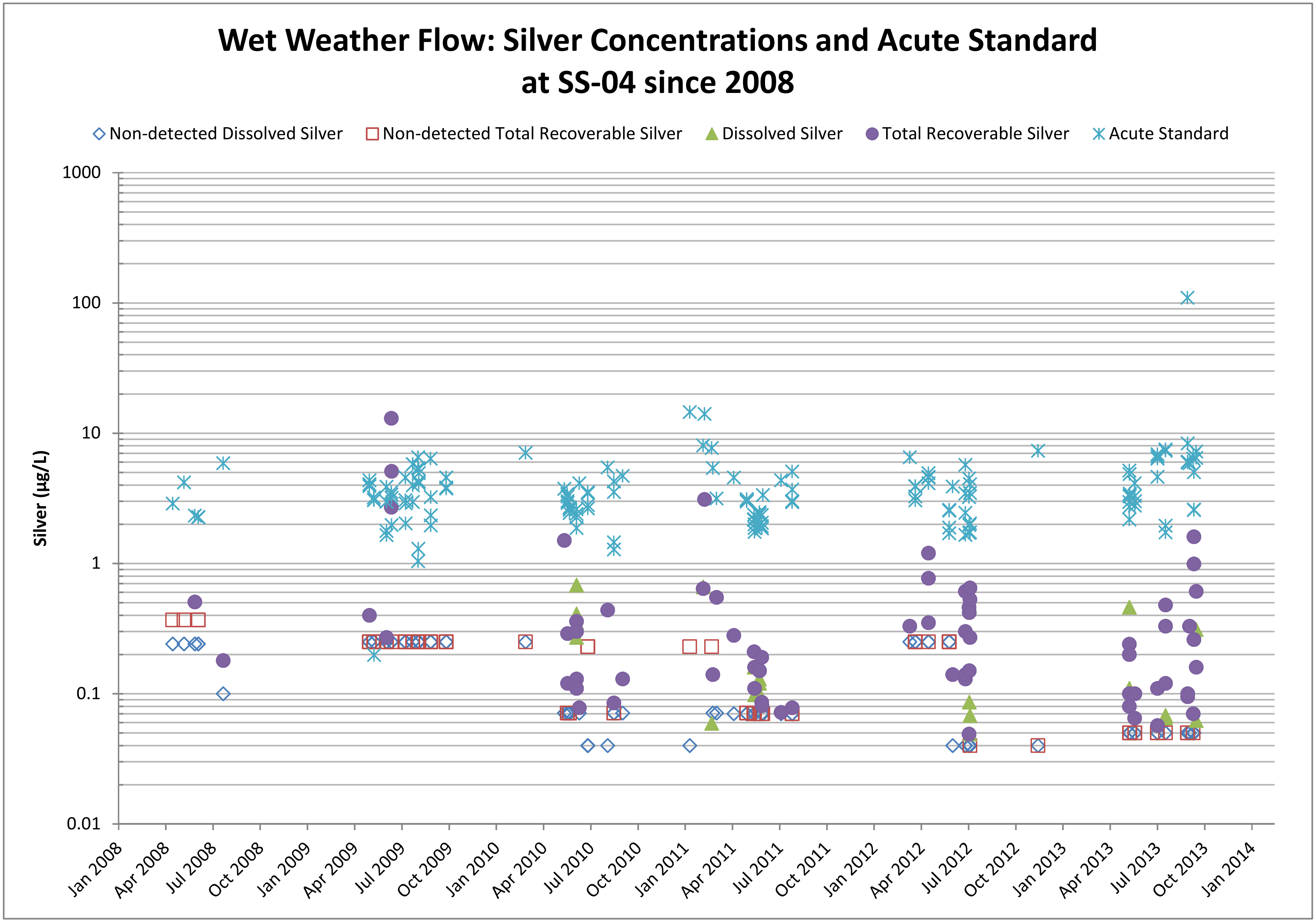

Figure 10-61
Wet Weather Flow Silver Concentrations at SS-04 - 2008 to 2013

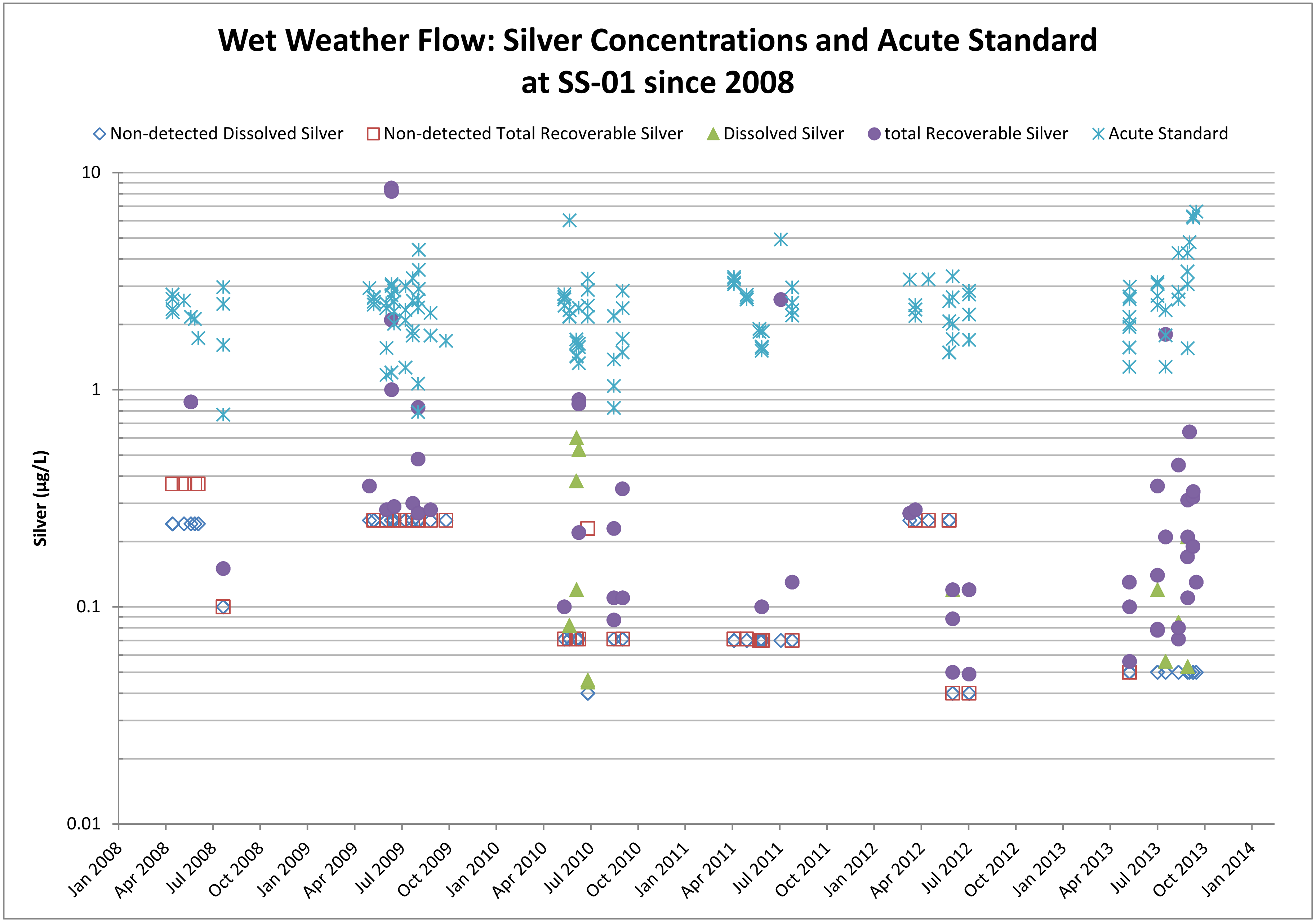

Figure 10-62
Wet Weather Flow Silver Concentrations at SS-01 - 2008 to 2013

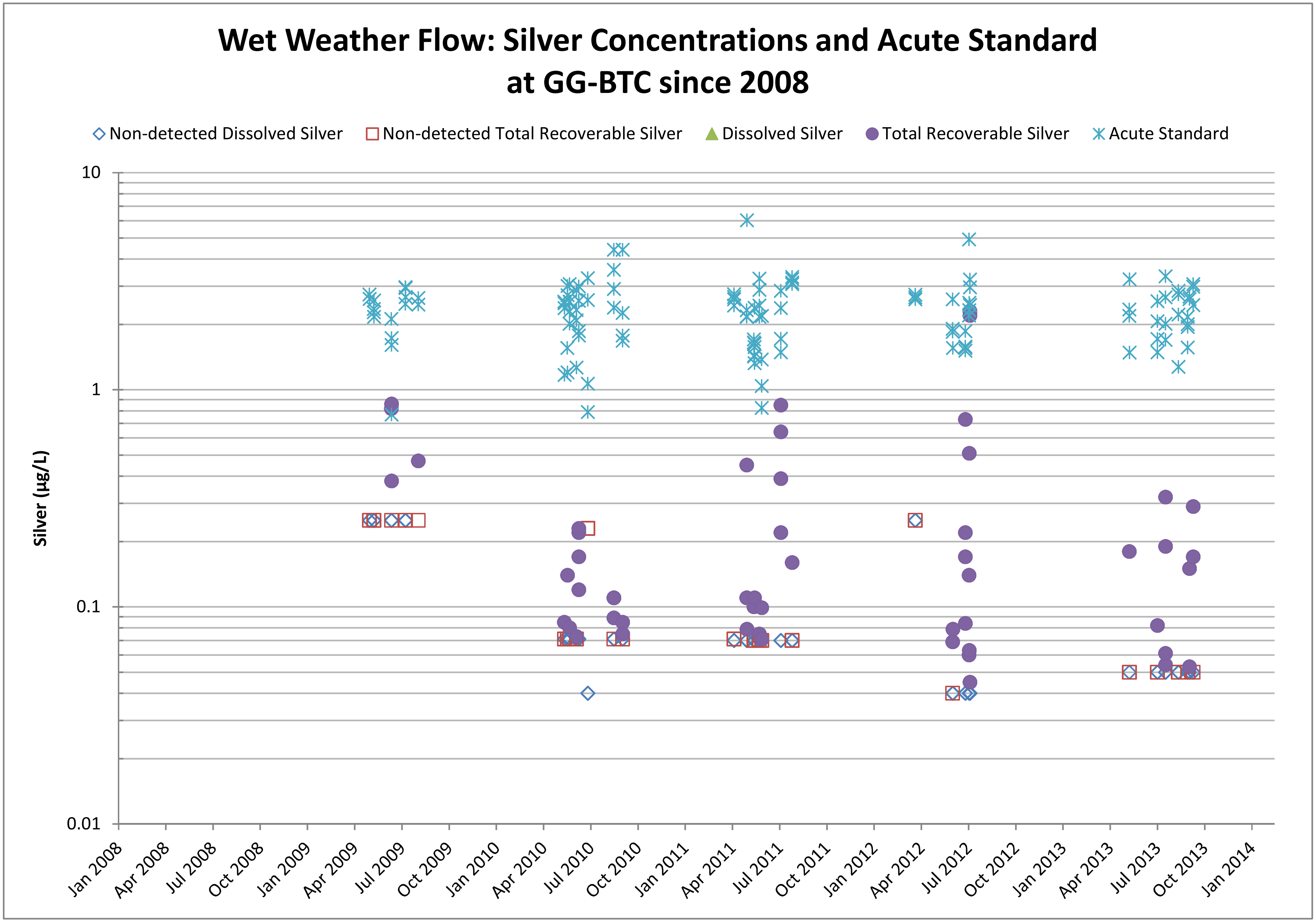

Figure 10-63
Wet Weather Flow Silver Concentrations at GG-BTC - 2008 to 2013

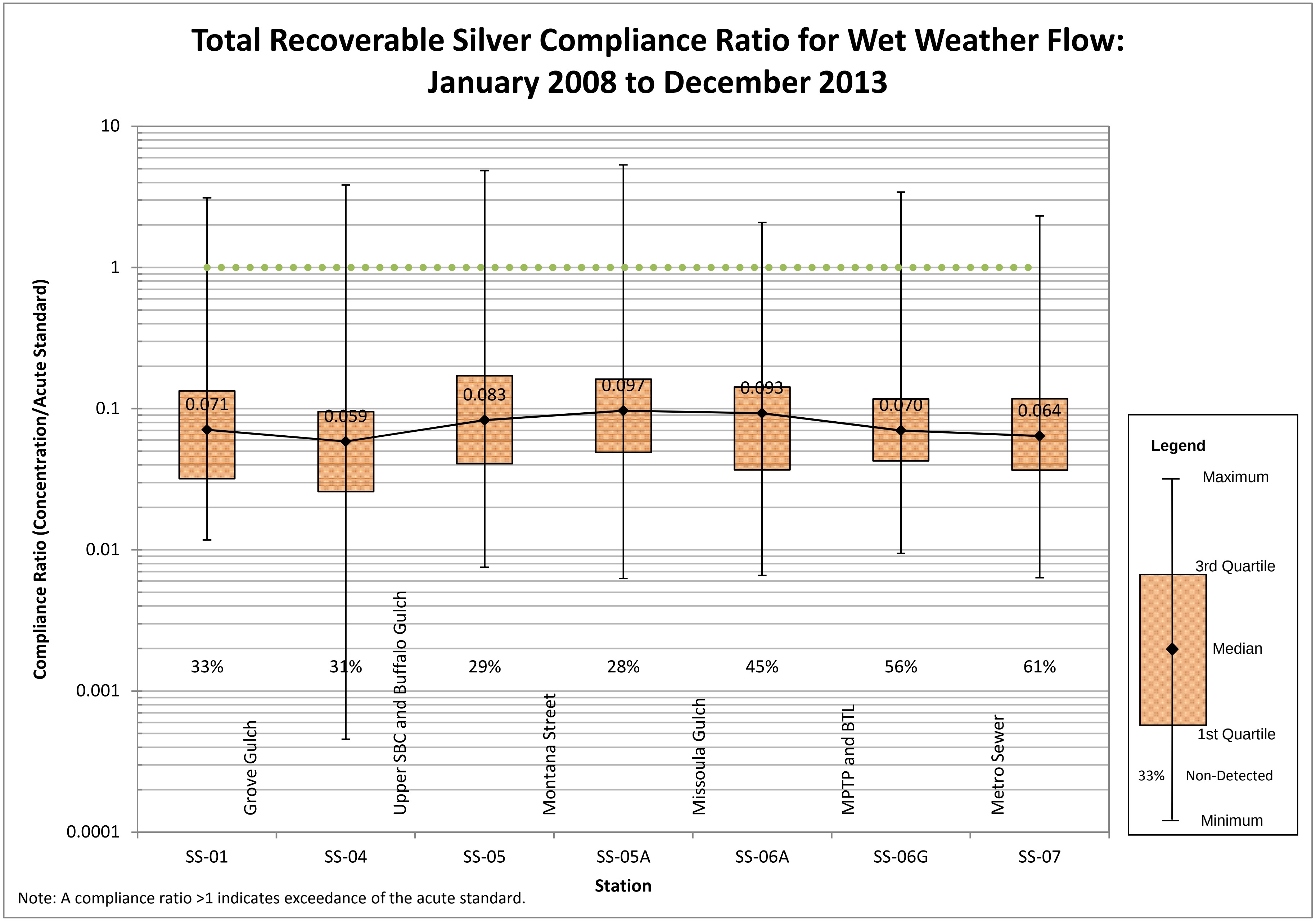

Figure 10-64
Wet Flow Total Recoverable Silver Compliance - 2008 to 2013

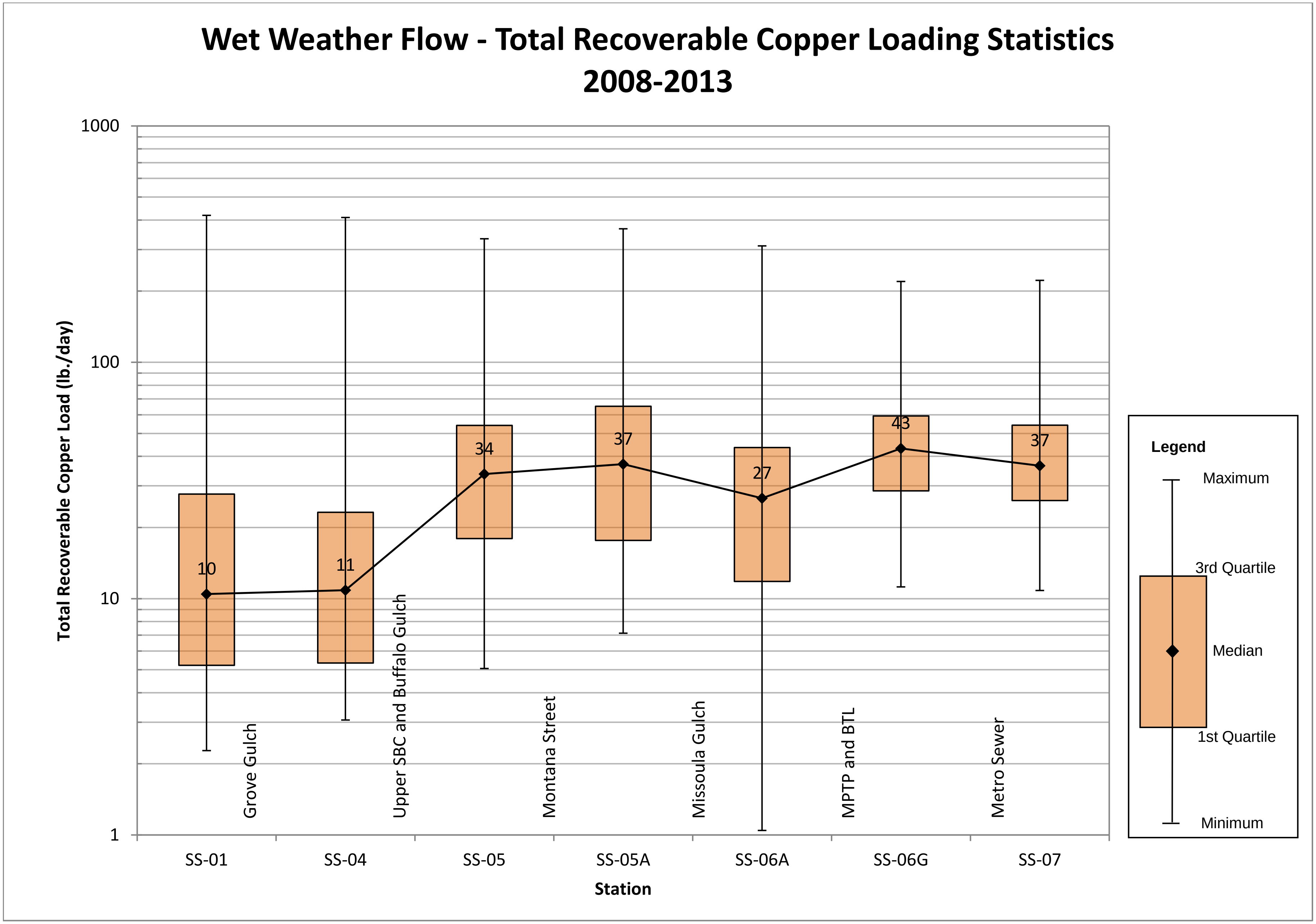

Figure 11-1
Wet Weather Flow: Main Stem TR Copper Loading 2008-2013

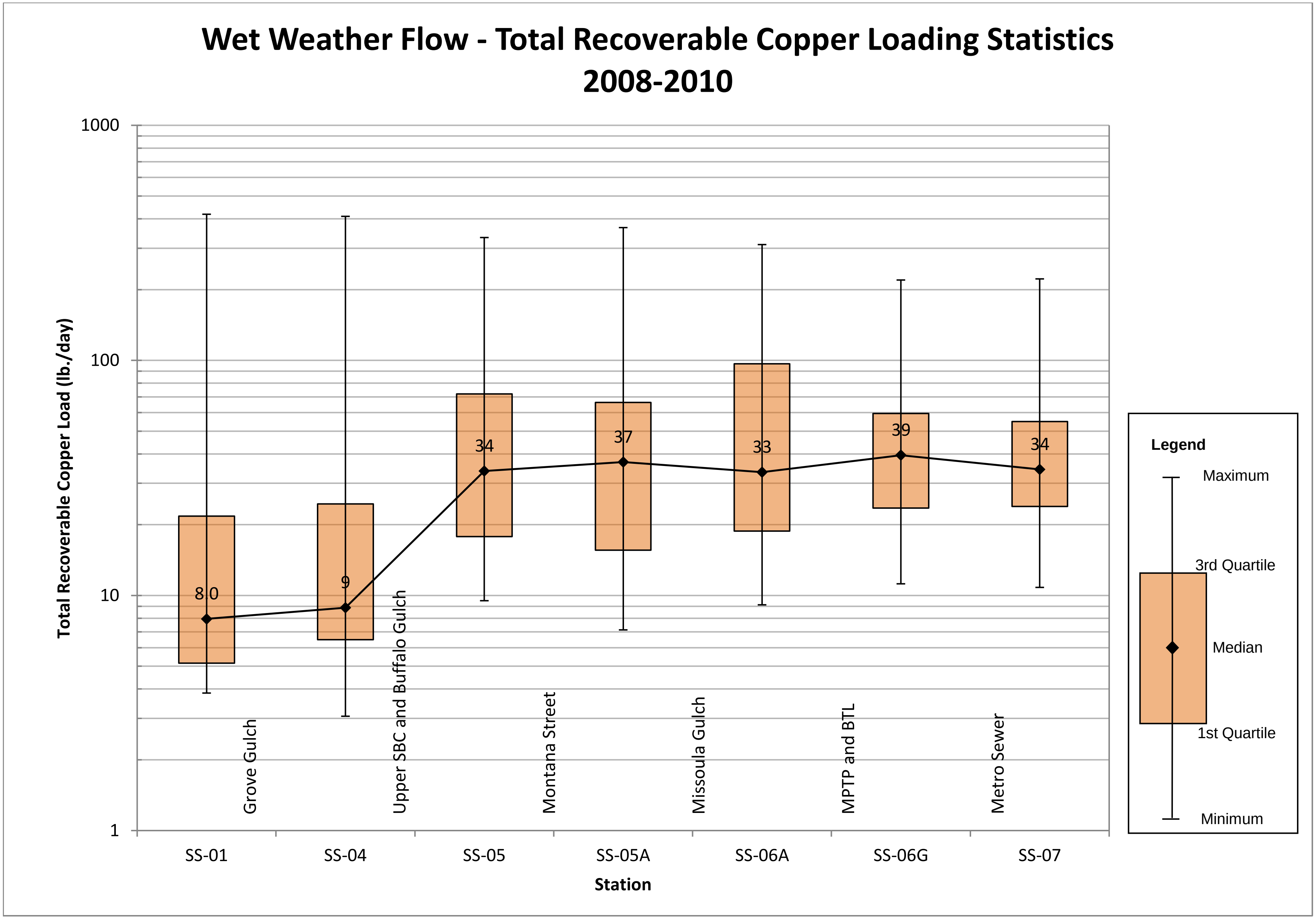

Figure 11-2
Wet Weather Flow: Main Stem TR Copper Loading 2008-2010

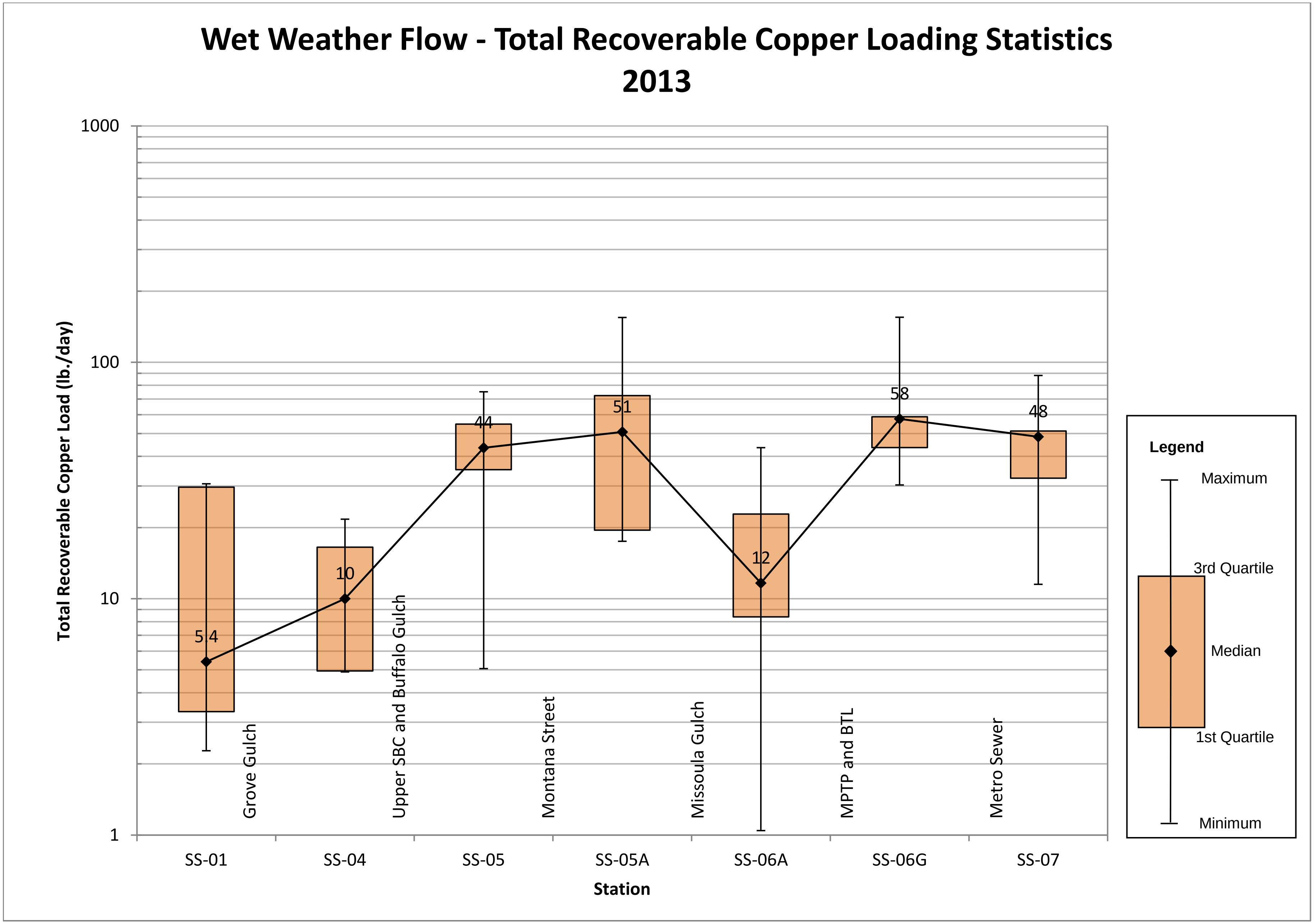

Figure 11-3
Wet Weather Flow: Main Stem TR Copper Loading 2013

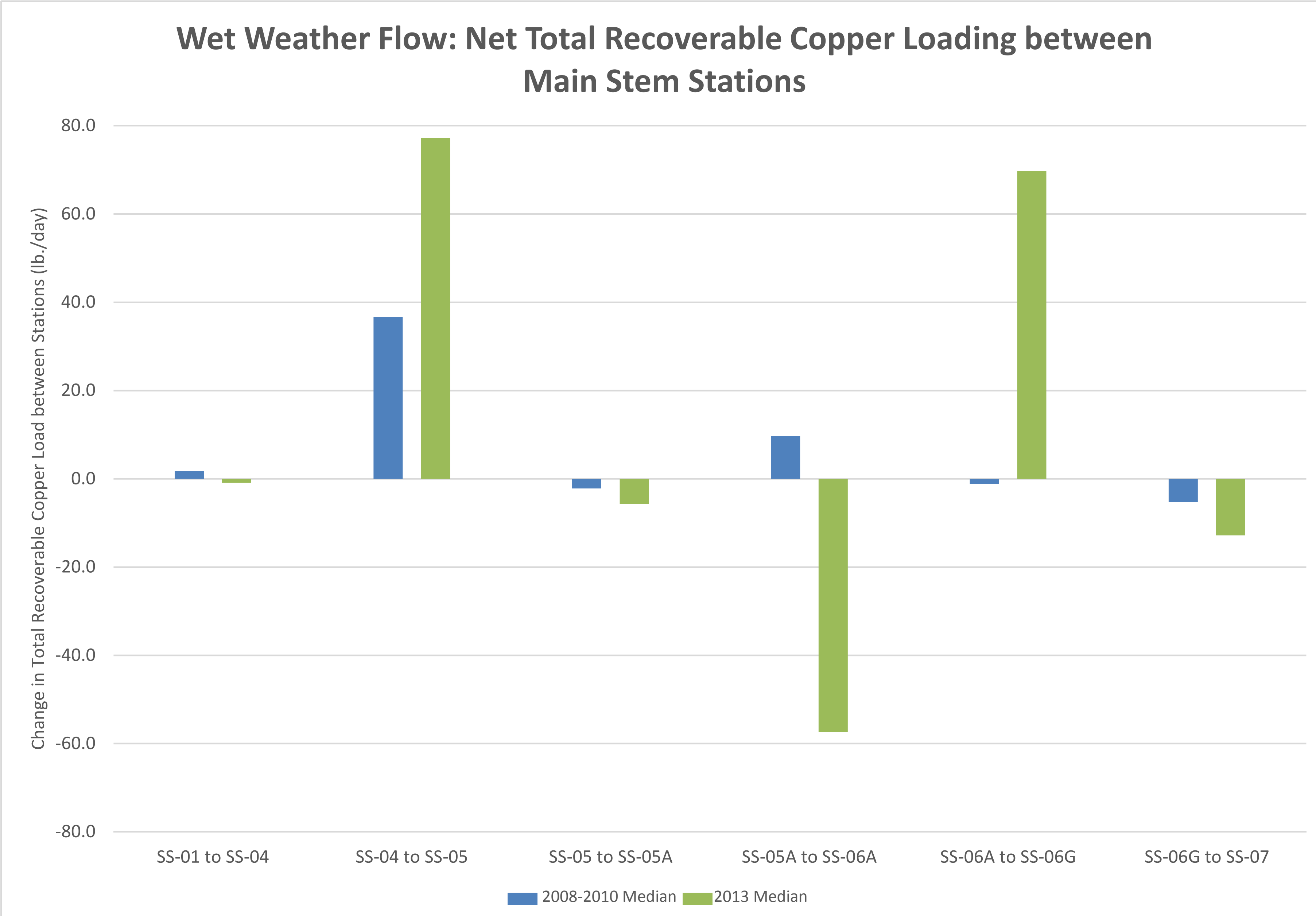

Figure 11-4
Wet Weather Flow: Main Stem TR Copper Net Loading Changes

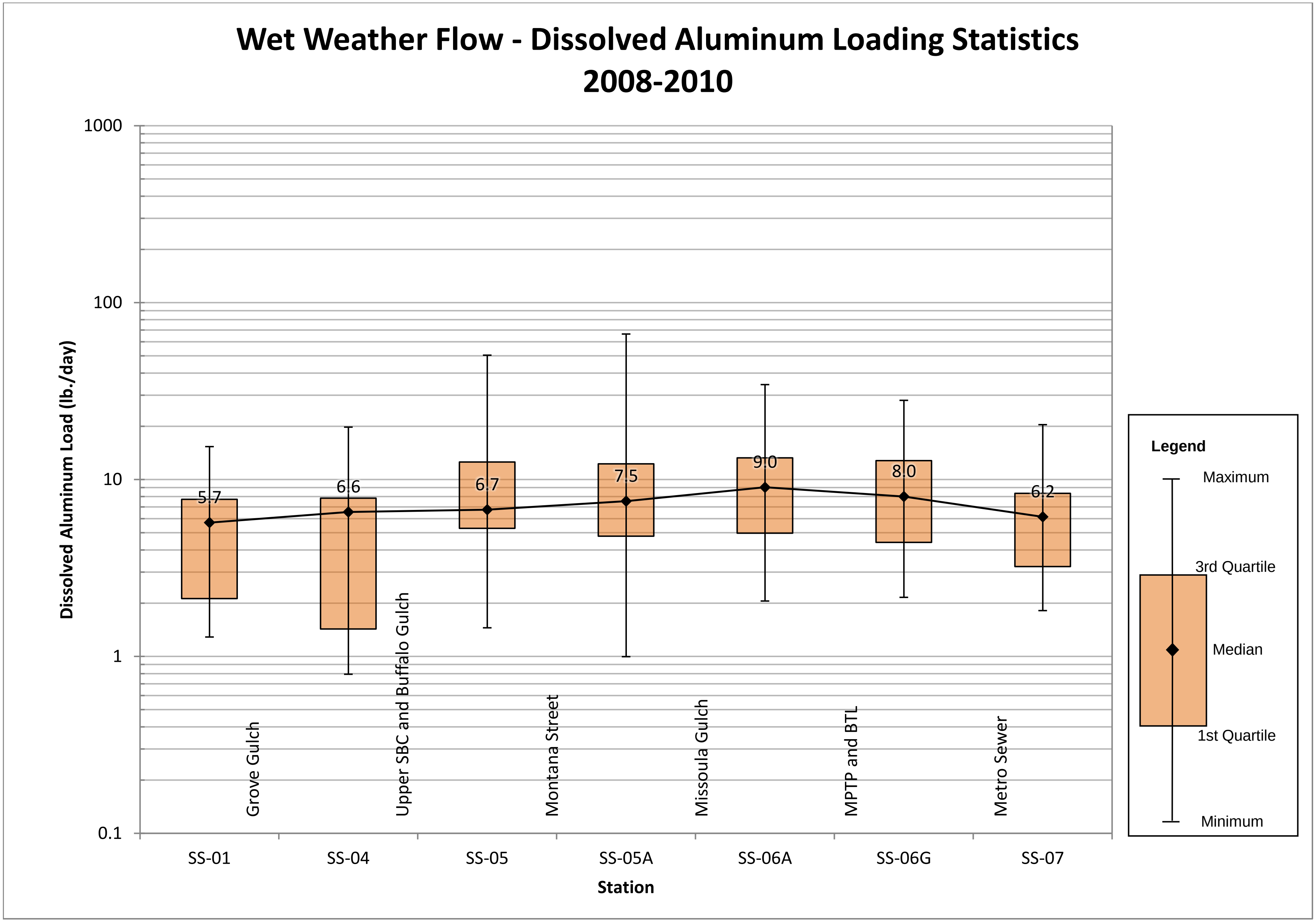

Figure 11-5
Wet Weather Flow: Main Stem Dissolved Aluminum Loading 2008-2010

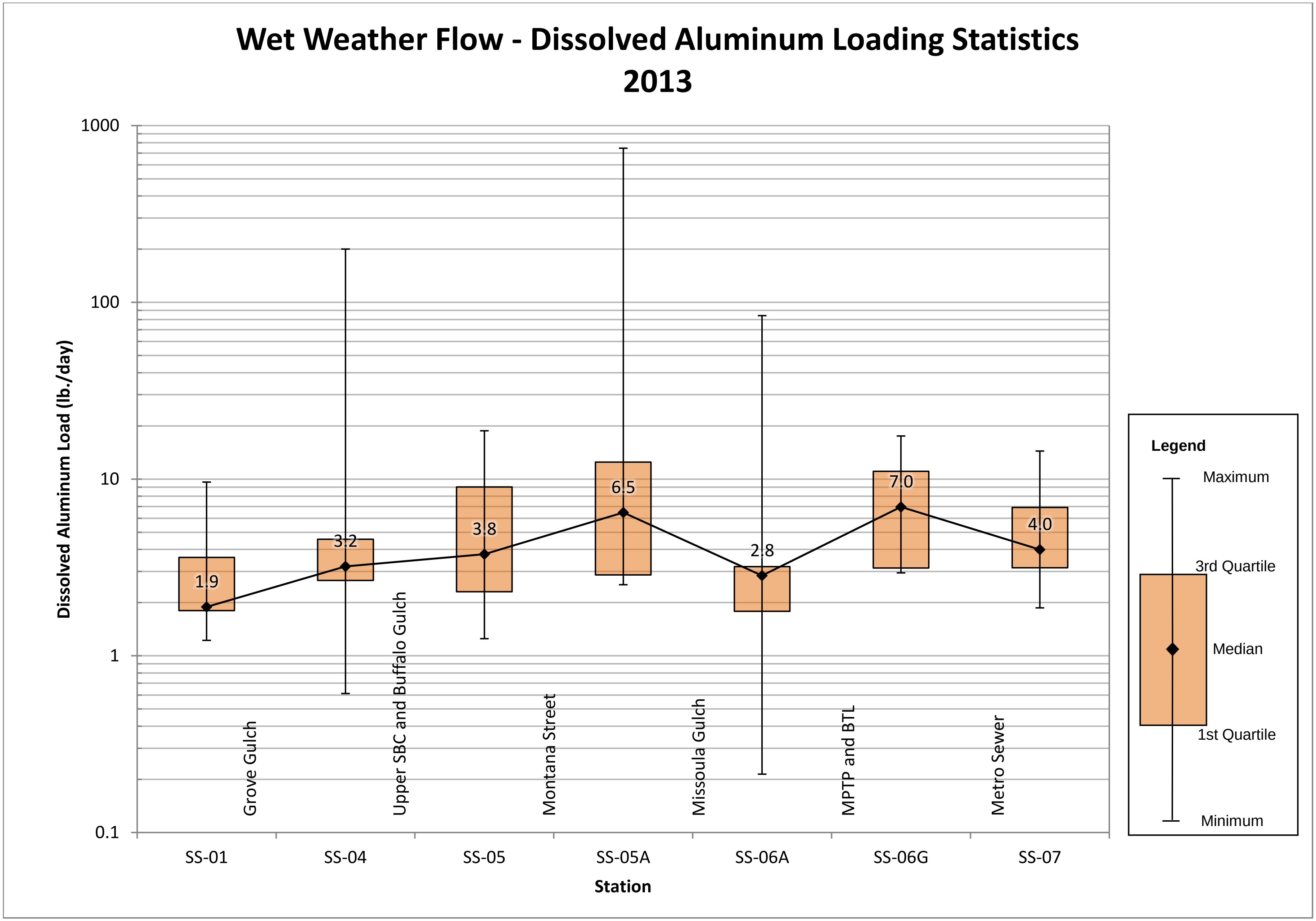

Figure 11-6
Wet Weather Flow: Main Stem Dissolved Aluminum Loading 2013

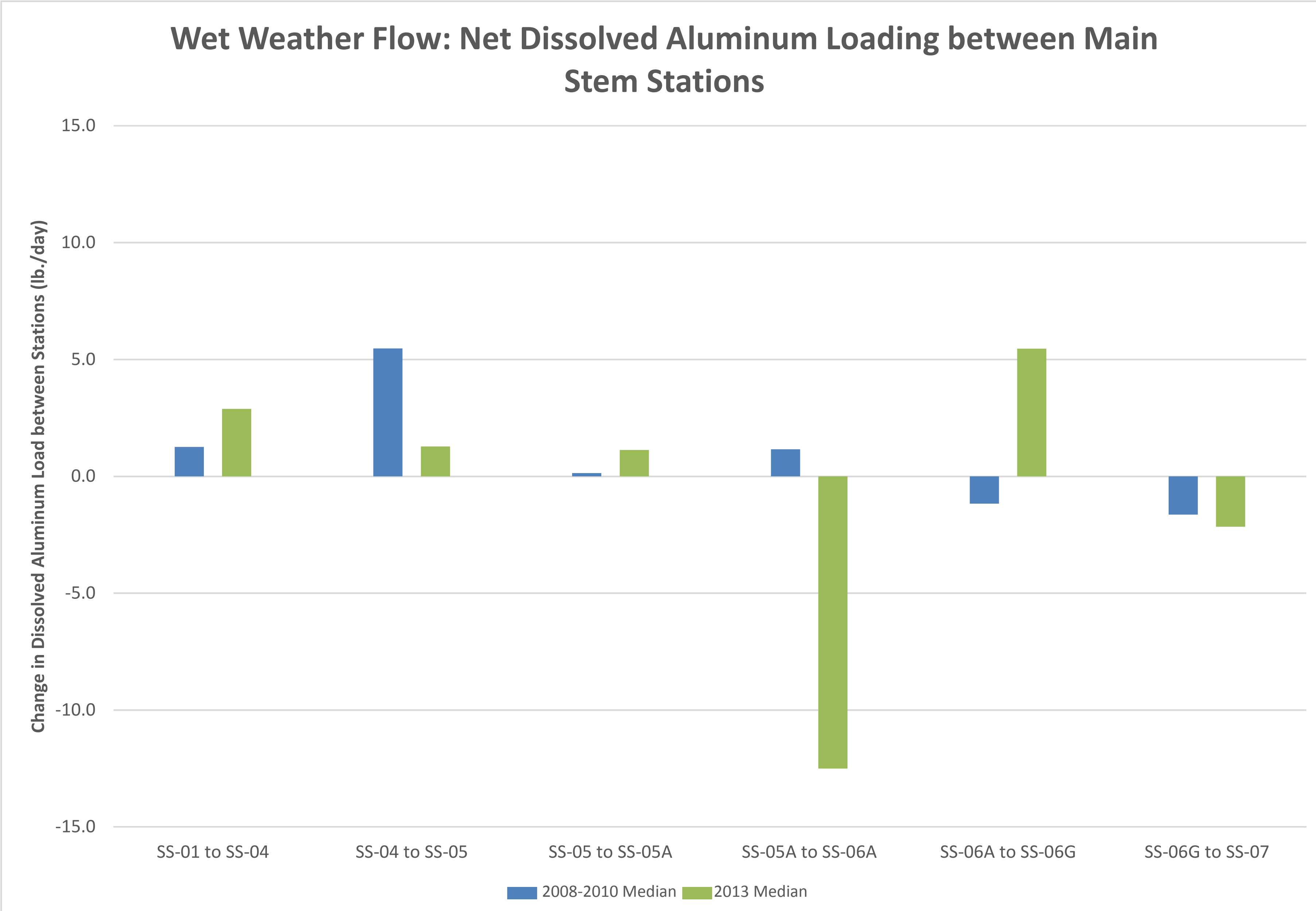

Figure 11-7
Wet Weather Flow: Main Stem Dissolved Aluminum Net Loading Changes

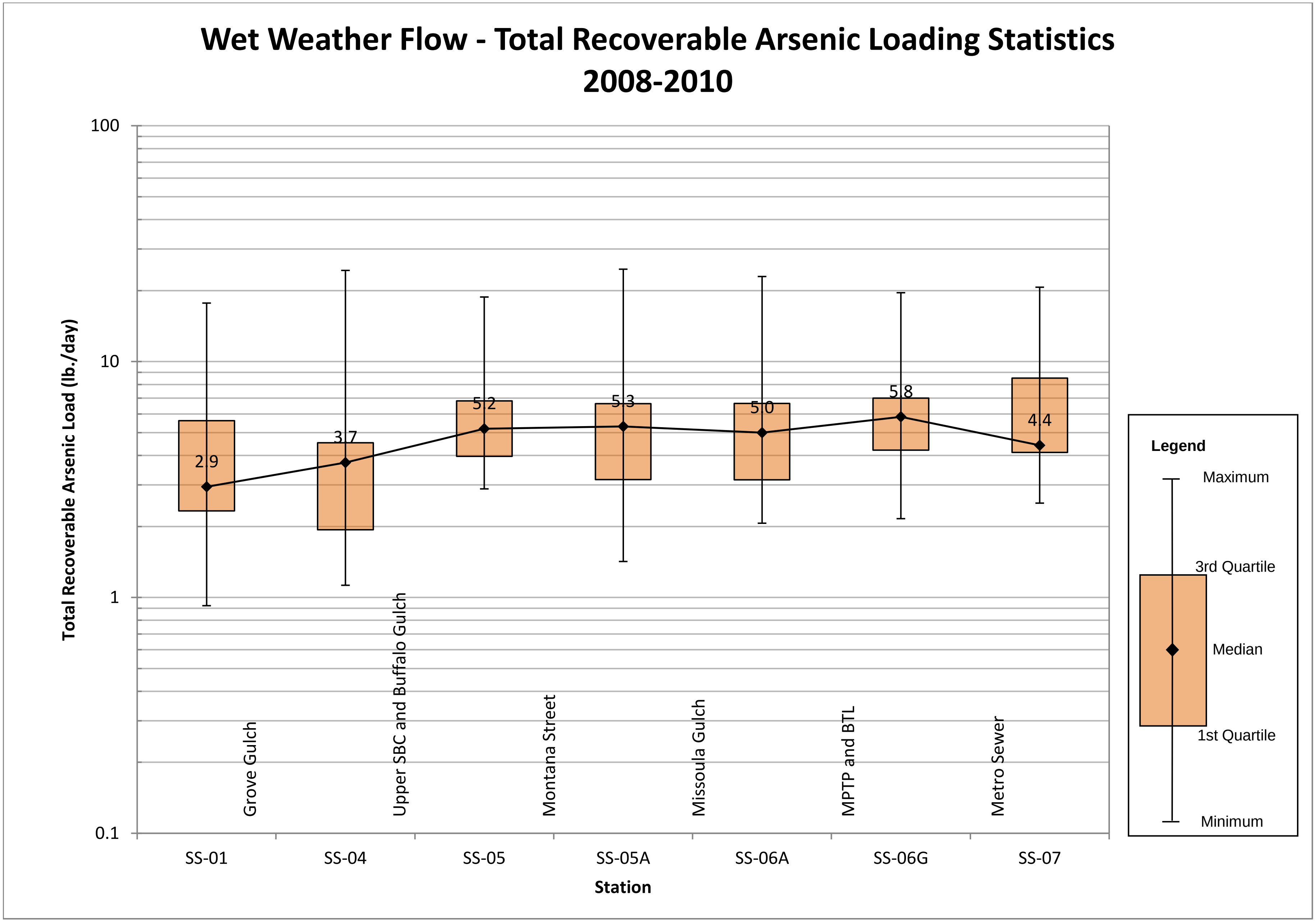

Figure 11-8
Wet Weather Flow: Main Stem TR Arsenic Loading 2008-2010

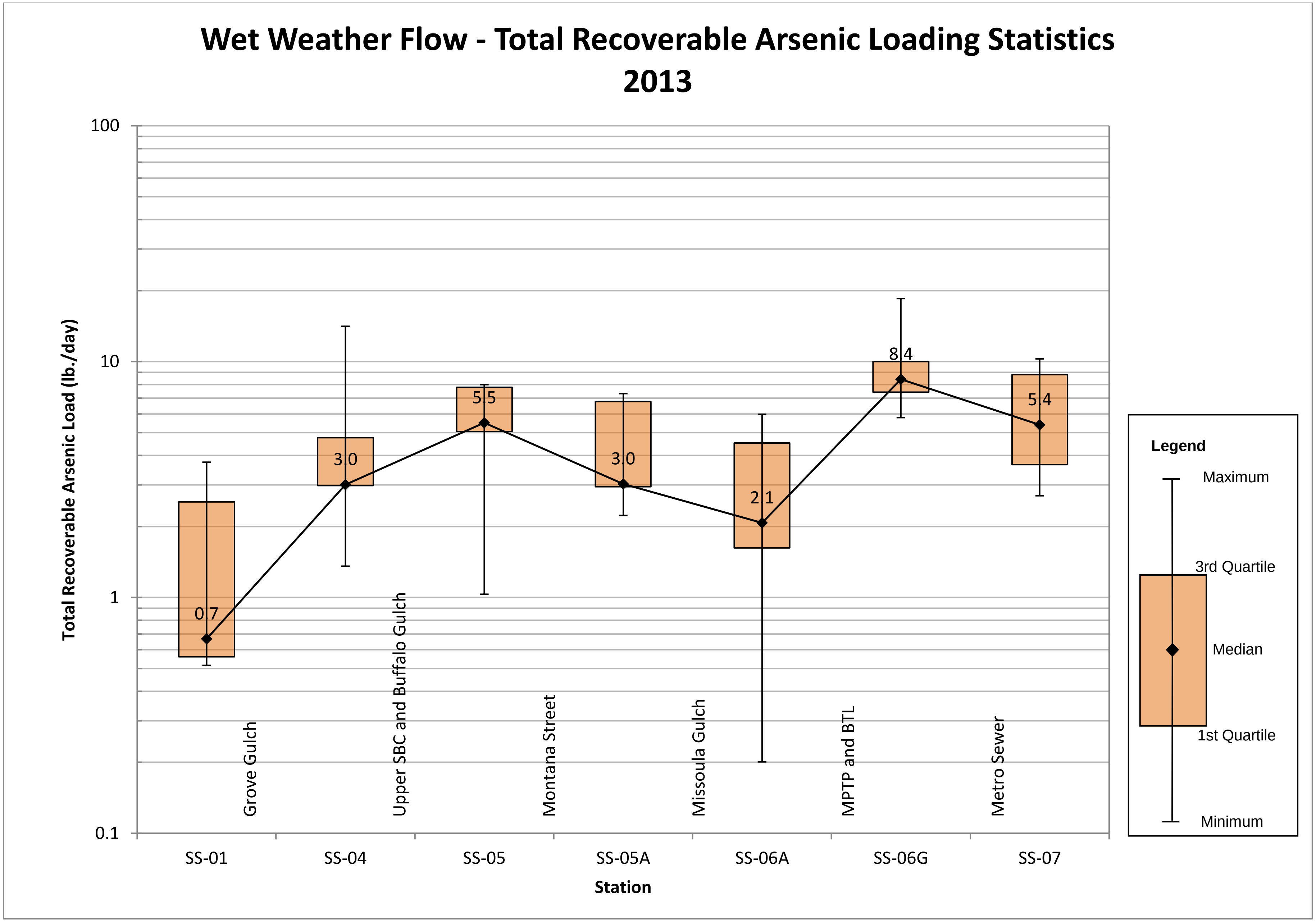

Figure 11-9
Wet Weather Flow: Main Stem TR Arsenic Loading 2013

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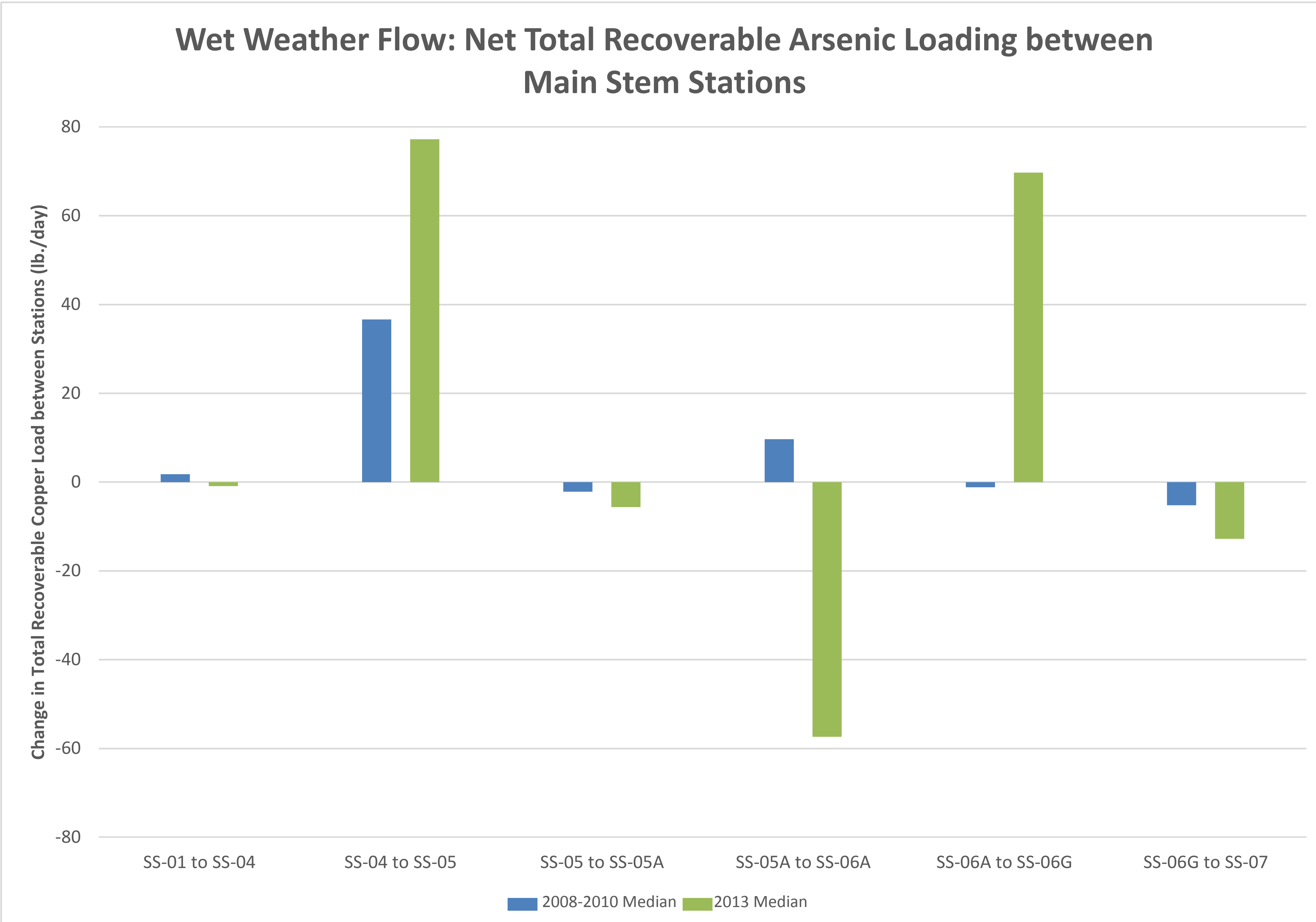

Figure 11-10
Wet Weather Flow: Main Stem TR Arsenic Net Loading Changes

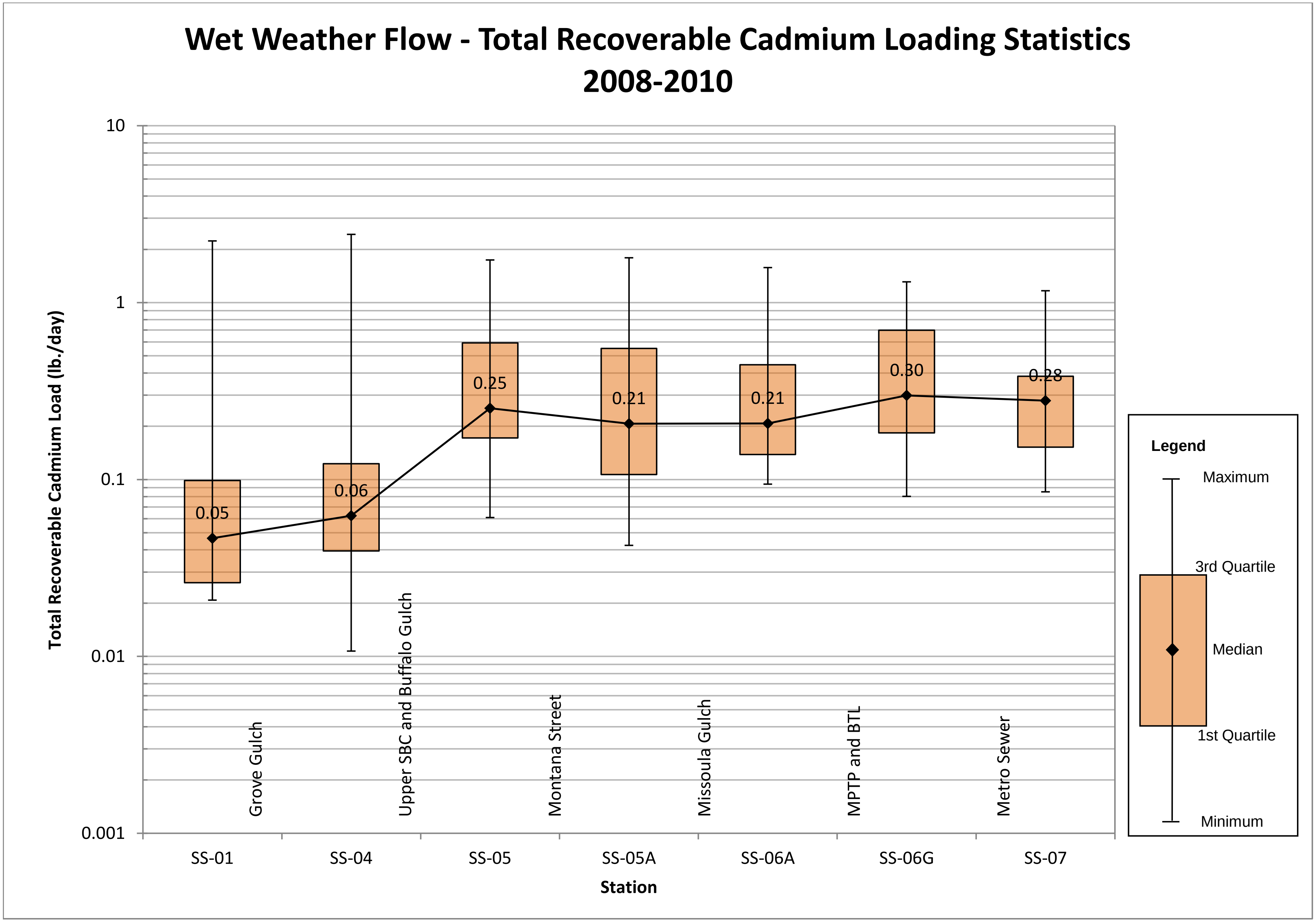

Figure 11-11
Wet Weather Flow: Main Stem TR Cadmium Loading 2008-2010

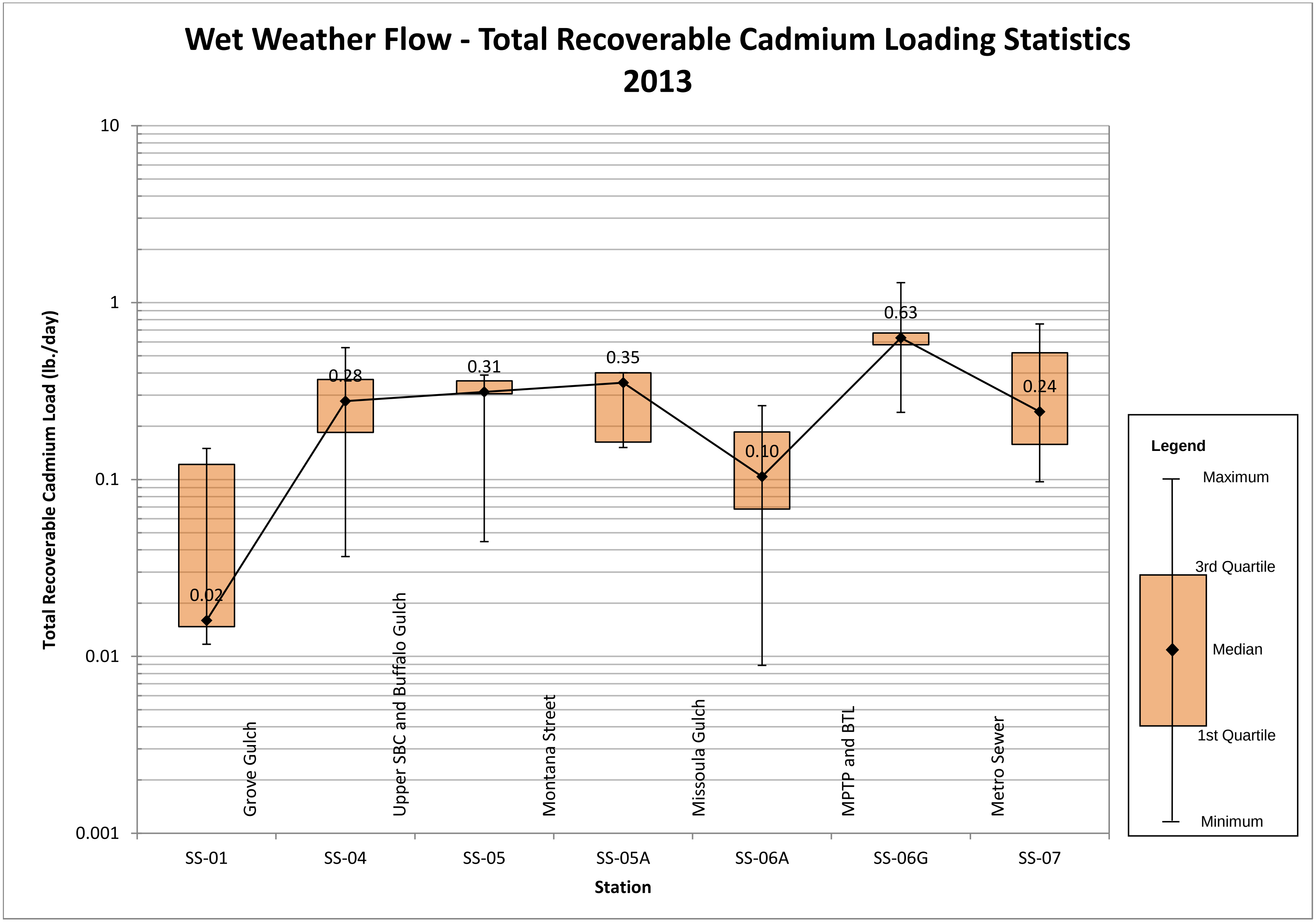

Figure 11-12
Wet Weather Flow: Main Stem TR Cadmium Loading 2013

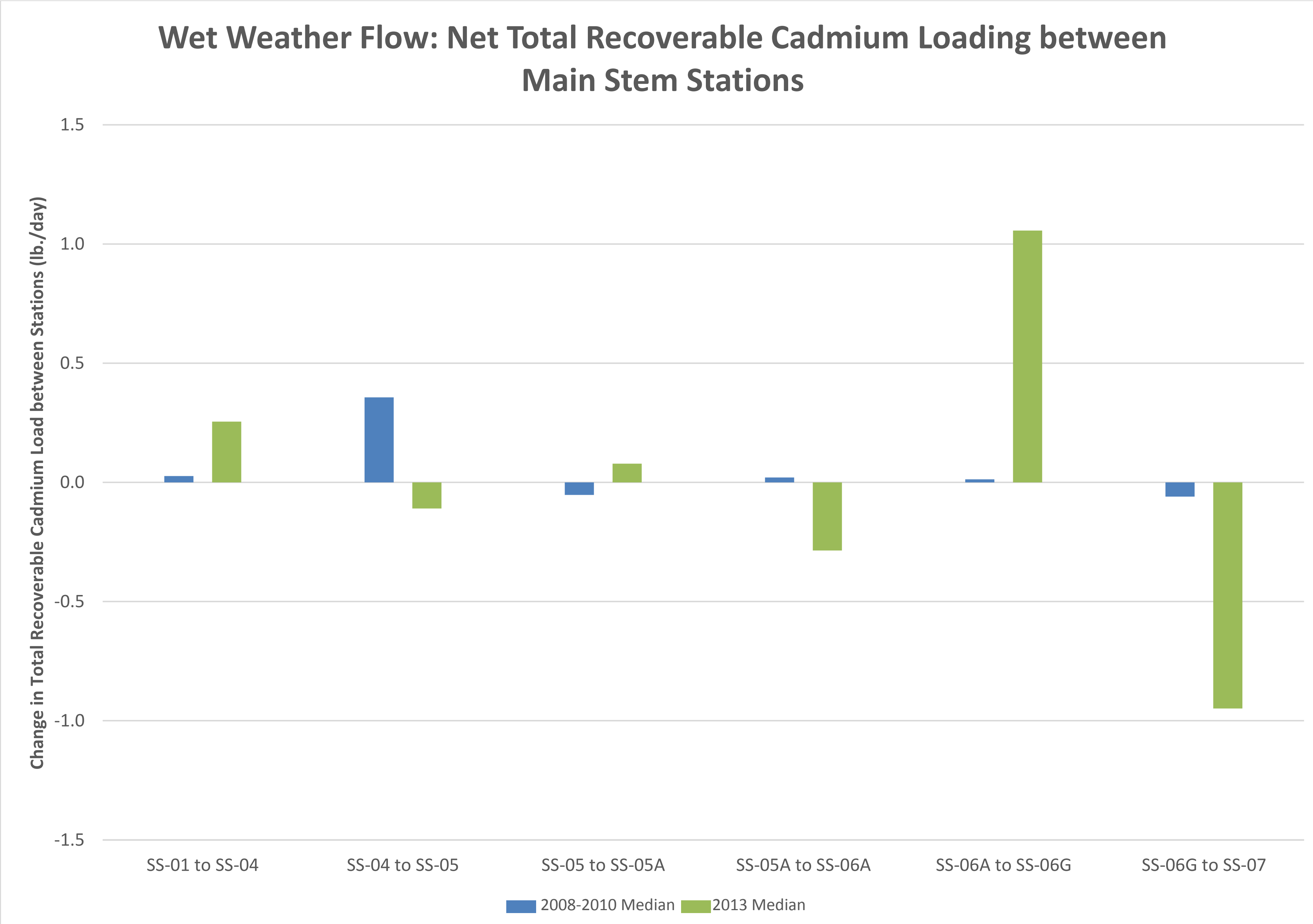

Figure 11-13
Wet Weather Flow: Main Stem TR Cadmium Net Loading Changes

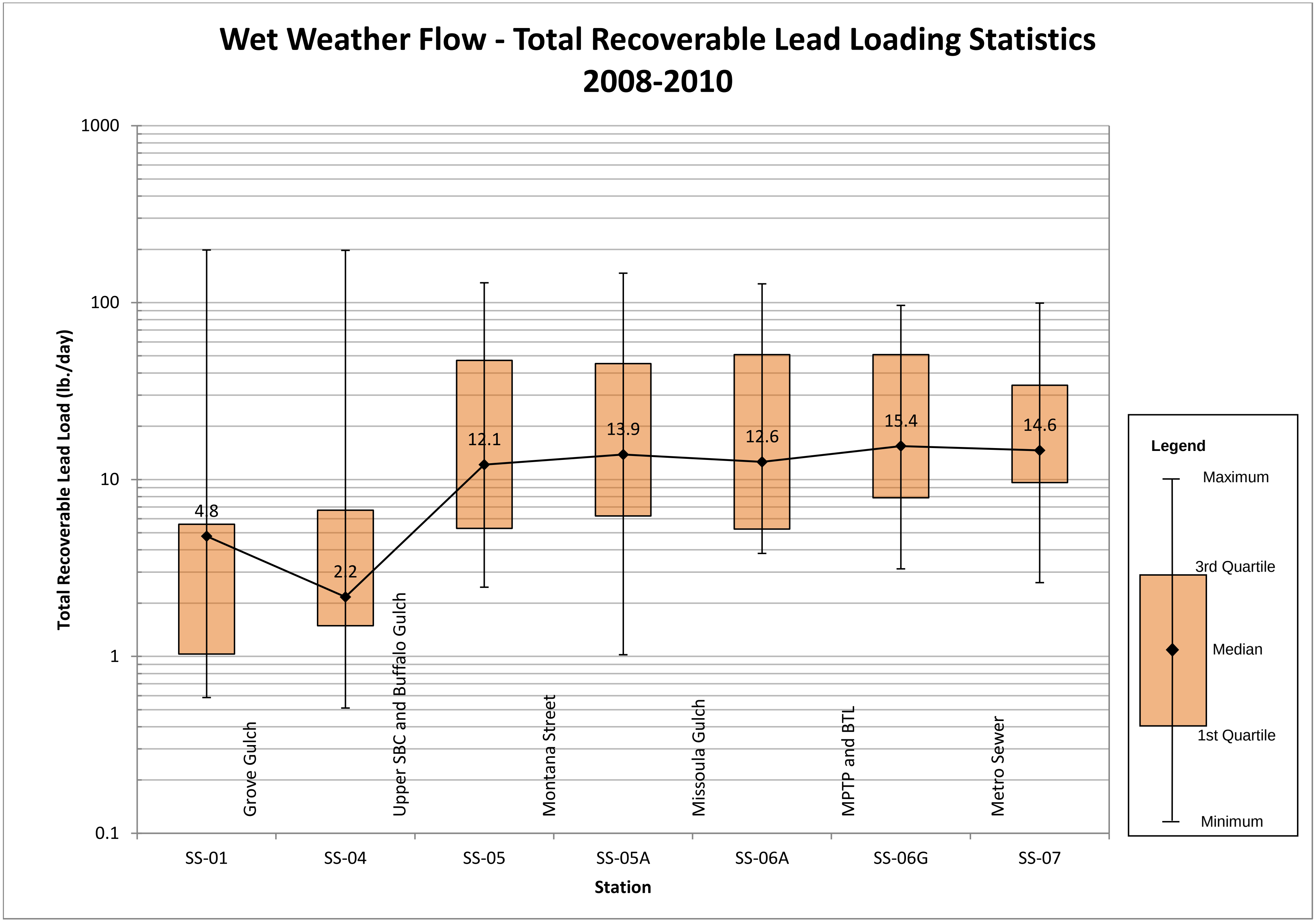

Figure 11-14
Wet Weather Flow: Main Stem TR Lead Loading 2008-2010

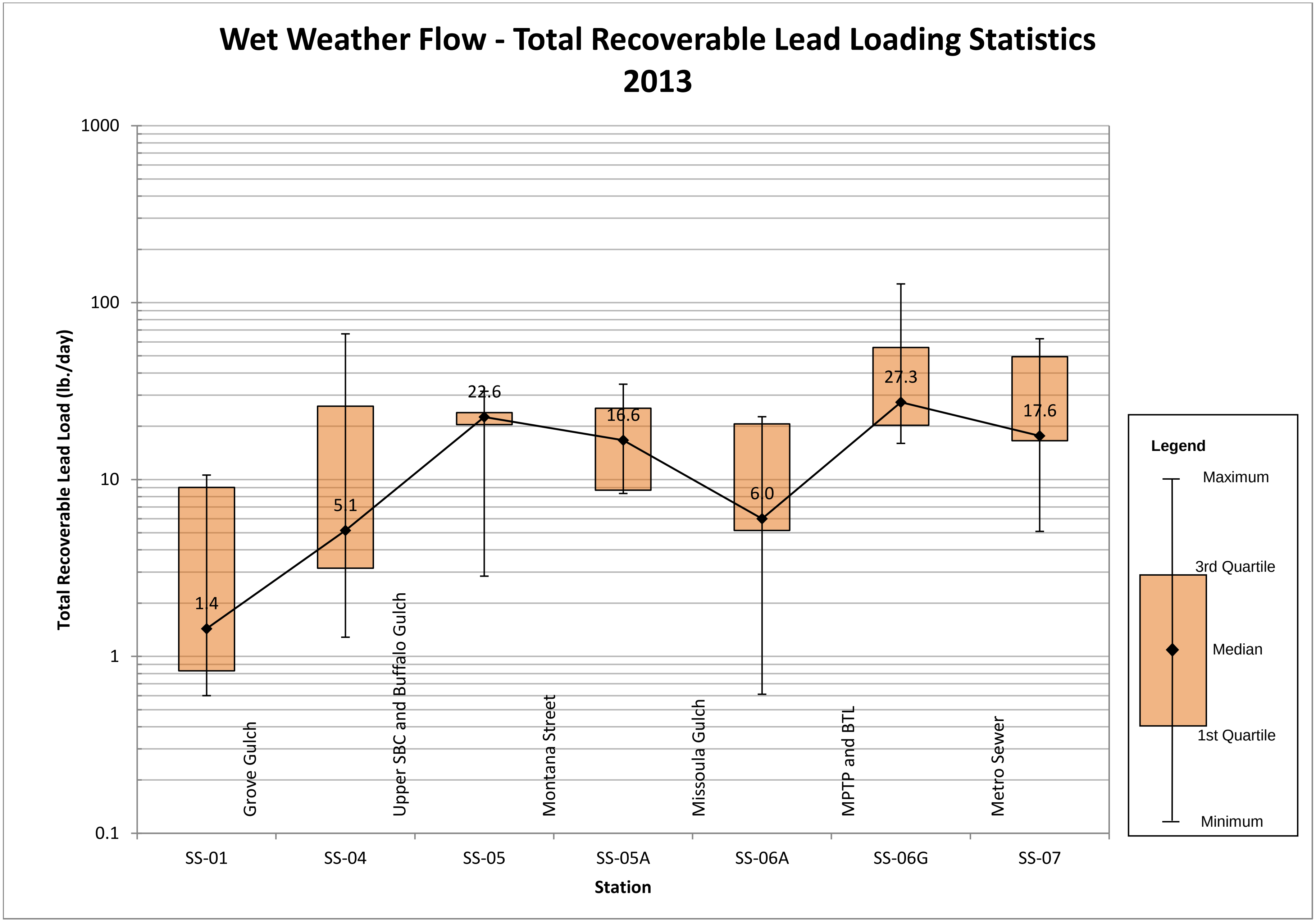

Figure 11-15
Wet Weather Flow: Main Stem TR Lead Loading 2013

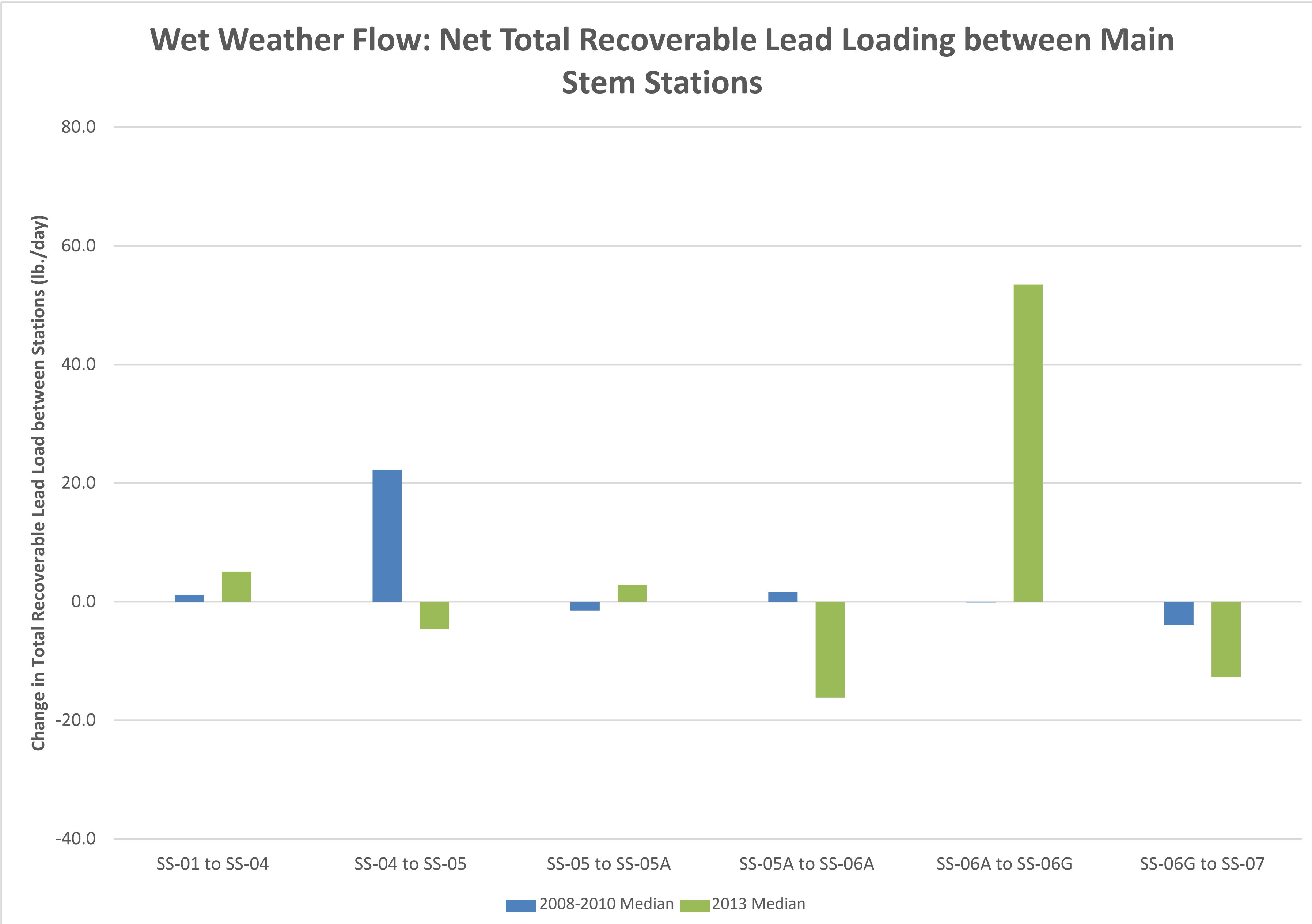

Figure 11-16
Wet Weather Flow: Main Stem TR Lead Net Loading Changes

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Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

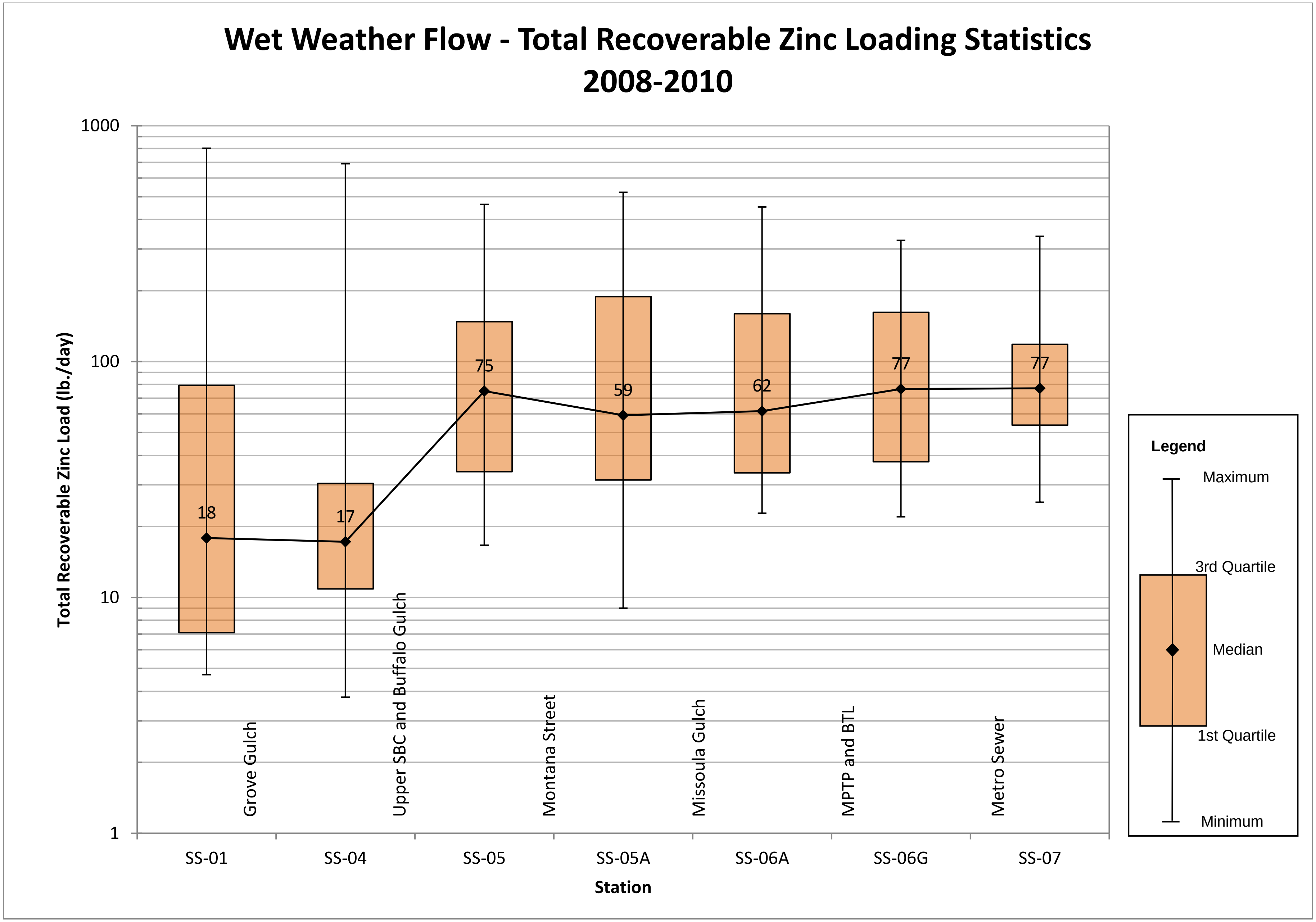

Figure 11-17
Wet Weather Flow: Main Stem TR Zinc Loading 2008-2010

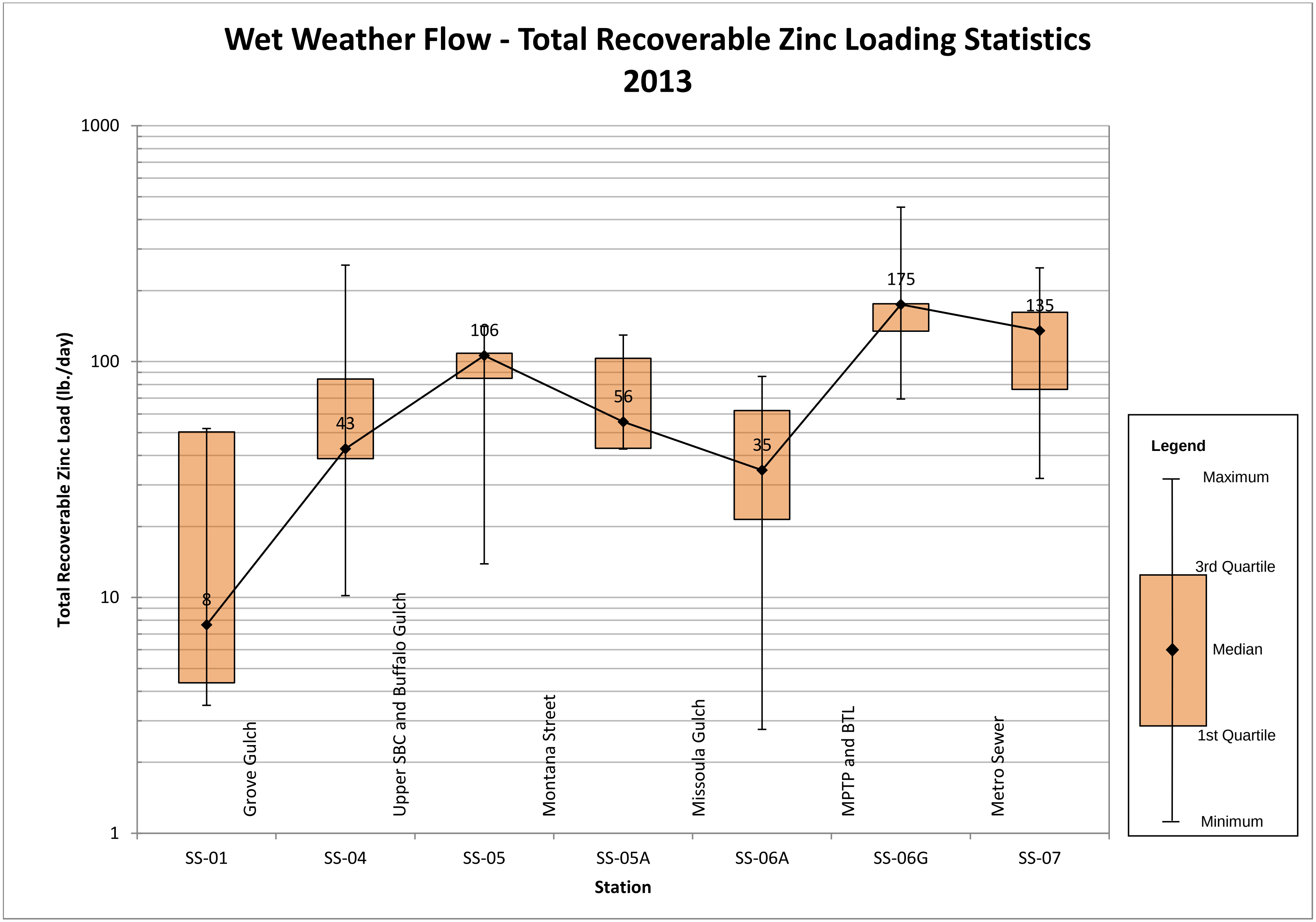

Figure 11-18
Wet Weather Flow: Main Stem TR Zinc Loading 2013

Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

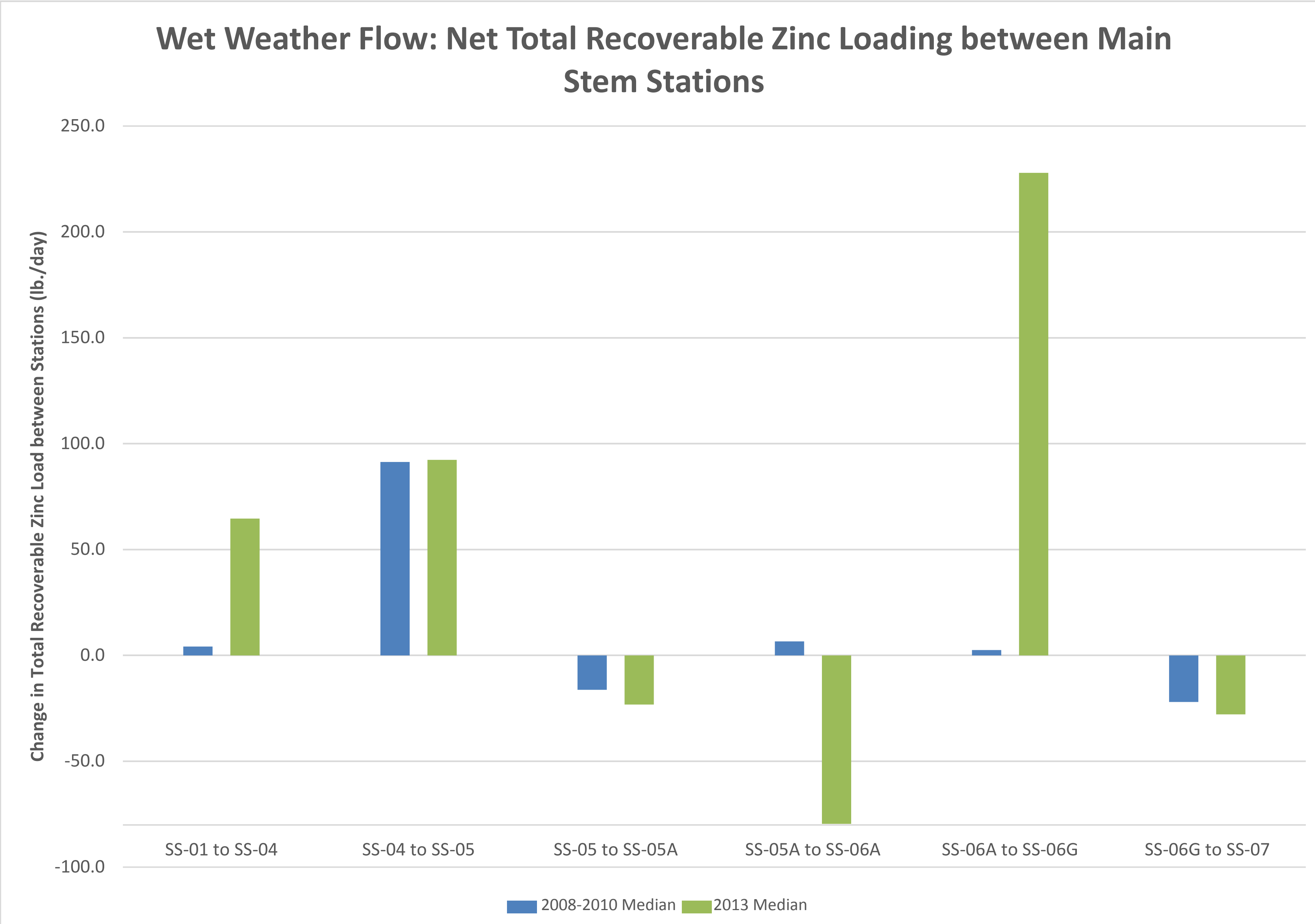

Figure 11-19
Wet Weather Flow: Main Stem TR Zinc Net Loading Changes

Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

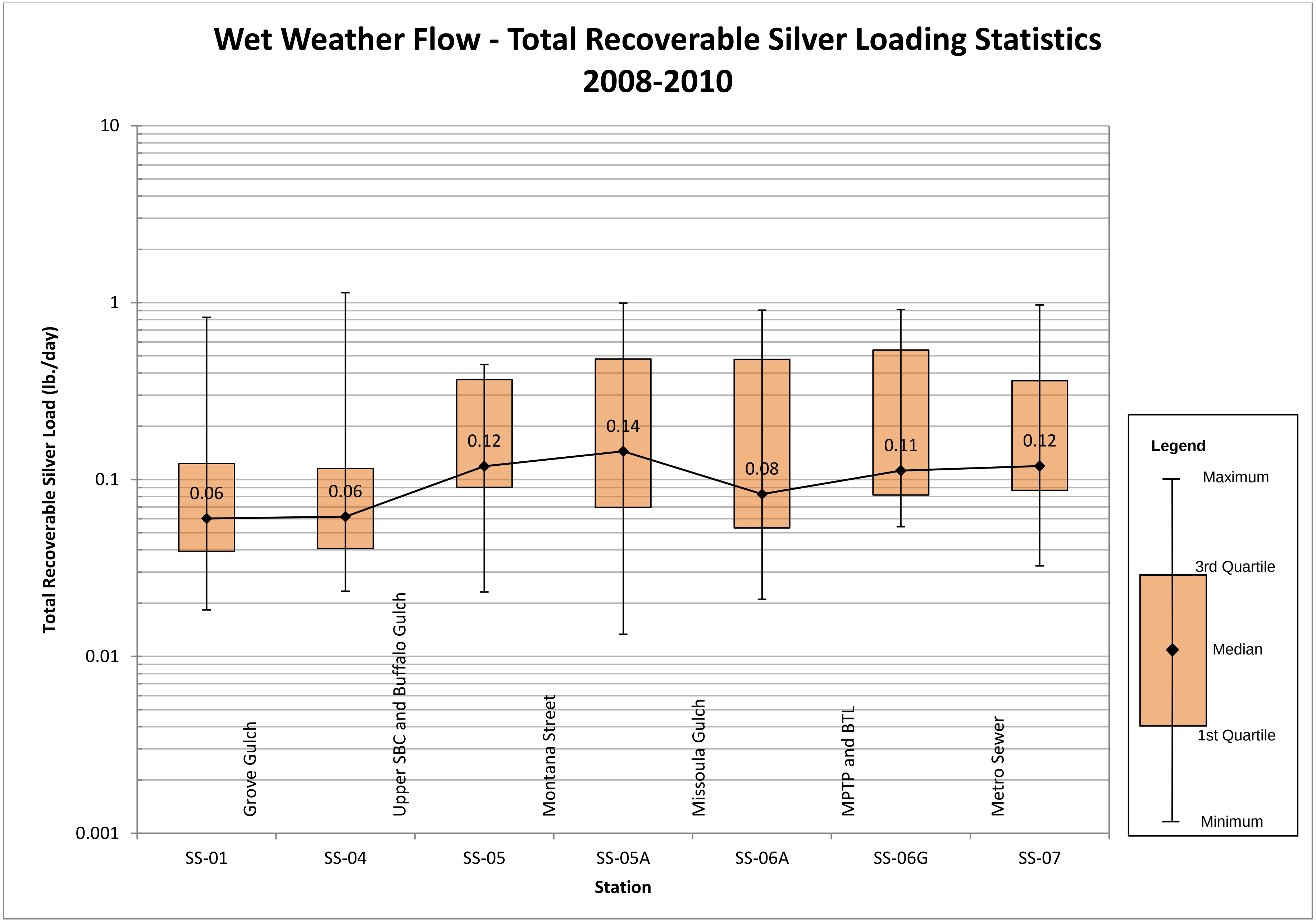

Figure 11-20
Wet Weather Flow: Main Stem TR Silver Loading 2008-2010

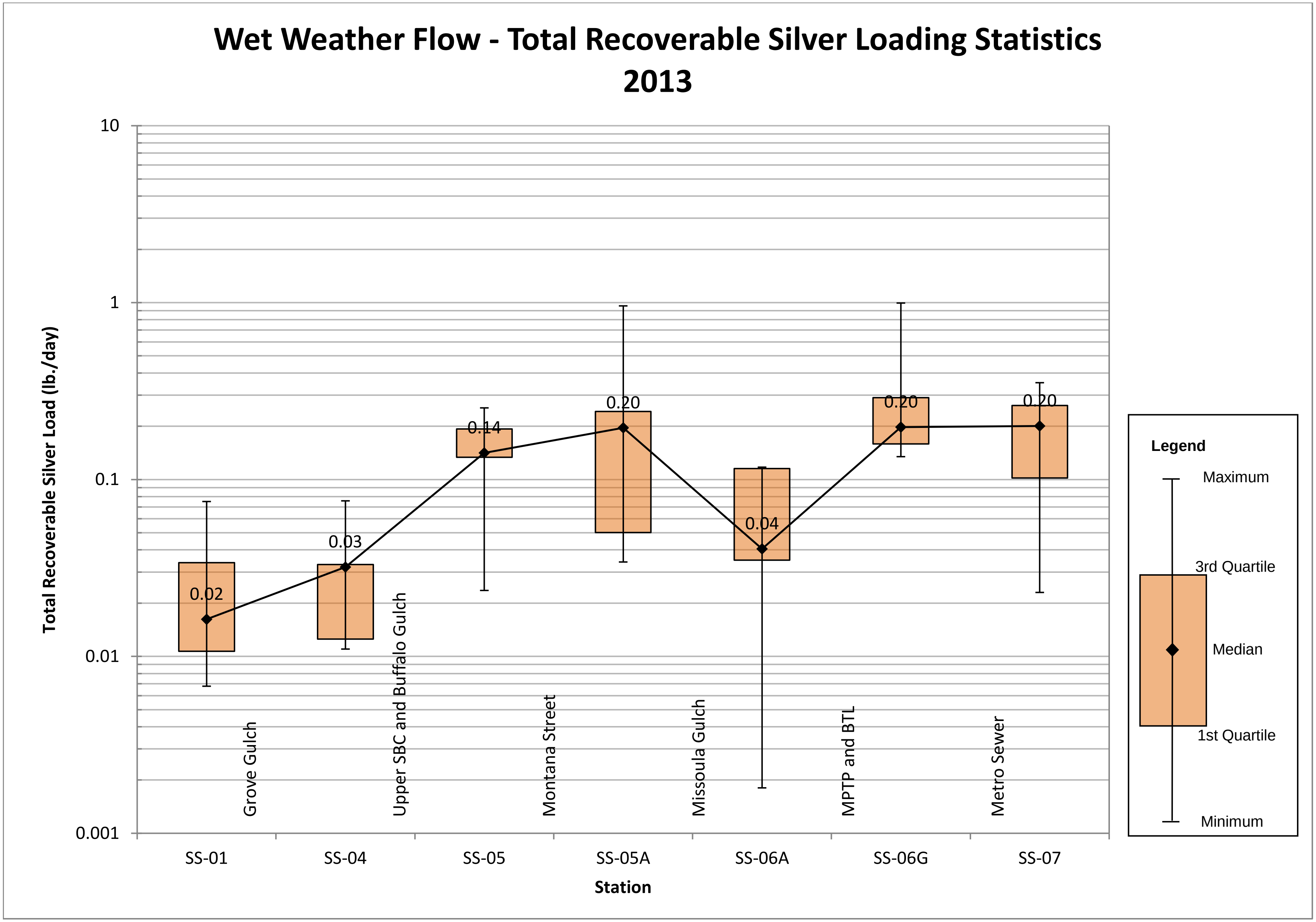

Figure 11-21
Wet Weather Flow: Main Stem TR Silver Loading 2013

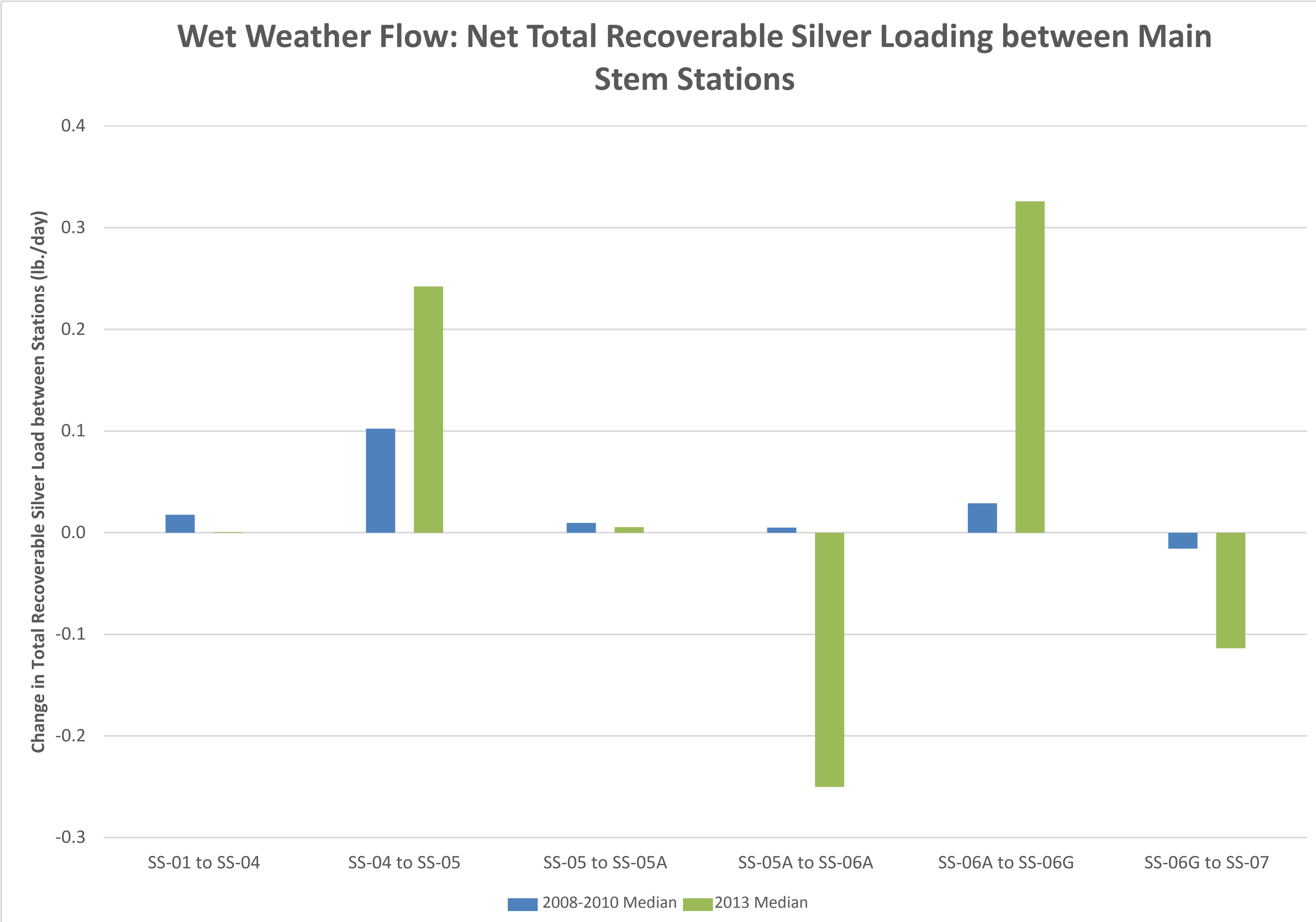

Figure 11-22
Wet Weather Flow: Main Stem TR Silver Net Loading Changes

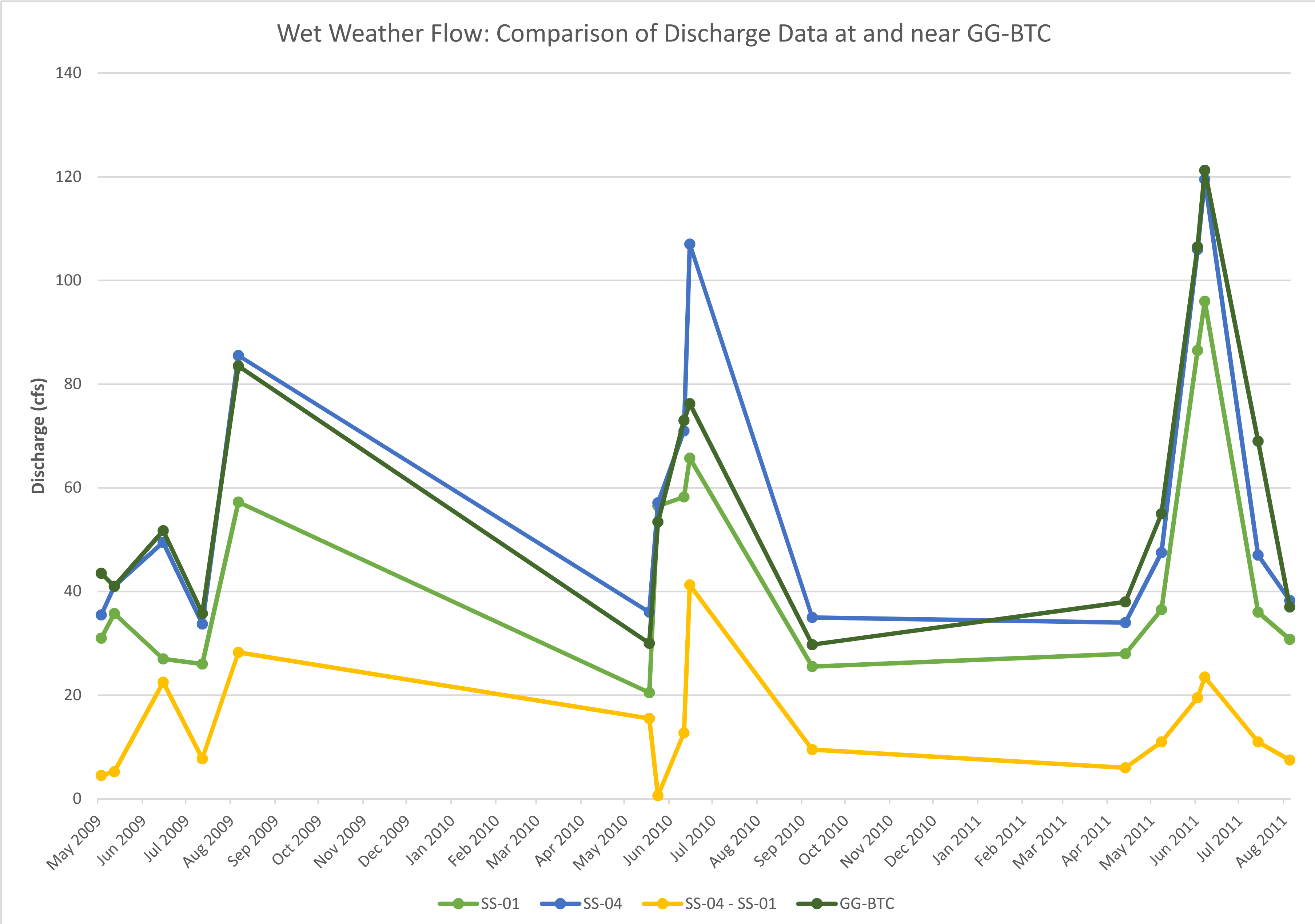

Figure 11-23
Comparison of Discharge Data at GG-BTC and Blacktail Creek

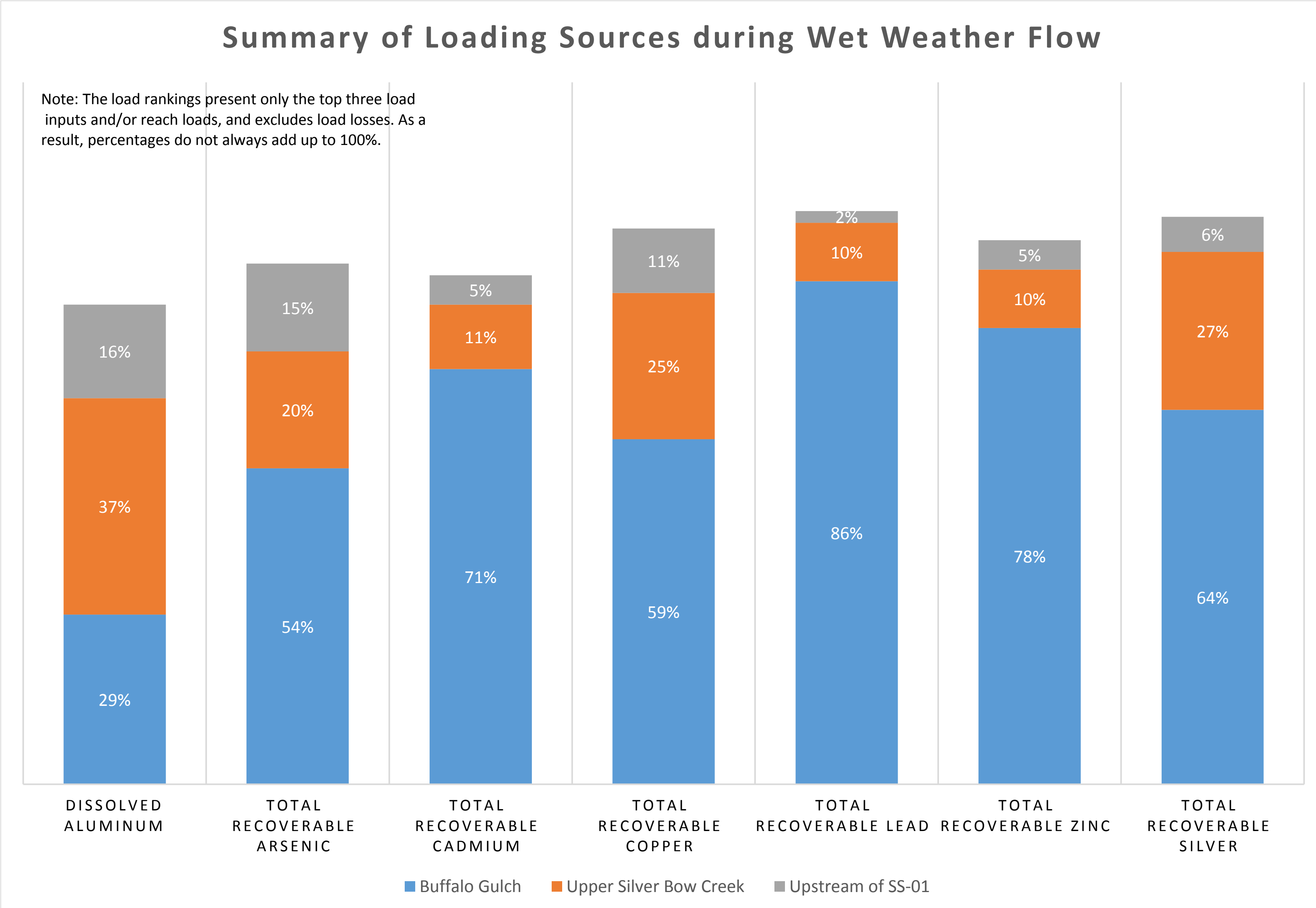

Figure 11-24
Summary of Loading Sources during Wet Weather Flow

Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

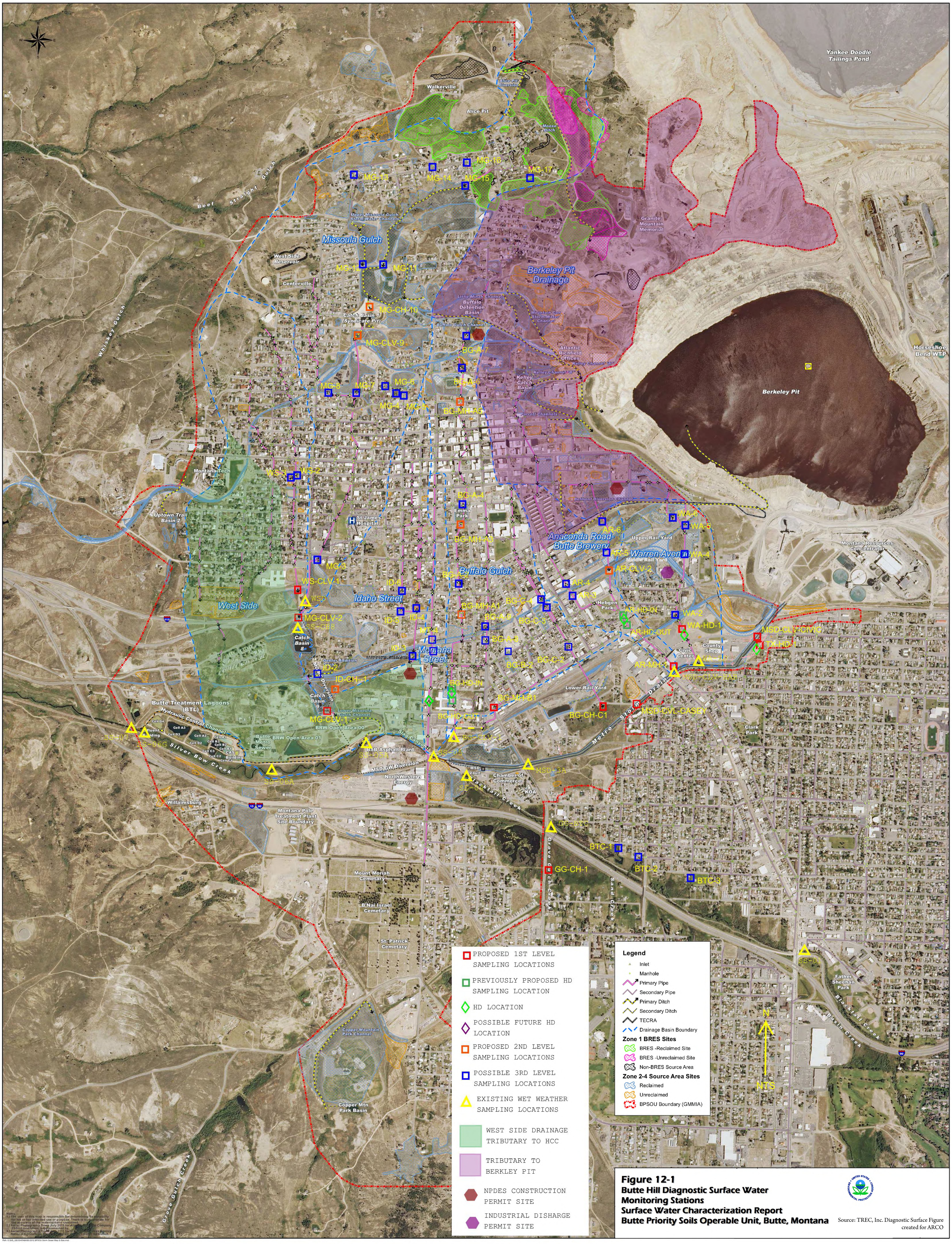

Figure 12-1
Butte Hill Diagnostic Surface Water Monitoring Stations
Surface Water Characterization Report
Butte Priority Soils Operable Unit, Butte, Montana

Source: TREC, Inc. Diagnostic Surface Figure created for ARCO

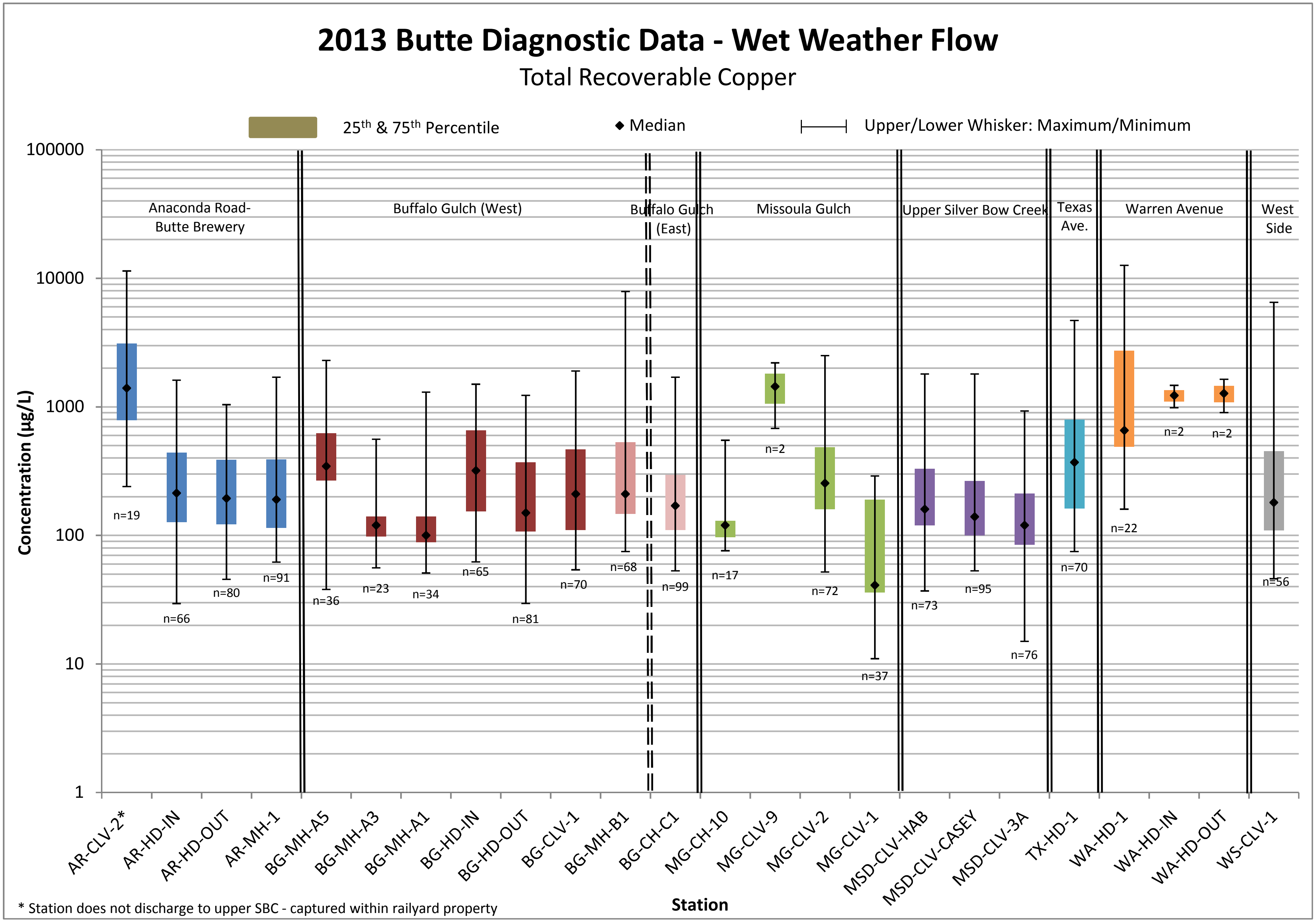

Figure 12-2
Butte Diagnostics Data - TR Copper Concentration Stats

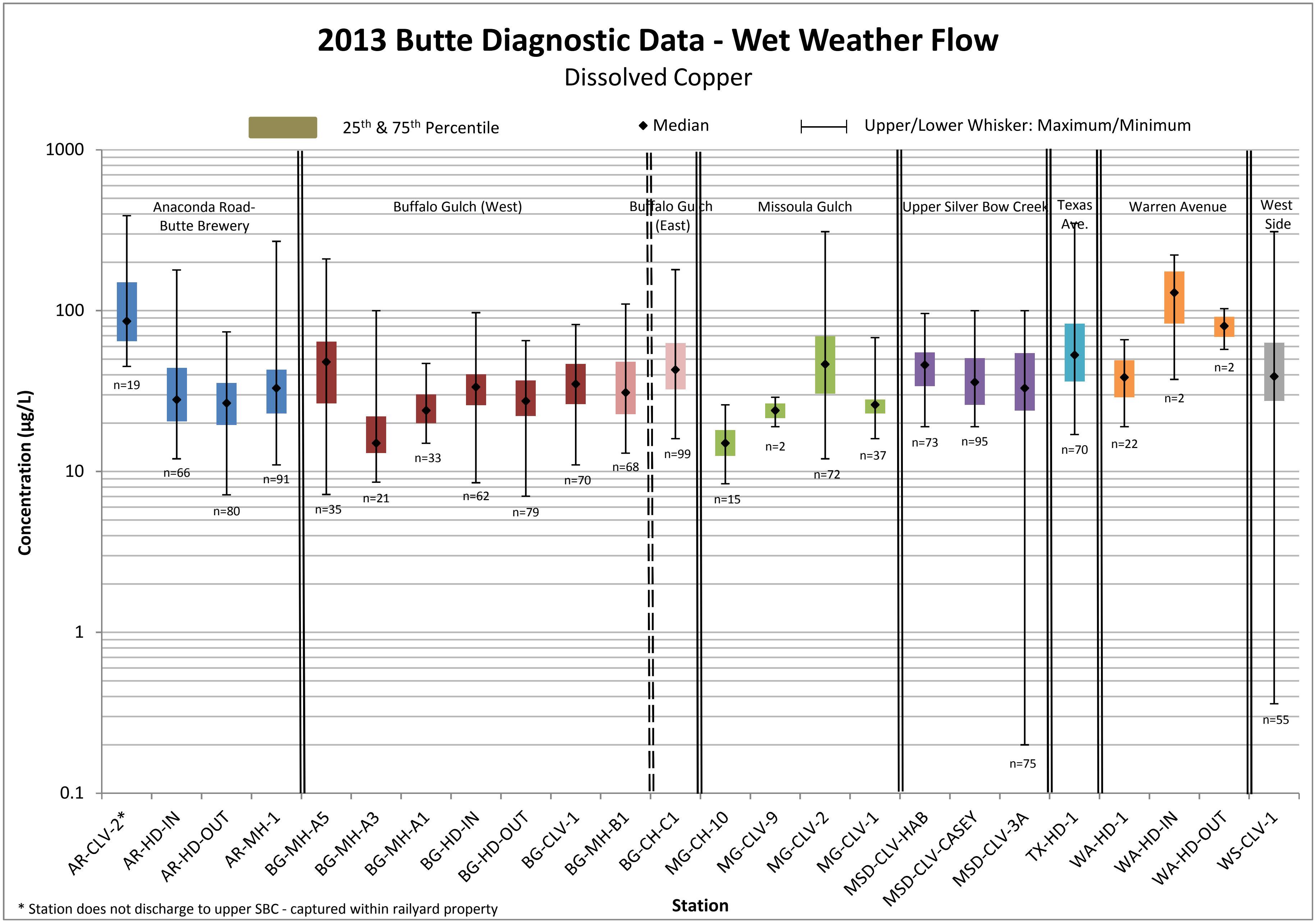

Figure 12-3
Butte Diagnostics Data - Dis. Copper Concentration Stats

Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

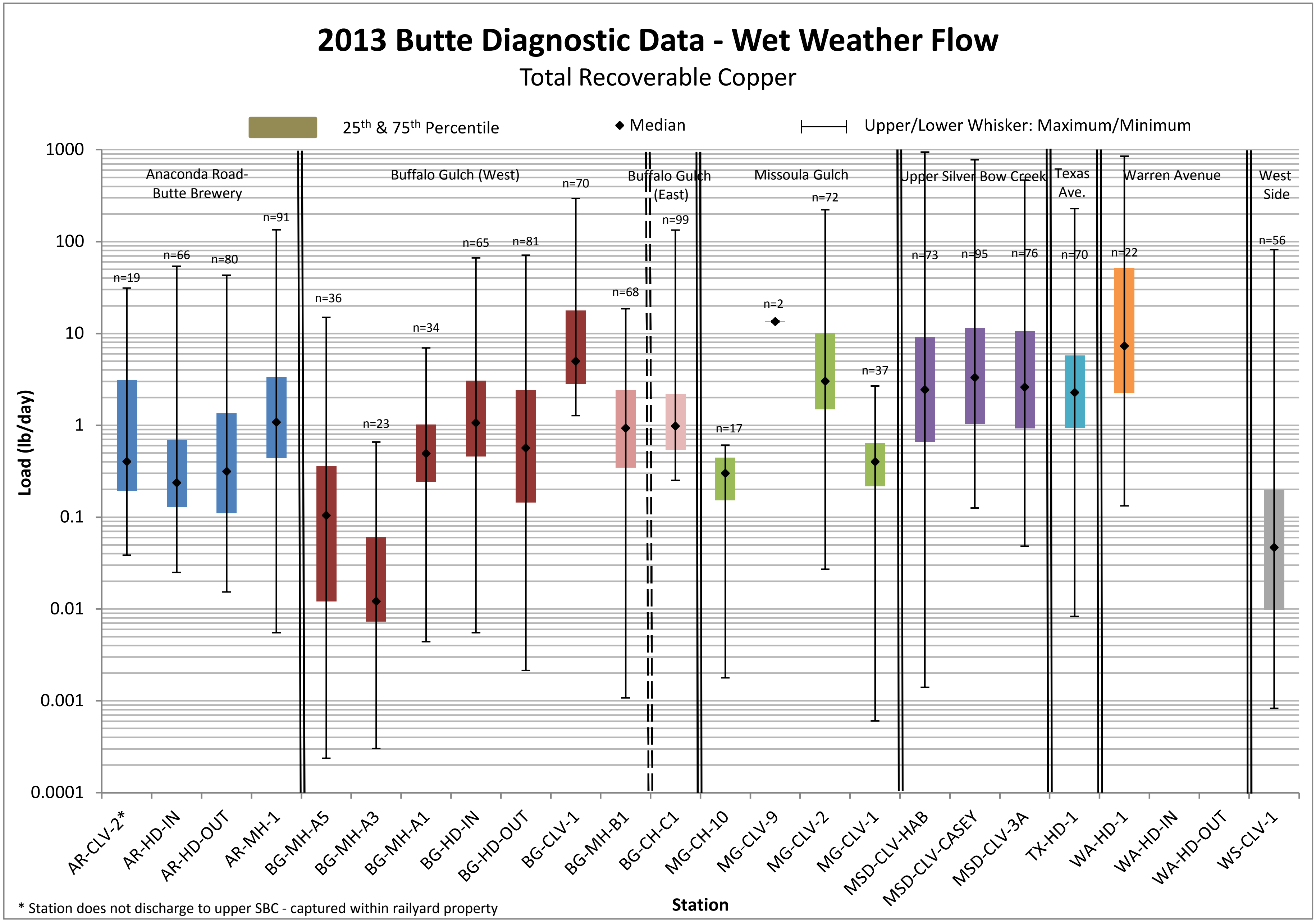

Figure 12-4
Butte Diagnostics Data - TR Copper Loading Stats

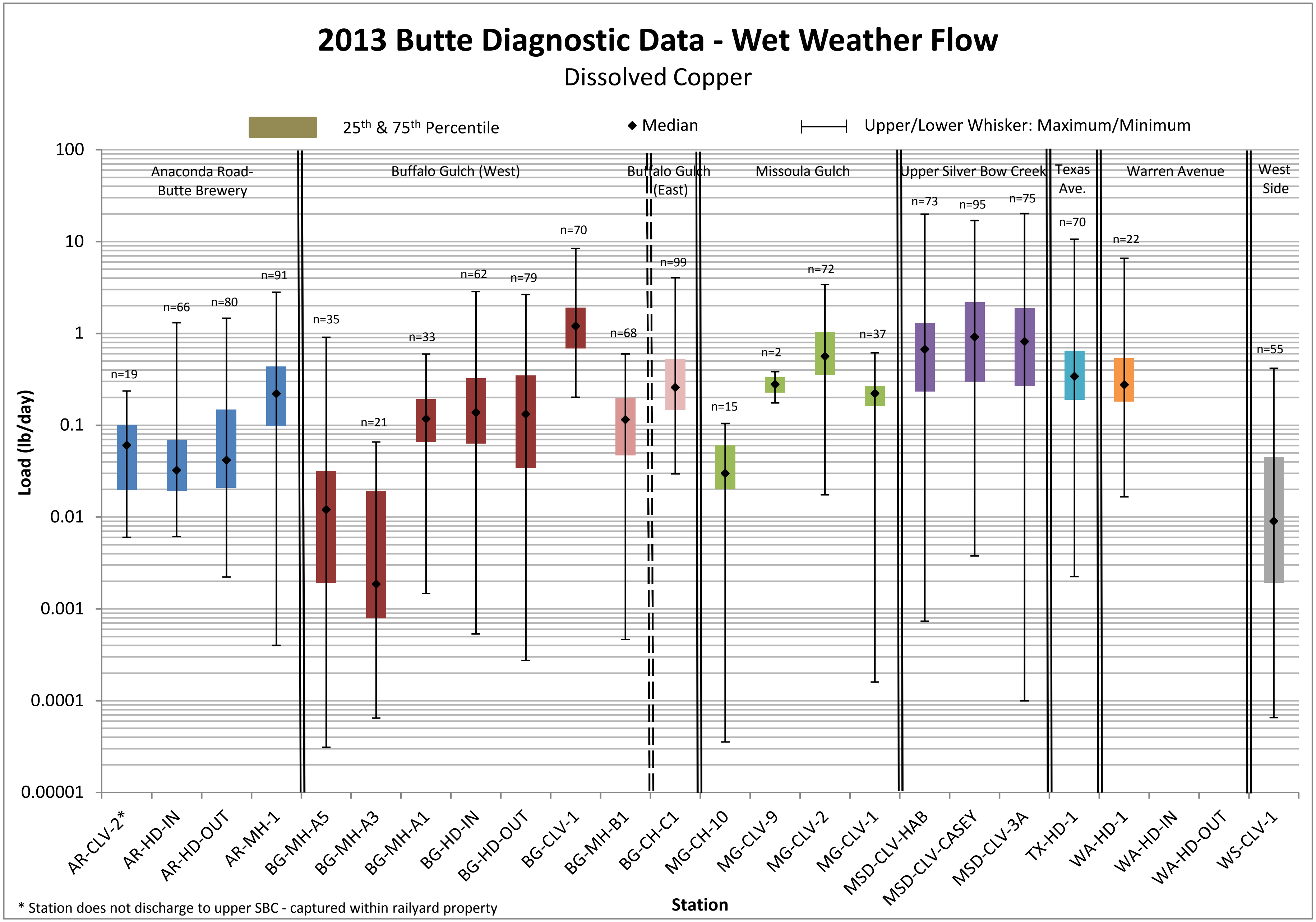

Figure 12-5
Butte Diagnostics Data - Dis. Copper Loading Stats

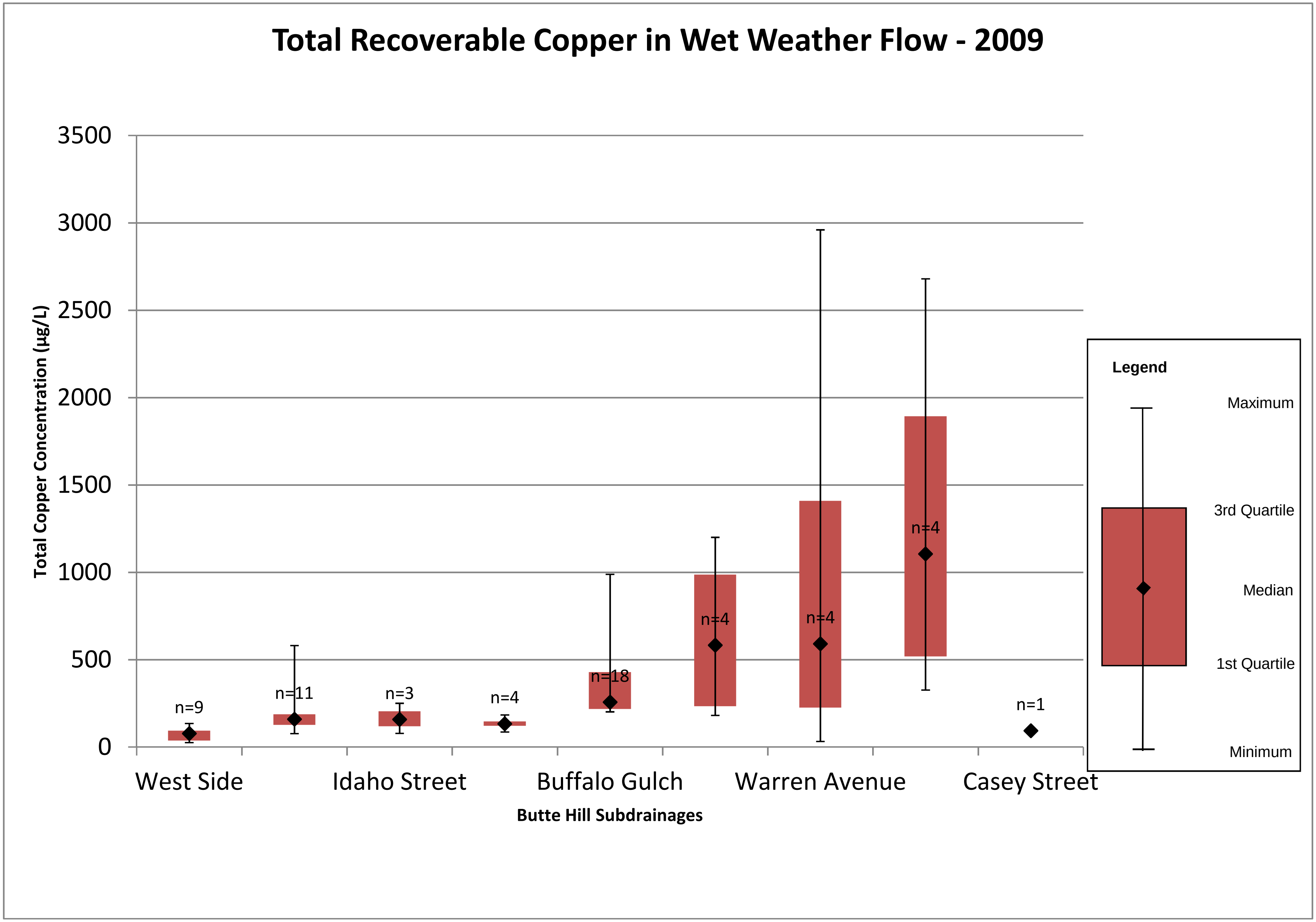

Figure 12-6
Total Recoverable Copper in Wet Weather Flow - 2009

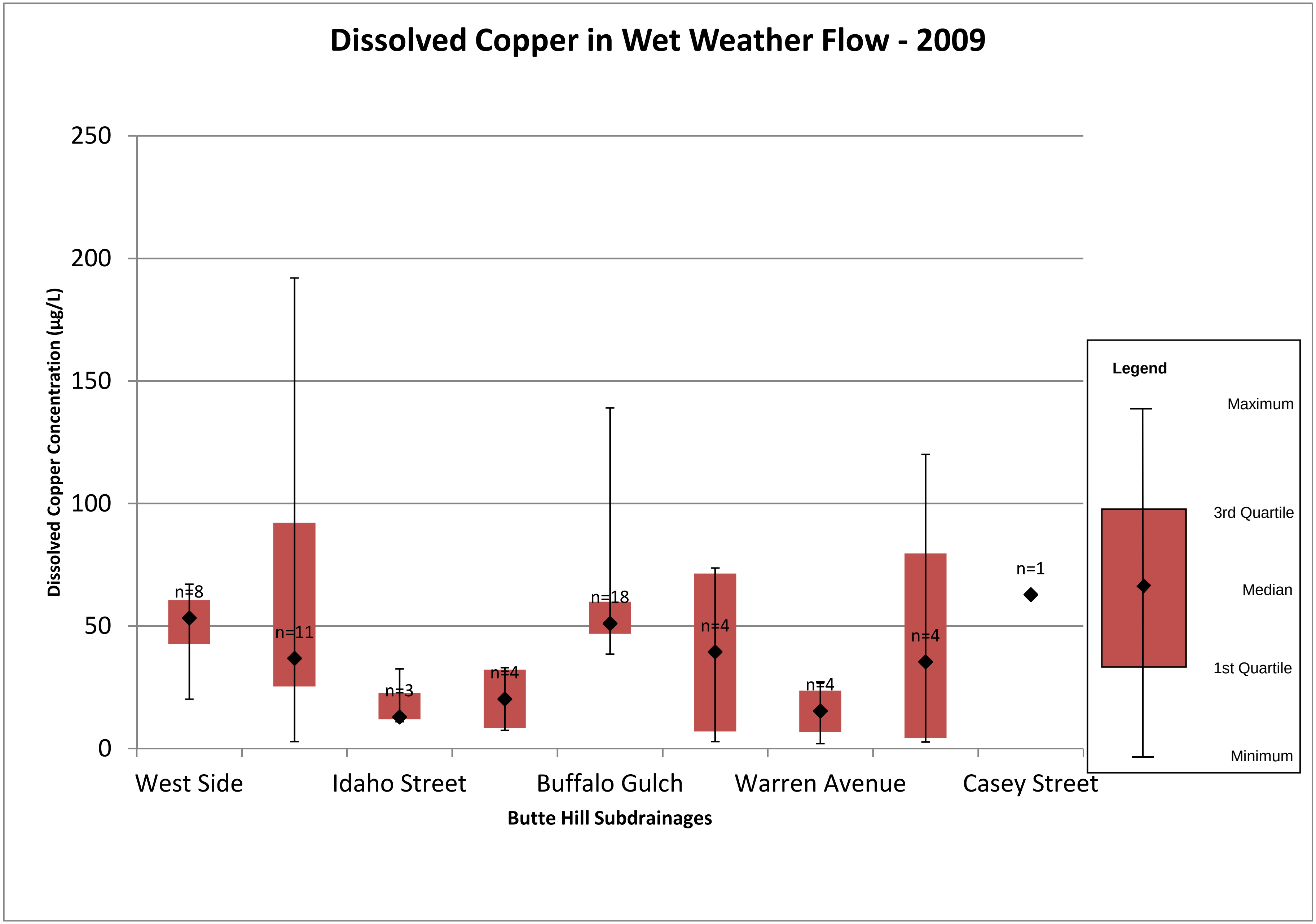

Figure 12-7
Dissolved Copper in Wet Weather Flow - 2009

Z:\gis\Public\Butte\Surface_Water_2014\MXD\BuffaloGulchSWSampLoc_CharRpt_2014.mxd

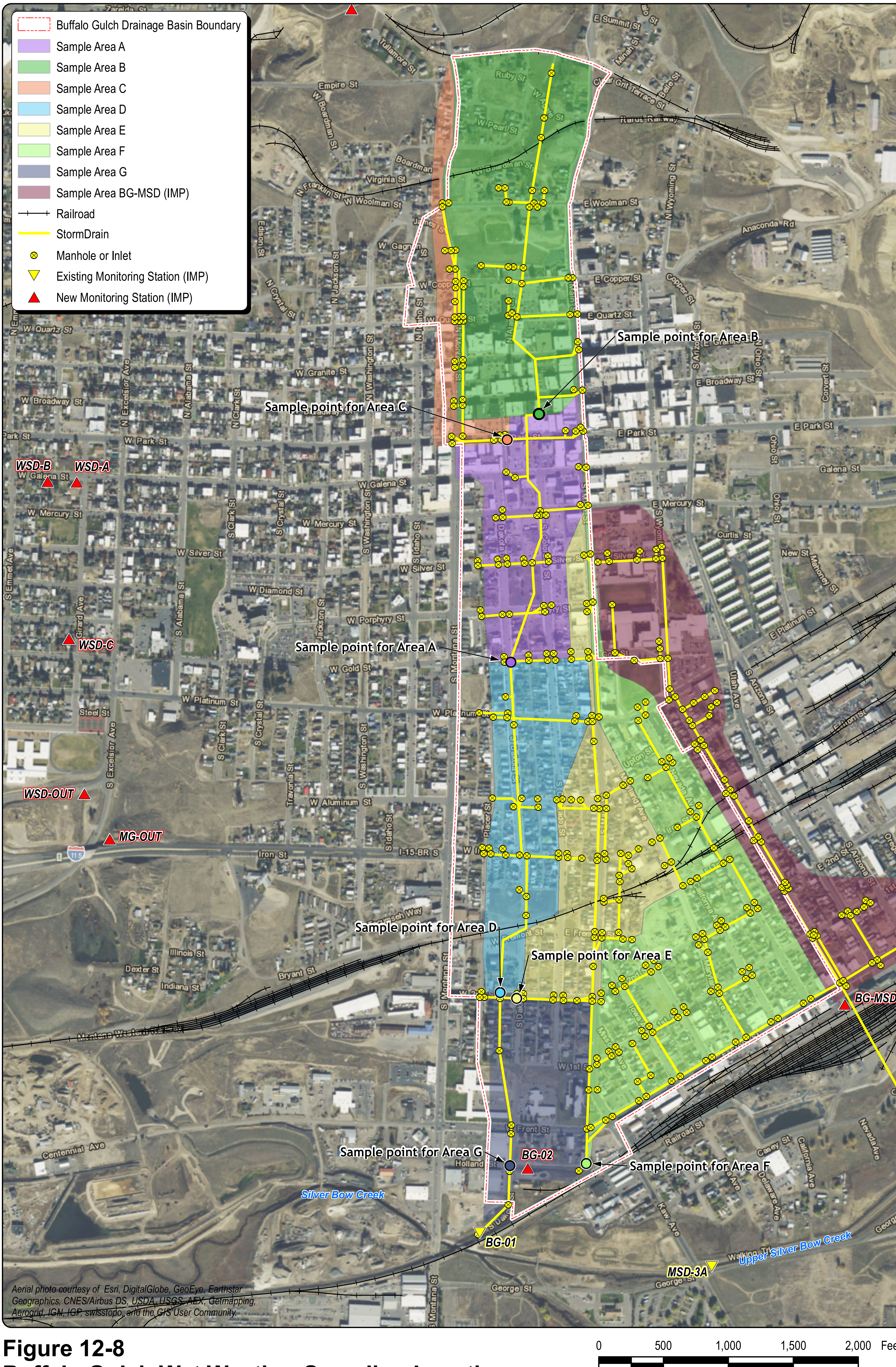

Figure 12-8
Buffalo Gulch Wet Weather Sampling Locations
Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

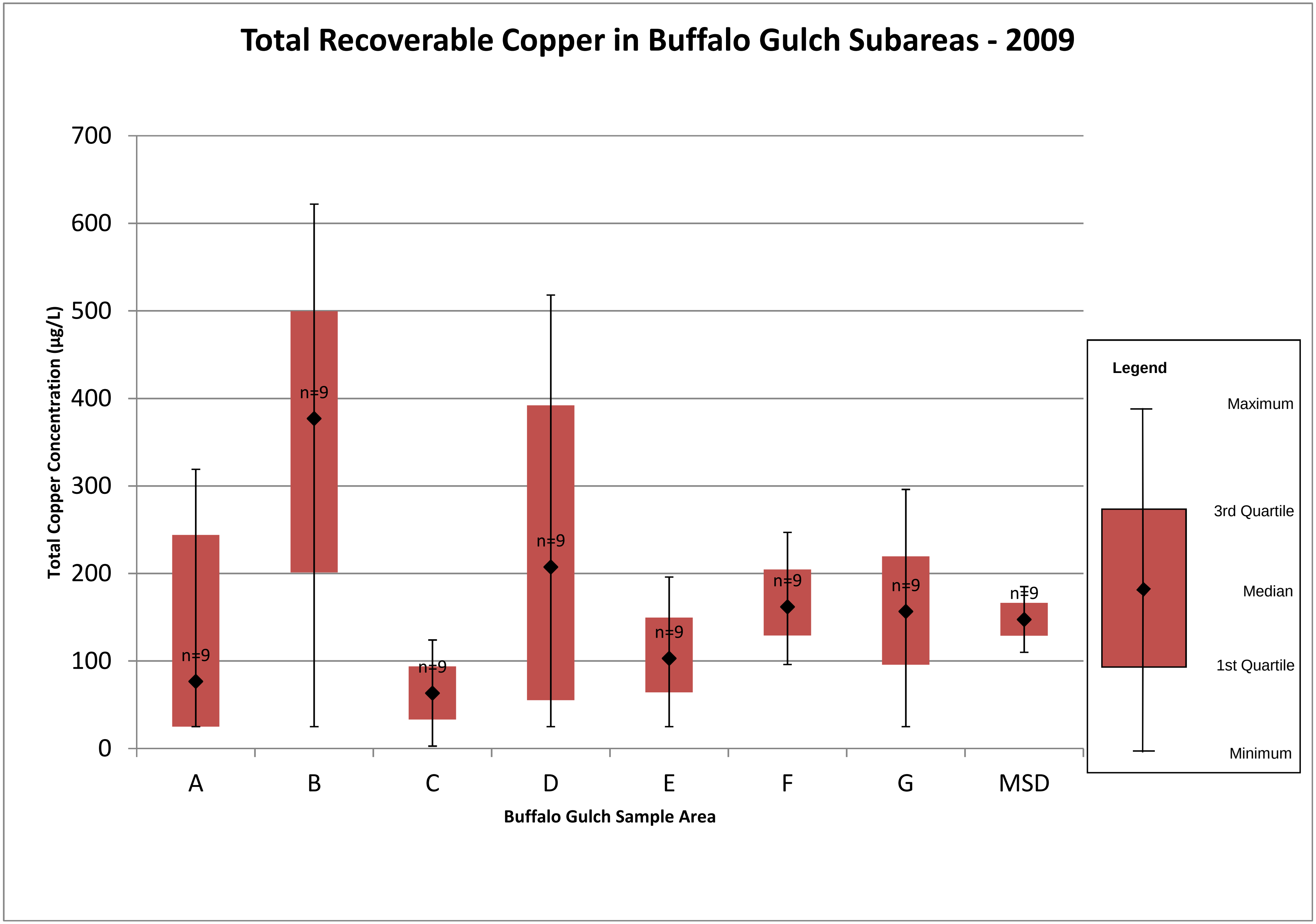

Figure 12-9
Total Recoverable Copper in Buffalo Gulch Subareas - 2009

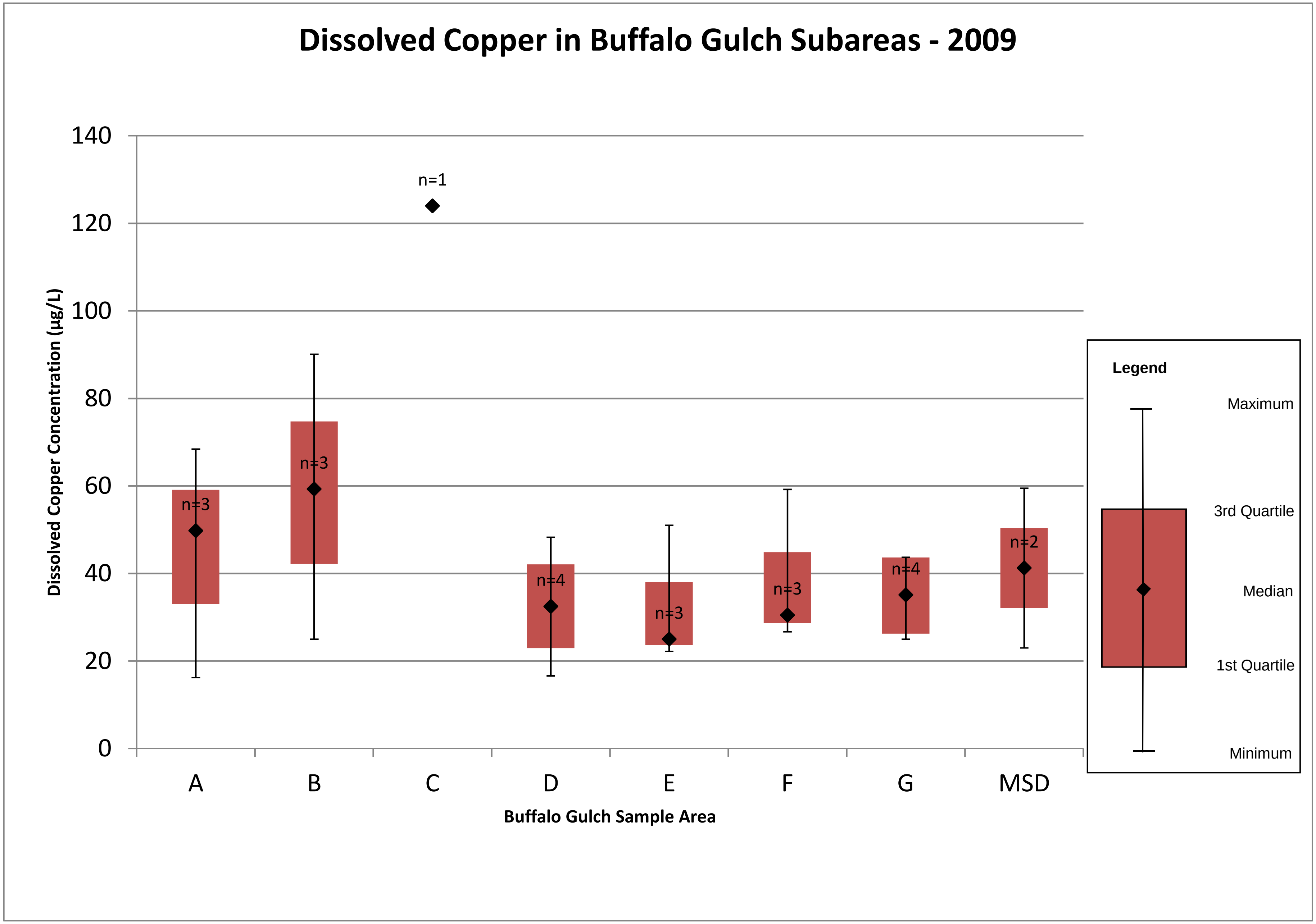

Figure 12-10
Dissolved Copper in Buffalo Gulch Subareas - 2009

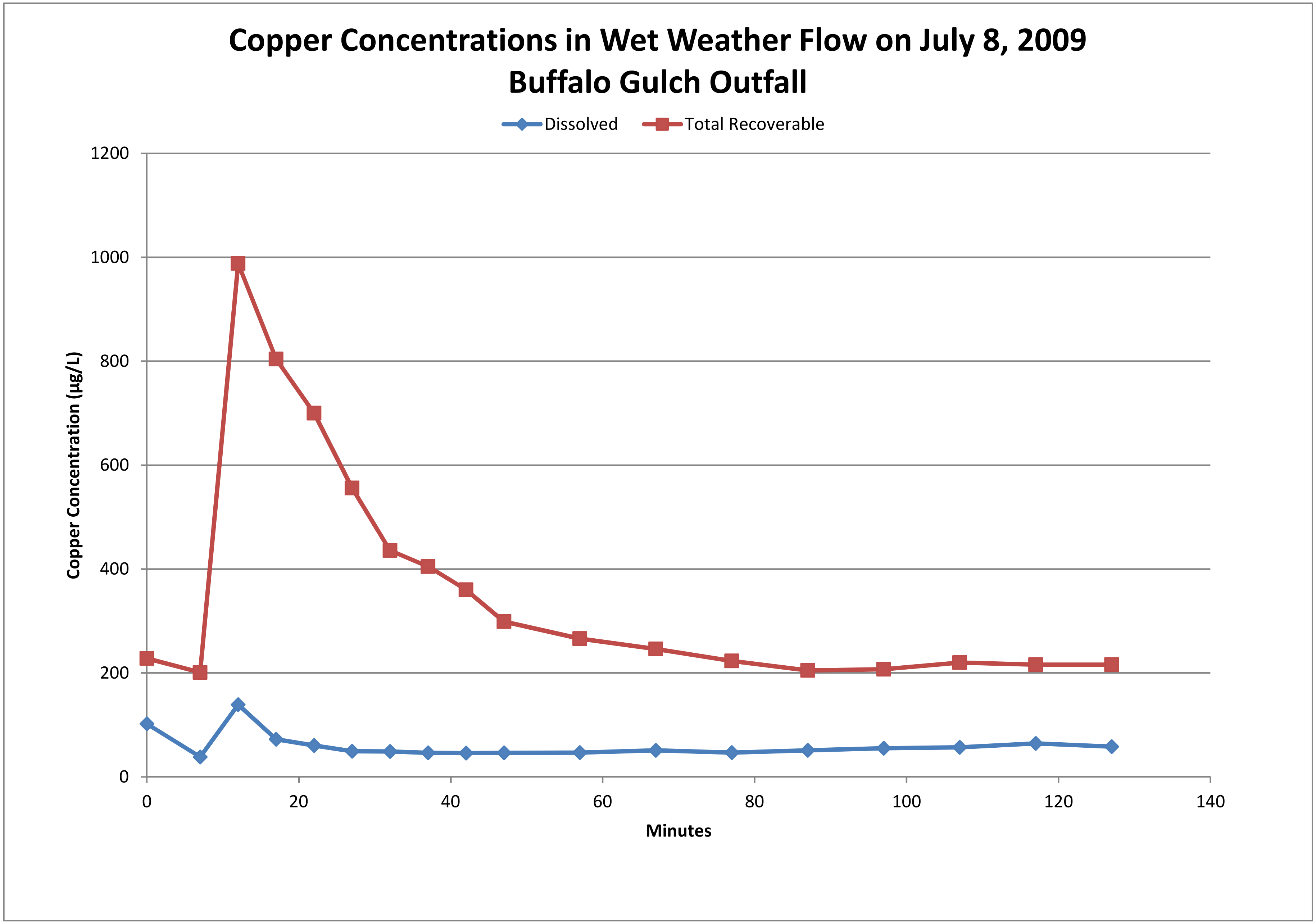

Figure 12-11
Copper Concentrations in Wet Weather Flow on July 8, 2009

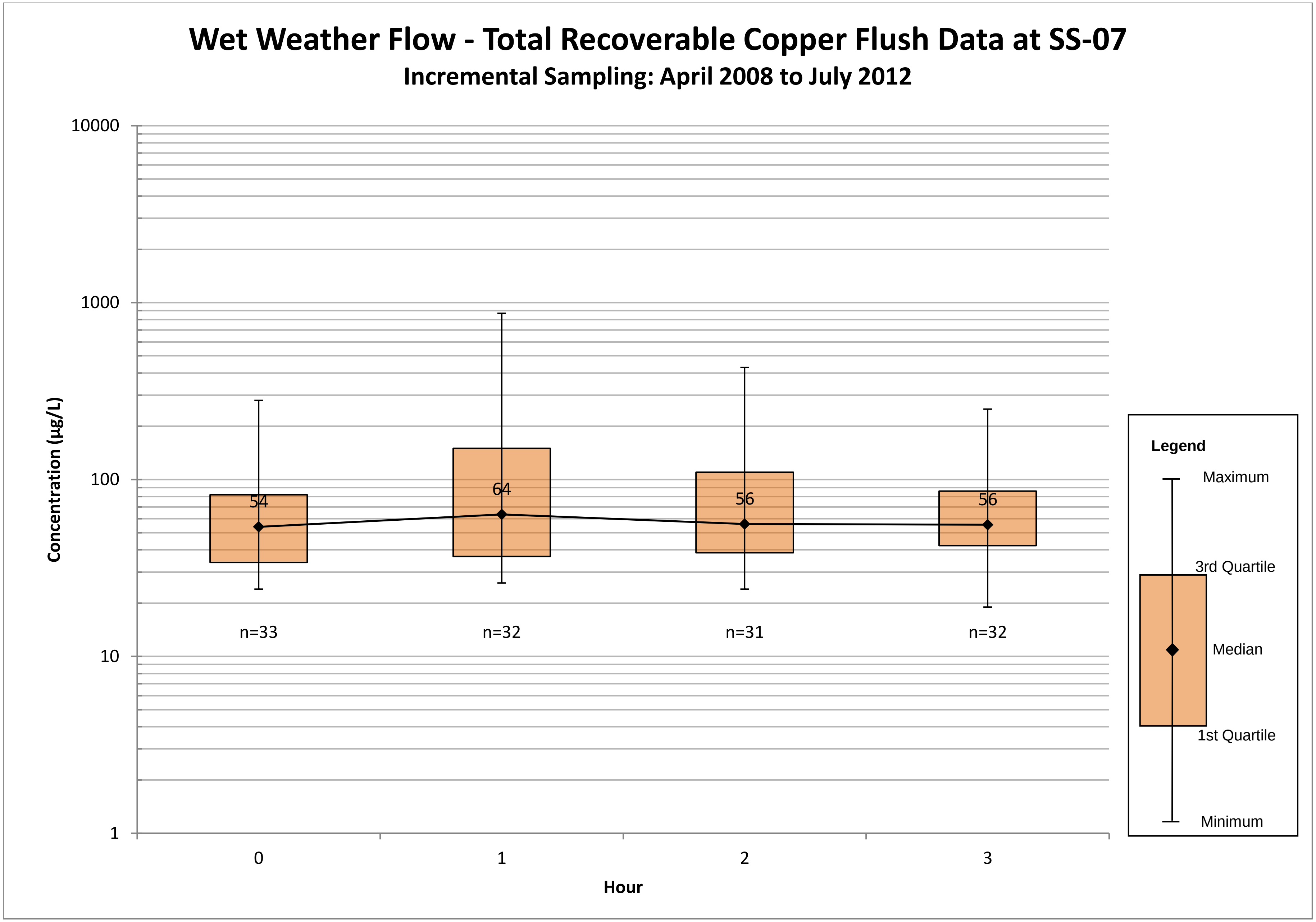

Figure 12-12
Wet Flow Total Copper - Flush Data at SS-07 - 2008 to 2012

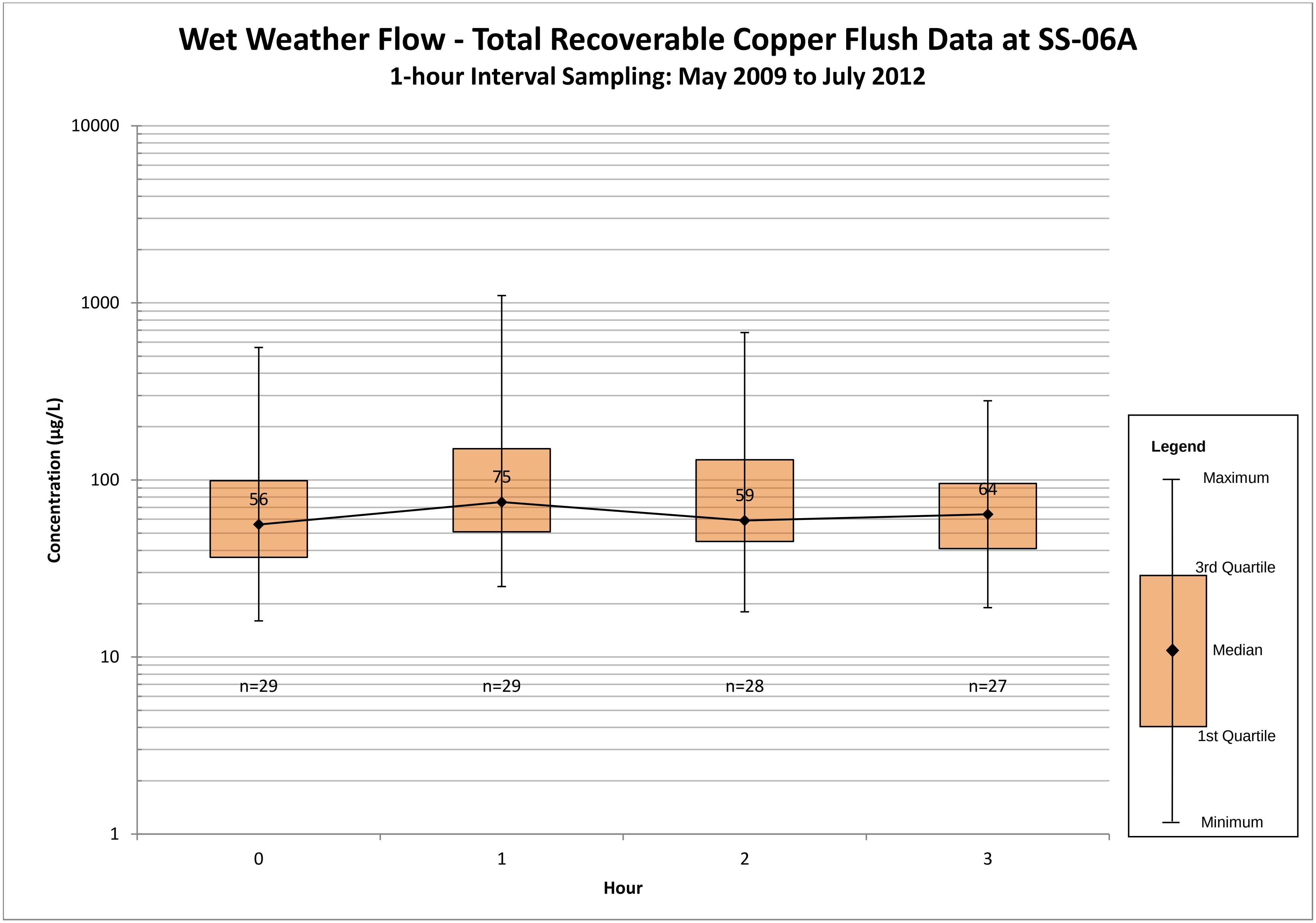

Figure 12-13
Wet Flow Total Copper - Flush Data at SS-06A - 2009 to 2012

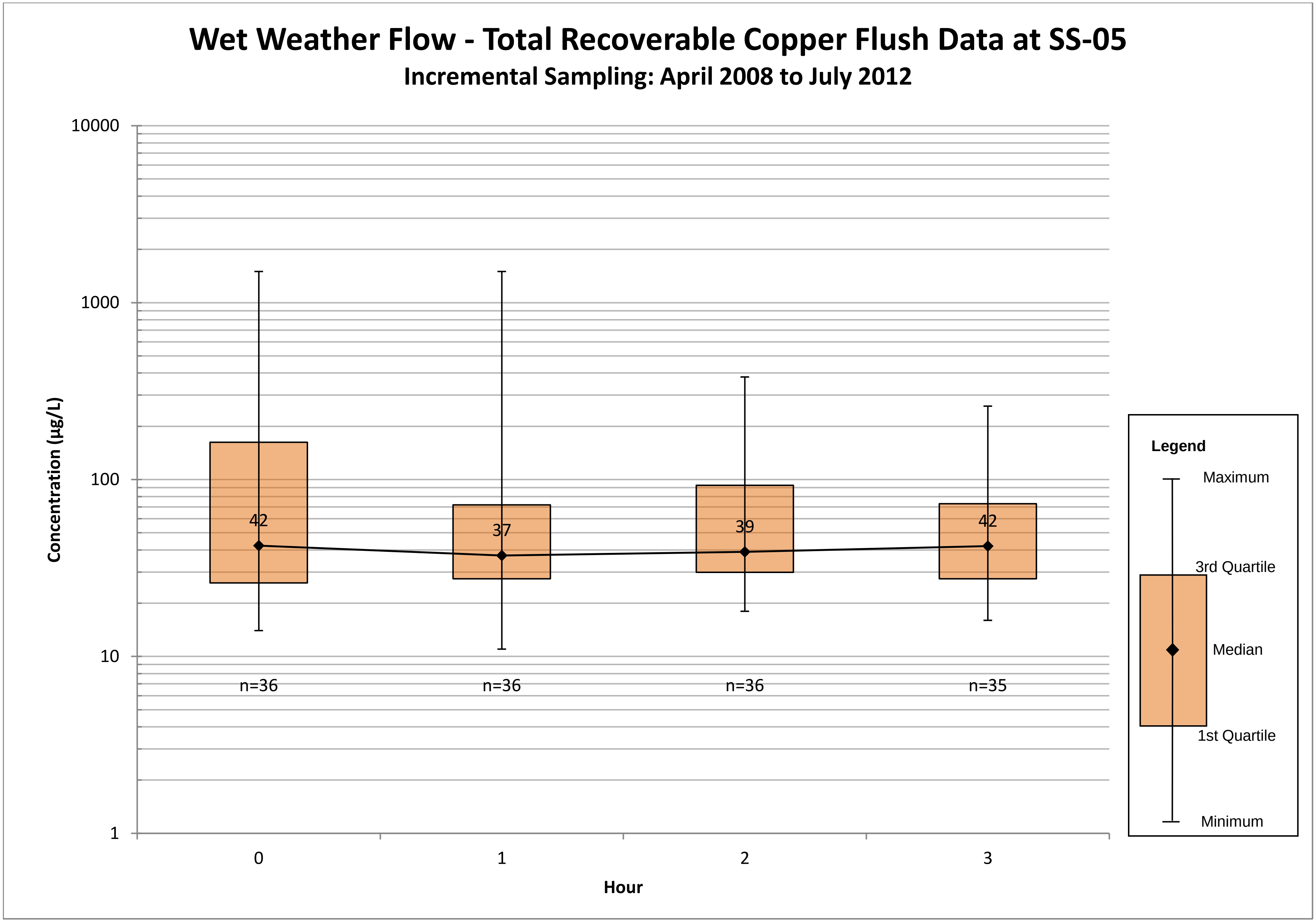

Figure 12-14
Wet Flow Total Copper - Flush Data at SS-05 - 2008 to 2012

Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

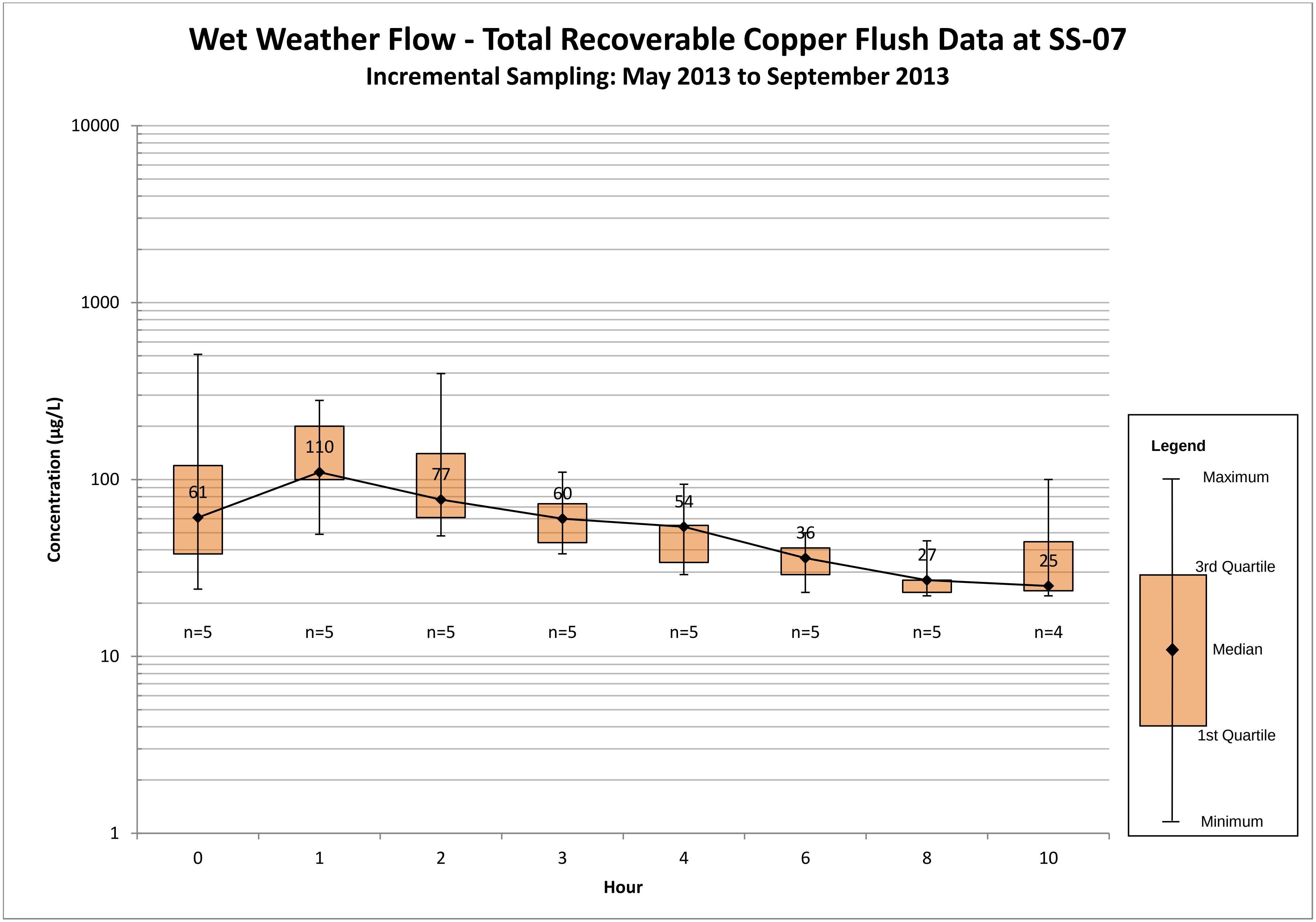

Figure 12-15
Wet Flow Total Copper - Flush Data at SS-07 - 2013

Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

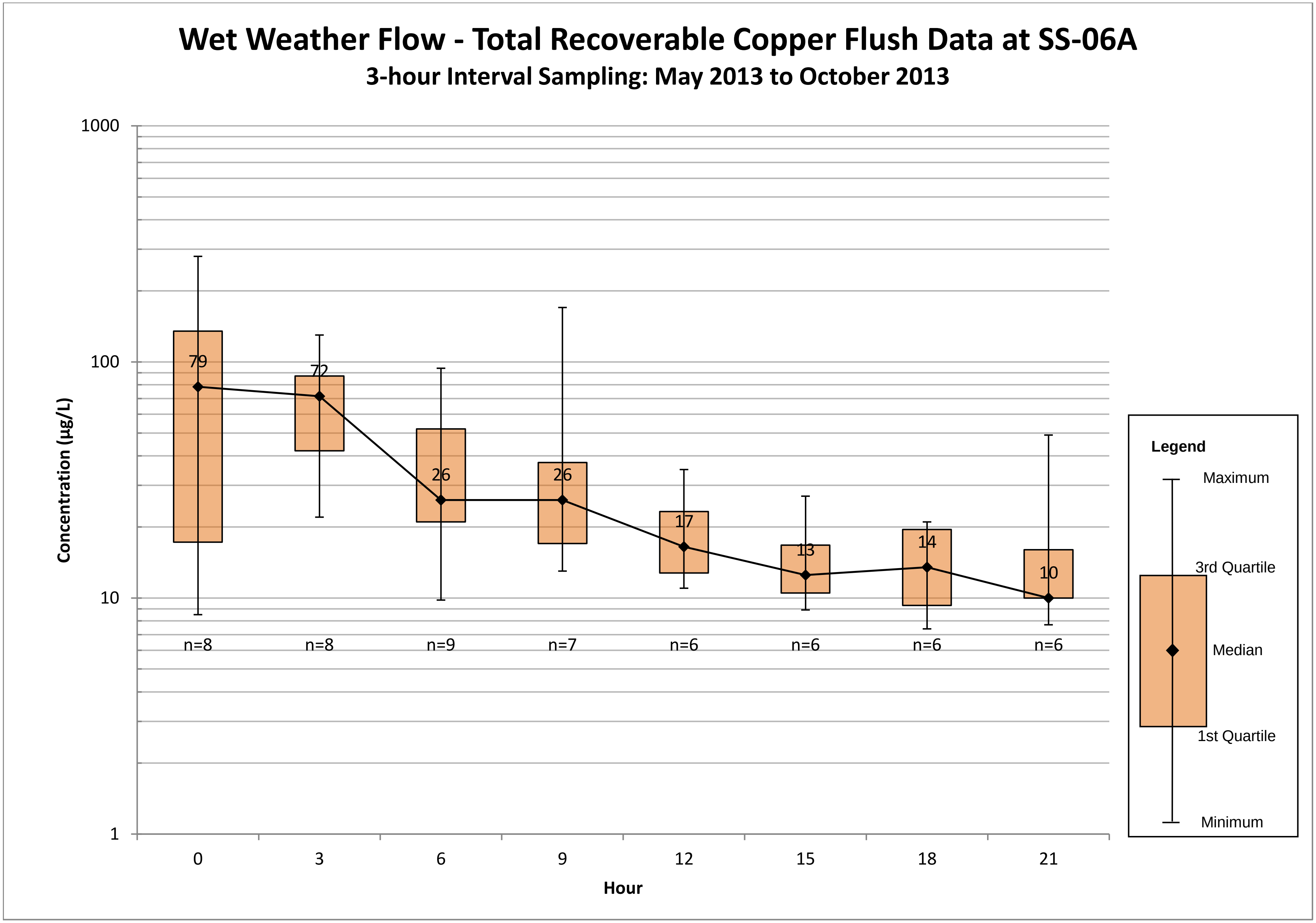

Figure 12-16
Wet Flow Total Copper - Flush Data at SS-06A - 2013

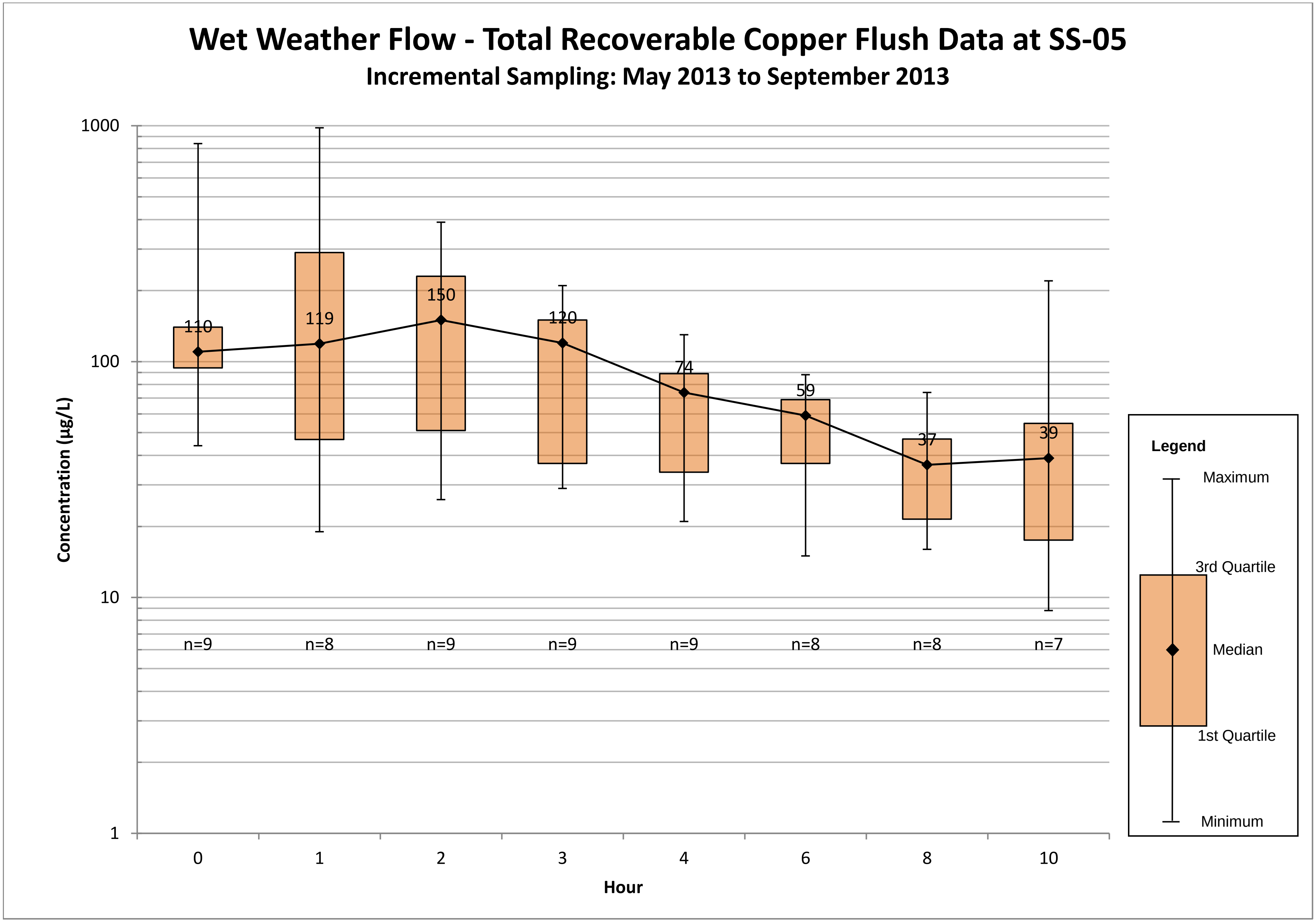

Figure 12-17
Wet Flow Total Copper - Flush Data at SS-05 - 2013

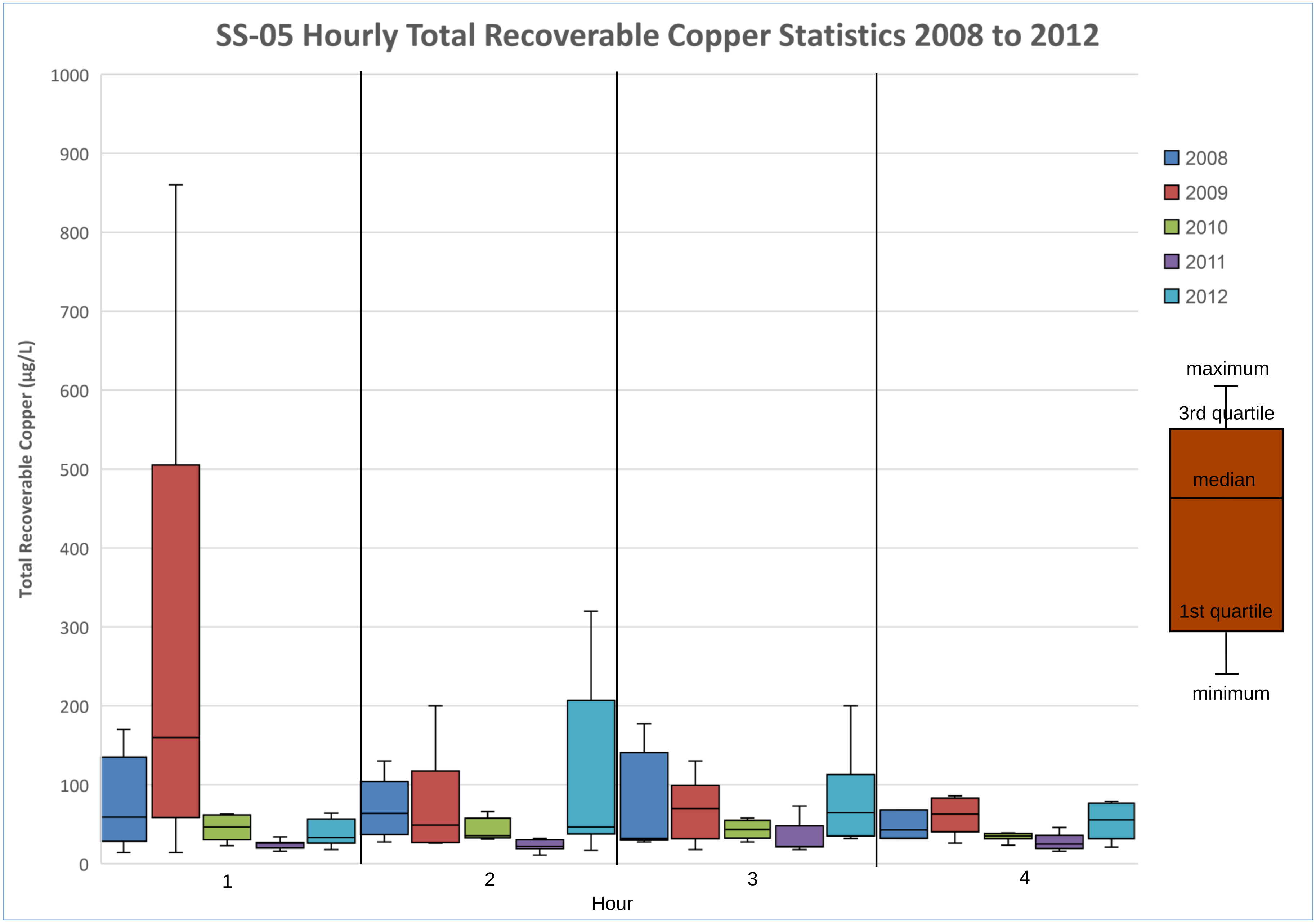

Figure 12-18

Wet Weather Total Recoverable Copper SS-05 - 2008 to 2012

Surface Water Characterization Report

Butte Priority Soils Operable Unit

Silver Bow Creek/Butte Area NPL Site

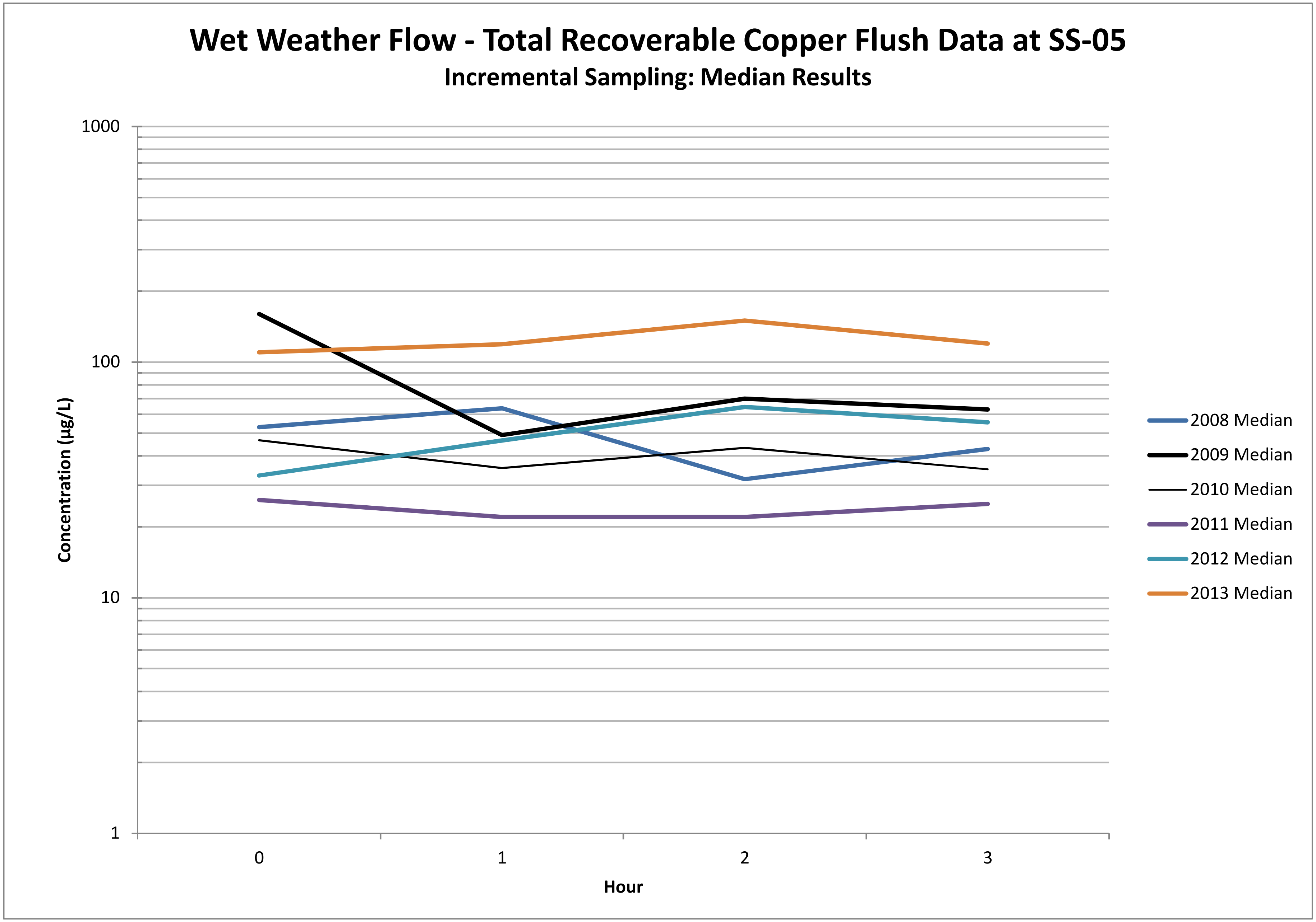

Figure 12-19
Wet Flow Total Copper - Flush Data at SS-05 - Median

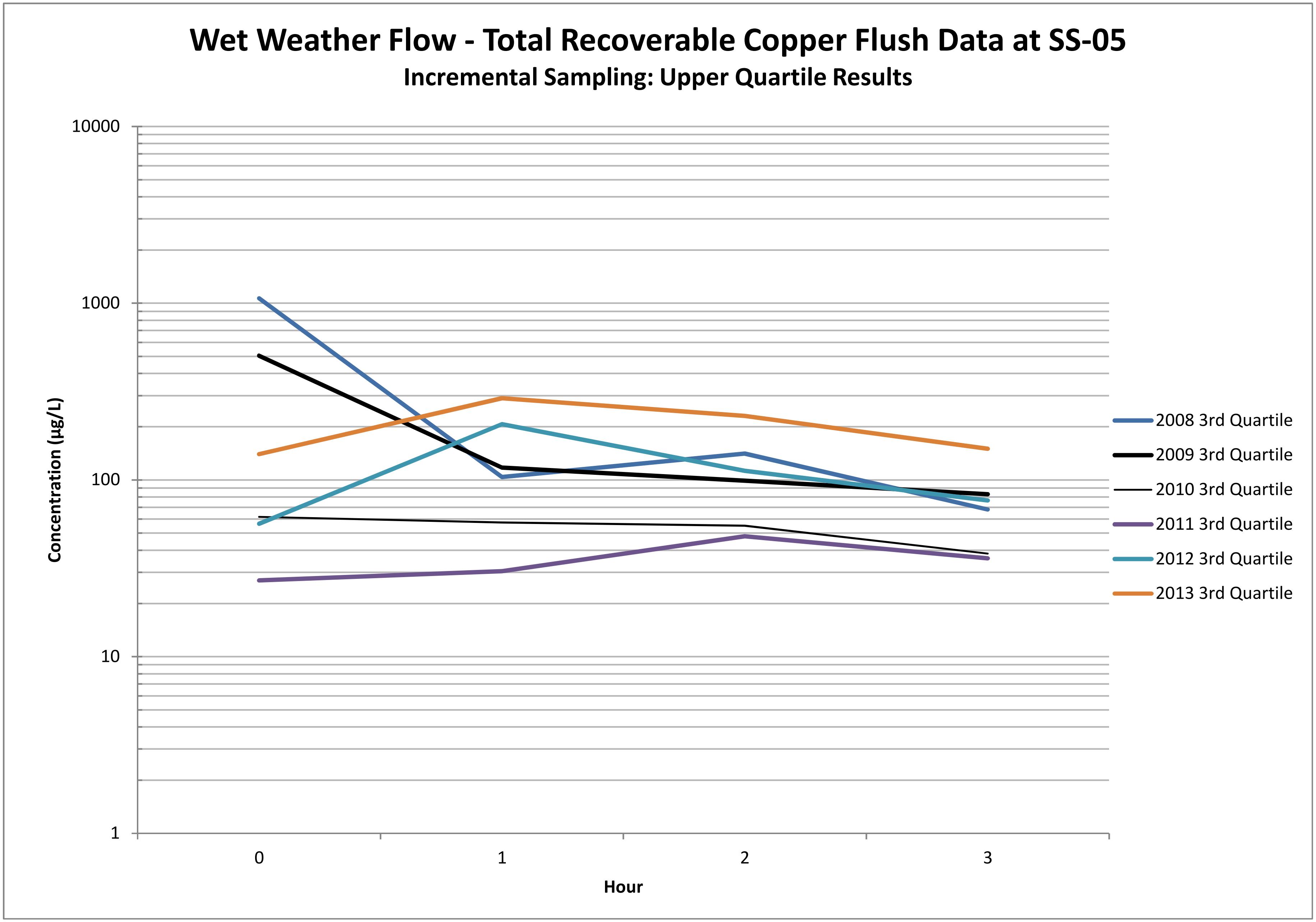

Figure 12-20
Wet Flow Total Copper - Flush Data at SS-05 - Upper Quartile

Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

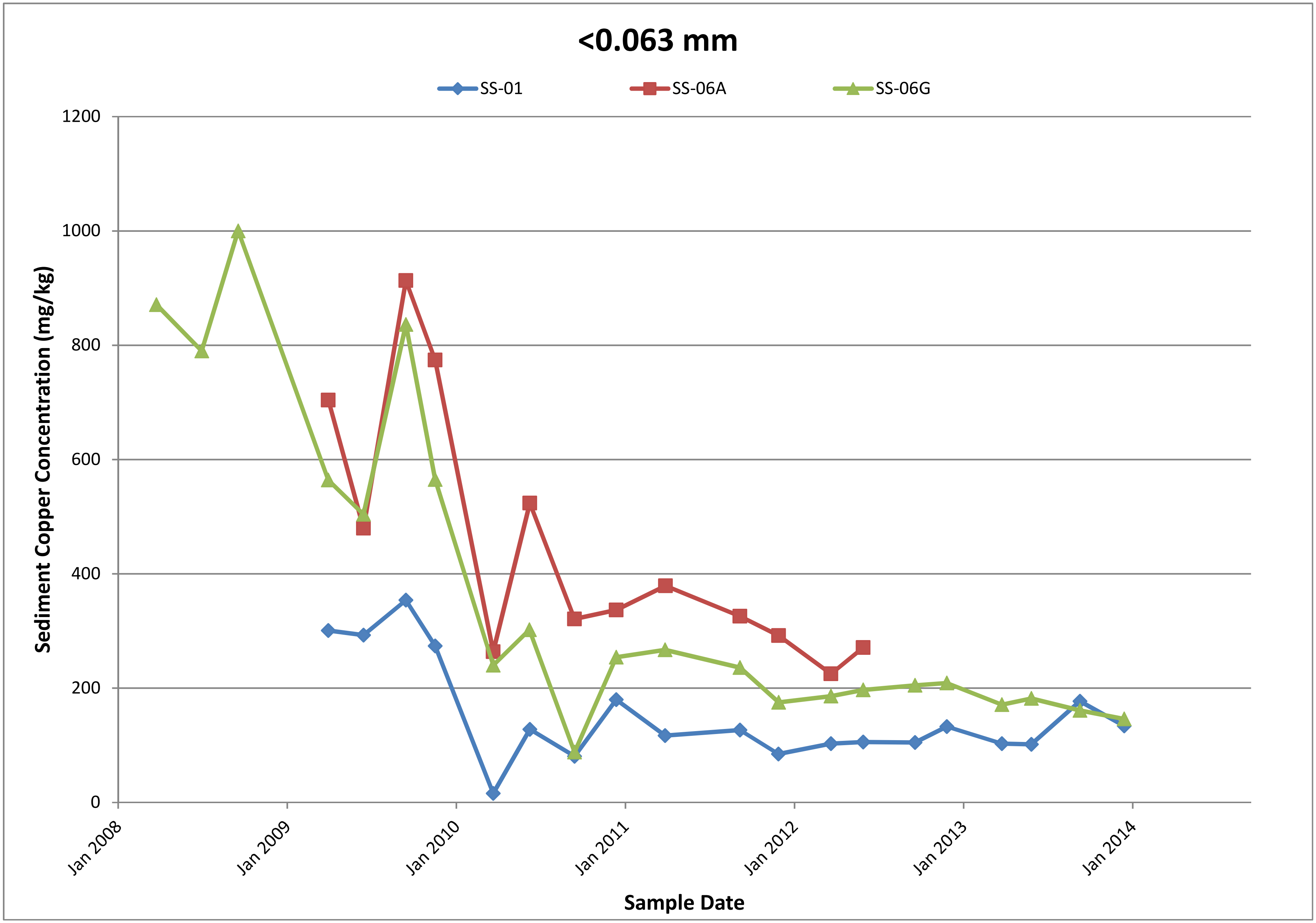

Figure 12-21
Sediment Copper Conc. vs. Time for <0.063 mm Fraction

Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

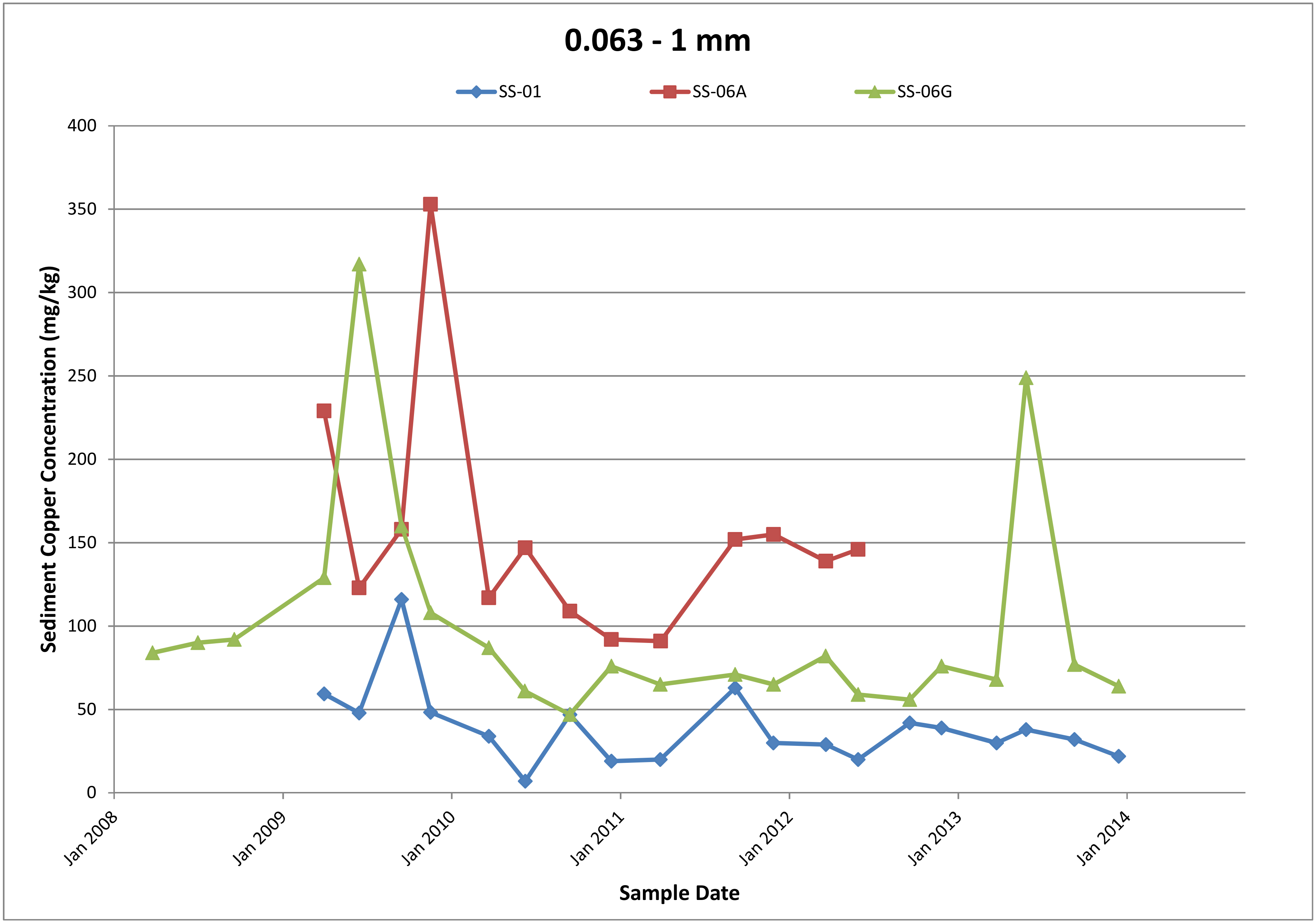

Figure 12-22
Sediment Copper Conc. vs. Time for 0.063 to 1 mm Fraction

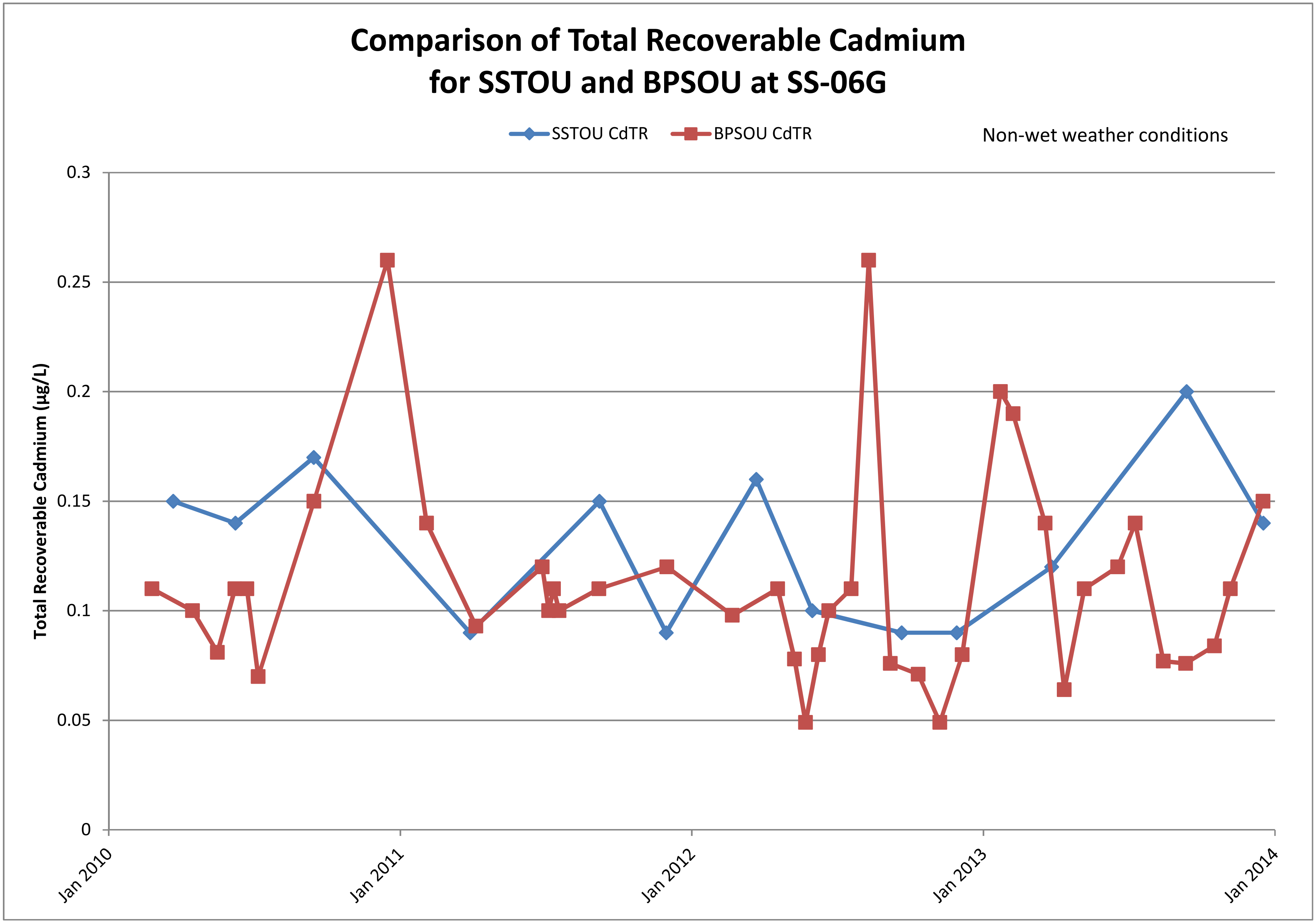

Figure 12-23
Comparison of Total Recoverable Cadmium - SSTOU and BPSOU

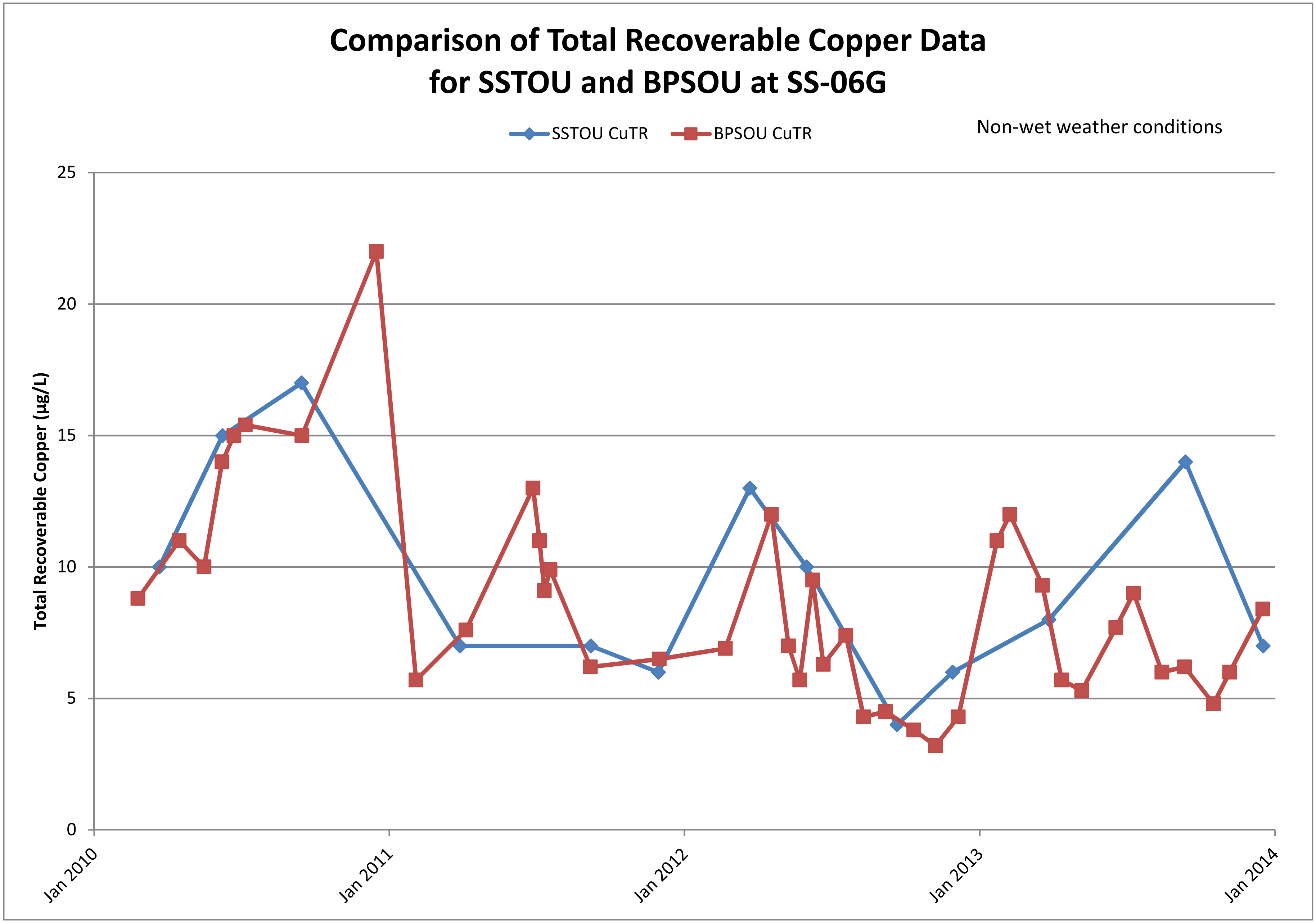

Figure 12-24
Comparison of Total Recoverable Copper Data for SSTOU and BPSOU

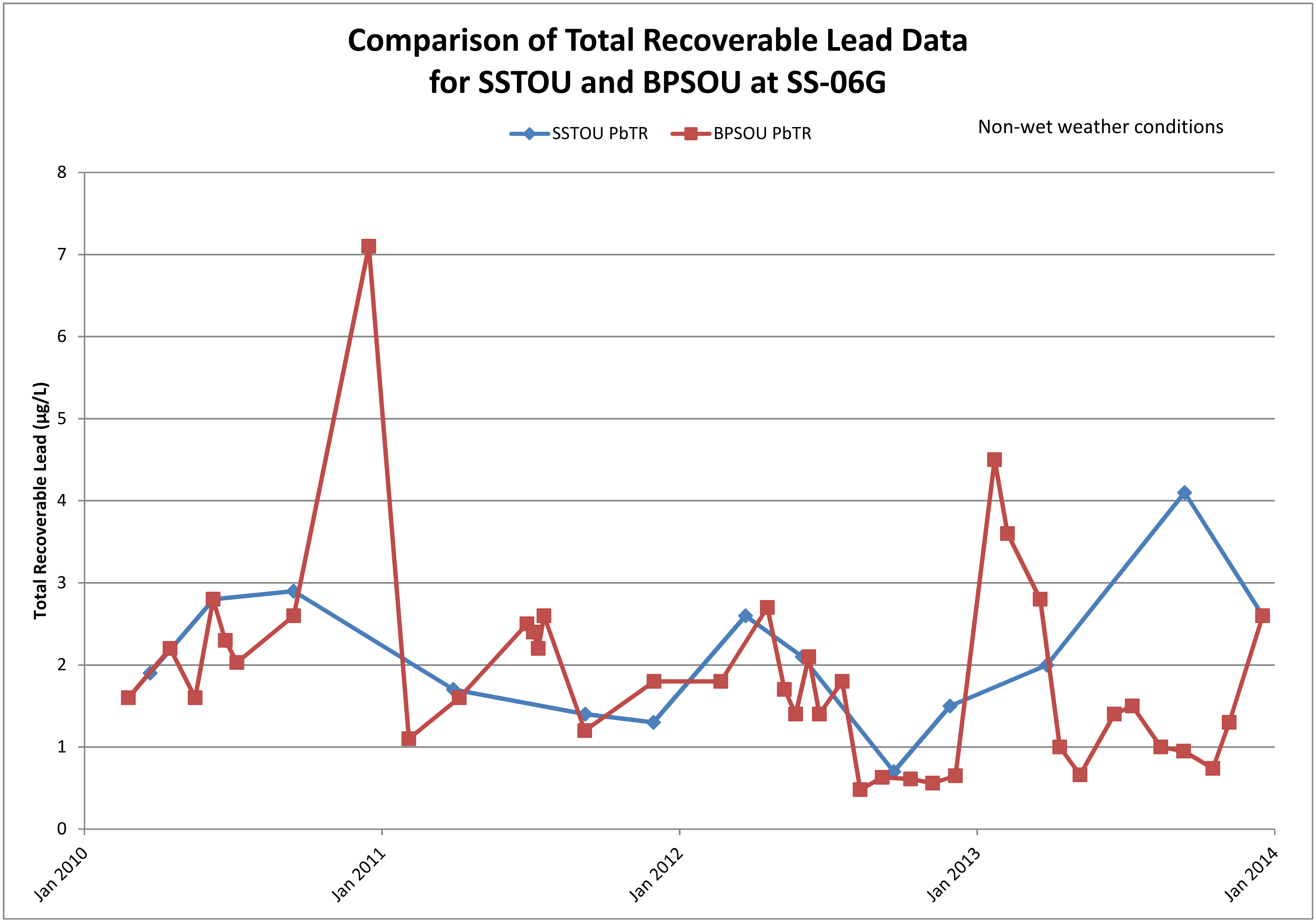

Figure 12-25
Comparison of Total Recoverable Lead Data for SSTOU and BPSOU

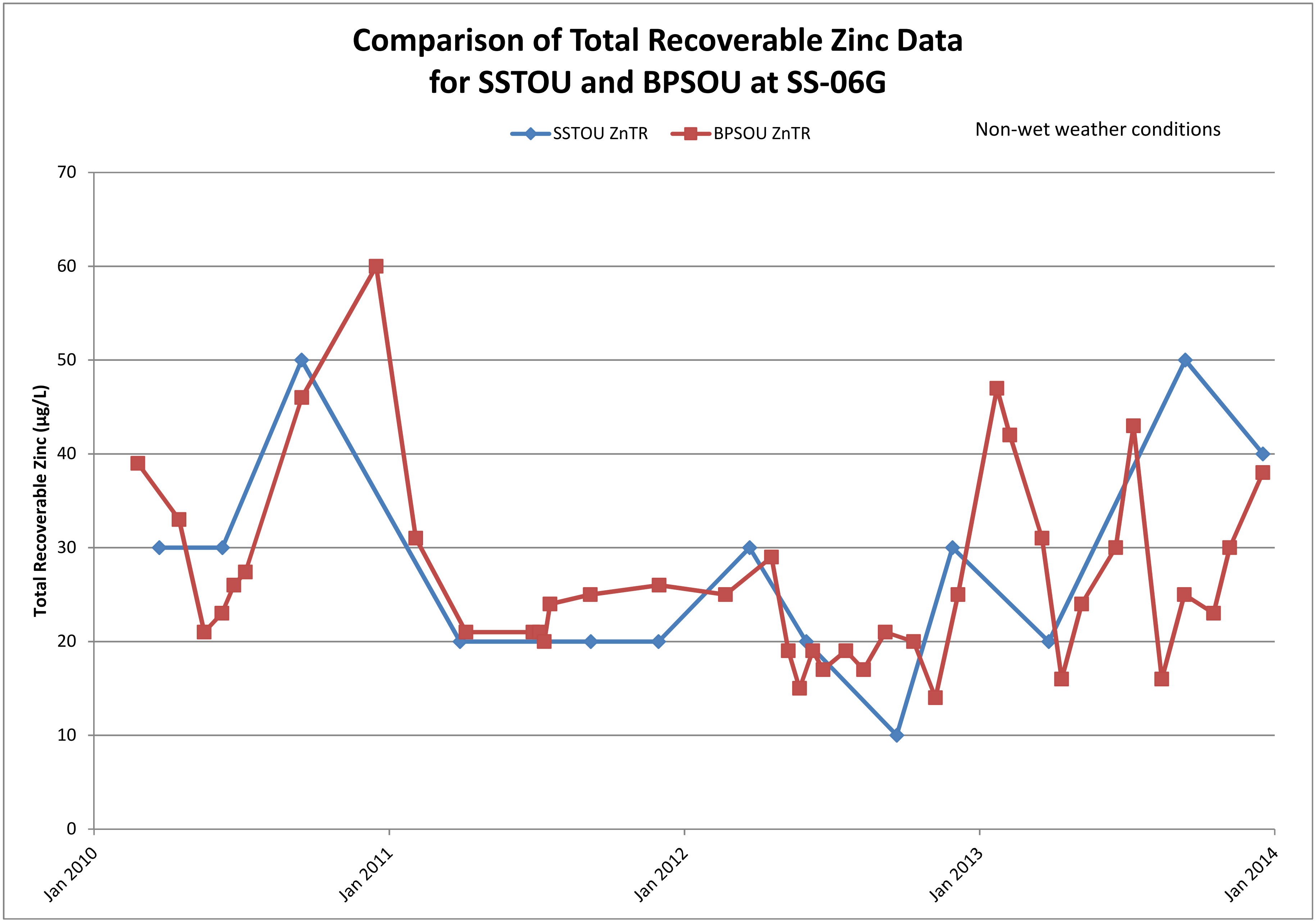

Figure 12-26
Comparison of Total Recoverable Zinc Data for SSTOU and BPSOU

Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

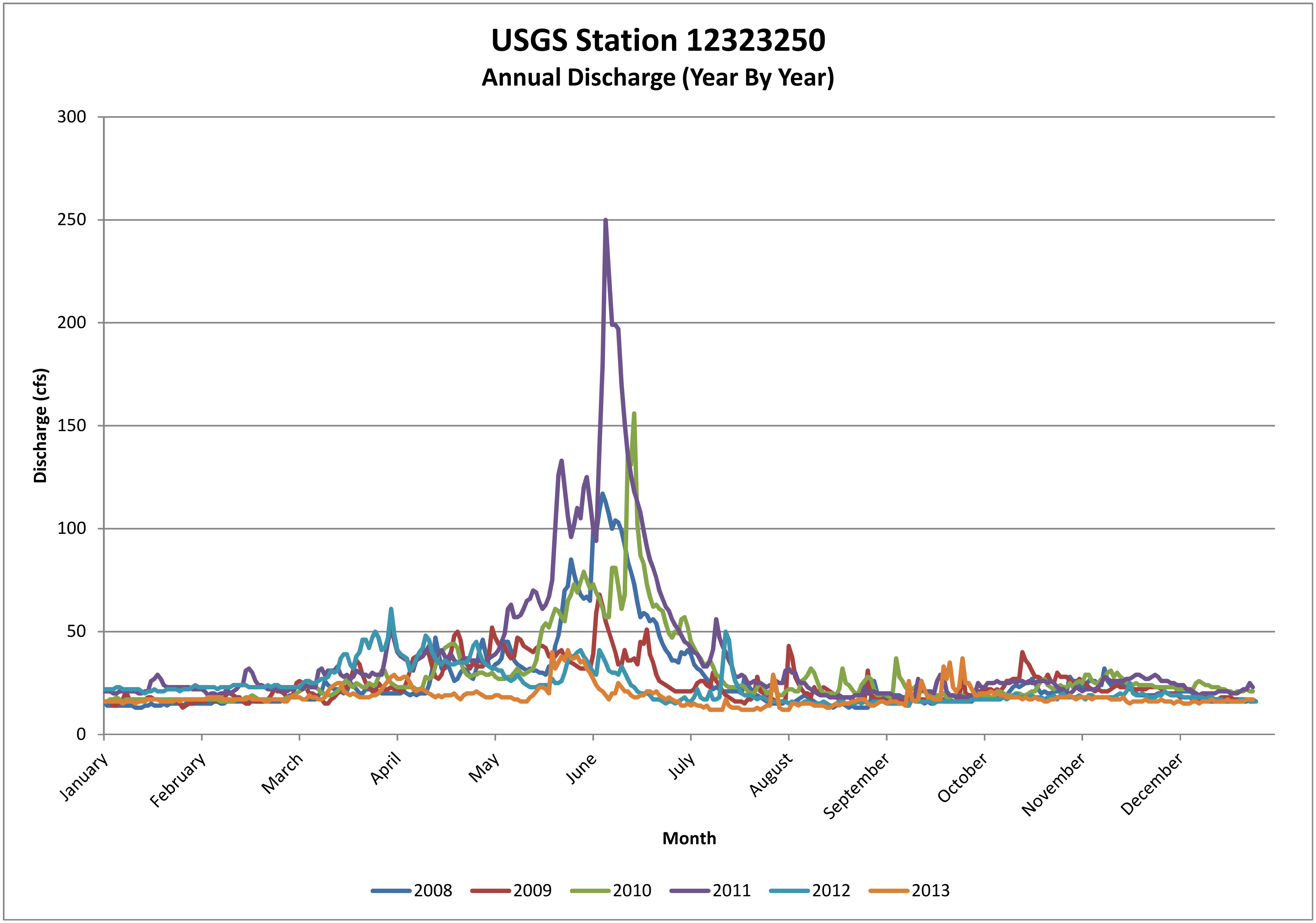

Figure 12-27
USGS Station 12323250 Year by Year Discharge

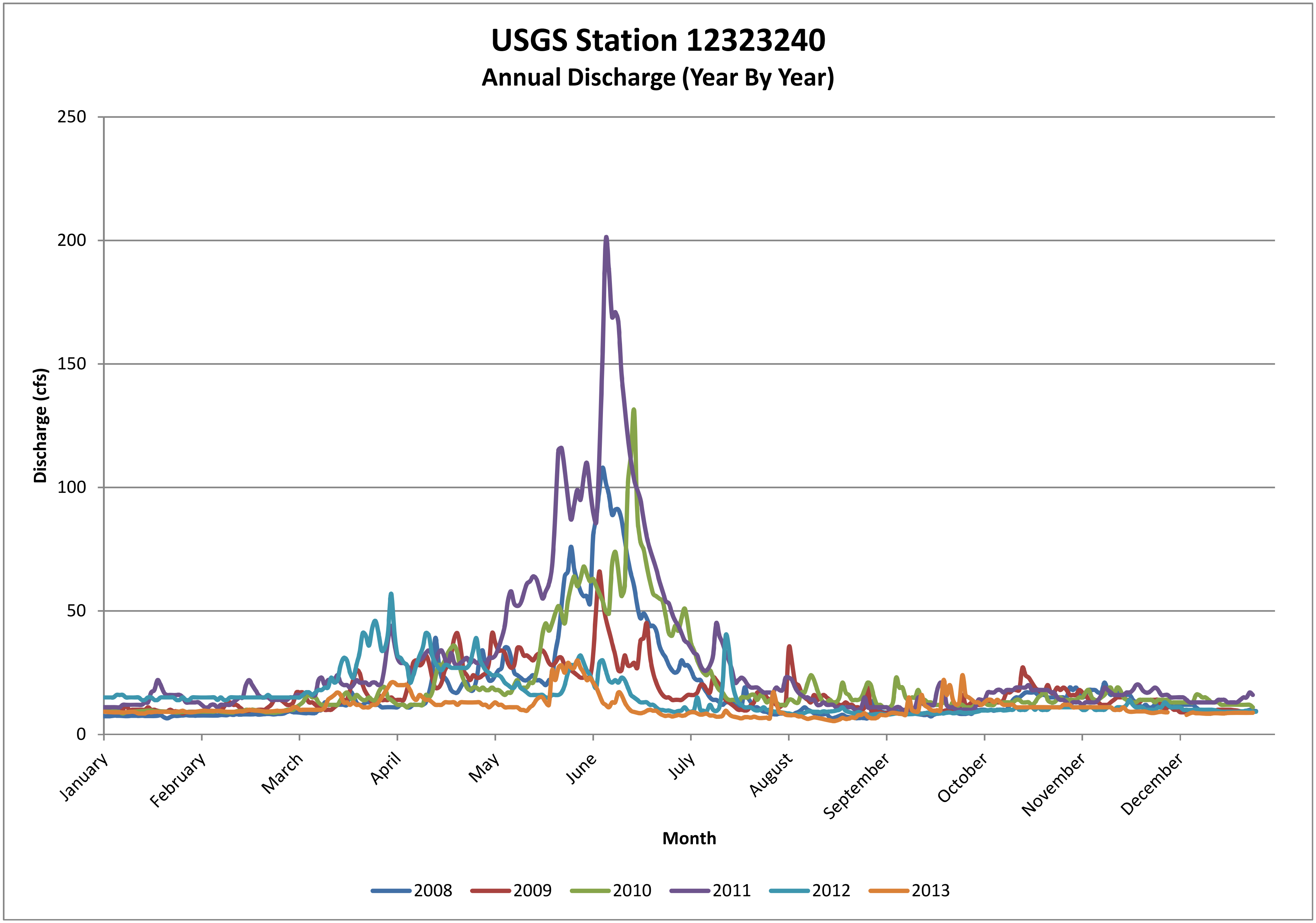

Figure 12-28
USGS Station 12323240 Year by Year Discharge

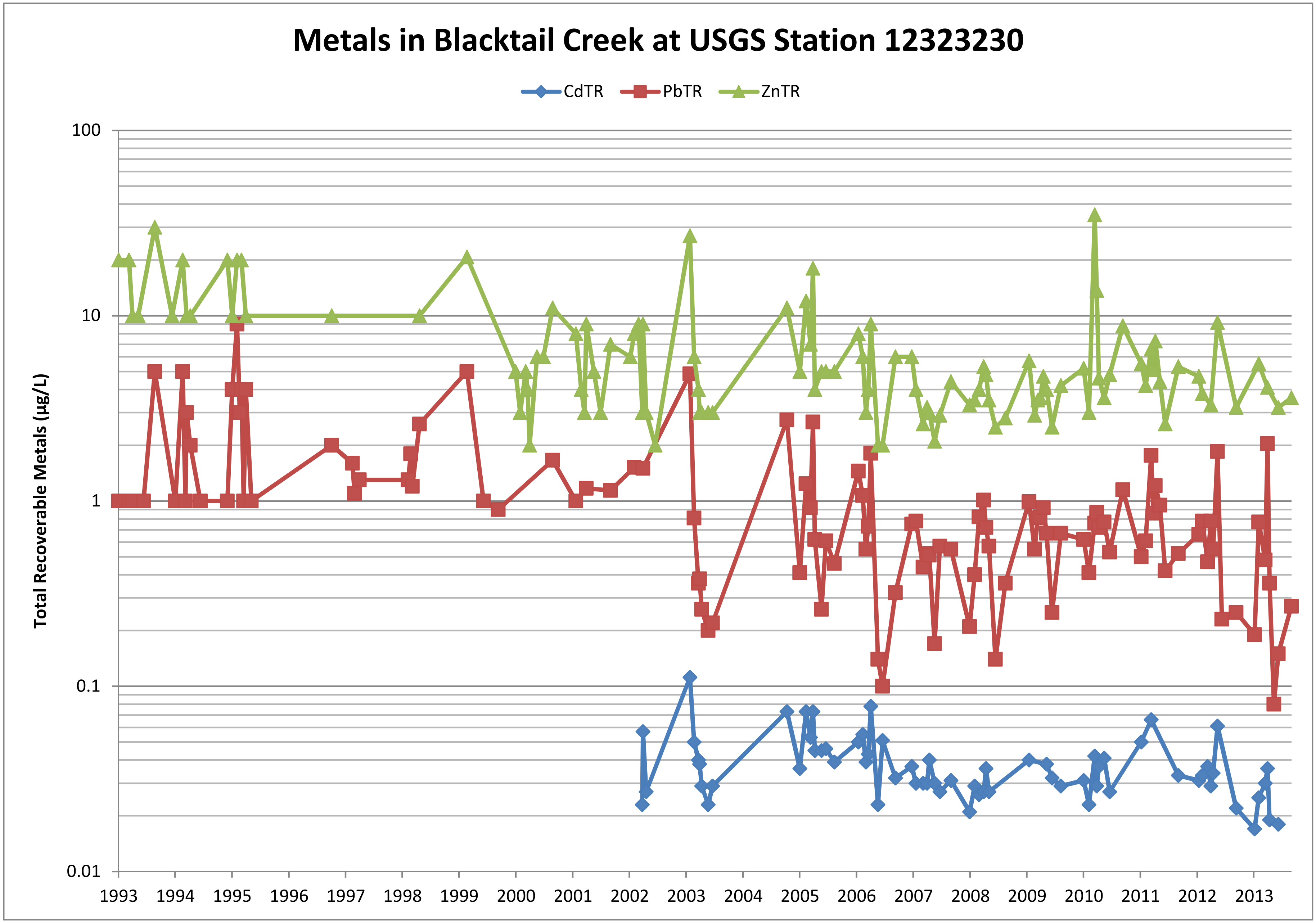

Figure 12-29
Metals in Blacktail Creek USGS Station 12323230

Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

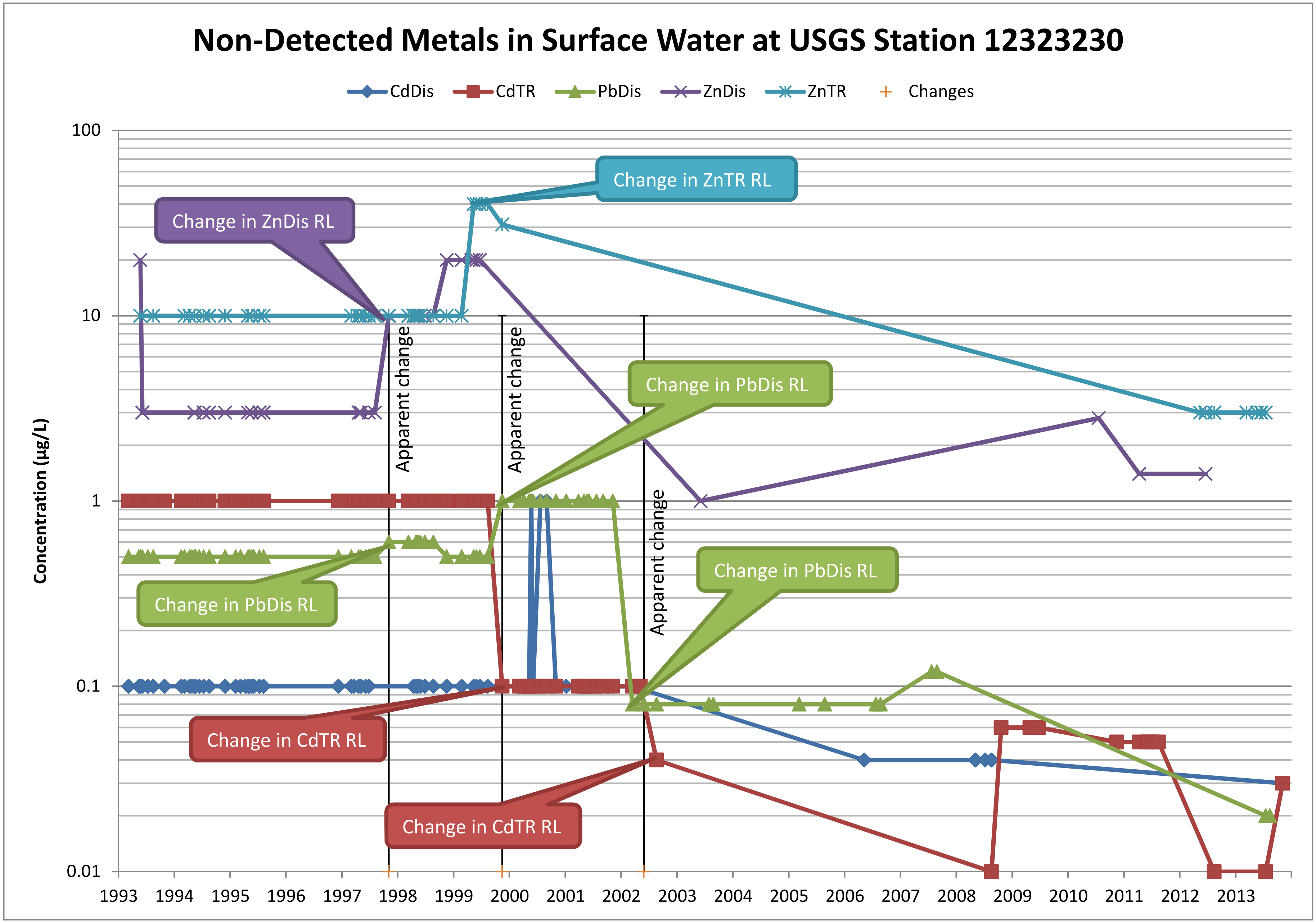

Figure 12-30
Non-Detected Results for Selected Metals USGS Station 12323230

Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL SIte

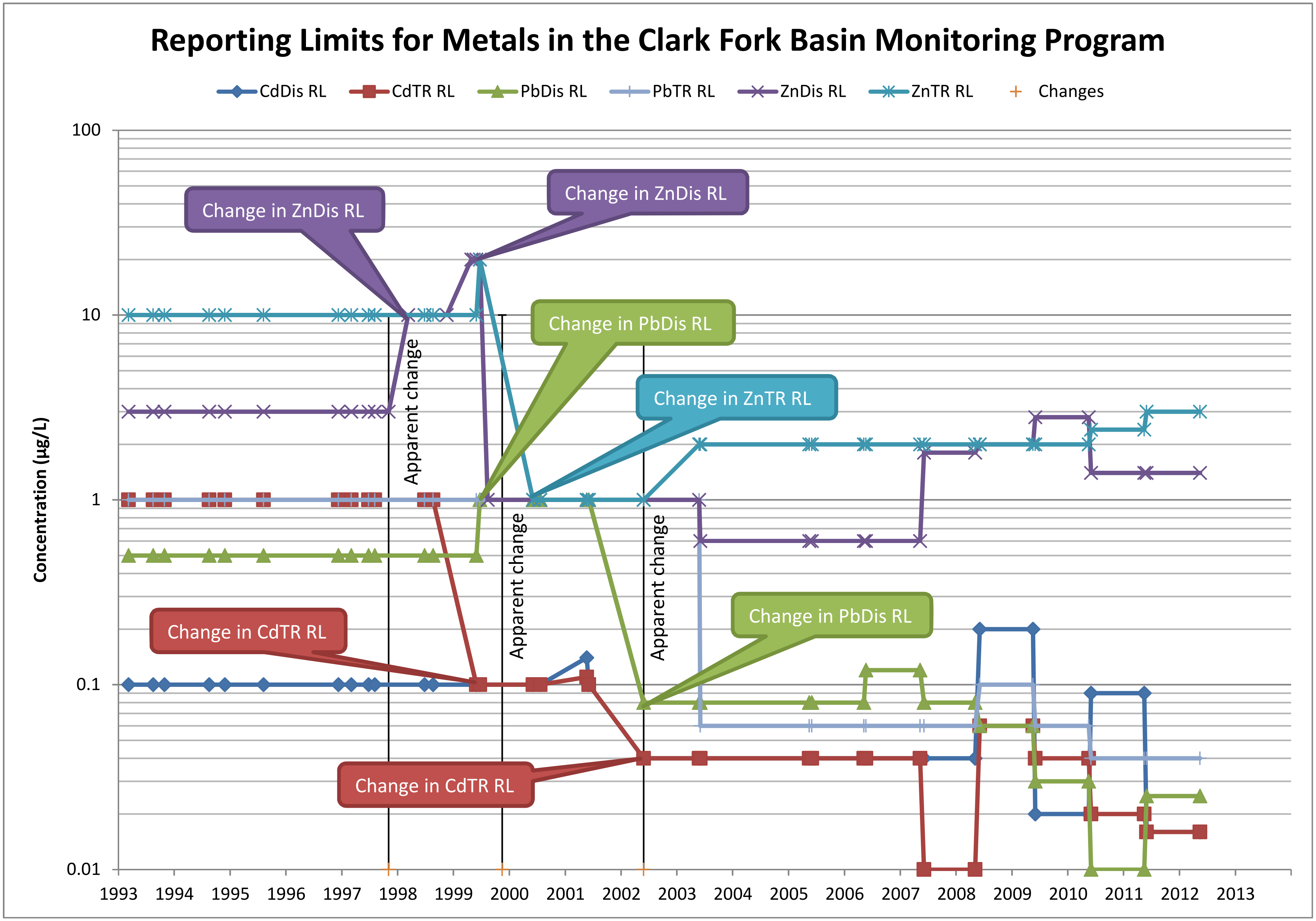

Figure 12-31
Reporting Limits for Metals in CFR Monitoring Program

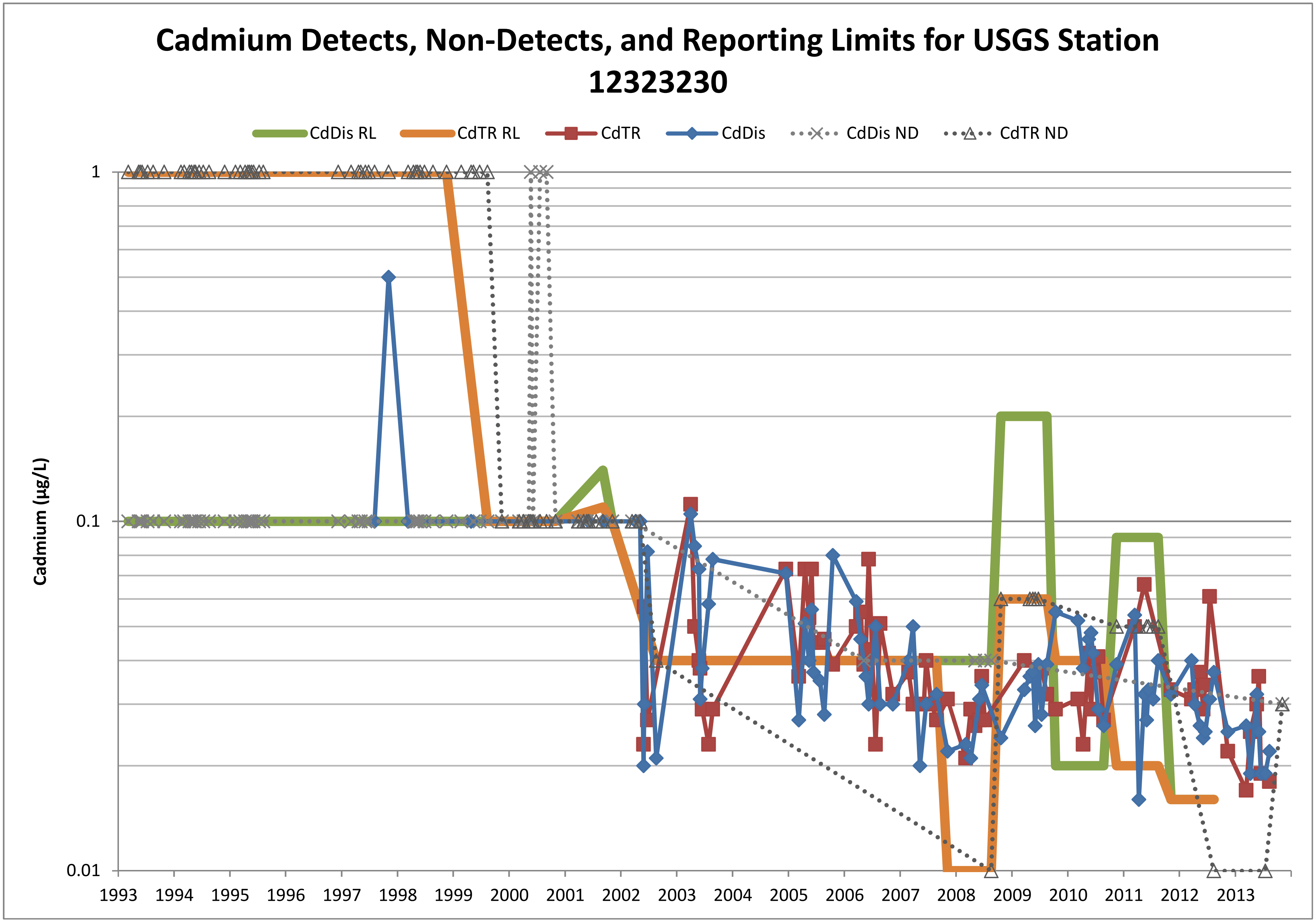

Figure 12-32
Cadmium Detects, Non-Detects, and Reporting Limits USGS Station 12323230

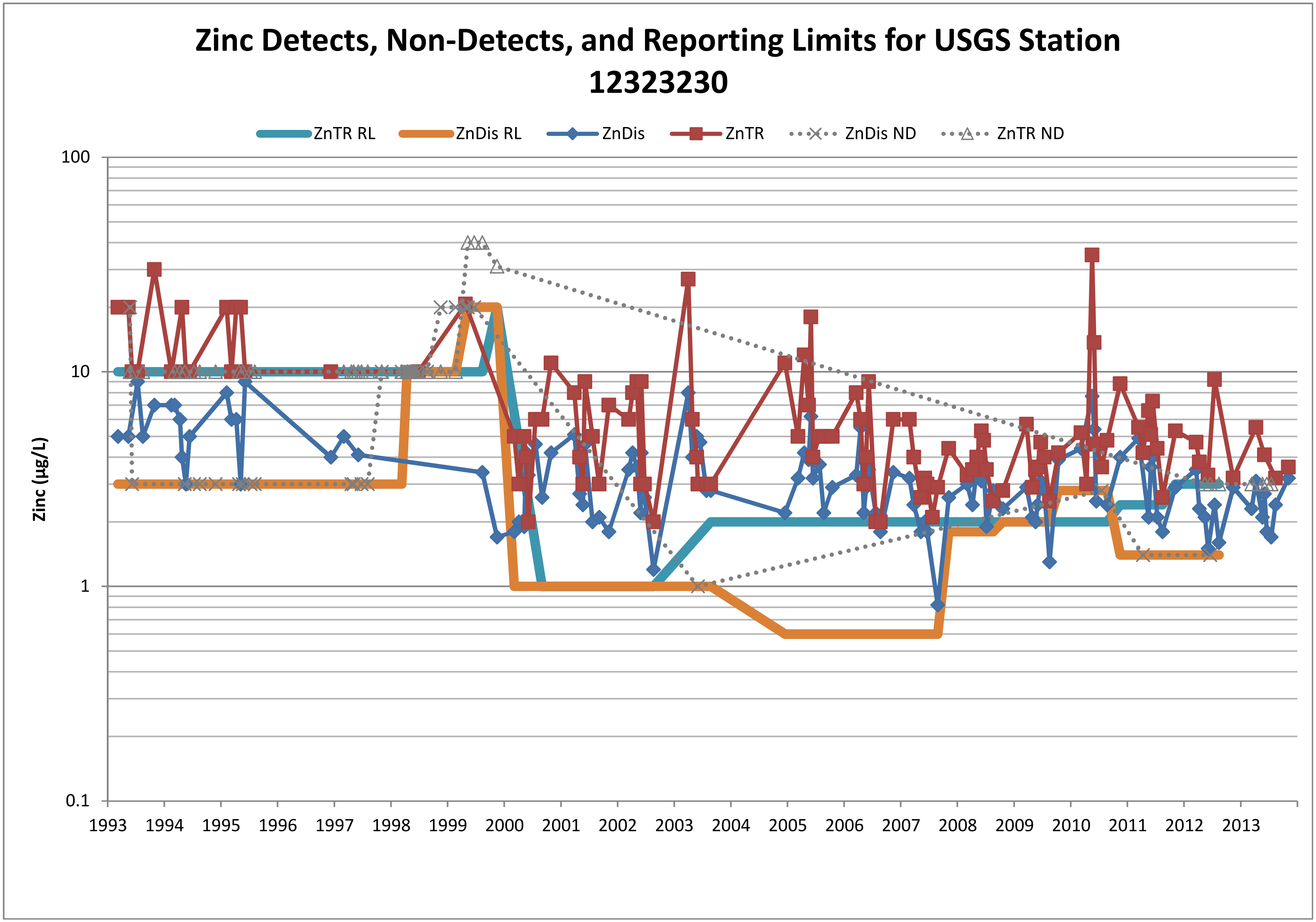

Figure 12-33
Zinc Detects, Non-Detects, and Reporting Limits USGS Station 12323230

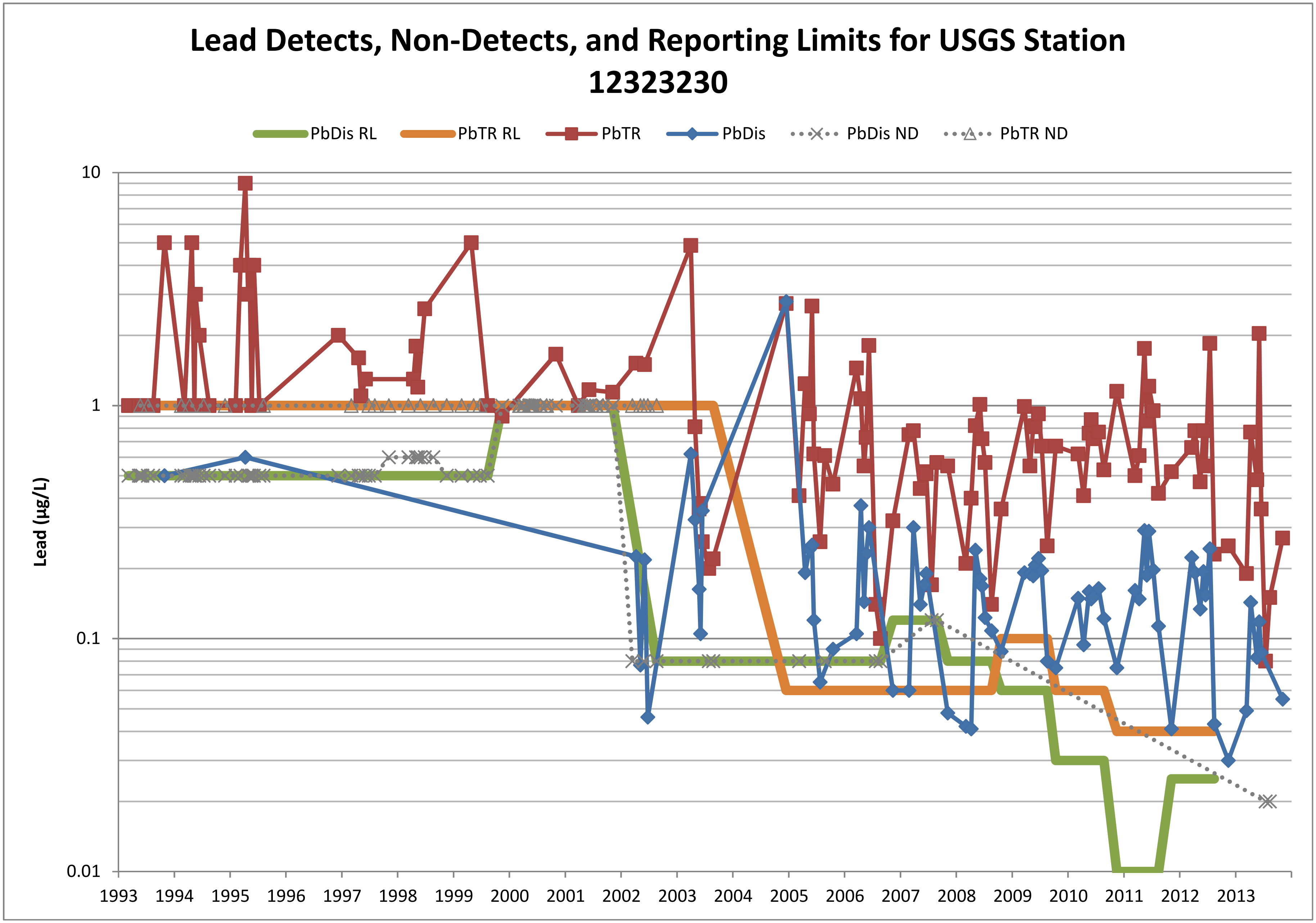

Figure 12-34
Lead Detects, Non-Detect, and Reporting Limits USGS Station 12323230

Surface Water Characterization Report
Butte Priority Soil Operable Unit
Silver Bow Creek/Butte Area NPL Site

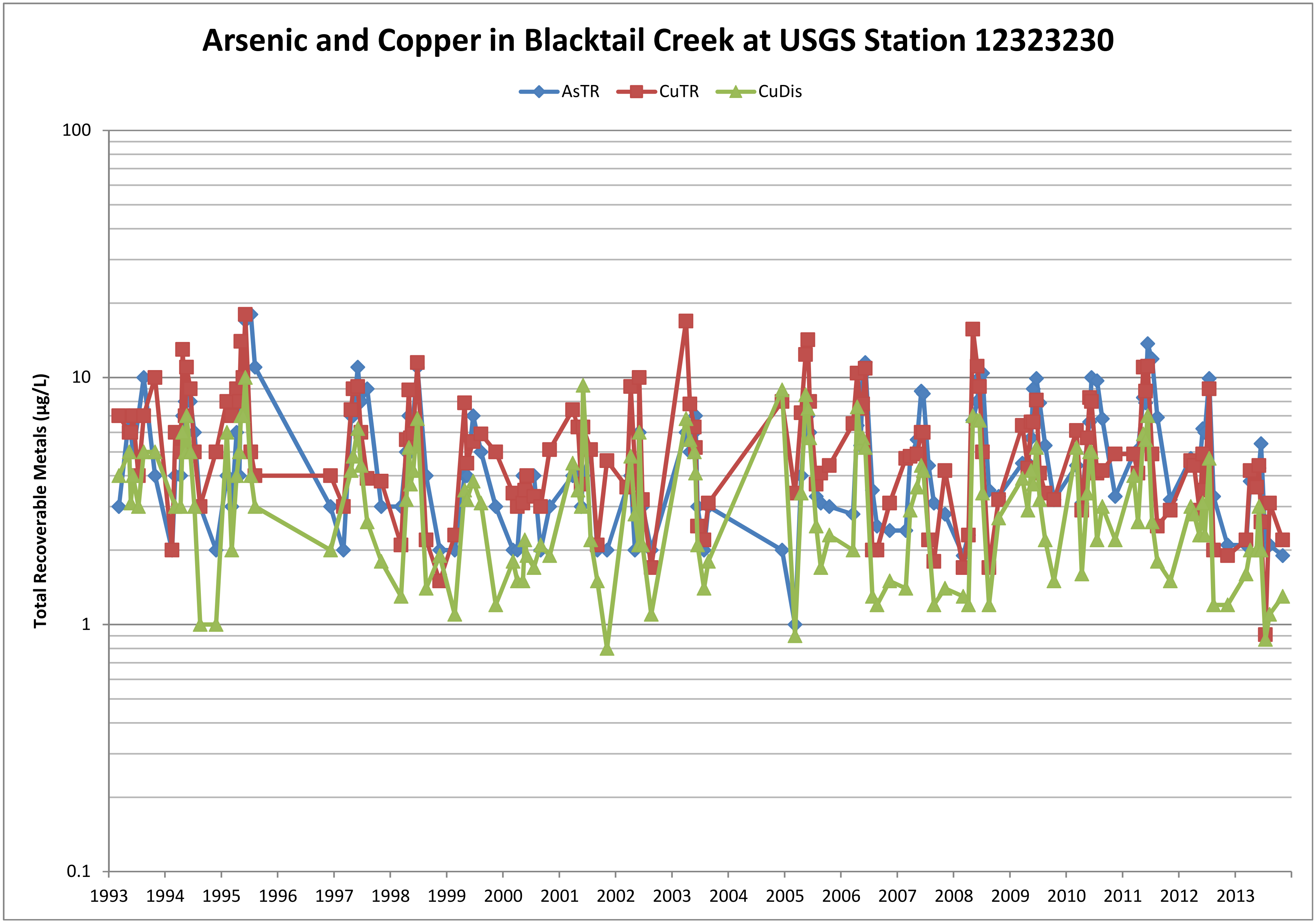

Figure 12-35
Arsenic and Copper in Blacktail Creek USGS Station 12323230

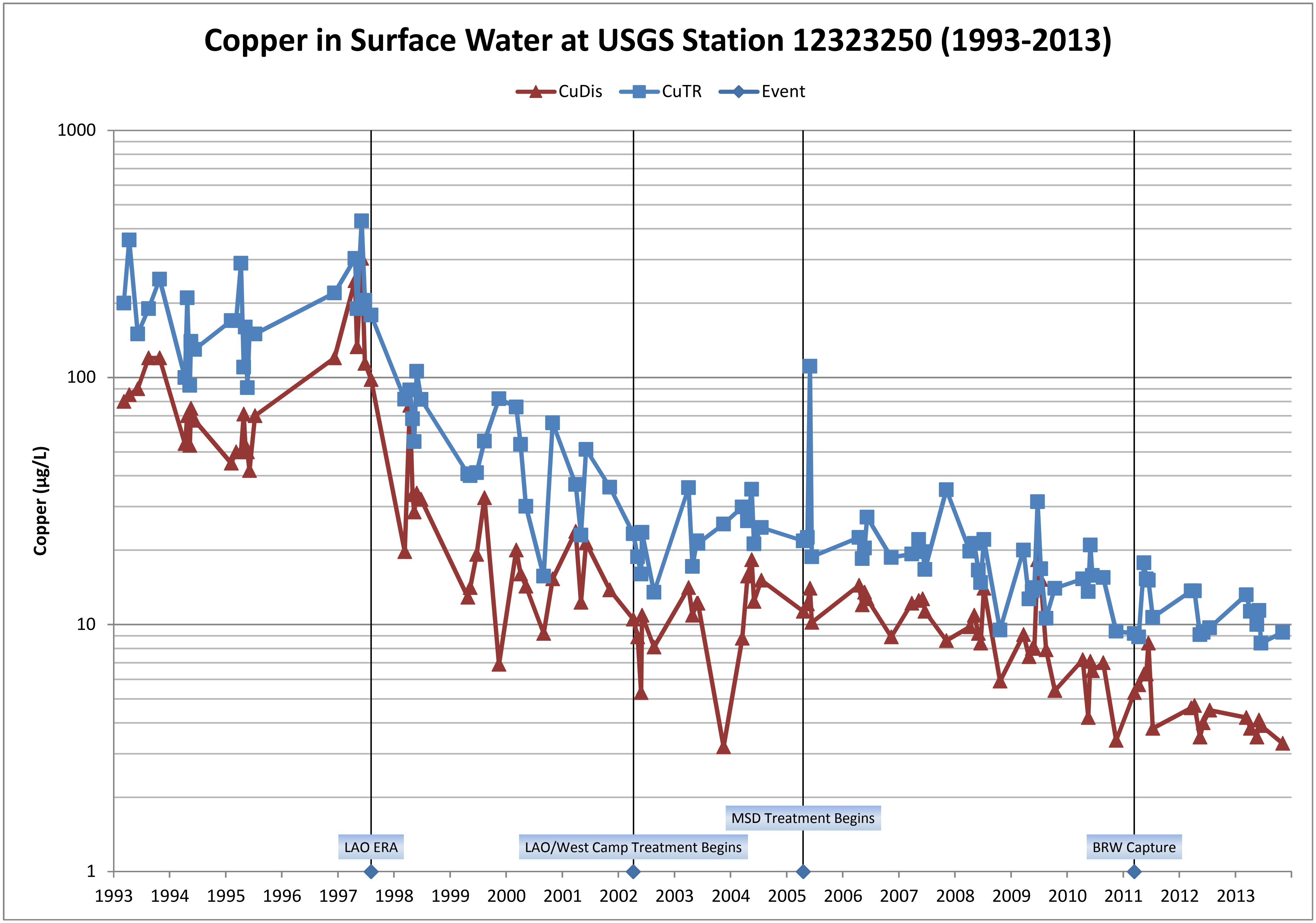

Figure 12-36
Copper in Surface Water at USGS Station 12323250 (1993-2013)

Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

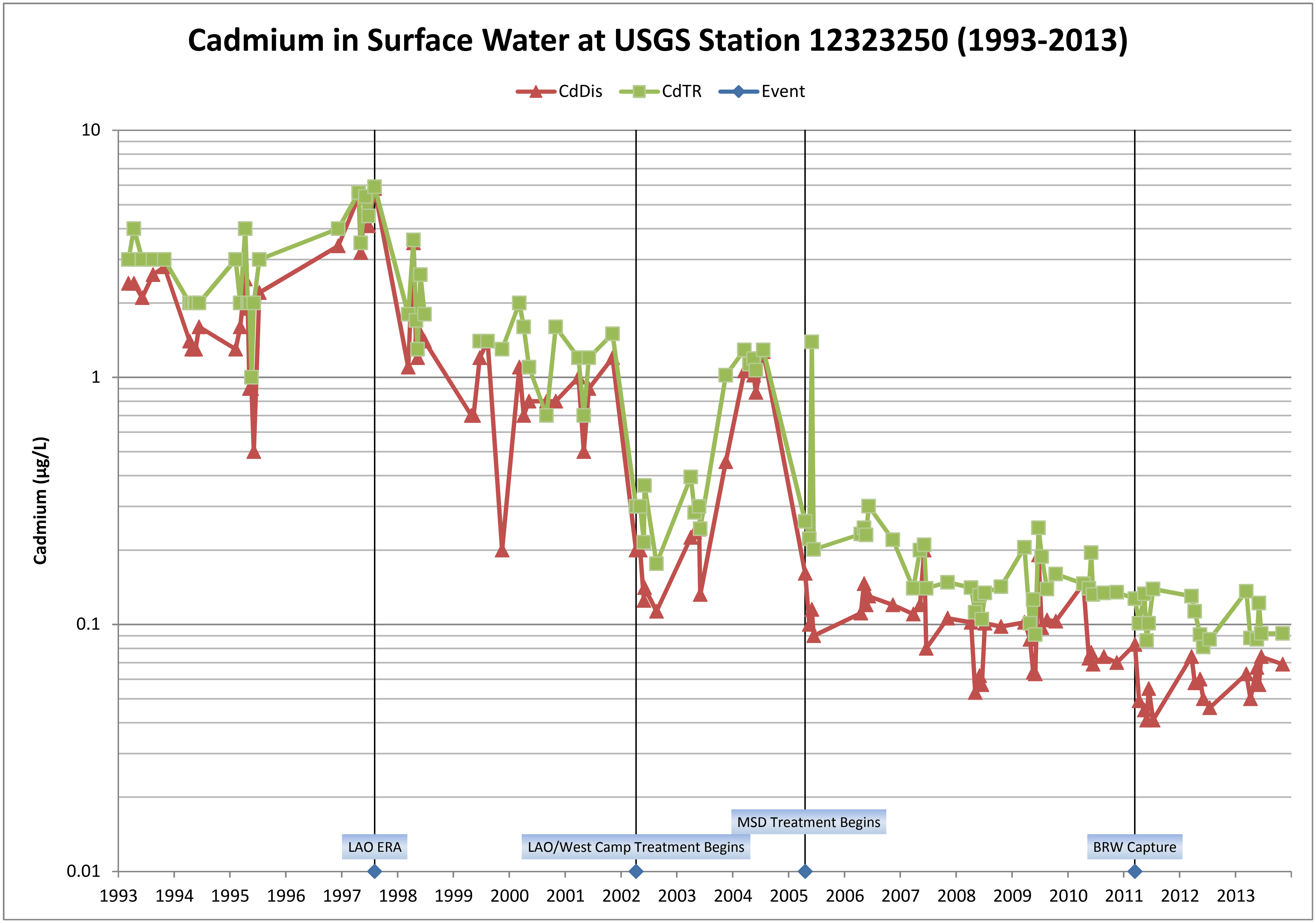

Figure 12-37
Cadmium in Surface Water at USGS Station 12323250 (1993-2013)

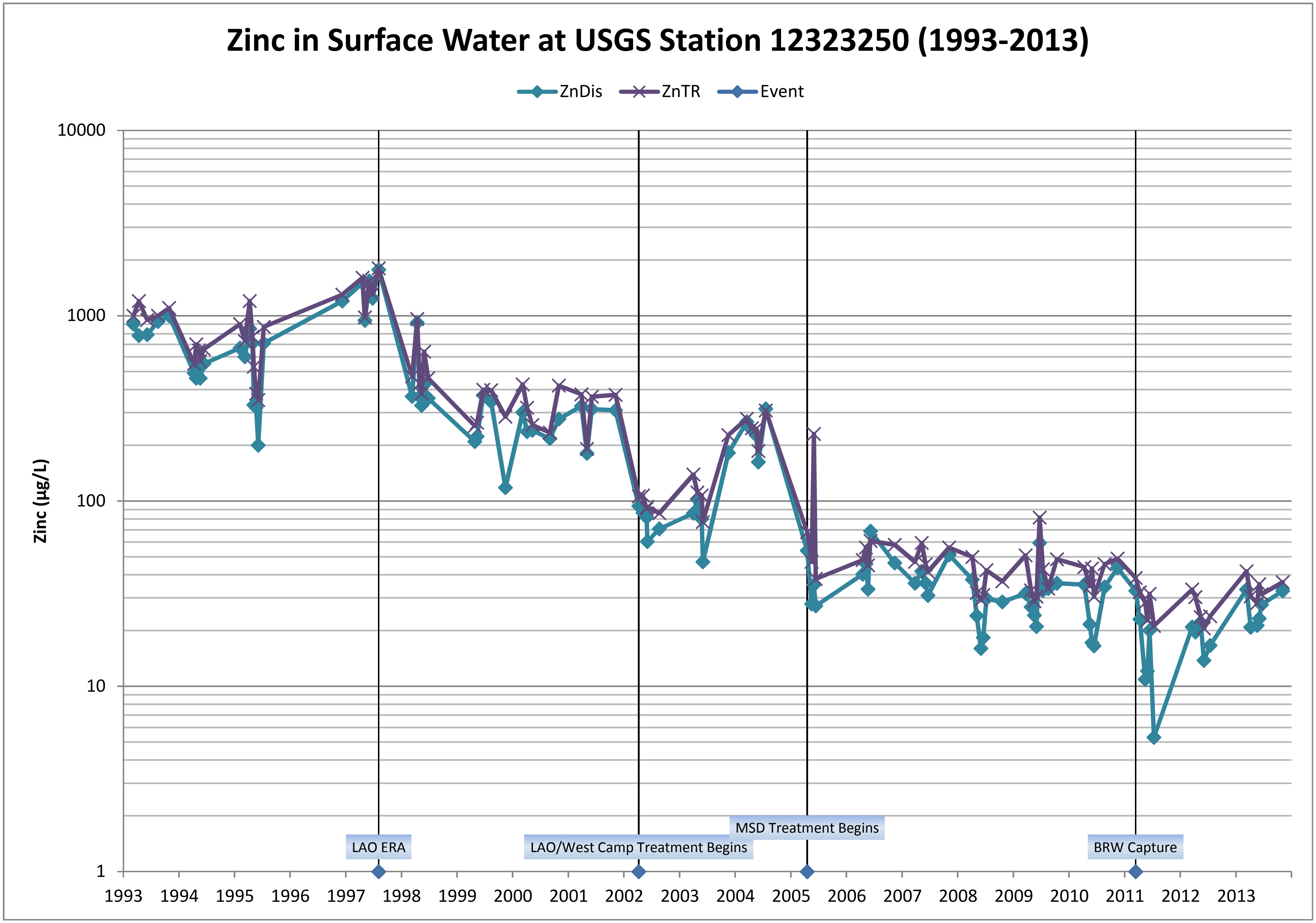

Figure 12-38
Zinc in Surface Water at USGS Station 12323250 (1993-2013)

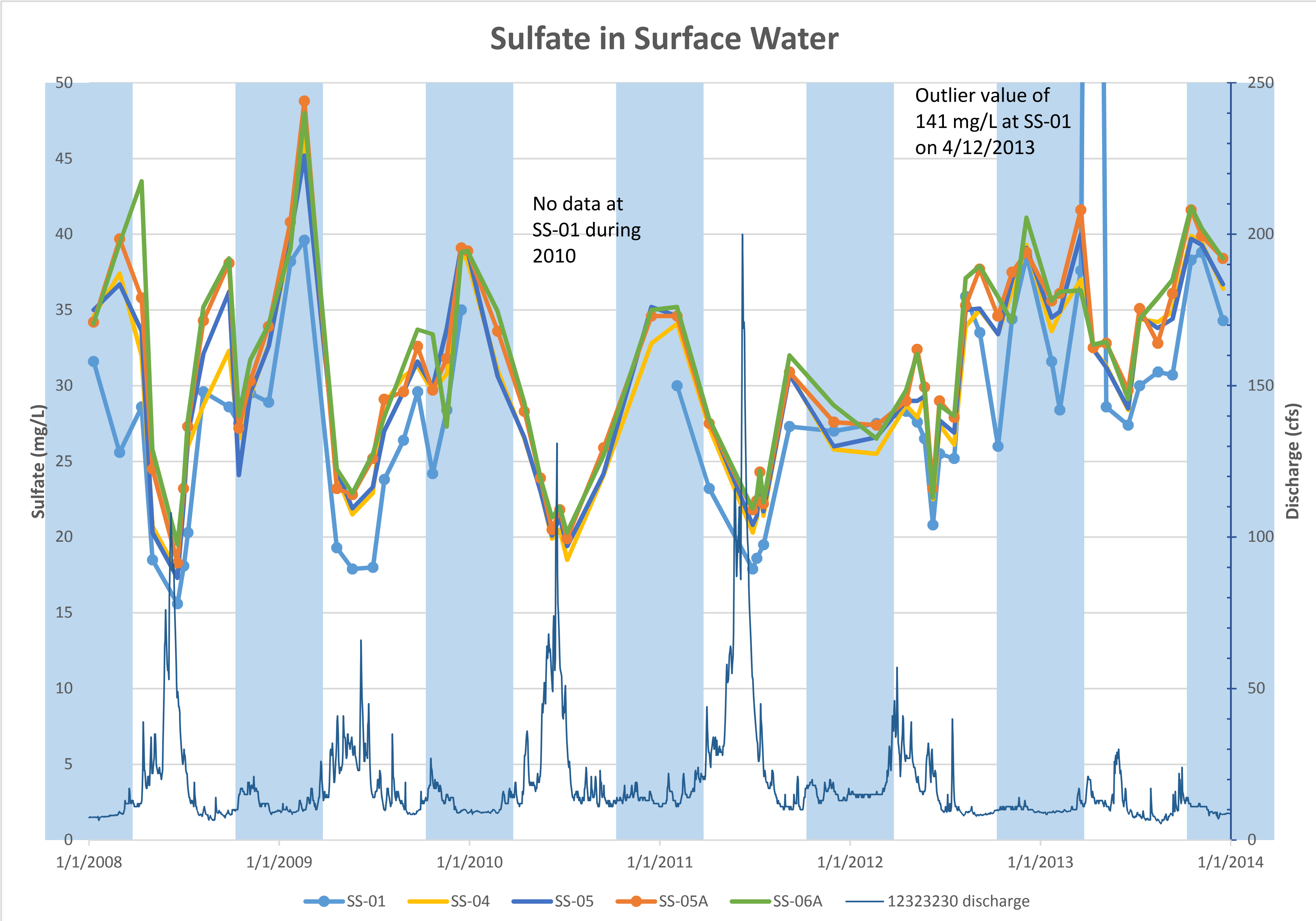

Figure 12-39
Sulfate in Surface Water

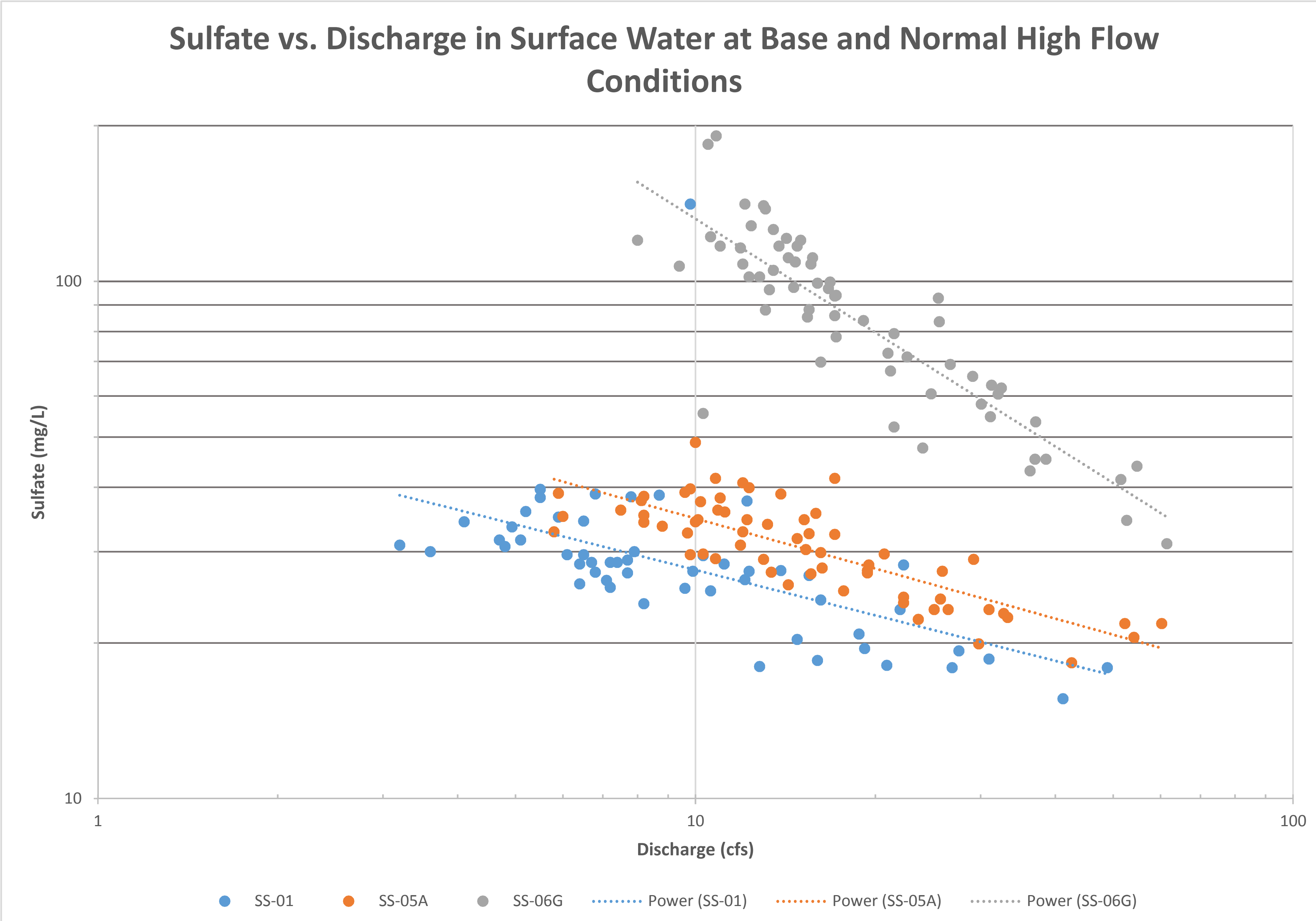

Figure 12-40
Sulfate vs. Discharge in Surface Water

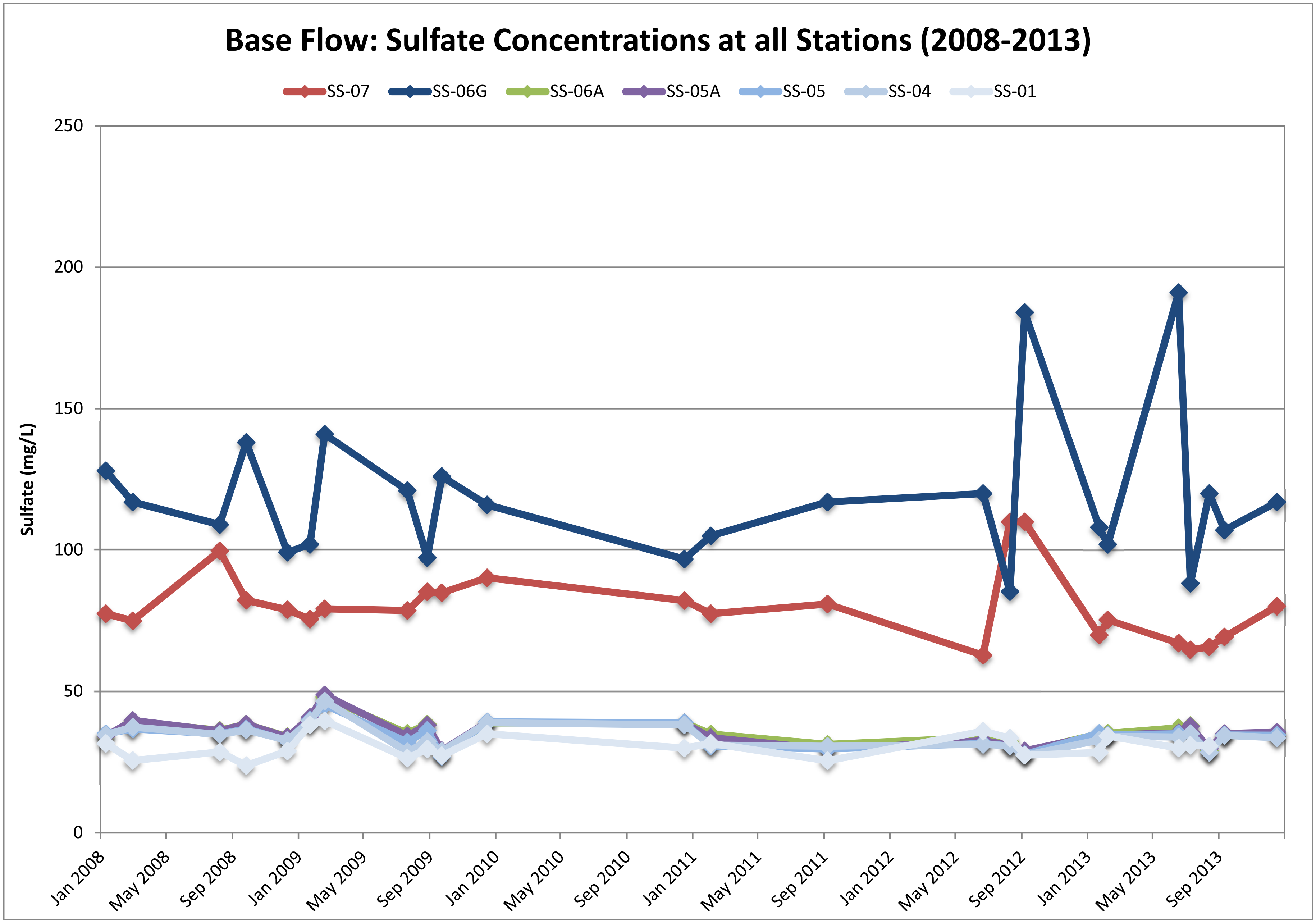

Figure 12-41
Base Flow Sulfate Concentrations - 2008 to 2013

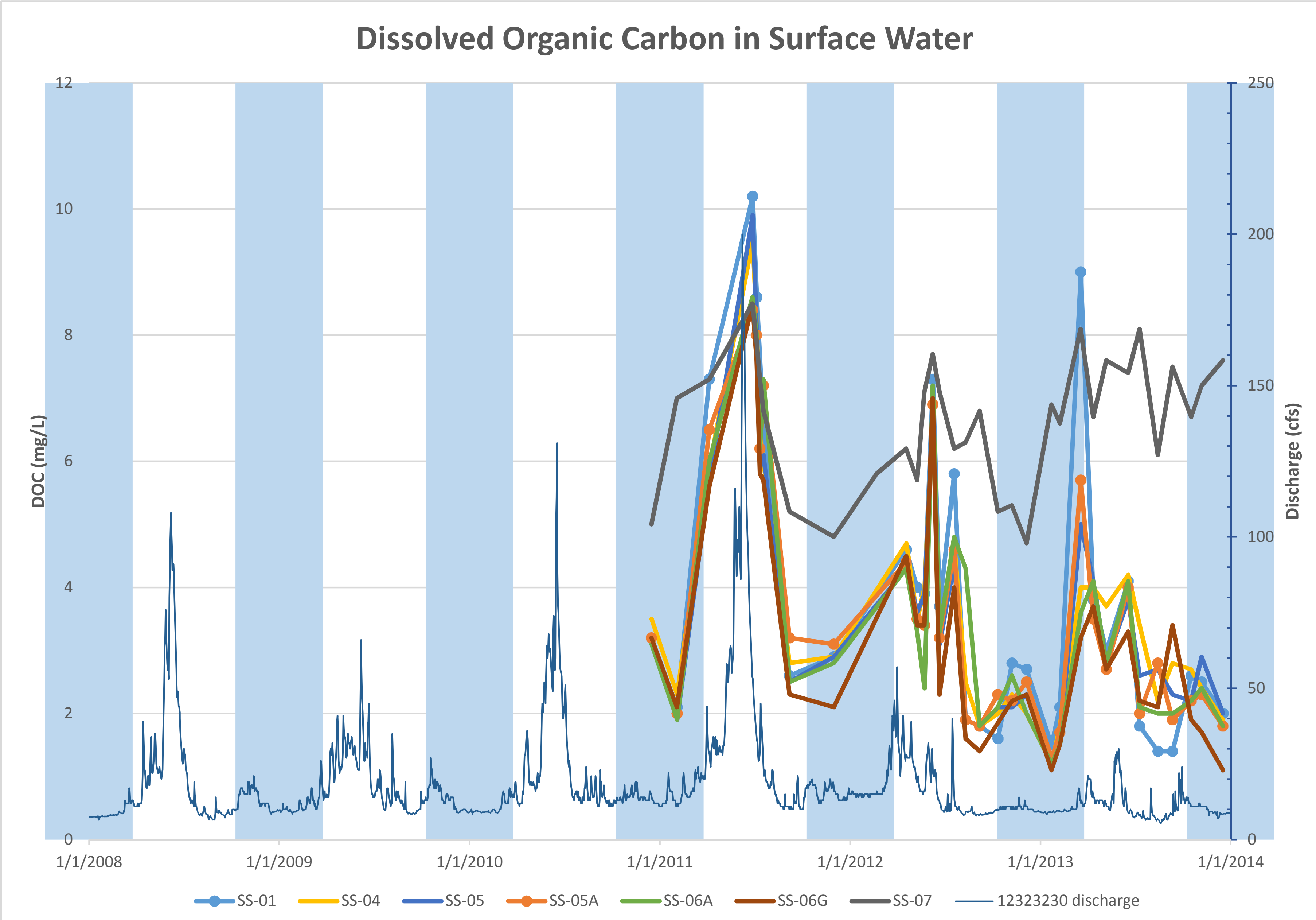

Figure 12-42
Dissolved Organic Carbon in Surface Water

Surface Water Characterization Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

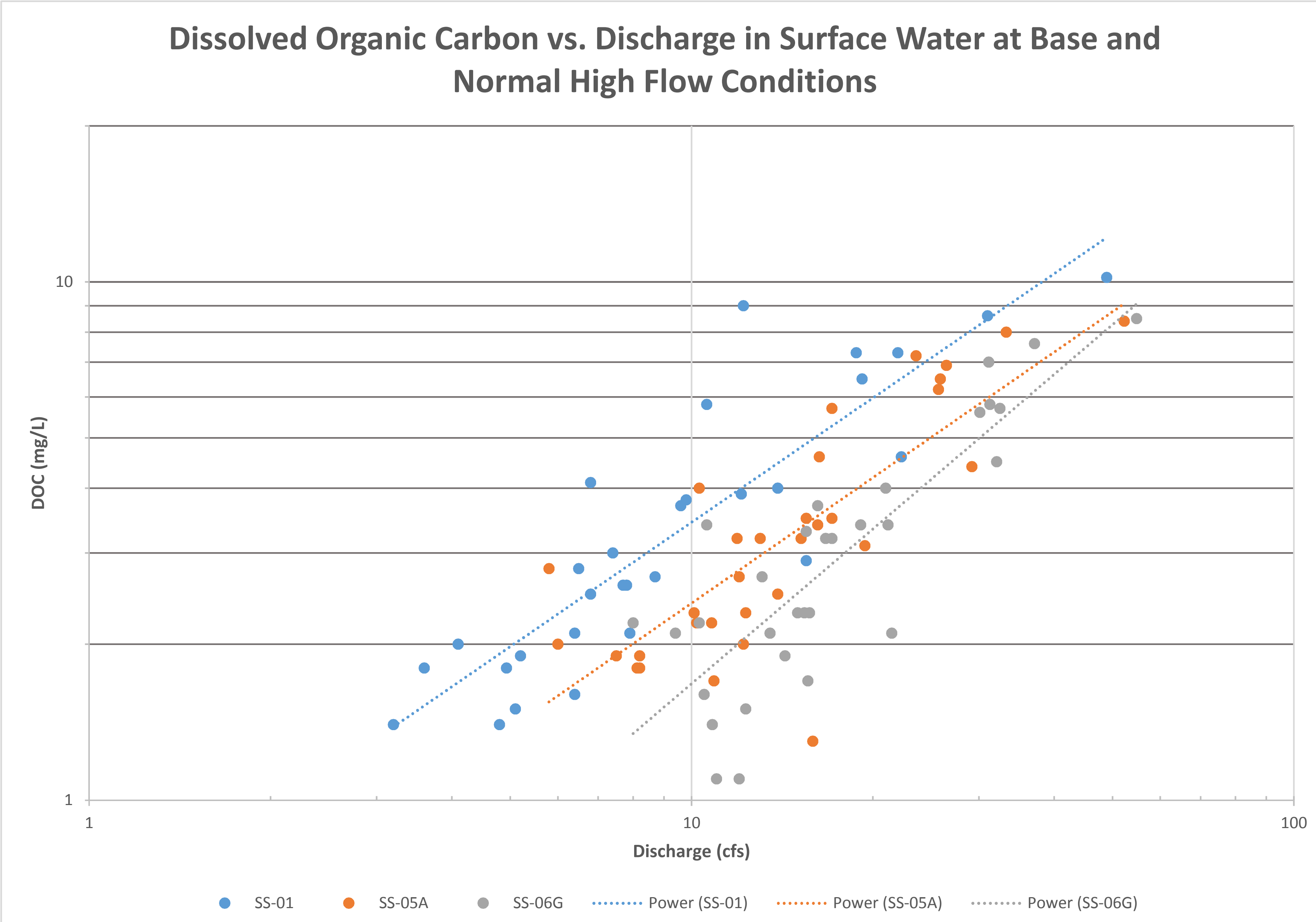

Figure 12-43
Dissolved Organic Carbon vs. Discharge in Surface Water

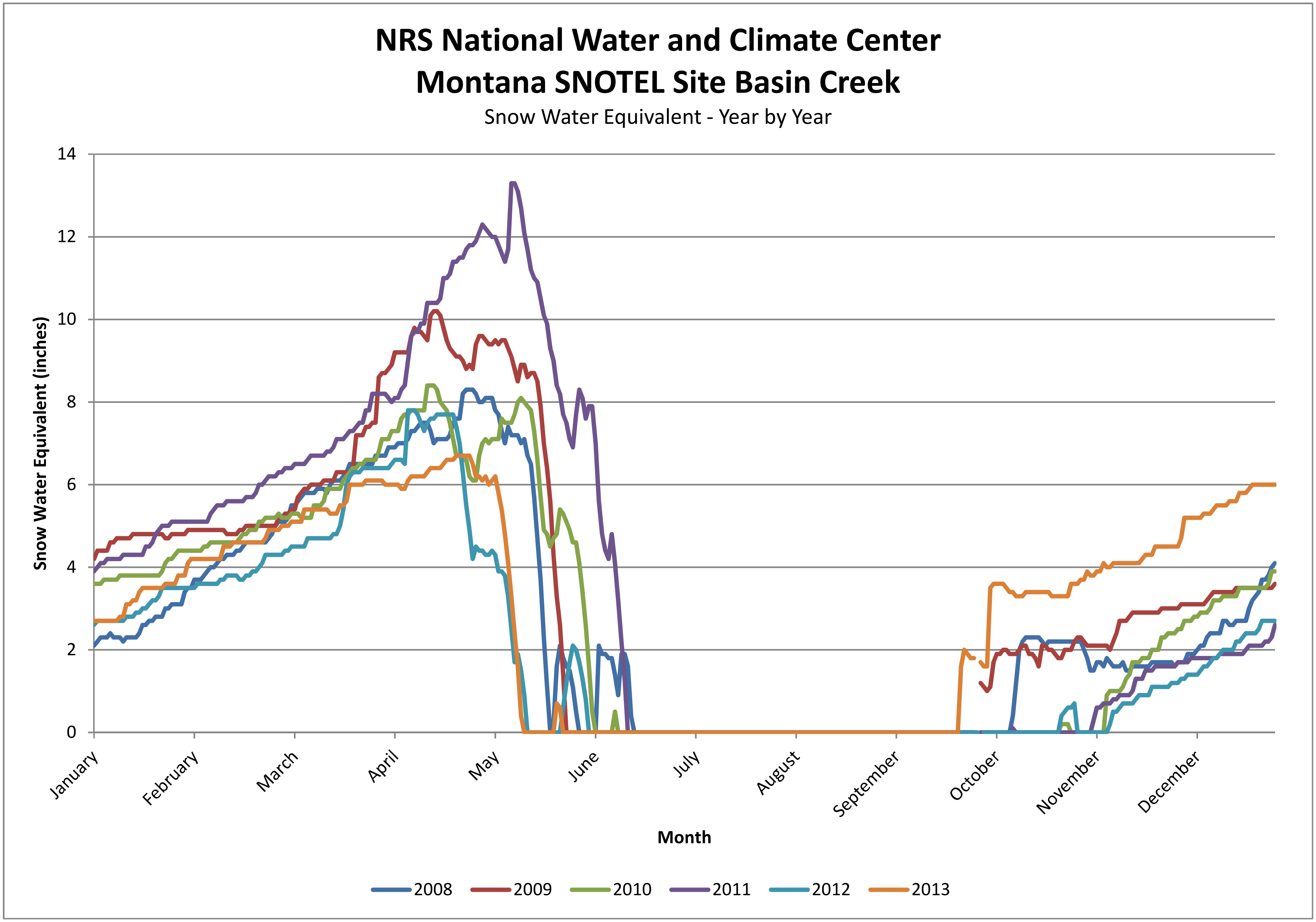

Figure 12-44
Montana SNOTEL Site Basin Creek Snow Water Equivalent

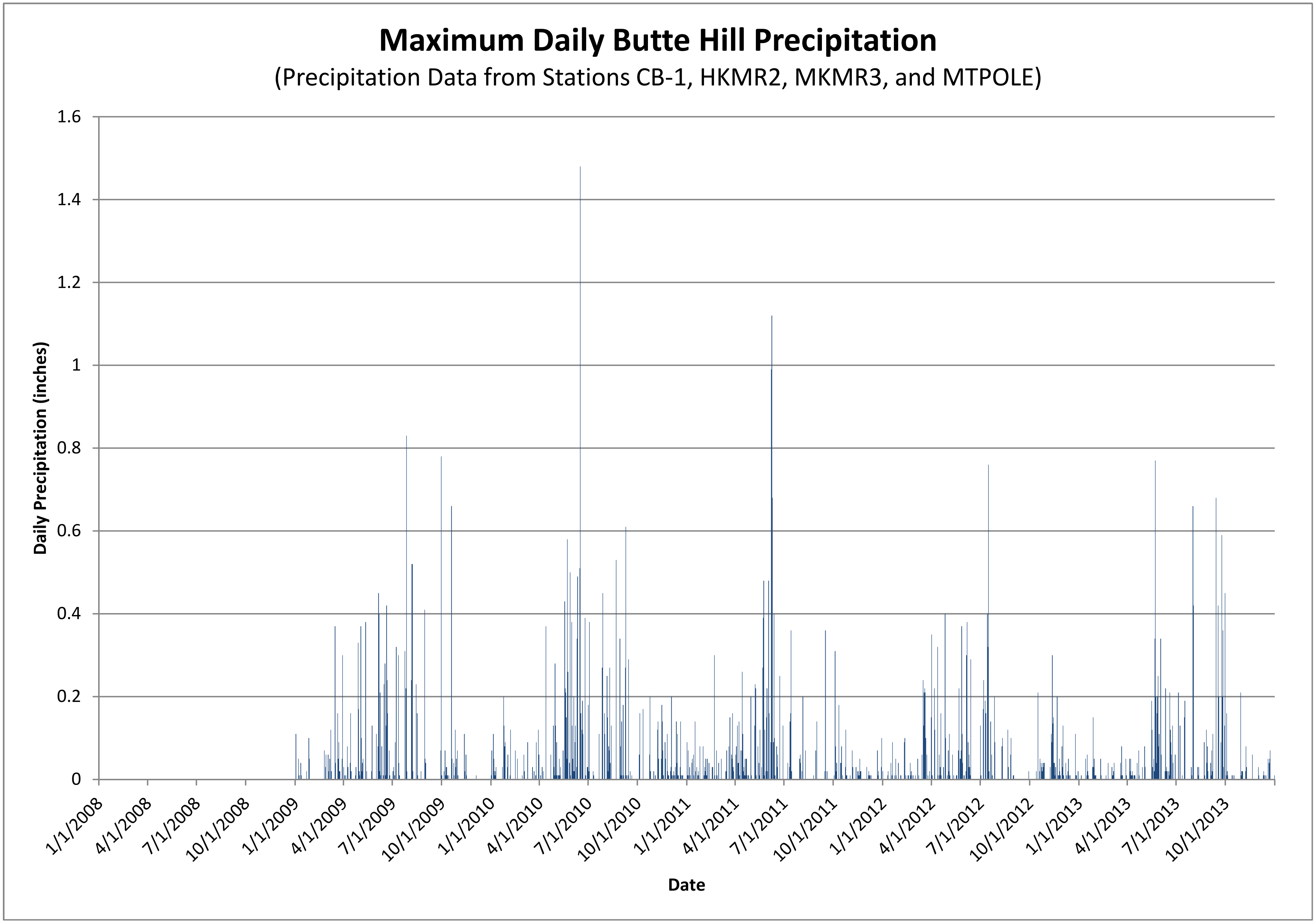

Figure 12-45
Butte Hill Precipitation Data

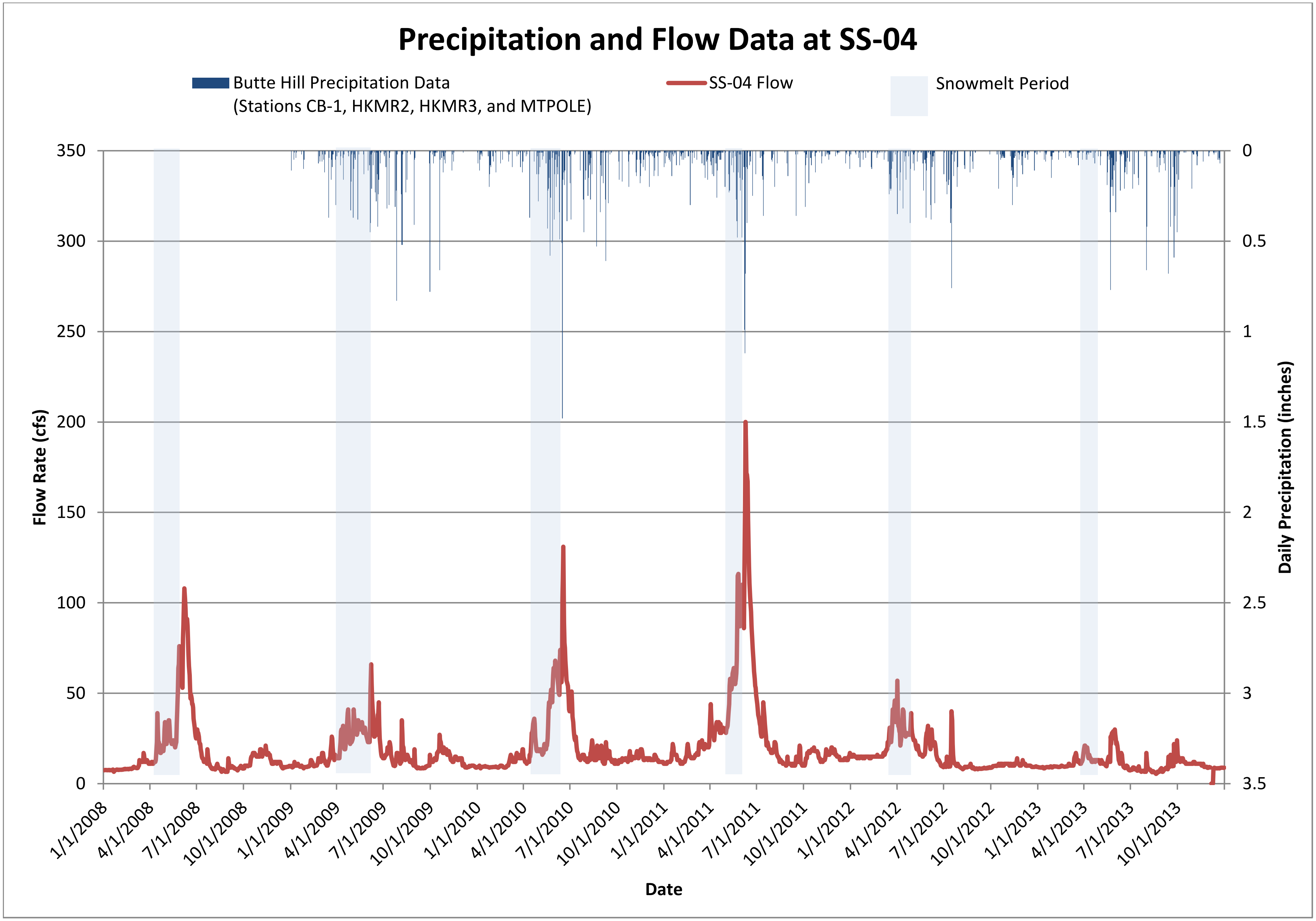

Figure 12-46

Butte Hill Precipitation Data and SS-04 Flow Rate