REMEDIAL ACTION CONTRACT
FOR REMEDIAL, ENFORCEMENT OVERSIGHT, AND NON-TIME-CRITICAL REMOVAL ACTIVITIES AT SITES OF RELEASE OR THREATENED RELEASE OF HAZARDOUS SUBSTANCES IN EPA REGION 8

U.S. EPA CONTRACT NO. EP-W-05-049

2010 Ground Water Data Analysis Report
Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area National Priorities List Site
Butte, Montana

Work Assignment No.: 311-NGNG-0822

January 2012

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List of Acronyms

µg/L	micrograms per Liter
ARAR	Applicable or Relevant and Appropriate Requirement
BMFOU	Butte Mine Flooding Operable Unit
BPSOU	Butte Priority Soils Operable Unit
BRW	Butte Reduction Works
CDM	CDM Federal Programs Corporation
CGWA	Controlled Ground Water Area
COC	contaminant of concern
DEQ	Montana Department of Environmental Quality
DSR	Data Summary Report
EPA	Environmental Protection Agency
GWIC	Ground Water Information Center
GWMP	Ground Water Monitoring Plan
HCC	hydraulic control channel
LAO	Lower Area One
MBMG	Montana Bureau of Mines and Geology
MSD	Metro Storm Drain
RAO	Remedial Action Objective
RD	remedial design
RG	remedial goal
ROD	Record of Decision
TI	technical impracticability

Appendices

Section 1 Introduction

1.1 Purpose of Report

The purpose of this report is to summarize ground water monitoring and ground water remedial design (RD) activities that have occurred since the initiation of the of the Interim Comprehensive Ground Water Monitoring Plan (GWMP) (U.S. Environmental Protection Agency [EPA] 2007)[1] by the responsible parties as part of the initial efforts at remedial design and remedial action implementation following the issuance of the Record of Decision (ROD) (EPA, with partial concurrence by the Montana Department of Environmental Quality [DEQ] 2006). The primary activities described in the ROD and addressed in this report are associated with development of a ground water monitoring program. The monitoring program activities performed since 2007 are as follows:

- Installation of additional ground water monitoring wells monitor ground water contamination within the Butte Priority Soils Operable Unit (BPSOU);
- Monitoring ground water at regular intervals to evaluate the ground water flow and groundwater/surface water interaction and the effectiveness of remedial actions performed to date;
- Tracer test to determine metals loading within the Metro Storm Drain (MSD) subdrain; and
- Aquifer test to evaluate transmissivity of the middle gravel portion of the alluvial aquifer and lateral and vertical interconnection of the alluvial aquifer within the MSD.

During the implementation of the monitoring program and remedial actions, additional ground water tasks were identified and implemented. They include:

- Tests to isolate the lower portions of the MSD subdrain to better understand ground water loading in the area;
- Collection of ground water samples in the MSD area and analysis for a wide variety of constituents for the purpose of geochemical analysis; and
- Design and partial implementation of an extension of the ground water collection system in Lower Area One (LAO).

The data collected during these tasks have been previously presented in other data reports. This report presents a discussion or analysis of these data and focuses on elements not addressed in other reports.

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[1] The plan has since been replaced by a Revised Interim Ground Water Monitoring Plan (EPA 2011) which EPA ordered implemented in 2011.

1.2 Remedial Action Objectives and Remediation Goals

The remedial action objectives (RAOs) for ground water presented in the BPSOU ROD are to:

- *Prevent ingestion of or direct contact with contaminated groundwater that would result in unacceptable risk to human health.*
- *Prevent groundwater discharge that would lead to violations of surface water applicable or relevant and appropriate requirements (ARARs) and remedial goals (RGs) for the BPSOU.*
- *Prevent degradation of groundwater that exceeds current standards.*

The RGs for ground water presented in the BPSOU ROD are to meet numeric water quality standards for ground water established in the ROD except where standards are waived. The ROD established a Technical Impracticability (TI) Zone in the alluvial aquifer where standards for six contaminants of concern (COCs) were waived.

1.3 Ground Water Selected Remedy Components

The RAOs and RGs are expected to be met through implementation of the selected remedy. The first RAO - to prevent ingestion of or contact with contaminated ground water - is addressed through establishment of a Controlled Ground Water Area (CGWA). The Butte Alluvial and Bedrock CGWA was established in October 2009 and is currently in effect.

The second and third RAOs - to prevent ground water discharge and further ground water degradation – are addressed through the following ground water components of the remedy:

- Collection of contaminated ground water in the MSD area;
- Collection of contaminated ground water in the LAO area; and
- Treatment of collected ground water.

Other remedial measures, such as infiltration barriers or alternative snow storage areas may also be required and are being evaluated.

Ground water monitoring is required to evaluate whether the remedy is effective at meeting RAOs and RGs.

1.4 Ground Water Monitoring Program Requirements

To implement the ground water monitoring program, the following components were required by the ROD:

1. *All monitoring wells in the BPSOU aquifer (MSD, LAO, and between) will be sampled every 5 years. Additionally, EPA in consultation with DEQ will identify a network of wells for annual water quality sampling.* The Interim Comprehensive Ground Water Monitoring Plan was developed in 2007 (EPA 2007) and was implemented in October 2007. These data form much of the basis for this report.

2. *Water levels will be measured in all wells and certain surface water locations twice per year. Water levels will be measured in a select network on a monthly basis, or more frequently if necessary for operation of the capture and treatment system.* This activity is ongoing and is discussed in Section 2.

3. *Ground water monitoring will be coordinated with the Butte Mine Flooding Operable Unit (BMFOU) monitoring program managed by the Montana Bureau of Mines and Geology (MBMG) as there is overlap in the monitoring well networks.* This activity is ongoing and is discussed in Section 2.1.1.

4. *Additional monitoring wells will be installed throughout the MSD as needed to determine flow direction, gradients, and ground water quality. Additional monitoring wells will be installed in areas where the extent(s) of ground water plumes are uncertain. These will also include additional nested well sets in key areas of the floodplain, additional mid-level and deep wells, and possibly bedrock wells.* This activity has been implemented and is discussed in Section 2.

5. *Wells will also be installed, as necessary, to monitor the subdrain.* This activity has been implemented and is discussed in Section 2.

6. *One pumping test will be conducted on a mid-level well (AMW-1B) in upper MSD to determine if the subdrain will influence flow in the mid-level portion of the aquifer.* This activity has been implemented and is discussed in Section 2.1.3.

7. *The ground water loads entering the MSD subdrain will be monitored annually in the fall (base flow) using dye tracer methods to determine flow and standard sampling to measure metals and arsenic concentrations. Load monitoring will assure that the subdrain continues to operate as expected and is not fouling or clogging.* This activity has been implemented and is discussed in Section 2.1.5. *In addition, two monitoring wells will be installed adjacent to MSD just downgradient of the pump vault to assure that captured ground water is not leaving the capture system.* This activity has been implemented and is discussed in Section 2.

8. *A network of nested wells will be installed between the MSD and Blacktail Creek.* This activity has been partially implemented and is discussed in Section 2.

9. *At least two nested well groupings (three wells per grouping) will be installed at the very west end of the BPSOU as point-of-compliance wells. Each well group will consist of a shallow well, a deeper weathered bedrock well, and a deep solid bedrock well.* This activity has been implemented and is discussed in Section 2.

10. *There is no ground water capture system between the end of the MSD subdrain and the start of the hydraulic control channel (HCC). If ground water inflow between the MSD and LAO capture systems is found to adversely affect surface water quality, additional ground water capture and hydraulic control shall be developed and implemented in this area.* This activity has been partially implemented and is discussed in Section 2.2.2.

Section 2 Ground Water Monitoring Activities

2.1 Ground Water Monitoring Program Implementation

The first step in implementation of ground water monitoring was completion of the Interim Comprehensive GWMP (EPA 2007). The overall goals of the GWMP were to:

- Ensure that ground water capture and treatment systems are effective;
- Determine that contaminated ground water is not leaving the TI Zone or discharging to surface water to the extent that standards are violated or that protectiveness is not achieved;
- Provide additional information as necessary on the movement, quality, and quantity of ground water to assure that ground water contamination plumes are not spreading and ground water quality is not degrading; and
- Provide data for review of the ground water remedy.

This plan identified six tasks to address the overall goals as well as the 10 requirements listed in Section 1.4:

Task 1 - Ground Water Sampling and Analysis

Task 2 - Well Installation

Task 3 - Upper MSD Pumping Test

Task 4 - Data Management

Task 5 - MSD Subdrain Load Monitoring

This section describes the status of each task.

2.1.1 Ground Water Sampling and Analysis

The GWMP (EPA 2007) specified procedures, data quality objectives, locations, and a schedule for ground water monitoring. Ground water monitoring was implemented in 2007 with monthly water level measurements and annual ground water sampling occurring since that time. The most recent 2010 sampling event occurred in October to November 2010. Two Data Summary Reports (DSRs) have been submitted (Atlantic Richfield 2009 and Atlantic Richfield 2011) and electronic data have been periodically submitted to EPA. The data summary reports include wells sampled, deviations from the sampling and analysis plan, and analytical results. Limited analysis of the water level data is presented in Section 3.4 and limited analysis of the water quality data is presented in Sections 3.1.1.3 and 3.1.2.4.

BMFOU ground water monitoring is being conducted under a separate plan and the analyses of the results are published in an annual report (e.g., Duaime and Tucci 2009). Additionally, analytical data are available from the authors of the annual report and online from the Ground Water Information Center (GWIC). Although the sampling and analysis is coordinated to minimize duplication, the results have not been effectively incorporated into analysis of ground water data for BPSOU. Some pertinent water level data from BMFOU are evaluated in Section 3.4.2 of this report.

2.1.2 Additional Well Installation

Twenty-seven additional monitoring wells were installed at BPSOU between 2007 and 2010. Additional monitoring well locations are shown on Figure 2-1. The need for additional monitoring wells at the site was presented in the GWMP. The GWMP divided the site into separate areas of interest to aid in the evaluation and interpretation of site data and to ensure that the needs and objectives of each area of interest are being met. The following areas of interest were established for this purpose:

- Technical Impracticability (TI) Zone;
- MSD capture system;
- LAO capture system;
- Ground water area between MSD and LAO capture systems; and
- Private wells.

Each area of interest was developed with a specific purpose, described in detail in the GWMP.

The initial specific monitoring well locations and proposed construction details were first presented in the Draft Ground Water Monitoring New Well Installation Plan (Atlantic Richfield 2007). Sixteen wells were proposed in the plan as follows:

- Six wells within or just outside the TI zone;
- Five wells within the MSD capture system;
- Four wells between the MSD and LAO capture systems; and
- One well in the Colorado Smelter repository area.

Twelve of the 16 wells were installed in December 2007. The installation details were presented in the Draft Final Groundwater Monitoring New Well Installation Plan Construction Completion Report (Atlantic Richfield 2008). Well BPS07-10A (Colorado Smelter repository area) was not installed because the static water level in the monitoring well borehole (approximately 37 feet below ground surface) was greater than 10 feet below the bottom of the repository.

Based on directions from and correspondence with EPA, 14 additional monitoring wells were installed in early 2008. The well locations proposed by EPA and corresponding well nomenclature are as follows:

- Shallow alluvial well paired with HCA-B2 (BPS07-17A);
- Nested wells by surface water station SS-07 (BPS-7- 18A/B);
- Shallow well located west of pump vault in peninsula formed by confluence of Blacktail Creek and MSD channel (BPS07-07);
- Shallow well in wetlands north of confluence and north of MSD (BPS07-23);
- Two shallow wells north and south of pump vault far enough away not to interfere with construction (BPS07-20 and BPSOU-22);
- Well nest adjacent to pump vault(BPS07-21 and BPSOU-21B);
- New well pair south of BT98-02 to delineate TI Zone (BPS07-16A/B);
- New well pair to delineate TI zone southwest of Clark Park (BPS07-05A/B); and
- Wells evaluating water quality on the south side of the slag canyon (BPS07-14A and BPS07-15A).

Installation details regarding these wells are included in the Groundwater Monitoring New Well Installation Plan Construction Completion Reports (Atlantic Richfield 2010a and 2010b).

Four additional wells (AMC-24C, AMW-13C, BPS07-21C, and BPS07-24) were installed in 2010 by CDM to provide additional monitoring points within the middle gravel layer.

Collectively, the additional wells add to the knowledge of the alluvial aquifer at BPSOU and supplement the previous well network to provide additional water quality information where it was sparse or lacking. Discussion of the alluvial aquifer is presented in Section 3.

2.1.3 Upper MSD Pumping Test

The Phase I MSD pumping test was conducted between January 25 and February 10, 2010, to determine if the MSD subdrain would influence flow in the mid-level portion of the aquifer. Pumping test procedures were set forth in the *Final 2010 Metro Storm Drain (MSD) Sub-Drain Pumping Test Work Plan* (Atlantic Richfield 2010h). Independent analyses were provided by MBMG and EPA.

Monitoring well AMW-01B was utilized as the pumping well during the test. The Phase I pumping test consisted of three steps as follows:

- A step-drawdown test conducted from January 25 through 27 to determine the pumping rate needed to maintain groundwater elevation below the MSD subdrain invert. The step-drawdown test consisted of pumping at four different pumping rates (9, 30, 61, and 92 gallons per minute), with a total pumping time of 329 minutes.

- A 73.5-hour pumping test starting on February 1, 2010, at a pumping rate of 90 gallons per minute. The pumping rate was determined based on the step-drawdown test data.

- Monitoring of groundwater recovery from February 4 through 10, 2010.

A summary of pumping test results and estimates of aquifer transmissivity were included in the Draft Final 2010 Metro Storm Drain (MSD) Sub-Drain Pumping Test Technical Memorandum (Atlantic Richfield 2010f).

Significant conclusions included in the memorandum are as follows:

- Based on well logs, the aquifer test was conducted in a permeable gravelly layer approximately 15 feet thick underlain and overlain by less permeable materials.

- Response to pumping was observed in wells not completed in the middle gravel layer indicating some hydraulic connectivity between all layers monitored.

- Aquifer storativity was found to range from 0.0003 to 0.002. These storativity values are representative of a semi-confined to leaky confined aquifer.

- The calculated transmissivity ranged from 1,793 to 24,000 square feet per day with an average of 8,500 square feet per day. The calculated hydraulic conductivity values for the middle portion of the aquifer ranged from 130 to 930 feet per day with an average of 600 feet per day.

- Based on poor curve matching during data analysis, transmissivity estimates for the upper and lower portions of the aquifer were considered to be invalid.

- Based on derivative analysis, the pumping test characteristics were found to be consistent with an unconfined aquifer with delayed yield or secondary porosity/permeability.

Prior to conducting the aquifer test, the portion of the aquifer near the Parrot tailings had been described as relatively low hydraulic conductivity and low gradient (EPA 2006). A previous aquifer test in the area indicated a hydraulic conductivity on the order of 1 to 3 feet per day (Appendix B-7 PRP Group 2002). Due to observed contamination at depth beneath the tailings, a deep circulation flow path was visualized with ground water eventually rising toward the ground surface in the middle and lower reaches of the MSD (EPA 2006). The results of the aquifer test showed that the hydraulic conductivity of the aquifer in this area is significantly higher than previously estimated.

Overall, the aquifer physical characteristics and response to pumping did not precisely match any of the numeric models evaluated during data analysis primarily because of the lack of an aquiclude below the pumped layer. Generally, the alluvial aquifer can be described as multiple layers each having contrasting transmissivities. All layers appear to be interconnected with evidence of delayed response.

2.1.4 Data Management

Ground water data collected under the BPSOU GWMP are managed by Atlantic Richfield, the primary data generator. The 2007 GWMP required development of a data management plan addressing the following elements:

- Electronic format of data packages;
- Database management;
- Data accessibility;
- Quality control procedures; and
- Roles and responsibilities of system managers and data users.

Currently, a data management plan specific to ground water monitoring has not been approved. Data management is conducted in accordance with Clark Fork River Standard Operating Procedures.

The largest generator of ground water data at BPSOU is Atlantic Richfield. Two general types of data are generated: discrete data associated with sampling and analysis and monthly manual water level measurements, and continuous data such as water levels collected by automatic loggers. The data are evaluated for quality in accordance with standard operating procedures and entered into Microsoft Access databases maintained by an Atlantic Richfield contractor. Data access is provided by request from data users and production of a data package specific to the request.

Occasionally, ground water data are generated by other entities. MBMG maintains data loggers in some wells pertinent to BMFOU and conducts discrete investigations at the request of DEQ or Natural Resources Damage Program. Examples of recent investigations include installation of wells and ground water sample collection in the Parrot Tailings area; collection and analysis of ground water samples for geochemical analysis; and collection and analysis of samples from new wells installed in 2010. Data collected by MBMG are available from the investigators or online from GWIC.

As a part of required ground water monitoring for BMFOU, MBMG collected ground water data from select wells within BPSOU. Monitoring data are available from the investigators or online from GWIC.

Currently, Atlantic Richfield and MBMG databases are maintained separately; however, for the purposes of this report, EPA has combined selected data for analysis as presented in Section 3.4.2.

2.1.5 MSD Subdrain Load Monitoring

The ROD requires load monitoring to ensure that the subdrain operates as expected and is not fouling or clogging. In addition, the monitoring data are to be used to determine if the pumping rate properly matches the groundwater collection rate and that contaminated water is not re-entering the aquifer near the pump vault. The GWMP required development of a load monitoring plan to establish procedures and schedules for tracer tests and standard water sampling.

A load monitoring event using tracers was conducted in 2009. The results are presented in the Draft Final Metro Storm Drain 2009 Tracer-Dilution Study Technical Memorandum (Atlantic Richfield 2010c). In addition to tracers, load measurements were conducted using portable flow meters and conventional sampling in 2009 and previously in 2005. Precision of measurements proved difficult to evaluate, because water can flow into and out of the central perforated pipe and flow through the gravel portions of the subdrain. It is not currently possible to measure the flow in the gravel. This investigation concluded that alternative methods of measuring flows and loading would be equally effective and easier to implement than dye tracer methodology. Dye tracer monitoring is no longer recommended.

A load monitoring plan has not been prepared to date; however, changes to the MSD subdrain are being implemented. Cleanouts where previous sampling and flow measurements were conducted are being removed and replaced with manholes. Manholes have been installed at two locations and included wing walls to force water out of the gravel and to flow through the manhole where is can be measured. Future measurements will be made at the manholes using permanent or temporary flumes or other conventional flow measurement devices. A load monitoring plan will be prepared following further installation of manholes and evaluation of flow devices.

2.2 Ground Water Remedial Design Activities

In addition to activities associated with the ground water management program, additional activities have occurred as a part of RD.

2.2.1 MSD Subdrain Isolation Study

Load monitoring in the MSD subdrain determined that the lower reaches are characterized by high ground water inflow with apparently low COC concentrations. However, the sampling methodology lacked precision to determine how low the concentrations were in this area. If the concentrations were low enough to not adversely affect surface water, the subdrain could be adjusted to focus on the highly contaminated ground water and allow relatively clean ground water to remain in the aquifer. By not collecting relatively clean ground water, less capacity at the treatment plant is used that capacity may be more useful for other purposes.

To more accurately evaluate ground water concentrations and loading in the lower MSD subdrain, a MSD subdrain pilot study was designed to determine if groundwater collection from the lower reach of the subdrain could be purposefully limited. *The Draft Final 2010 Metro Storm Drain (MSD) Sub-Drain Isolation Test Phase III Pilot Study Work Plan* (Atlantic Richfield 2010d) establishes procedures for conducting this pilot test.

The isolation test proposed utilizing two previously installed groundwater isolation lines extending downstream of manhole MH-MSD-108, and abandoning a similar upstream isolation line. A plug was installed in the main MSD outlet pipe from MH-MSD-108, and the downstream flow was subsequently plugged. The upstream water collecting in MH-MSD-108 was then pumped directly to the MSD vault via the isolation lines.

The MSD isolation test has been completed and summary report of the MSD isolation test results is in process.

2.2.2 Area between MSD and LAO Capture Systems

Analysis of ongoing surface water monitoring data identified copper loading that appeared to be a results of ground water inflow between the MSD capture system and the LAO capture system. Additional surface water sampling was conducted in 2008 to verify the results and identify the location of ground water inflow. The additional sampling identified two locations where potentially contaminated ground water appeared to be entering Silver Bow Creek: 1) within slag canyon just upstream of the bridge from the asphalt plant and 2) just below the bridge along the slag tunnel.

Samples were collected in the seepage areas as a part of surface water monitoring. The upstream seepage was blue in color, but contained low concentrations of copper and elevated arsenic concentrations. The lower seepage contained significantly elevated copper concentrations and appeared to be the source of copper loading in Silver Bow Creek.

2.2.2.1 Blue Water Seep

Further investigation of the blue water seep included excavating a pit north of the slag wall (WET 2010). The excavation revealed visually identifiable tailings and a wooden culvert penetrating the slag wall and allowing water to flow to Silver Bow Creek. The culvert was plugged with concrete and the tailings were left in place. Because the seep sample did not contain significantly elevated metals concentrations, the tailings did not appear to be affecting water quality measured at the blue water seep.

2.2.2.2 Slag Tunnel Seep

The lower seepage was investigated in two phases. The first phase involved detailed monitoring of ground water and surface water elevation and quality while manipulating ground water levels in Butte Reduction Works (BRW) north of Silver Bow Creek. Details of the activities and results were presented in the Surface and

Ground Water Manipulation Investigation Butte Reduction Works (Atlantic Richfield 2010e). This investigation concluded that reversing the ground water gradient so that water flows away from the stream results in an improvement in surface water quality. Reestablishing a gradient toward the stream resulted in degradation of surface water quality. Additionally, highly contaminated ground water was confirmed in the vicinity of the slag tunnel including in the seep. In short, the investigation indicated that contaminated ground water in the BRW area seemed to be impacting surface water quality.

2.2.2.3 BRW Test Pits

Further investigation of the slag tunnel seep was conducted by excavation of five test pits in the BRW area. Sampling focused on areas immediately adjacent to the slag wall and the slag and concrete tunnel where waste may have been left behind during the LAO Expedited Response Action. Significant tailings were encountered in three of the test pits and analyses indicated elevated concentration of arsenic, copper, lead, and zinc (Atlantic Richfield 2010g). Additionally, ground water was encountered in the test pits and minor copper plating was observed on the bucket of the excavator indicating significant ground water contamination. Cumulatively, these investigations impart the following information:

- Tailings containing elevated arsenic and metals are present in the BRW area.
- Highly contaminated ground water is present near the tailings.
- There is a relationship between the ground water gradient and surface water quality.

2.2.2.4 Extension of the LAO Capture System

Ground water monitoring program element number 10 requires additional capture and hydraulic control of ground water if contaminated ground water inflow is identified in the area between the capture systems that adversely affects surface water quality. As a result, a preliminary design for extension of the LAO capture system to the slag tunnel area has been prepared and approved (Atlantic Richfield 2010g).

The overall design of the extension of the capture system is to enlarge an existing pond in BRW and excavate a new pond near the slag tunnel. The BRW ponds are below the water table and direct flow to the HCC for treatment at BTL. The ponds are to be connected via a culvert or siphon with controls for adjustment of the ground water level in the ponds. Based on field observations, the ponds and culvert have been installed, but construction is not fully complete. Completion and data collection is expected to continue in 2011.

2.2.2.5 Preliminary Results

Based on information presented in a technical meeting, the new BRW ponds were partially operational in December 2010 when a surface water base flow monitoring event was completed. Based on this single data set, metals concentrations in Silver

Bow Creek near the slag tunnel did not increase as previous data had shown. This indicates that ground water inflow was not adversely affecting surface water during sampling. Further operation and monitoring is ongoing.

2.2.3 Ground Water Fingerprinting

In an effort to better understand sources and fates of contamination in the MSD area, samples were collected synoptically from numerous wells and analyzed for a wide variety of elements and constituents. The samples were collected and analyzed by MBMG at the request of Atlantic Richfield. The data have been subjected to various geochemical and statistical models in an effort to correlate sources and downgradient wells to develop a conceptual model of fate and transport. Currently, no reports prepared by Atlantic Richfield have been finalized and a summary of draft reports is not appropriate at this time because of anticipated revisions. Analysis of the data by CDM is provided in Section 3.3.3 and Appendix A.

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Section 3 Data Analysis

Ground water data collected since 2007 has been analyzed for specific investigations such as the MSD Loading Investigation, the Upper MSD Pumping Test, and fingerprinting. Significantly less evaluation has been conducted on the data from ongoing ground water monitoring. The following sections present analysis of select ground water monitoring data with the intent of meeting the overall goals of the GWMP:

- Ensure that ground water capture and treatment systems are effective;
- Determine that contaminated ground water is not leaving the TI Zone or discharging to surface water to the extent that it contributes to the ground water remedy being not protective of surface water;
- Provide additional information as necessary on the movement, quality, and quantity of ground water to assure that ground water contamination plumes are not spreading and ground water quality is not degrading; and
- Provide data for review of the ground water remedy.

The goals are evaluated in the following sections.

3.1 Effectiveness of Capture and Treatment Systems

Two ground water capture systems (the MSD capture system and the LAO capture system) and one treatment system (Butte Treatment Lagoons) are currently operational at BPSOU.

Effectiveness of the capture systems is measured in multiple ways. The purpose of the systems is to prevent contaminated ground water from impacting surface water quality; therefore, the direct method of determining effectiveness is to review surface water data downstream of the capture systems.

3.1.1 MSD Capture System

3.1.1.1 Surface Water Impacts

A review of the data was presented in the 2008 Surface Water Characterization report (EPA 2008). In the report, data were presented that indicated metals were slightly impacting surface water near the mouth of MSD, specifically at sampling station MSD-OUT, during base flow conditions from 2005 to 2007. The impact was small and did not significantly contribute to exceedances of RGs. During that period, the water level in the pump vault at the end of the MSD subdrain was maintained at or above the invert of the subdrain pipe as it entered the vault. Because of this configuration it was possible for some water to dam in the subdrain and bypass the vault.

As a part of upgrades to the pumping vault, the pumping level was changed in early 2008 to below the invert of the subdrain pipe. Monitoring data at MSD-OUT show that cadmium and zinc concentrations have decreased significantly since 2007 (See Figure 3-1).

Direct impacts to Silver Bow Creek near the MSD subdrain pump vault can be evaluated by evaluating increases in metals loading from surface water stations SS-04 and SS-05. Gains and losses between SS-04 and SS-05 for dissolved copper and zinc for 2008 and 2009 are shown on Figure 3-2. Net metals loading calculations indicate that there is not a consistent gain or loss of copper or zinc between SS-04 and SS-05. Cadmium is not detectable in base flow samples at these stations.

Two ground water methods are available to evaluate effectiveness of the MSD capture system: monitoring of COC concentrations in wells and delineation of hydraulic capture using ground water elevations.

3.1.1.2 Hydraulic Capture Zone

As discussed in Section 2.1.1, water levels have been monitored monthly since 2007. Impacts to surface water are more likely when the surface water is low and annual ground water sampling occurs in the fall. To evaluate hydraulic capture, a water table map is needed. October 2010 water elevations from BPSOU were combined with water elevation data from BMFOU and Montana Pole. All three sites use a common elevation datum of NAVD29, but well surveys have not been coordinated and some variation in well measuring point elevations is expected. Variations are expected to be less than 1 foot between sites.

Using only elevations from shallow wells, a site wide water table map was constructed and is presented on Figure 3-3. The water table contours for October 2010 near the MSD subdrain are shown on Figure 3-4. The contours represent equal elevation of the water table and ground water flows perpendicular to the contours. The V-shaped contours along the subdrain clearly show that ground water is influenced by and flows toward the subdrain. The closed contours near well BPS07-03 indicated a low area in the water table where ground water flows from all directions toward the subdrain. West of the pump vault, a ground water divide exists that marks the limit of ground water capture. At a ground water divide, flow splits into two directions and the water table becomes somewhat level. Demarking the actual divide is difficult because of the relatively level water table. May 2010 contours are shown on Figure 3-5 and the divide may be near BPS07-07 and BPS07-23. Based on the same data, the contours may be drawn somewhat differently and the divide could be placed east or west of these wells. Although the precise location of the divide is difficult to identify, the existence of a divide indicates that a capture zone exists around the pump vault and extends east, north, and south. Generally, it appears that the shallow ground water in the TI Zone east of the pump vault is being captured by the MSD subdrain.

The vertical extent of the capture zone is more difficult to delineate. Well pairs and triplets near the pumping vault indicate an upward gradient. Results of the aquifer test in the upper MSD area indicated that the aquifer is layered with all layers connected, but having different hydraulic properties. The hydraulic properties of the aquifer near the pumping vault have not been fully characterized and delineation of the vertical extent of capture cannot be accurately obtained using the available data. Based on the upward gradient and interconnection of the aquifer, some ground water beneath the subdrain is being captured, but the depth of capture is uncertain.

3.1.1.3 Ground Water Quality Monitoring

Monitoring wells near the pumping vault evaluate changes in ground water quality and detect if contaminated water collected in the subdrain is being released back into the ground water. Wells around the pump vault have only been sampled two to four times, so no trends can be evaluated. Dissolved metals data from October 2010 for wells near the pump vault are shown in Table 3-1. Based on the data, well BPS07-03 located south of the subdrain is slightly elevated in cadmium, copper, and zinc, but concentration are significantly lower than water within the subdrain measured at cleanout 10 (MSDCL-10). Well BPS07-21A is also south of the subdrain and is slightly elevated in zinc. The significantly lower metals concentrations in these wells than the water in the subdrain indicate that there is not a major outflow of collected water into the aquifer south of the subdrain.

Table 3-1
Dissolved Metals in Ground Water near Pump Vault
October 2010

Well	Cadmium µg/L	Copper µg/L	Zinc µg/L	Location
BPS07-03	1.1	10	216	Adjacent to subdrain near cleanout 10
BPS07-21A	0.13	0.42	432	Southwest of subdrain terminus
BPS07-22	29	322	1,840	Northwest of subdrain terminus
BPS07-07	0.23	1.8	56	Near ground water divide
BPS07-23	<0.02	0.28	29	Near ground water divide
MSDCL-10	46.5	2,380	9,460	Last sampling point in subdrain

µg/L = micrograms per Liter

Well BPS07-22 northwest of the subdrain is elevated in cadmium, copper, and zinc. The only other sample collected from this well was in November 2009 and the metals concentrations were significantly higher: cadmium – 878 micrograms per liter (µg/L), copper – 6,140 µg/L, and zinc – 52,700 µg/L. The significantly higher metals concentrations in previous samples than water in the subdrain indicate a local source of contamination. BPS07-22 is located within an area of delineated waste referred to as the Lower MSD Tailings and the metals concentrations in ground water at this well are consistent with contamination from tailings. Based on Figure 3-5, the direction of ground water flow from well BPS07-22 appears to be toward the subdrain.

Metals concentration in wells BPS07-07 and BPS07-23 near the ground water divide are low indicating minimal to no impact from tailings. These wells are in an area that is a possible pathway for flow if contaminated water were to escape the subdrain. The lack of metals contamination in the wells indicates that collected water from the subdrain has not exited the capture system and impacted this location.

Collectively, the water quality data do not indicate a significant excursion past the pump vault at this location. Combined with the lack of surface water impacts and the hydraulic indication of capture, the data indicate that the MSD capture system appears be adequately preventing contaminated ground water within the TI Zone in the MSD area from significantly impacting to surface water at this time.

3.1.2 LAO Capture System

3.1.2.1 Surface Water Impacts

A review of surface water data near the end of the LAO capture system was presented in the 2008 Surface Water Characterization report (EPA 2008). In the report, data indicated that dissolved metals concentrations that were not attributed to a known source were increasing from surface water station SS-06G to SS-07 during base flow conditions from 2005 to 2007. The report suggested that the increase may be due to dissolution of suspended metals or a ground water inflow. The impact was small but contributed to slight exceedances of RGs for copper in surface water.

In 2010, more detailed surface water sampling was conducted in the reach from SS-0G to SS-07.

3.1.2.2 Hydraulic Capture

The LAO capture system is comprised of the HCC that collects ground water between BRW and the west end of the site. Ground water flows in the channel to cell D4 of the LAO lagoon system. Cell D4 is the lowest point in the collection system and all collected water flows to the cell and is pumped to the lime treatment plant for treatment. Cell D4 is normally operated at an elevation of 5,414 to 5,414.6 feet.

Since 2007, three new monitoring wells have been installed near the downgradient end of the LAO capture system. Additionally, monthly water level measurements have been collected since late 2007. To determine if hydraulic capture is occurring in LAO, select water elevation data were compiled and plotted. To evaluate the water table and the general direction of ground water flow at the water table, water elevations from shallow wells, ponds, the HCC, and Silver Bow Creek were selected for contouring. A range of conditions was evaluated including low water table in winter and high water table in spring and conditions in between during fall of 2010.

Water table elevations were designated by assuming wells as points, ponds as equal elevation surfaces, and the HCC as a line with elevations interpolated between stage locations. Stage locations in Silver Bow Creek were assumed to represent the water table and were used as points. Contours were generated using the 3D Analyst package of ArcView followed by smoothing. The most complete data sets were May and October 2010. The highest water table conditions generally occur May to July, so May is representative of a high water table. October 2010 is representative of base conditions occurring the rest of the year.

Contours for May 2010 in LAO are shown on Figure 3-6. Water table contours for October 2010 are shown on Figure 3-7. In the east half of LAO, water table elevation contours generally indicate that ground water flows toward the HCC. The contours cross the meandering Silver Bow Creek suggesting that the stream has less influence on water table contours than does the HCC.

In the eastern portion of LAO generally near the slag canyon, water table contours appear to be influenced by Silver Bow Creek between SS-05 and SS-05A. The HCC does not extend to this area and the V-shaped bends in the water table contours suggest that the Silver Bow Creek channel affects the water table in this area.

South of LAO, the Montana Pole capture systems influence the water table indicating groundwater is collected, treated, and discharged to surface water.

Around the treatment lagoons, the direction of ground water flow is less clear. The nine treatment ponds (A-1, A-2, A-3, B-1, B-2, B3, C-1, C-2, and C-3) are unlined and have a surface elevation higher that the adjacent HCC. Additional collection ponds (D2 and D3) are also maintained with a surface elevation below the adjacent treatment ponds and Silver Bow Creek. The water table maps assume that the water surface in the unlined ponds equals the water table elevation. As a result, ground water contours are strongly controlled by the edges of the ponds. Detailed water table maps near cell D4 for May and October 2010 are shown on Figure 3-8 and Figure 3-9, respectively.

Under high water table conditions in May 2010, cell D4, with an elevation of 5,414.54 feet is a low point in the area and it is surrounded by a 5,415-foot contour (see Figure 3-8). The Ranchland Packing pond west of cell D4 is significantly higher than the surrounding wells and HCC, and exerts considerable control over the water table and direction of ground water flow. Other ponds are also present with similar elevation, but none are monitored. Because cell D4 represents a low point and Silver Bow Creek at and downstream of SS-07 is also a low point, a ground water divide exists between these locations. The ground water divide is generally in the area shown by well BMW-03A and the end of the HCC shown as a purple line on Figure 3-8. Northeast of this divide ground water is captured by cell D4 and southwest of this divide ground water flows to Silver Bow Creek. Based on the water table contours for May 2010, cell D4 captures the vast majority of shallow ground water in this area during annual high water conditions. Vertical capture is discussed in Section 3.1.2.3.

Water table contours for October 2010 at relatively low water conditions are presented on Figure 3-9. Similar to May 2010 conditions, cell D4 represents a low area as does Silver Bow Creek at and below SS-07. The resulting ground water divide is again located near BMW-03A and the end of the HCC. The Ranchland Packing pond remains higher than the surrounding wells and controls ground water flow west of the HCC. Based on the water table contours for October 2010, cell D4 captures the vast majority of shallow ground water in this area during moderately low water conditions.

Lowest water conditions occur in January to February. Water table contours from January 2010 are shown on Figure 3-10. Because of cold weather, several wells and ponds were frozen reducing the data available for contouring. As a result, the divide between cell D4 and Silver Bow Creek is less well-defined. Cell D4 still represents a low point and ground water capture is evident, but the data are less definitive than in Figure 3-8 and Figure 3-9.

Cross-sections of water table measurements made in 2010 are shown on Figure 3-11. The cross-sections include shallow wells BPS07-17A and BPS07-18A as the left (west) end and cell D4 as the right (east) end. The upper cross-section passes through the HCC at point HCC-7 while the lower cross-section passes through well BMW-03A. Both sections indicate a ground water divide between BPS07-18A and cell D4.

3.1.2.3 Vertical Ground Water Potential

Wells completed below the water table near cell D4 range in depth from 35 to 196 feet and are completed in bedrock. Ground water elevation in bedrock wells less than 100 feet deep for October 2010 is shown on Figure 3-12. Significantly less data are available than for the water table, so the bedrock aquifer potentiometric surface is not contoured. For October 2010, wells BMW-04B, BMW-03B, HCA-B1, and HCA-B2 have a similar water level elevation, indicating that the potentiometric surface between these wells is fairly flat resulting in little horizontal flow. Well BMW-04B, adjacent to cell D4, has the lowest potentiometric elevation of the bedrock wells. All the bedrock wells have a higher potential than cell D4 indicating that an upward gradient exists in this area.

Bedrock water levels for May 2010 are shown on Figure 3-13. Conditions are similar with wells BMW-04B, BMW-03B, and HCA-B2 having a similar water level elevation. Again, cell D4 is lower indicating an upward gradient.

3.1.2.4 Ground Water Monitoring

Dissolved metals concentrations for October 2010 are shown in Table 3-12. All wells except for BPSOU07-18A, BMW-03A, and BMW-03B are contaminated with at least one exceedance of ground water RGs shown as bolded in the table. Since an RAO is to prevent ground water discharge that would lead to violations of surface water ARARs, surface water standards are relevant at this location. Exceedances of surface water standards are shown as underlined in the table. The relevant surface water standard is the chronic aquatic life standard. All wells except BMW-03B exceeded the chronic aquatic life standard for zinc.

Table 3-2
Ground Water Quality in Wells near Cell D4

Well	Screen (feet)	Cadmium (µg/L)	Copper (µg/L)	Zinc (µg/L)
		Water Table Wells		
NW-03	9-14	**8.14**	81.5	240
GS-26	9-14	**27.9**	**2090**	**9800**
BPS07-17A	8-18	**17.7**	105	**5280**
BPS07-18A	8-18	3.5	12	1570
BMW-03A	14-19	<0.032	1.02	793
		Bedrock Wells		
HCAB-02	25-35	<0.023	1.41	1870
BPS07-18B	29-39	0.053	3.18	**6930**
HCAB-01	40-50	**58.2**	1260	**25700**
BMW-06B	59-79	**80.4**	**4410**	**24800**
BMW-03B	36-50	0.191	2.48	38.2

Bold = Exceedance of ground water RG. Underlined = Exceedance of surface water standard.
µg/L = micrograms per Liter.

Ground water quality at the west end of LAO has historically been poor and the monitoring results shown in Table 3-2 are typical. The purpose of the LAO ground water capture system is to prevent contaminated ground water from leaving the site and impacting surface water. Assuming that the ground water divide shown on Figure 3-8 represents the limit of ground water capture, wells BPS07-18A and BPS07-18B are likely to represent quality of ground water not captured. Except for zinc, ground water quality at these wells meets ground water RGs.

Cadmium, copper, and zinc data from 2007 to 2010 for shallow wells in the cell D4 area are shown on Figure 3-14, Figure 3-15, and Figure 3-16, respectively. There is some variability in the results, but no trends are obvious. Cadmium, copper, and zinc data for the bedrock wells near cell D4 are shown on Figure 3-17, Figure 3-18, and Figure 3-19, respectively. Again, no trends are obvious. Although only 4 years of data were used, the time-series plots indicate that ground water quality around cell D4 is not changing significantly.

3.2 TI Zone Perimeter Monitoring

The alluvial aquifer TI zone was established in the BPSOU ROD as shown on Figure 2-1and Figure 3-3. The perimeter was based on limited data and additional wells were drilled in 2007 and 2008 to better define the boundary. New wells included BPS07-01A, BPS07-01B, BT-98-02B, and AMW-13B. Following sampling of these and exiting wells BT-98-2 and AMW-13 in 2007, it was discovered that well BT-98-02 slightly exceeded the ROD performance standards for cadmium and zinc (see Table 3-3). To more accurately define the TI zone boundary, additional wells were drilled including BPS07-16a, BPS07-16B, BPS07-05A, and BPS07-05B south of the ROD TI Zone boundary. The new wells do not exceed ROD performance standards and were included as TI Zone perimeter monitoring wells.

In accordance with the 2007 BPSOU Interim Ground Water Monitoring Plan, TI Zone perimeter wells have been sampled annually in the fall since 2007. Data for the five COCs with ROD performance standards are shown in Table 3-3. No exceedances of standards have occurred for the four sampling events shown. Because only four annual events have been completed, no trend evaluation has been completed at this time.

MBMG has sampled some of the TI Zone boundary wells for purposes other than compliance monitoring. The data are included in Table 3-3 and show no exceedances of performance standards.

Based on the additional data collected since the ROD was prepared, the southern limit of the TI zone near wells BT-98-02 and BPS07-16A has changed. This change is not significant and does not represent a threat to human health or the environment. It does however indicate a change should be made to the TI Zone boundary. This change should be reflected in a ROD modification.

Table 3-3
TI Zone Perimeter Well Monitoring Results since 2007 (µg/L)

Location	Date Sampled	Source	Arsenic	Cadmium	Copper	Mercury	Lead	Zinc
AMW-13	12/21/2007	AR	0.435	2.85	11.8	0.01449	0.045	454
AMW-13	10/2/2008	AR	2.9	2	8	0.1	0.05	610
AMW-13	11/6/2009	AR	1.9	2.4	13	0.1	0.05	225
AMW-13	4/16/2010	MBMG	6.59	0.582	3.65	NR	<2.5	190
AMW-13	8/11/10	MBMG	0.70	3.58	27.80	NR	<0.20	1,061
AMW-13B	12/17/2007	AR	3.44	0.177	2.43	0.243	0.086	30.8
AMW-13B	12/17/2007	AR	3.59	0.231	2.36	0.031	0.045	30.8
AMW-13B	9/4/2008	AR	3.3	0.32	1.4	0.1	0.05	32
AMW-13B	10/8/2009	AR	3.8	0.45	1.7	0.1	0.05	33.7
AMW-13B	4/16/2010	MBMG	3.28	0.253	1.24	NR	<0.5	23.8
AMW-13B	8/10/2010	MBMG	3.53	0.278	1.18	NR	<0.20	24.3
AMW-13C	05/28/10	AR	4.47	2.76	0.88	NR	<0.055	325
AMW-13C	6/2/10	MBMG	5.00	2.56	0.97	NR	<0.15	293
AMW-13C	8/10/10	MBMG	5.35	2.62	1.84	NR	<0.20	287
BPS07-01A	12/19/2007	AR	3.36	0.026	2.23	0.01449	0.105	15.4
BPS07-01A	9/3/2008	AR	1.5	0.074	1.6	0.1	0.05	45
BPS07-01A	10/8/2009	AR	3.2	0.2	1.3	0.1	0.092	2.5
BPS07-01B	12/19/2007	AR	1.45	0.026	3.22	0.025	0.045	47.5
BPS07-01B	9/3/2008	AR	2.3	0.05	1.2	0.1	0.074	2.8
BPS07-01B	10/8/2009	AR	1.7	0.21	1.9	0.1	0.05	51.6
BPS07-05A	9/3/2008	AR	7.1	0.16	2	0.1	0.05	4.2
BPS07-05A	10/8/2009	AR	9.8	0.23	2.3	0.1	0.05	2.5
BPS07-05B	9/3/2008	AR	0.53	0.097	0.67	0.1	0.05	4.4
BPS07-05B	10/8/2009	AR	0.64	0.2	1	0.1	0.097	4.9
BPS07-16A	9/3/2008	AR	1.8	0.32	3	0.1	0.05	130
BPS07-16A	10/8/2009	AR	1.9	0.42	2.1	0.1	0.05	146
BPS07-16B	9/3/2008	AR	2	0.62	4.4	0.1	1.4	27
BPS07-16B	10/8/2009	AR	1.5	0.53	0.52	0.1	0.05	24
ROD Standard			10	5	1300	2	15	2000
Exceedance of Standard			0	0	0	0	0	0

AR = Atlantic Richfield

Table 3-4
Former TI Zone Perimeter Well Monitoring Results

Location	Date Sampled	Source	Arsenic	Cadmium	Copper	Mercury	Lead	Zinc
BT-98-02	12/21/2007	AR	0.888	4.66	7.73	0.03	0.047	1750
BT-98-02	4/24/2008	AR	1.35	**6.14**	5.29	0.01449	0.591	**2280**
BT-98-02	4/24/2008	AR	1.75	**6.2**	6.76	0.01449	0.591	**2350**
BT-98-02	9/3/2008	AR	1	**5.3**	5	0.1	0.05	**2200**
BT-98-02	10/8/2009	AR	1.2	**7**	5.8	0.1	0.05	**2550**
BT-98-02B	1/15/2008	AR	0.723	2.33	3.43	0.01449	0.15	84.5
BT-98-02B	9/3/2008	AR	0.69	1.7	1.8	0.1	0.05	68
BT-98-02B	10/8/2009	AR	0.83	1.9	2.4	0.1	0.05	78.2
AMW-11	2/11/2011	MBMG	**15.4**	0.74	1.19	--	1.04	121
ROD Standard			10	5	1300	2	15	2000
Exceedance of Standard			0	4	0	0	0	4

3.3 Additional Information

3.3.1 Investigation of the Middle Gravel

As described in Section 2.1.2, several investigations have been conducted since completion of the ROD and a better understanding of the significance of the middle gravel can now be described. Prior to conducting the aquifer test, the portion of the aquifer near the Parrot tailings had been described as relatively low hydraulic conductivity and low gradient (EPA 2006). A previous aquifer test in the area indicated a hydraulic conductivity on the order of 1 to 3 feet per day (Appendix B-7 PRP Group 2002). Due to observed contamination at depth beneath the tailings, a deep circulation flow path was visualized with ground water eventually rising toward the ground surface in the middle and lower reaches of the MSD (EPA 2006). Work conducted by MBMG suggested that a higher hydraulic conductivity gravel bed was present in the aquifer that may create an additional flow path with faster contaminant travel rates.

The middle gravel was described by Metesh and Madison (2004) as follows: "*The intermediate ground-water, 40 to 60 feet below ground surface, flows through discrete layers of gravel and sand with minor silt and clay. In the upper part of the drainage, this flow system is dominated by a continuous layer of coarse gravel; in the lower part of the drainage, the coarse gravel apparently grades to a fine gravel.*" This was based on lithology encountered in a line of wells from GS-41D to MSD-03. It was further described as having fairly high concentrations of dissolved constituents.

An aquifer test was conducted in this unit in 2010. Monitoring well AMW-01B was selected as the pumping well, because its construction was amenable for pump installation and it was within the identified middle gravel area. A summary of the test and results are presented in Section 2.1.3. Generally, the aquifer test indicated that the middle gravel has a high transmissivity. Additionally, boundary conditions were not encountered demonstrating the middle gravel has significant lateral extent. Wells completed in the alluvium deeper and shallower than the middle gravel also showed response to pumping indicating that confining layers are not continuous. Comparison to type curves indicated that the aquifer type is leaky or multi-layer with leaky interbeds.

Since initial identification of the middle gravel, several additional wells have been completed in an effort to delineated the downgradient limit of the contamination within the gravel and improve understanding of the lithology in the lower MSD area. Wells MSD-04 and MSD-05 were installed by MBMG in 2004 and 2007, wells AMC-24B, AMW-13B, and BPS07-21B were installed by Atlantic Richfield in 2007 and 2009, and wells AMC-24C, AMW-13C, BPS07-21C, and BPS07-24 were installed by EPA in 2010. See Figure 2-1 for well locations.

Based on these new wells, the alluvium is generally finer grained in the lower MSD area than around the Civic Center. Identification of a gravelly layer with minor fines that correlates with the upper MSD is not readily made. Additionally, the degree of contamination in the aquifer is significantly lower such that definition of the middle gravel based on elevated concentrations of dissolved metals is not possible.

A cross-section of wells from the Parrot Tailings to the eastern part of LAO is shown on Figure 3-20. Well pairs and triplets are shown where available. Because of the variety of drilling techniques used, the sample quality and resulting lithologic descriptions are inconsistent making correlation difficult between wells. On the cross-section, the lithology has been simplified to emphasize grain size. Well screens are also shown on the cross-section along with zinc concentrations from October 2010. Water table and potentiometric elevations are shown in text for each well and the water table is shown as a blue line.

Wells from GS-41D to MSD-03 were completed in the middle gravel. Screens and zinc concentrations show a general correlation between the orange lines on the cross-section. The lithologic descriptions within this area include gravel as a major component. GS-42D is completed deeper and gravel is not identified within the screened interval, but the zinc concentration is consistent with the middle gravel and it responded to pumping. On this basis, GS-42 may be completed below the middle gravel, but is apparently hydraulically connected.

The middle gravel correlates to MSD-05 based on screened depth and zinc concentration, but gravel was not a major component of the lithology. Further correlation to GS-09 can be made based on zinc, but the lithologic descriptions for the well are sparse. Since GS-09 is only 180 feet from MSD-05, it is expected that the lithology is similar. The screen depth is lower than MSD-05 indicating that the contamination is spread vertically. BPS07-24 has an appropriate screened interval and zinc concentration as well as some gravel that is sufficient to correlate it with the middle gravel in other wells.

Wells further downgradient are not easily correlated to the middle gravel. Wells AMC-24B, AMW-13B, and BPS087-21B are too shallow to be correlated to the bedding of the middle gravel; however, AMC-24B contains somewhat elevated concentrations of zinc. Wells AMC-24C, AMW-13C, and BPS07-21C are completed at a more appropriate depth for correlation to the middle gravel and coarse sand or gravel was observed, but the contaminant correlation is lacking. The fine grained and coarser grained layers are not easily correlated between wells in this area. Based on well depth, elevation, and zinc concentrations, it is inconclusive if any of these six wells are completed in the middle gravel and are directly downgradient of the contaminant plume.

Vertical ground water gradients are shown on Figure 3-20. Generally, gradients are downward around the Parrot tailings. Ground water contamination has been carried from the shallower ground water in the tailings source area to the middle gravel as seen in well GS-41S. Within the middle gravel, contamination from this source has traveled as far as BPS07-24. Slight upward gradients from the middle gravel to the shallow ground water are present from wells AMW-01 to GS-09. At AMC-24, there is an upward gradient from the deeper well (AMC-24C) to the mid-level well (AMC-24B). Although the screened interval in AMW-024B is too shallow to be the same bedding layer as the middle gravel, the slight upward gradient and the lack of continuity of fine grained layer allows for the possibility that the contamination in AMC-24B may be related to that in BPS07-24.

The potentiometric surface of the middle gravel is shown on Figure 3-21. Only a few wells are completed in the middle gravel and most are aligned on the MSD. The limited water level data provide for contours of limited accuracy, especially at the west end of Figure 3-21. The data are too sparse to define a horizontal capture zone for the model gravel, but the direction of flow is generally parallel to the MSD.

3.3.2 Middle Gravel Water Quality

The wells completed within the middle gravel that appear to be along the axis of the metals plume consist (from upgradient to downgradient) of the following (see geologic cross section Figure 3-20):

- GS-41D (installed in 1989)
- AMW-1B (2004)
- MSD-1B (2004)
- MSD-2B (2004)
- MSD-3 (2004)
- MSD-5 (2004)
- GS-9 (1985)

- BPS07-24 (2010)
- AMC-24C (2010)

3.3.2.1 Middle Gravel - Spatial Trends

The analysis of spatial trends will be limited to the nine wells along the presumed path of the metals plume. The analysis of spatial trends will help to identify wells that may be off of the axis of the plume or otherwise anomalous. Figure 3-22 shows the spatial trend for the nine presumed on-axis wells for copper and zinc. The decrease in concentrations with distance from the Parrot Tailings is consistent for wells GS-41D, AMW-1B, MSD-2B (for copper), MSD-5, GS-9, BPSO7-24, and AMC-24C. Wells MSD-3 and MSD-1B are anomalously low in that they have lower concentrations than the next well downgradient within the series. The same anomalously low concentrations for these two wells are consistently observed for other sampling dates and parameters (see Figure 3-23 and Figure 3-24 for the July-August 2004 sampling event for copper and cadmium, respectively).

MSD-3 is either off axis or MSD-5 and GS-9 has been impacted by the local Diggings East Tailings. However, the groundwater gradient appears to be consistently upward in the area, which would preclude the transport of shallow tailings-impacted ground waters to the deeper middle gravel zone.

3.3.2.2 Middle Gravel - Temporal Trends

On-Axis Wells

Well GS-41-D

The trend for well GS-41-D appears to be consistently upward. The spike in copper and zinc for October 2009 appears to be anomalous. Copper concentrations appear to have increased from approximately 300,000 µg/L in 1990 to 1,110,000 µg/L for 2010, representing a threefold increase.

Such a trend is not unexpected, given the upward trend in the shallow well (GS-41S) and the downward groundwater gradient in this area (see Figure 3-26).

Well AMW-1B

The temporal trend for well AMW-1B is shown in Figure 3-27. The trend is generally flat, despite the relatively strong increasing trend for well GS-41D.

Well MSD-1B (possibly off axis)

Unlike wells GS-41D and AMW-1B, the trend for AMW-1B is clearly downward. Unfortunately, the well was not installed until 2004 (about the same time the MSD subdrain was installed), so it is unclear if the trend was caused by the changes in groundwater flow vectors initiated when the subdrain was brought on line. The fact that the well may be off axis is another possible explanation for the downward trend.

Well MSD-2B

The temporal trend for well MSD-2B is shown in Figure 3-29.

Neglecting the anomalously low point in May 2006, the trend is fairly flat. However, with the degree of variability in the data and the relatively recent installation of the well it is difficult to be sure.

Well MSD-3 (possibly off axis)

The temporal trend for well MSD-3 is shown in Figure 3-30.

The trends for MSD-3 are cyclical with both upward and downward trends since 2004. The cycles do not appear to be seasonal, as the times of the year when the highs and lows occurred were not consistent. However, as the trend appears to be regular (as opposed to an irregular and variable pattern dominated by alternating high and low spikes), the variations in concentration appear to have a specific cause, such as differences in precipitation in the recharge area (presumably the Parrot complex).

Well MSD-5

The trend plot for well MSD-5 is presented in Figure 3-31.

The trends for copper, zinc, and cadmium appear to be flat from 2004 through 2010. Cadmium was added to identify possible impacts from the Diggings East Tailings, which have a relatively high cadmium concentration compared to the Parrot metals plume. The variations for MSD-5 are not regular and are more “spikey” in nature, with no evidence of a seasonal trend.

Well GS-9

The trend plot for well GS-9 is presented in Figure 3-32.

The trends for copper, zinc, and cadmium, appear to be generally upward, although it is difficult to tell with the large gap in data between the late 1980s and 2004. There also appears to a seasonal trend in the data with highs in the summer and lows in the winter, which is unusual for a deep well. Interestingly, the same peaks occur, but in a more pronounced fashion, in well GS-11, which is the shallow well in the GS-11/GS-9/GS-8 triplet (Figure 3-33).

The final two wells in the series (AMC-13 and BPS07-24) were not installed until 2010, have too few data points to plot a trend, and are not considered in the temporal analysis.

3.3.3 Geochemical Fingerprinting

“Fingerprinting” is a process where information is derived from an evaluation of the chemical analyses for the waters at a site with the goal of deriving information about the sources of waters or the geochemical processes that are occurring. CDM performed a fingerprinting analysis using a different statistical approach from that employed by Atlantic Richfield (*Appendix C of their September 2010 Draft Technical Memorandum* Groundwater/Surface Water Conceptual Site Model*, prepared by Formation Environmental).* CDM used cluster analysis to group the ground waters and surface waters, while Atlantic Richfield used factor analysis and discriminant function analysis. A more detailed discussion of the fingerprinting analysis is provided in Appendix A, while a summary of the groupings is provided below.

Table 3-5
Summary of Cluster Analysis Groupings using April and August 2010 Data

Group	Description	Signature
1	Parrot wells, middle gravel wells near the Parrot, and the upper MSD subdrain	Very high in metals, low pH, very low alkalinity, and low molybdenum.
2	Surface water, BRW seep, lower MSD subdrain, and some visitor center and slag canyon area wells	Low in most constituents except molybdenum, which is comparatively high.
3	Lower middle gravel wells, North Side tailings, and Diggings East tailings wells	High calcium, sulfate, sodium, REDOX, copper, zinc, cadmium, and nickel. Very high strontium and moderate pH. Iron is low.
4	East Ridge wells, and wells between the East Ridge and the Parrot tailings.	High aluminum, REDOX, copper, cobalt, and cadmium. Low molybdenum, magnesium, and strontium.
5	Basin Creek/Blacktail Creek wells and miscellaneous wells from across the site	High alkalinity, zinc, molybdenum, and iron. Other metals and REDOX are moderate.
6	Summit Valley wells	High alkalinity, pH, and iron. Low REDOX.

The results are very similar to those obtained by Atlantic Richfield. Group 1 is similar to the "Parrot" group, Group 2 is similar to "Neutralized," Group 3 is similar to "2nd Tailings," Group 4 is similar to "East Ridge," and Group 6 is similar to "Summit Valley." Group 5 is a less definitive group, as the cluster is joined at a much greater distance than the other groups. Geographically, Group 5 locations are all across the site and can probably most accurately be described as samples that do not fit into the other groups for one reason or another. The fact that the lower middle gravel wells cluster with the North Side Tailings and Diggings East wells suggests that there is mixing between the lower middle gravel wells and the shallower wells that have been influenced by local tailings sources. The upward groundwater gradient and the poor seal for the GS-8/GS-9/GS-11 well cluster may also have resulted in localized vertical mixing.

3.4 Ground Water Level Trends

Ground water elevations were collected on a monthly basis during 2008 through 2010. For 2008 and 2010, the month containing the largest number of high water-level measurements in monitoring wells was June, and the month containing the largest number of low water-level measurements was December. A discussion of these trends related to the Parrot Tailings is included in this section.

3.4.1 Effect of Subdrain

Dewatering of the MSD subdrain began in April 2003 and the system reached equilibrium conditions in approximately January 2005. Time trend plots of ground water elevations and vertical gradients for several well nests near the subdrain were evaluated to determine the long-term effects of the subdrain on nearby ground water conditions. Data for the time trend plots were obtained from the GWIC database. Time trend plots may be affected by the following limitations:

The measuring point datum for some wells is uncertain and appears to be estimated in some cases. Therefore, the ground water elevations may be off by several tenths of a foot in some cases and vertical gradients may be correspondingly inaccurate. However, relative changes in elevations and gradients over time can still be evaluated.

Because of either the installation date of the wells or the lack of available data, pre-2004 data are not available for all wells. Therefore, not all trends can be evaluated vs. pre-startup conditions.

A summary of the time trend plots and brief discussion of trends is as follows:

GS-41-S/D (Figure 3-34**):** This well pair is located to the north of the MSD, near the Parrot Tailings area. Post-startup ground water levels have remained fairly consistent with pre-startup levels (the temporary increase of ground water elevations in the late-1990s is likely due to above average precipitation during that period). The vertical gradient is downward and has remained relatively stable throughout the monitoring period. Based on the data included in Figure 3-34, ground water in the area of this well pair appears to be minimally affected by the MSD subdrain.

GS-42-S/D (Figure 3-35**):** This well pair is located closer to the channel and to the southeast of GS-41 S/D. A slight decline in ground water elevations and vertical gradient appear to indicate MSD subdrain capture in the area of this well nest. The downward vertical gradient may also be an indicator that the deeper portion of the aquifer is also being dewatered.

AMW-A/B/C (Figure 3-36**):** This well triplet is located to the southeast of GS-42 S/D and near the subdrain. Ground water elevations in AMW-01A have decreased since startup. Pre-startup data are not available for comparison of the middle (AMW-1B) and deep (AMW-1C) wells. Post-startup vertical gradients within the well nest are fluctuating, and neither increasing/decreasing trends nor consistent upward/downward gradients were interpreted from the available data.

GS-30 S/D (Figure 3-37**):** This well pair is located to the south of the MSD. Ground water elevations in both the shallow and deep wells have declined post-startup. Vertical gradients in this well are variable. Given the relatively shallow total depth of well GS-30D (38.5 feet below ground surface), interpretations regarding the effect of the subdrain on the lower aquifer at this location cannot be made.

GS-8/9/11 (Figure 3-38**):** This well triplet is located to the south of GS-30S. Groundwater elevations in the middle (GS-9) and deep (GS-8) wells have generally declined post-startup. Pre-startup data for the shallow well (GS-11) were not available. There appears to be a slight upward gradient from the deeper portions of the aquifer to the shallow portion, although there is some fluctuation in these gradients. The gradient between the mid-level and deep well appears to be neutral and has remained fairly constant since startup.

GS-46-S/D (Figure 3-39**):** This well pair is located to the south and upgradient of the MSD, and is not expected to be significantly affected by the subdrain. The well pair is included for reference as a location that may be somewhat comparable to background conditions. Groundwater elevations and vertical gradient appear to be fairly comparable between pre-startup and post-startup conditions, with the exception of a drop in both over approximately the last year. Additional data are needed to confirm the cause of this drop and whether the declines represent a long-term trend.

3.4.2 Ground Water Divide in the Parrot Tailings Area

It has long been recognized that a ground water divide exists near the Parrot Tailings (e.g., Atlantic Richfield 1993 and EPA 2006). Northeast of the divide, ground water flows toward the Berkeley Pit and southwest of the divide, ground water flows along or into the MSD subdrain. The location of the divide has most often been delineated near GS-41s with more recent delineations centering on AMW-20 (Tucci 2010). In reviewing the data on which the ground water contours were based, there is a lack of consistency in the well list used to delineate the ground water divide. The most complete data set near the Parrot tailings is presented on Figure 13 of Tucci (2010) based on data collected on December 2, 2009. This map places the divide at AMW-20 and the adjacent water bodies referred to by Tucci (2010) as the Ecology Ponds. Tucci also presents water level data showing a rise in the water table related to filling of the ponds in 2003. The map shown on Figure 3-40 uses October 2010 data from multiple sources to contour the water table and delineate the ground water divide. This map is similar to Tucci's map in that AMW-20 is a high point and demarks the divide in the Parrot Tailings area. Filling of the ponds coincident with restarting of milling operations at Montana Resources in 2003 is readily observed as a rise in the water levels in AMW-20 (Figure 3-41 and Tucci 2010). It appears that operation of the Ecology Ponds may control the local water table.

Limited water level data for AMW-20 are not available before 2003; however, other wells in the vicinity have a longer history. Pertinent wells that form a cross section through the Parrot Tailings and the ground water divide include GS-42s, GS-41A, AMW-08, AMW-20, and AMC-05. Water levels in AMC-05 are significantly lower than in the other wells in this cross section and always lie on the northeast side of the divide. Water table elevation data collected since 1993 for the other wells along this cross-section are shown in Figure 3-41. The water table elevation is almost always highest in well AMW-20 indicating it is near the ground water divide for the dates when this well was measured. Wells AMW-08 and GS-41S show a lower water table than AMW-20 since 2004 indicating that they are on the southwest side of the ground water divide while the Ecology Ponds are being used.

The ponds adjacent to AMW-20 are referred to by Duaime and Tucci (2009) as the Emergency Ponds. In reviewing water level data for alluvial wells near the concentrator, they said: "*This pond received considerable input of fresh water prior to MR's start-up in the fall of 2003. The water level trend for 2003-2005 shown on figure 2-3 for this well [AMC-5] is similar to the trend seen in 1986-1987, which coincides with the startup of mining following ARCO's 1983 suspension of mining. It is apparent that filling the Emergency Pond with make-up water for milling operations has a considerable influence on alluvial water levels in the immediate area.*"

Recent operation of the MR Concentrator has occurred from 1986 to present with a shutdown period between July 2000 and September 2003. Figure 3-41 shows that all wells were declining from 1998 to 2003, because reduced precipitation caused the regional water table to decline. The effect of the concentrator shutdown can be seen on Figure 3-42 as the difference in elevation between wells AMW-08 near the ponds and GS-41S southwest of the ponds. During concentrator operations before 2001 and after 2003, the elevation difference in these wells is 0.5 to 1.2 feet. During the suspension period, the difference between these wells decreased to around 0.1 feet. This results in a shift in the ground water divide away from AMW-20 and toward GS-41S.

Figure 3-43 shows water levels along the cross section before (1994 to 2000), during (2001 to 2003), and after (2004 to 2010) the shutdown period. Water table elevations before and after the shutdown period show that AMW-20 is usually higher than the other wells indicating that the ground water divide is near or northeast of that well. During the suspension period, water levels from July 2002 and August 2003 indicate that GS-41S is higher than AMW-08. As a result, the ground water divide is shifted southwest of AMW-8 for these dates.

A complicating factor in evaluating water elevations in this area is the installation of the MSD subdrain beginning in 2004. This is expected to affect wells southwest of this cross section, but may also influence GS-42S. Comparing elevation differences from GS-42S to GS-41S before and after installation of the subdrain shows no significant differences except when the MR Concentrator operations were suspended. This suggests operation of the Emergency Ponds has a greater affect on the ground water gradient near the Parrot Tailings than installation of the MSD Subdrain.

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Section 4 References

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Figures

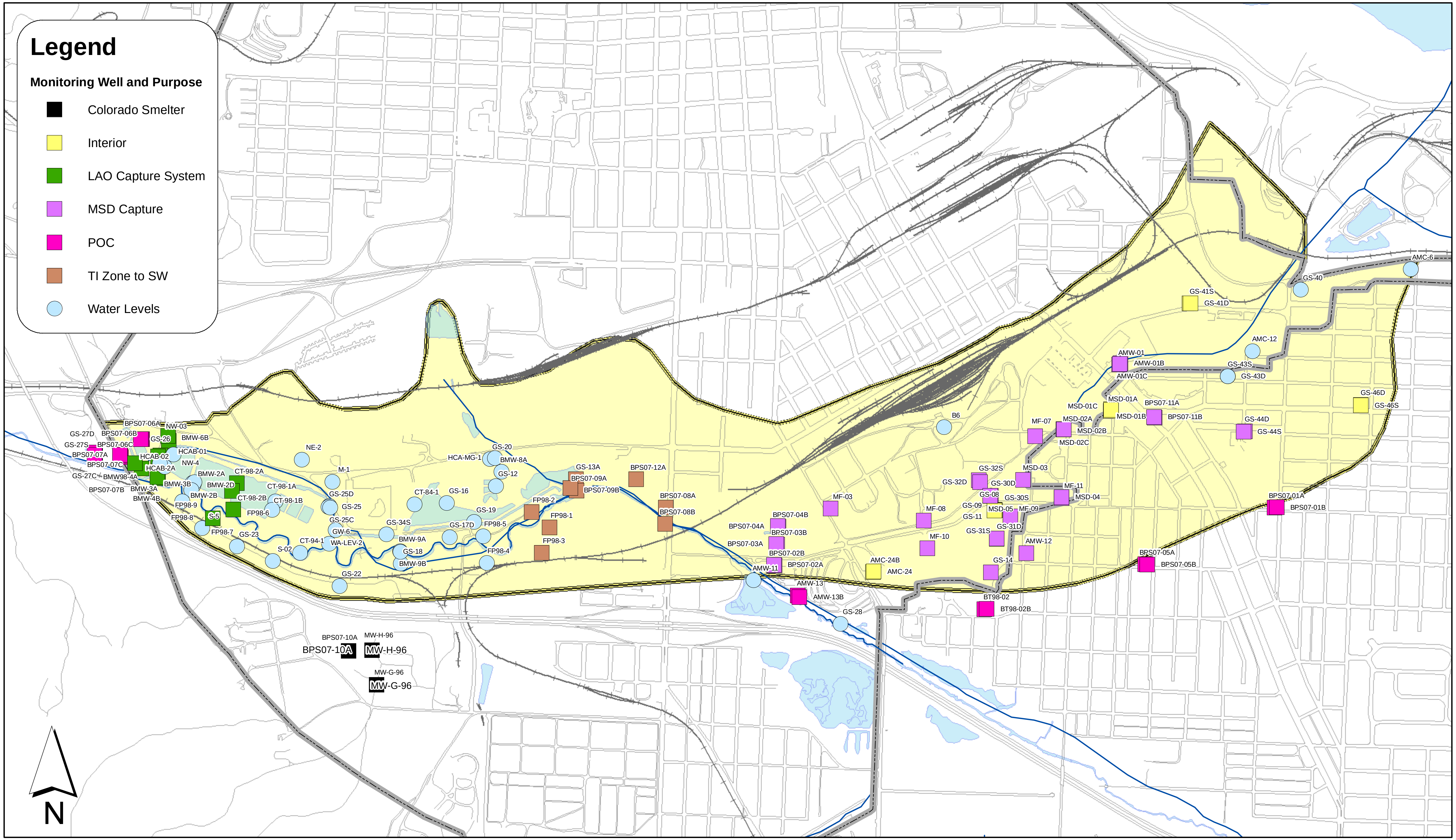


Figure 2-1
Ground Water Monitoring Wells

Butte Priority Soils Operable Unit

Silver Bow Creek / Butte Area NPL Site
Butte / Silver Bow County, Montana

Figure 3-1
Dissolved Metals at Station MSD-OUT

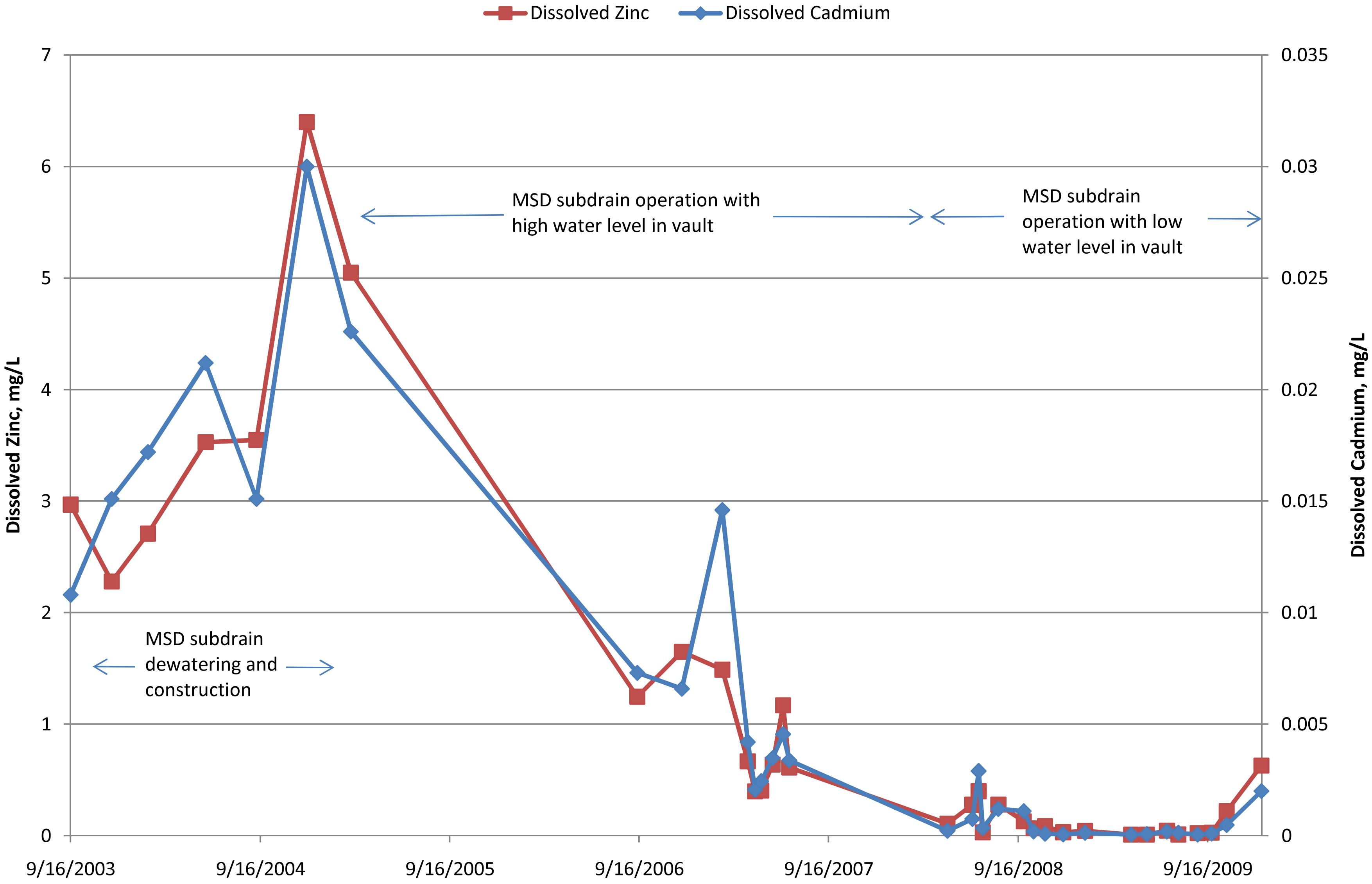
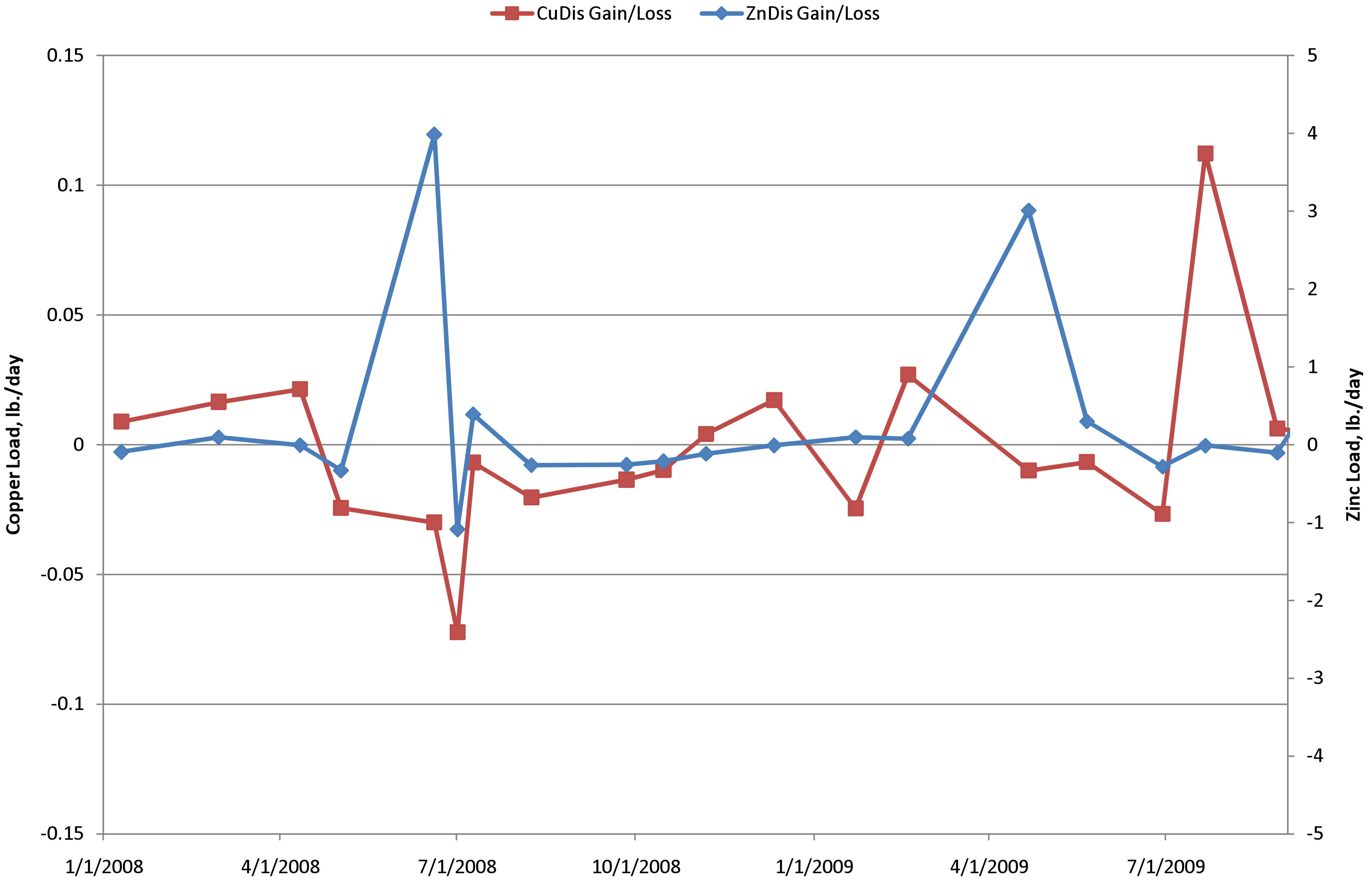


Figure 3-2:
Gains and Losses in Silver Bow Creek between SS-04 and SS-05



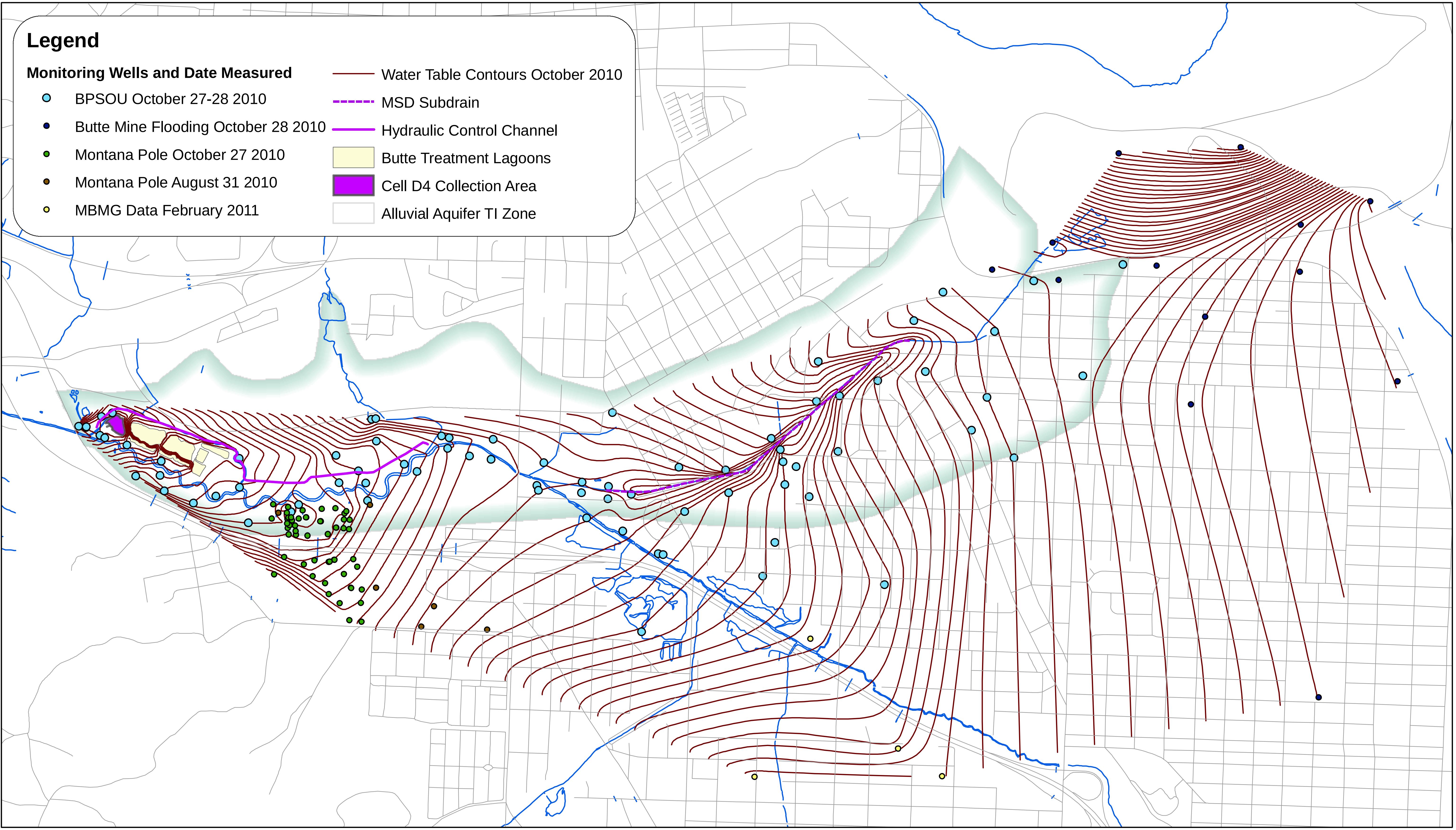


Figure 3-3
Alluvial Aquifer Water Table October 2010
Butte Priority Soil Operable Unit

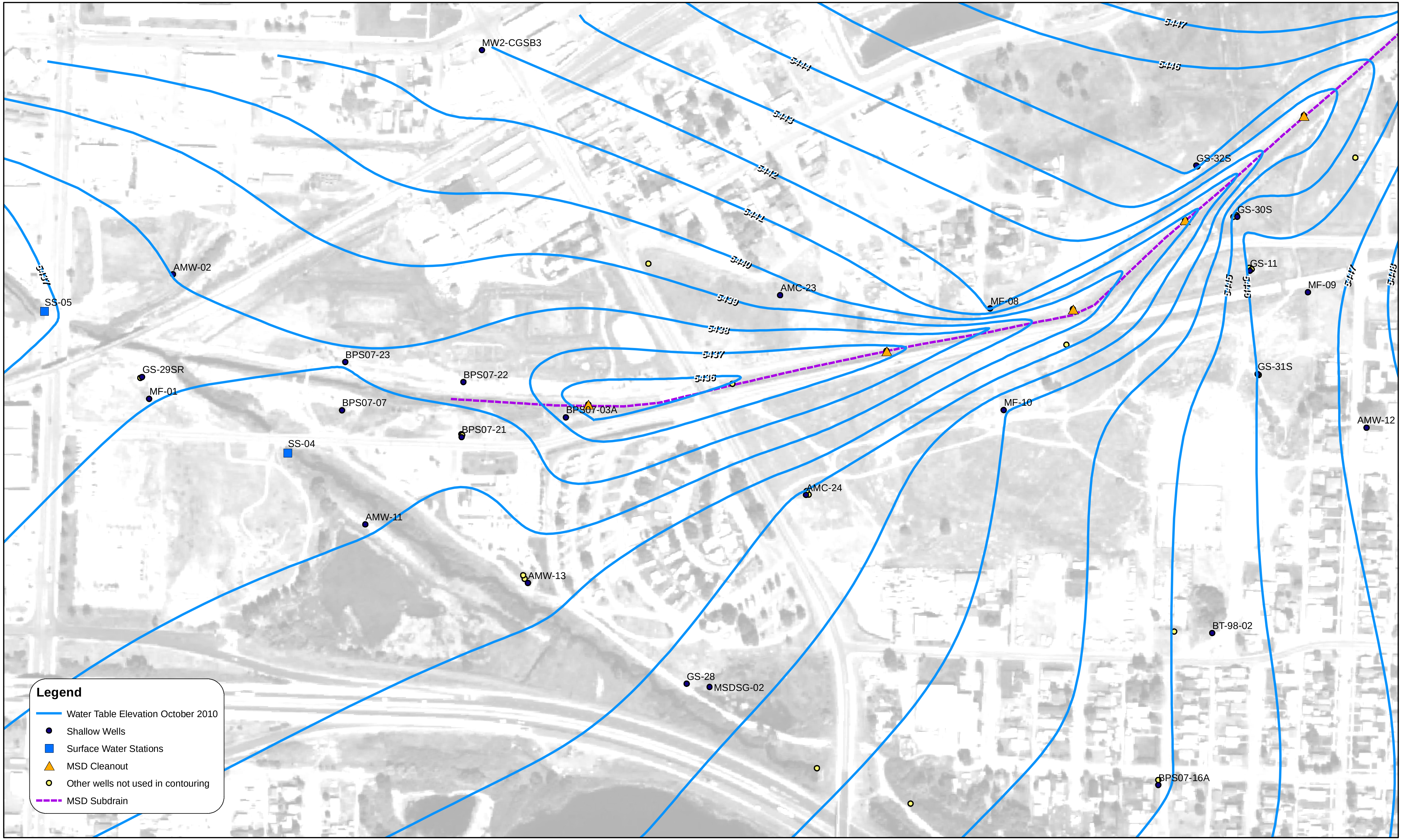


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Figure 3-4
Alluvial Aquifer Water Table in Lower MSD October 2010
Butte Priority Soils Operable Unit

0 250 500 750 1,000 1,250 Feet

N

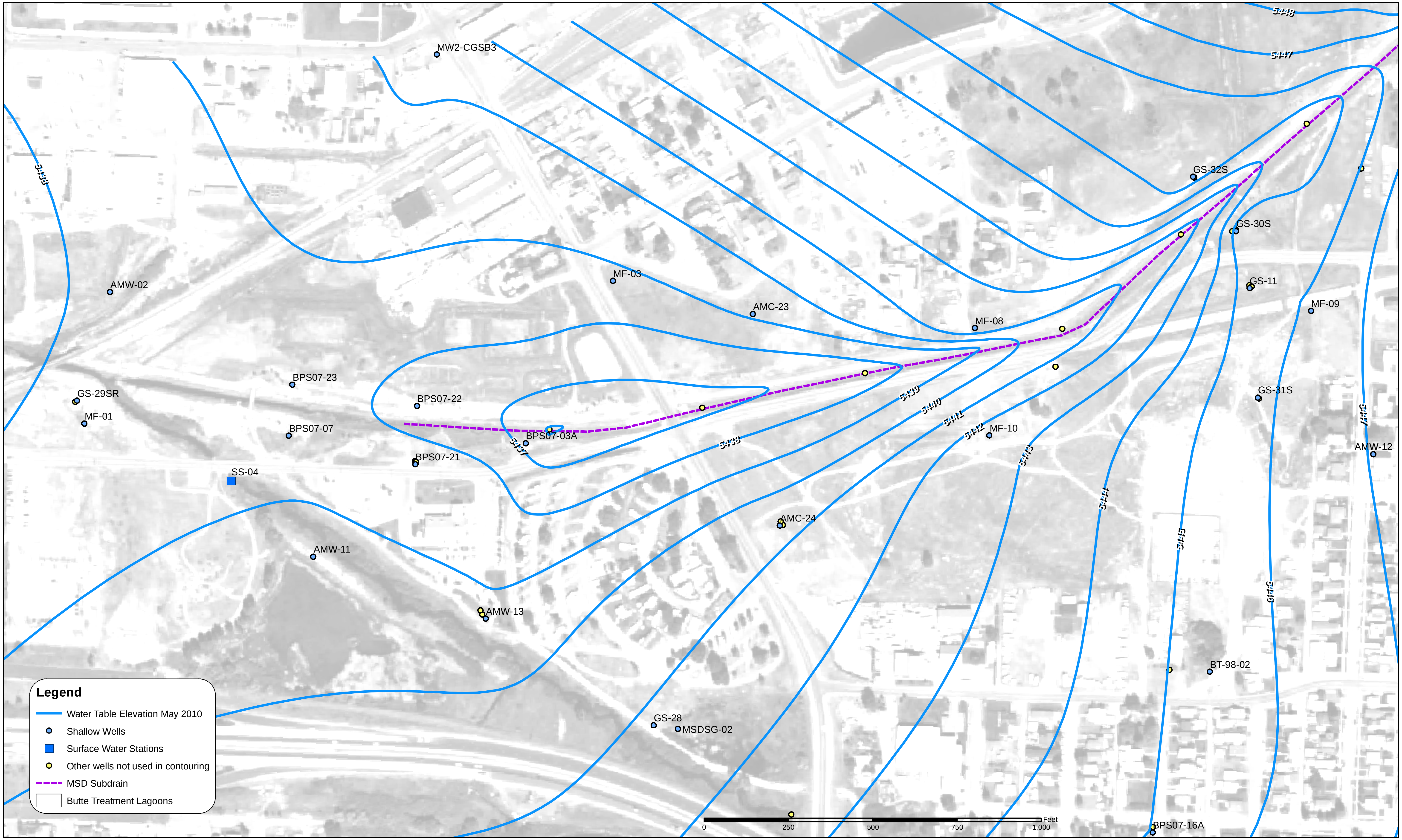

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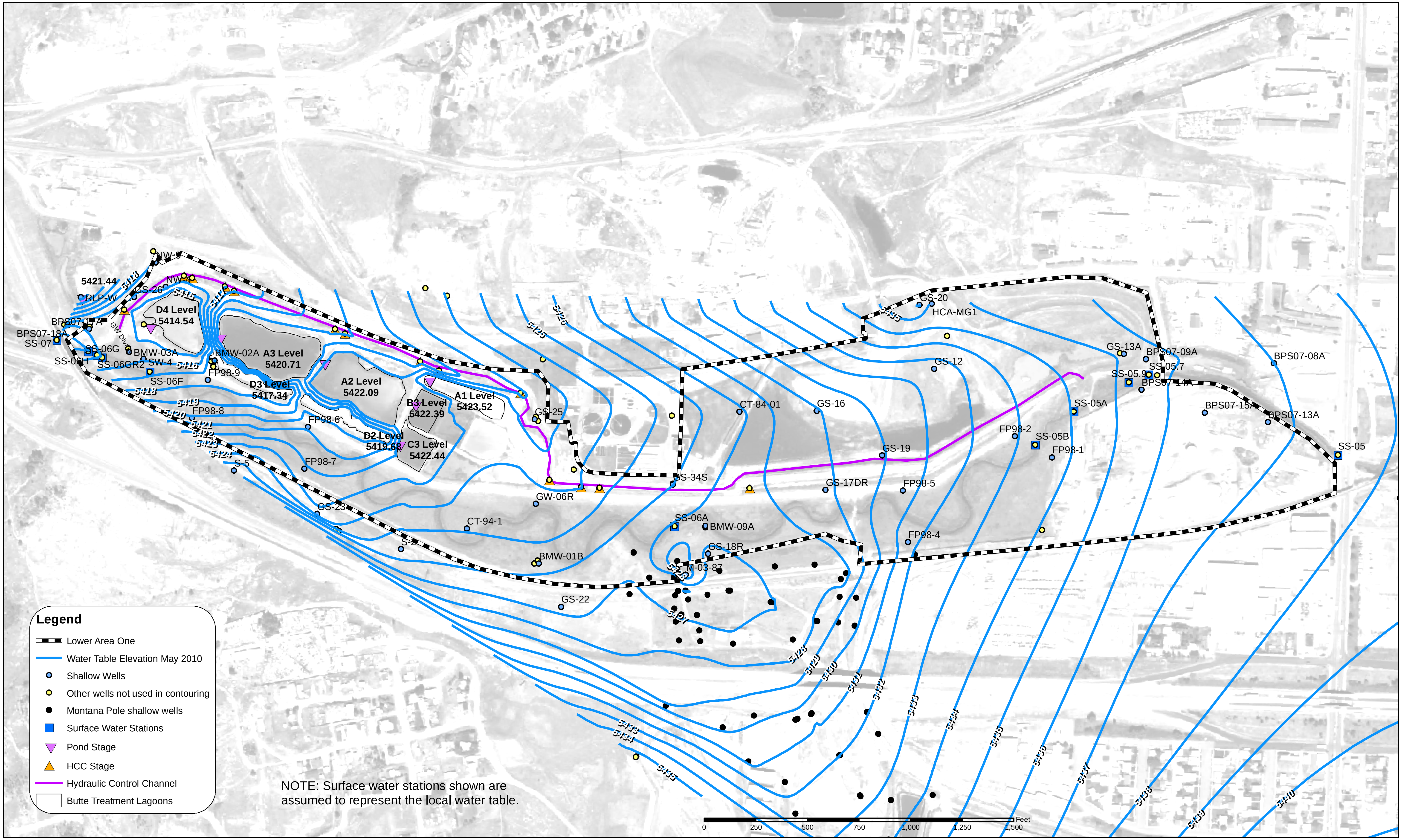
Figure 3-5
Alluvial Aquifer Water Table in Lower MSD May 2010
Butte Priority Soils Operable Unit

N



NOTE: Surface water stations shown are assumed to represent the local water table.

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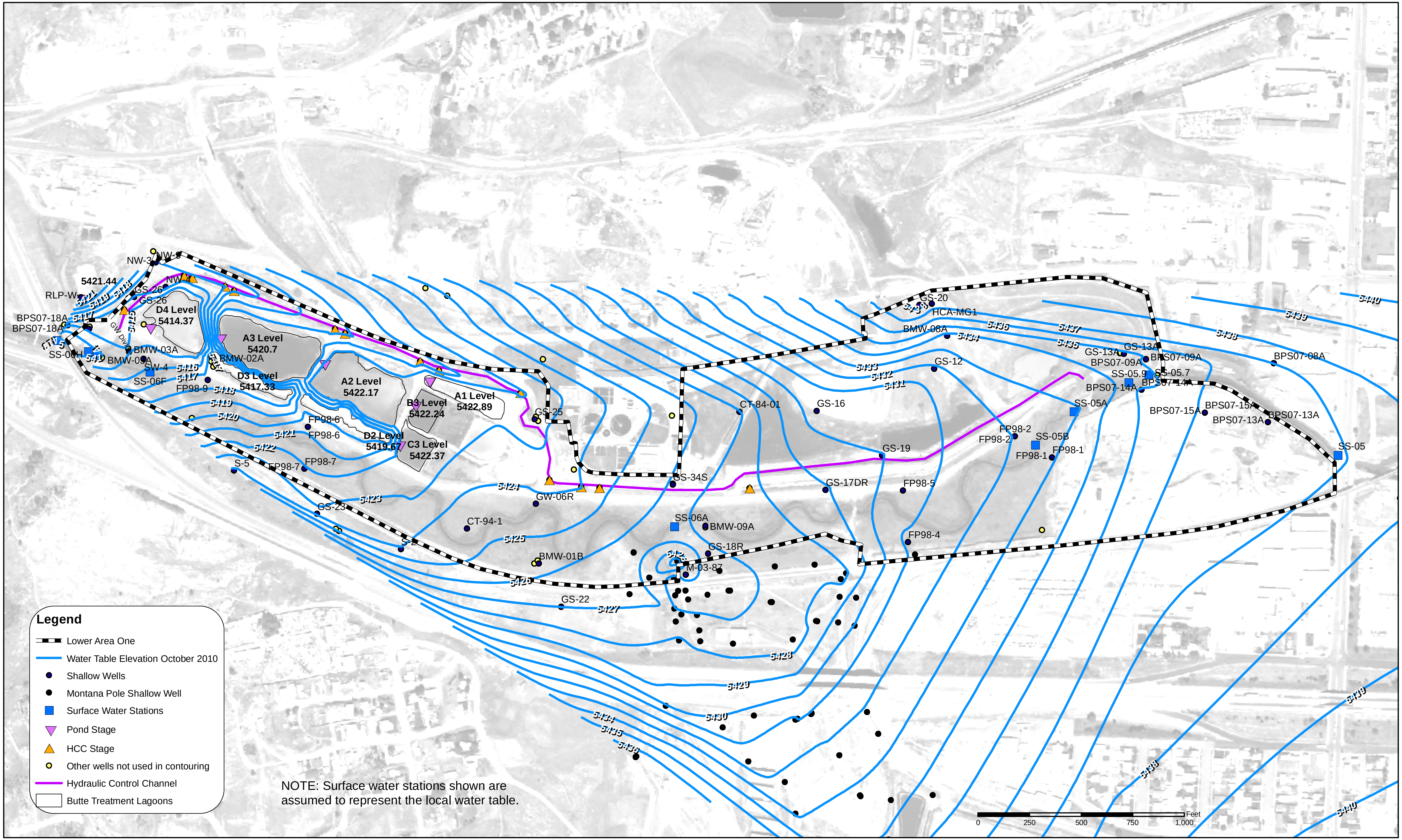
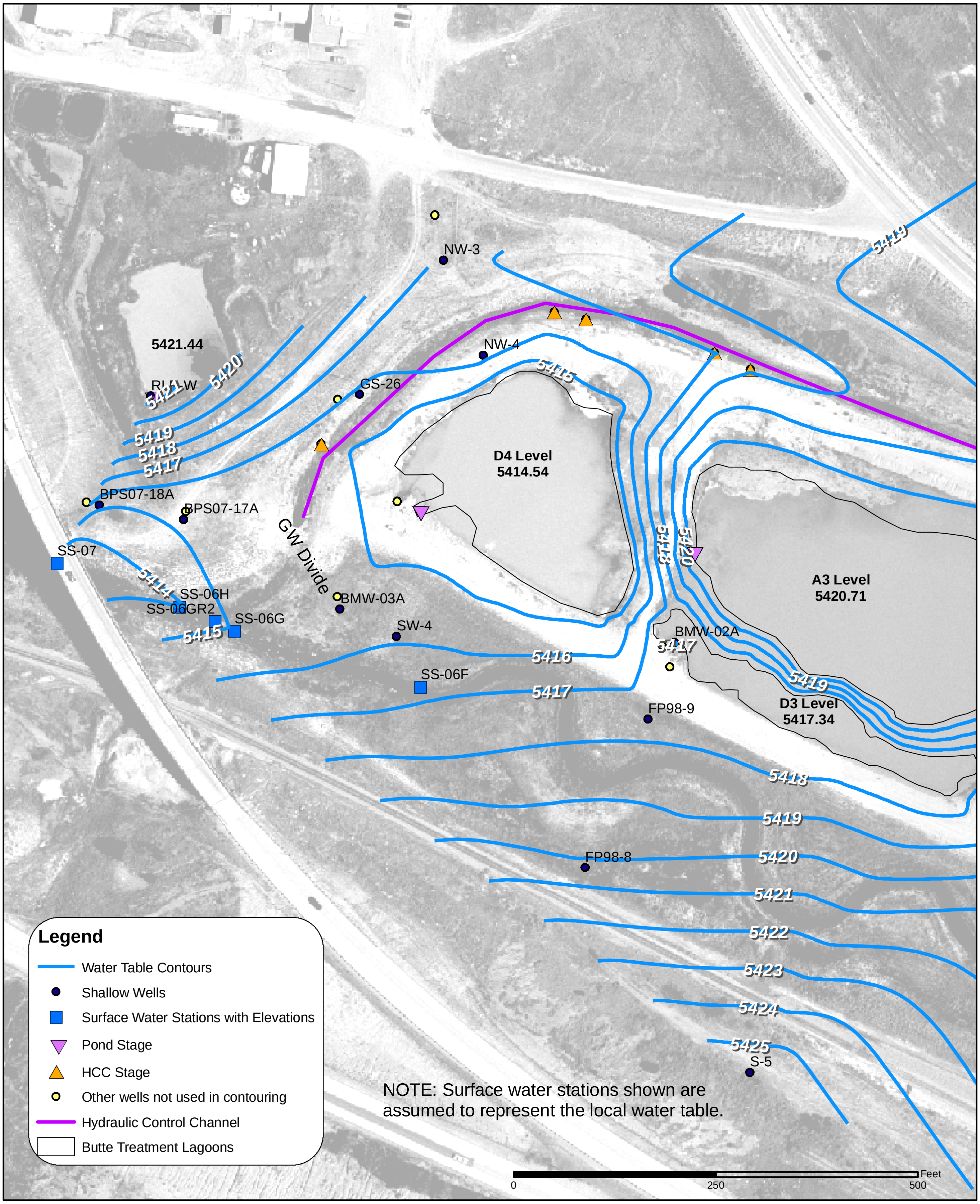
Figure 3-6
Alluvial Aquifer Water Table in LAO May 2010
Butte Priority Soils Operable Unit



NOTE: Surface water stations shown are assumed to represent the local water table.

Figure 3-7
Alluvial Aquifer Water Table in LAO October 2010
Butte Priority Soils Operable Unit



NOTE: Surface water stations shown are assumed to represent the local water table.

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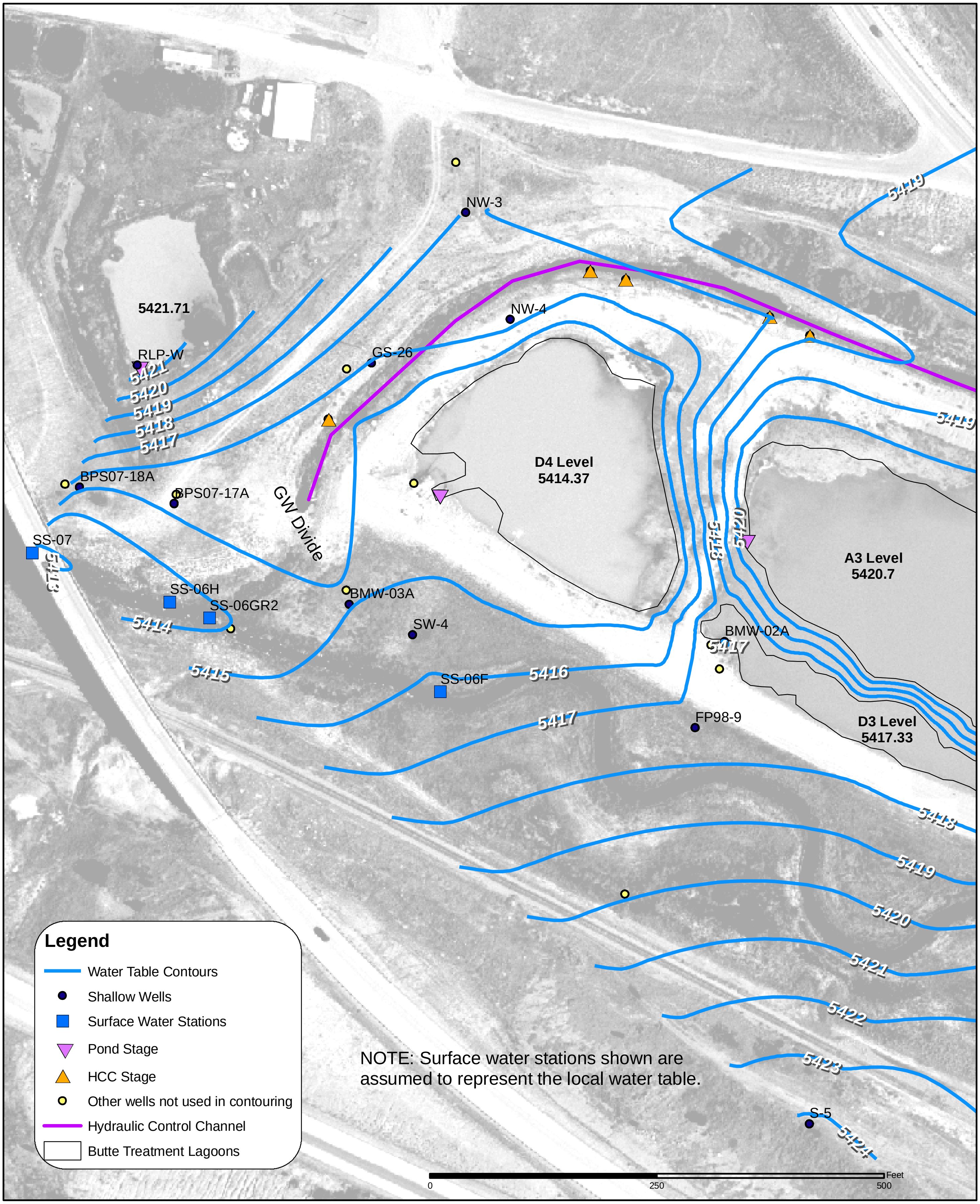
Figure 3-8
Alluvial Aquifer Water Table Near Cell D4 May 2010
Butte Priority Soils Operable Unit



NOTE: Surface water stations shown are assumed to represent the local water table.

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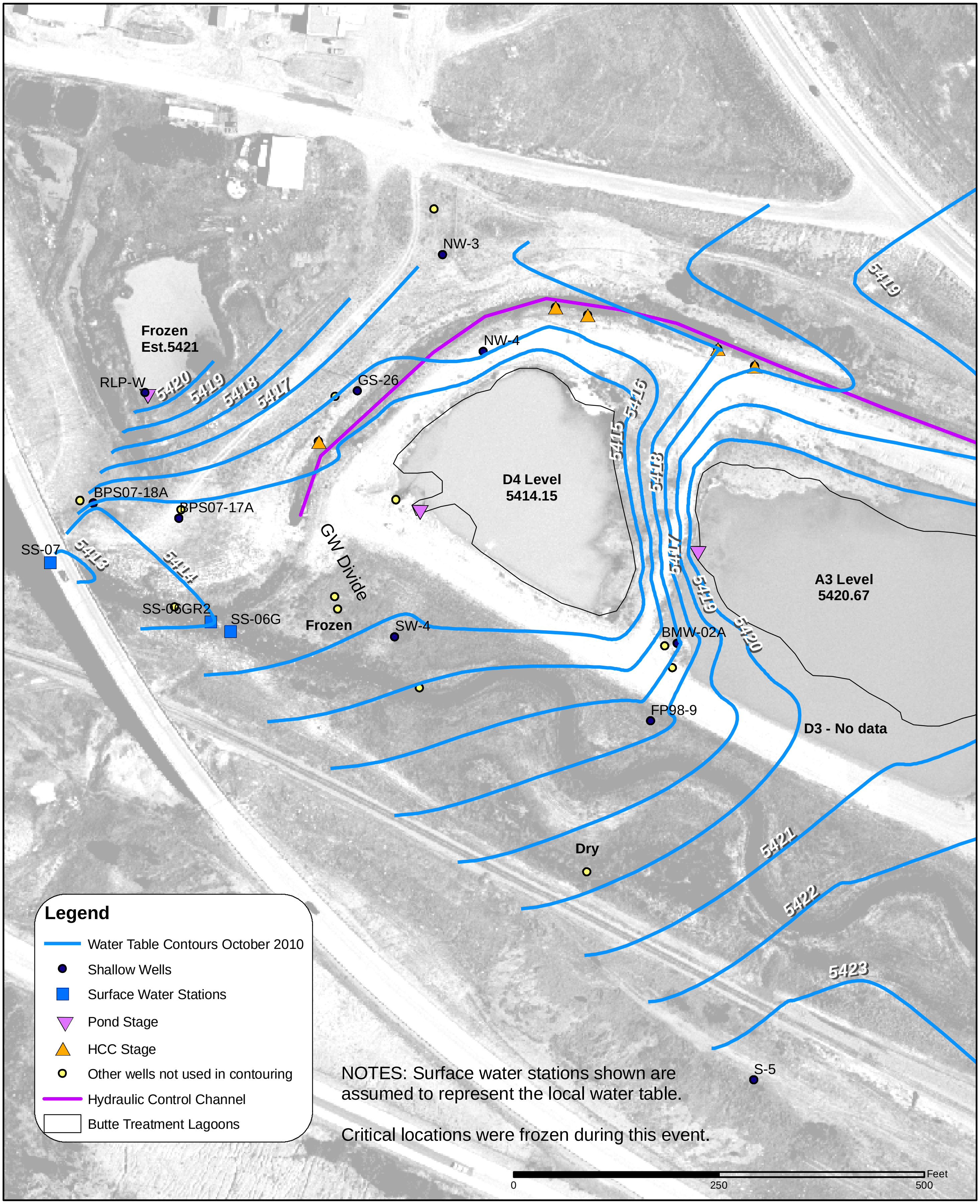
Figure 3-9

Alluvial Aquifer Water Table Near Cell D4 October 2010

Butte Priority Soils Operable Unit

N



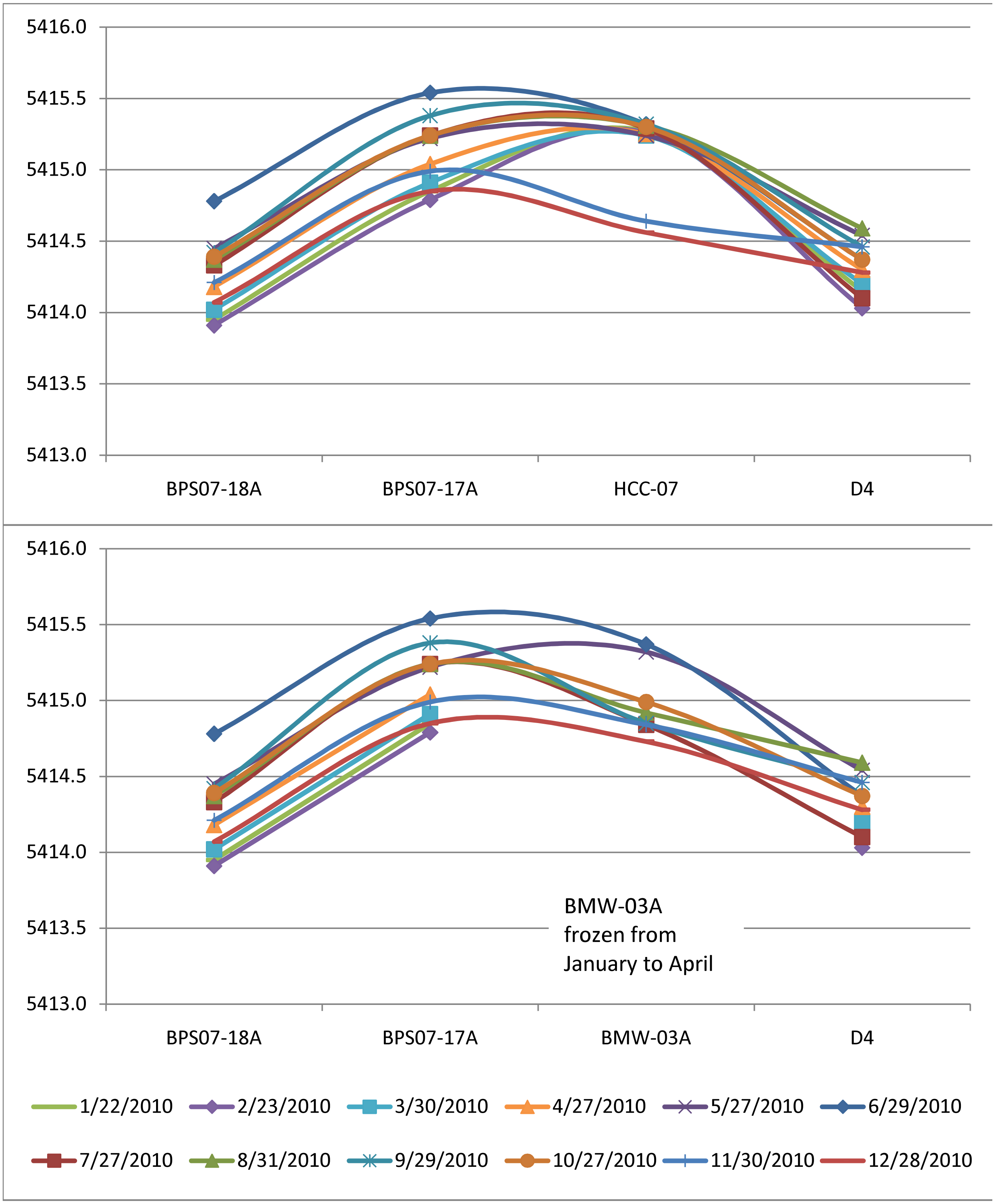
NOTES: Surface water stations shown are assumed to represent the local water table.

Critical locations were frozen during this event.

Z:\gis\Public\Butte\Water_Table\MXD\WL_D4_Jan10.mxd

Figure 3-10
Alluvial Aquifer Water Table Near Cell D4 January 2010
Butte Priority Soils Operable Unit

N



Water table elevation in feet.

Figure 3-11

Water Table Cross-Section through Cell D4 Area

Butte Priority Soils Operable Unit

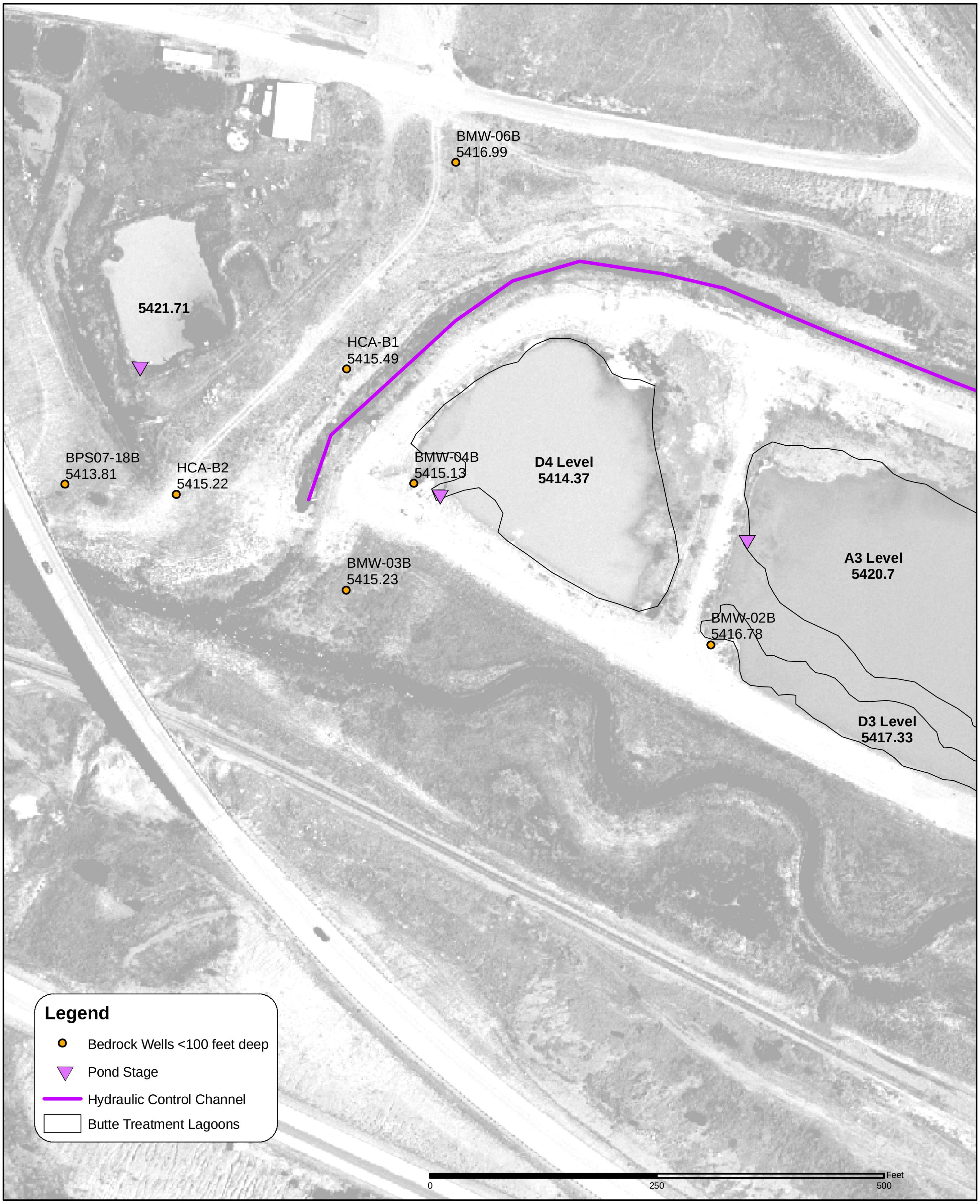


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Figure 3-12
Bedrock Aquifer Potential Near Cell D4 October 2010
Butte Priority Soils Operable Unit

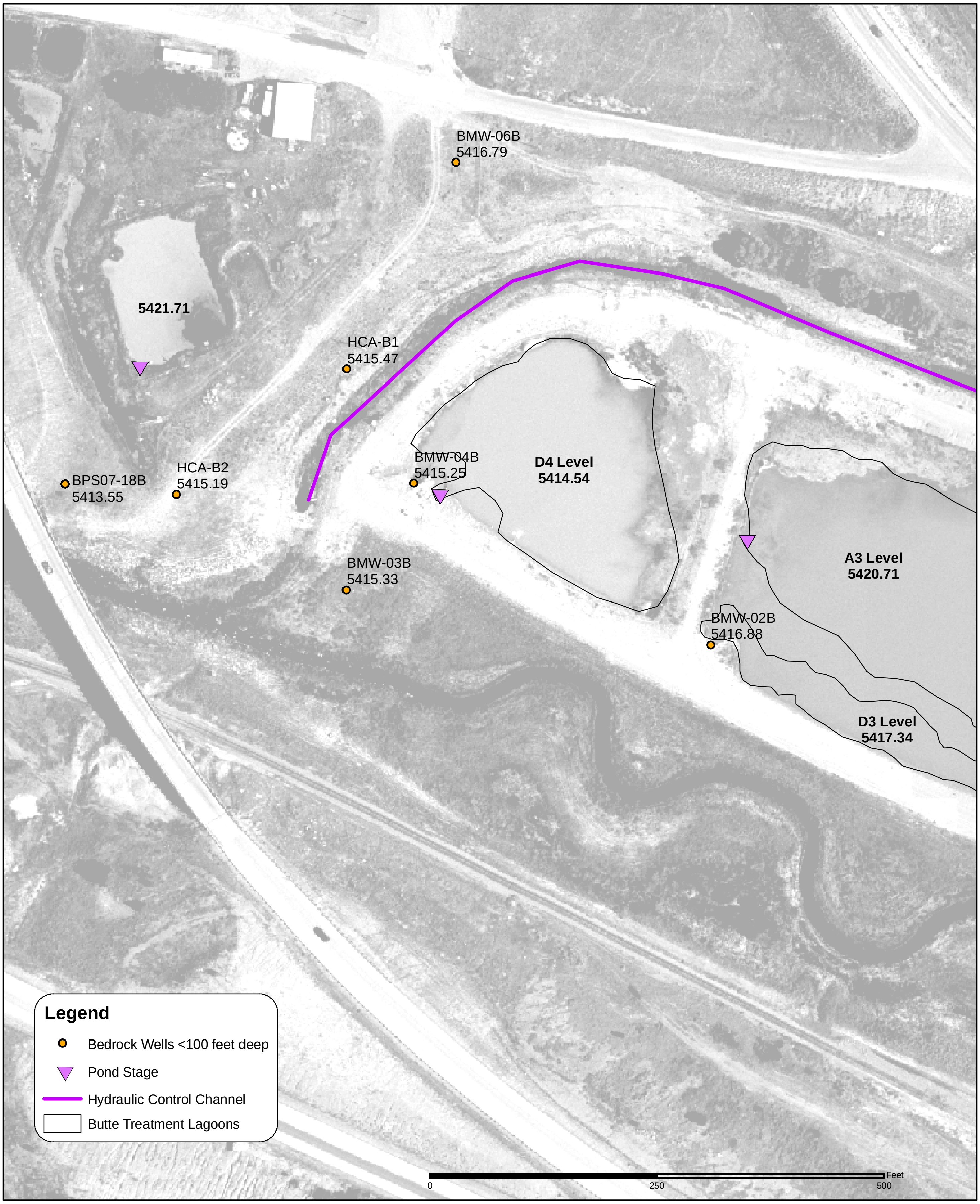

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Figure 3-13
Bedrock Aquifer Potential Near Cell D4 May 2010
Butte Priority Soils Operable Unit

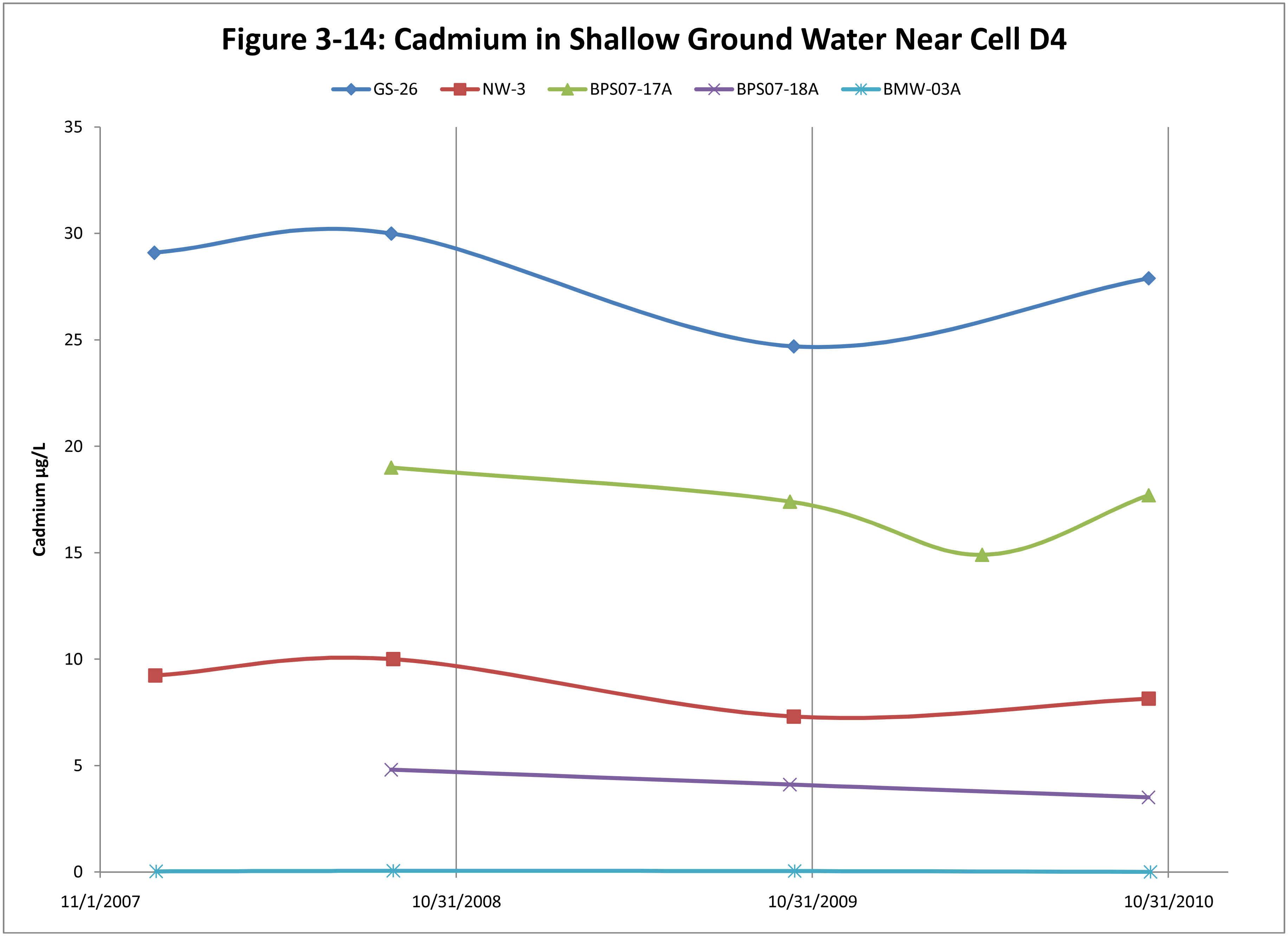


Figure 3-14: Cadmium in Shallow Ground Water Near Cell D4

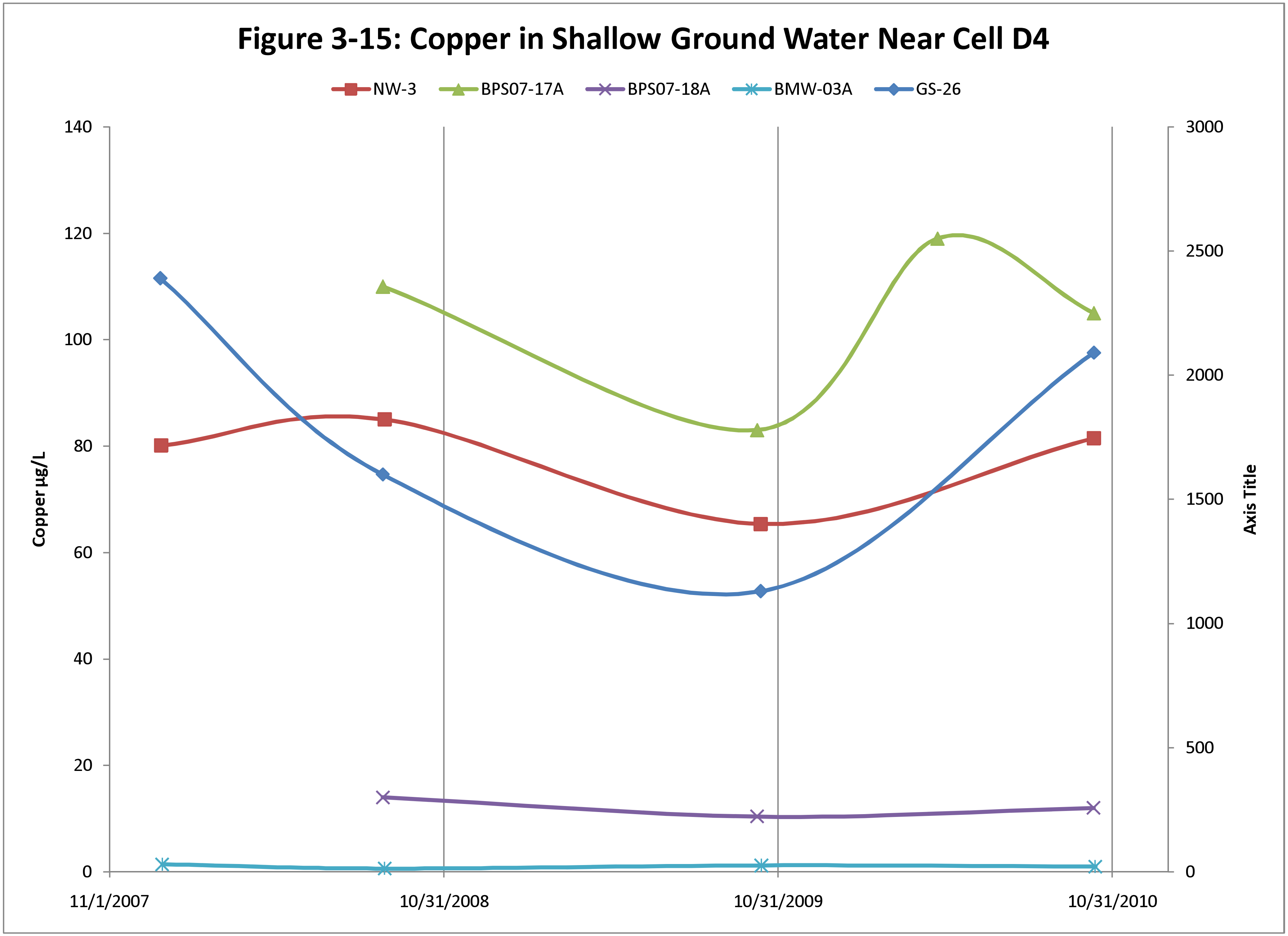
Figure 3-15: Copper in Shallow Ground Water Near Cell D4
NW-3
BPS07-17A
BPS07-18A
BMW-03A
GS-26
Copper µg/L
Axis Title
140
120
100
80
60
40
20
0
3000
2500
2000
1500
1000
500
0
11/1/2007
10/31/2008
10/31/2009
10/31/2010

Figure 3-16: Zinc in Shallow Ground Water Near Cell D4

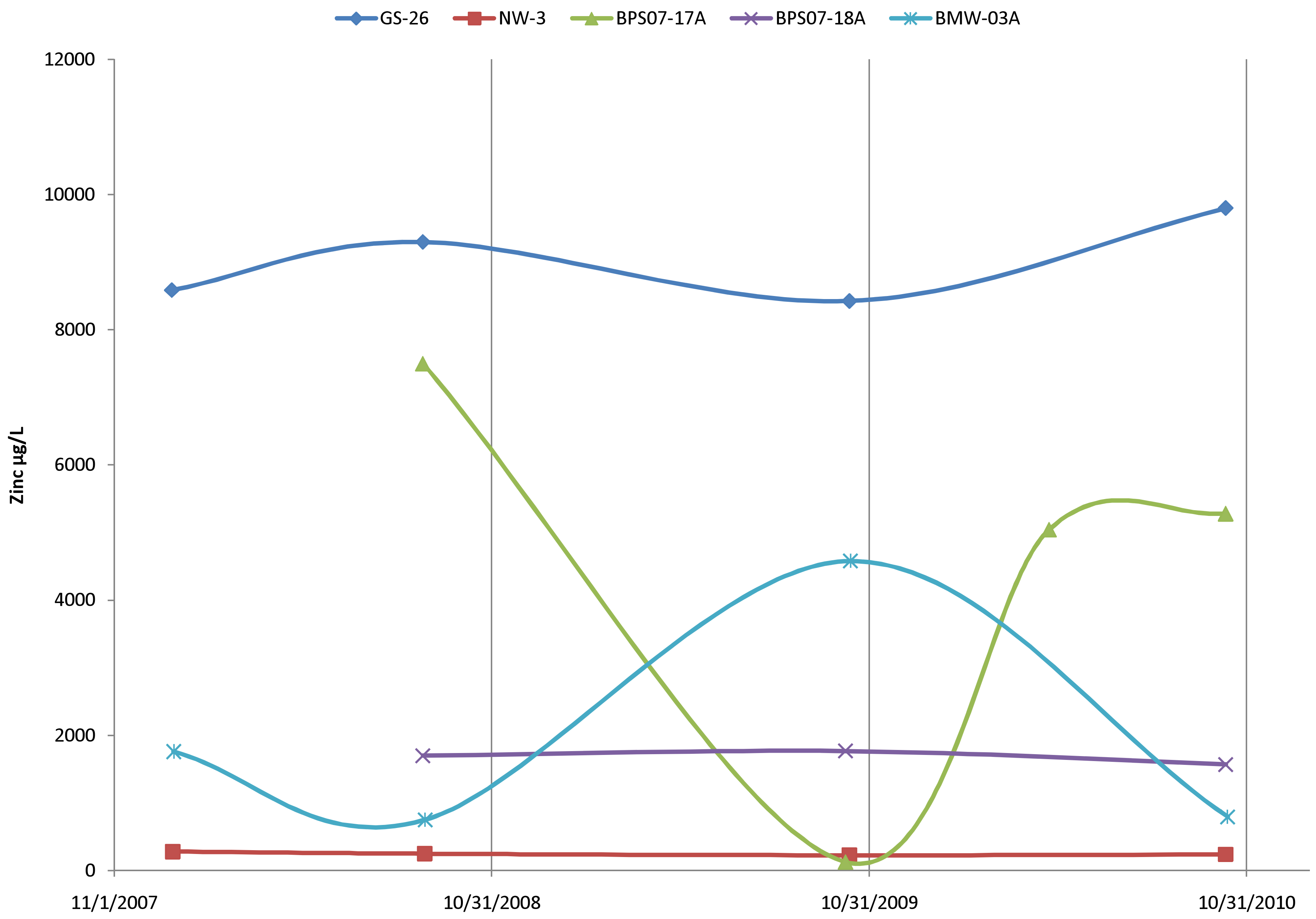
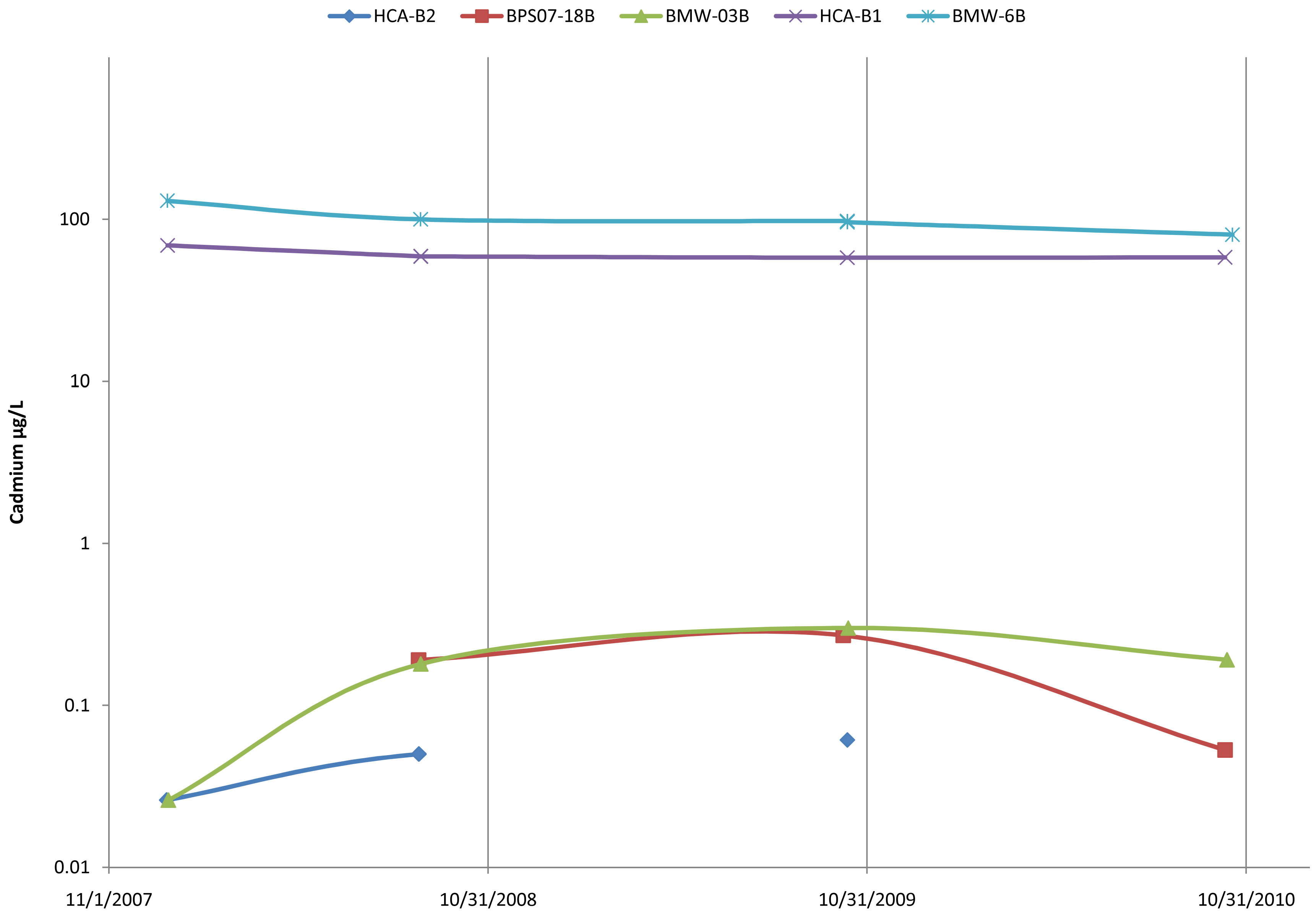


Figure 3-17: Cadmium in Bedrock Ground Water Near Cell D4



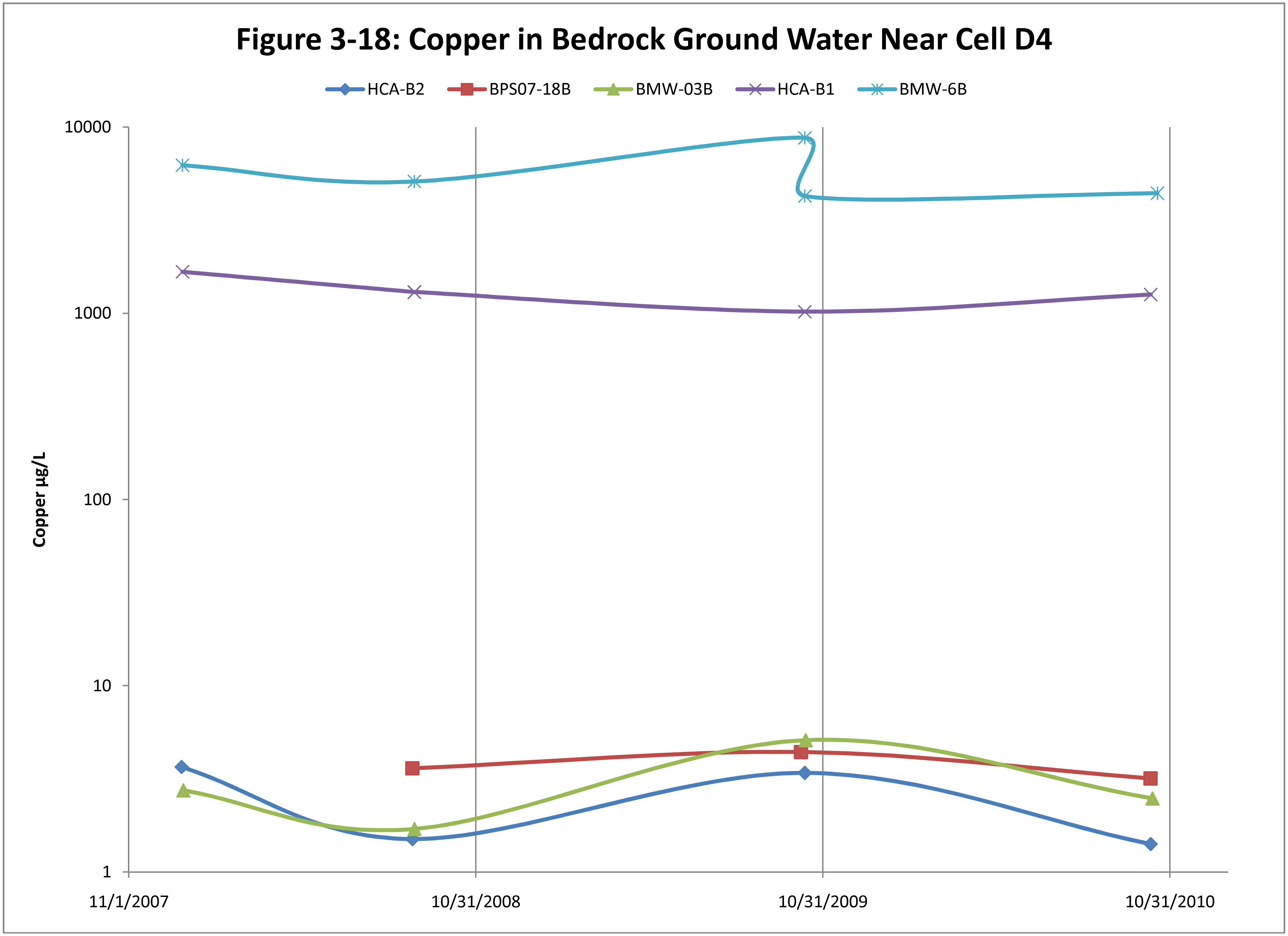


Figure 3-18: Copper in Bedrock Ground Water Near Cell D4
HCA-B2
BPS07-18B
BMW-03B
HCA-B1
BMW-6B
Copper µg/L
10000
1000
100
10
1
11/1/2007
10/31/2008
10/31/2009
10/31/2010

Figure 3-19: Zinc in Bedrock Ground Water Near Cell D4

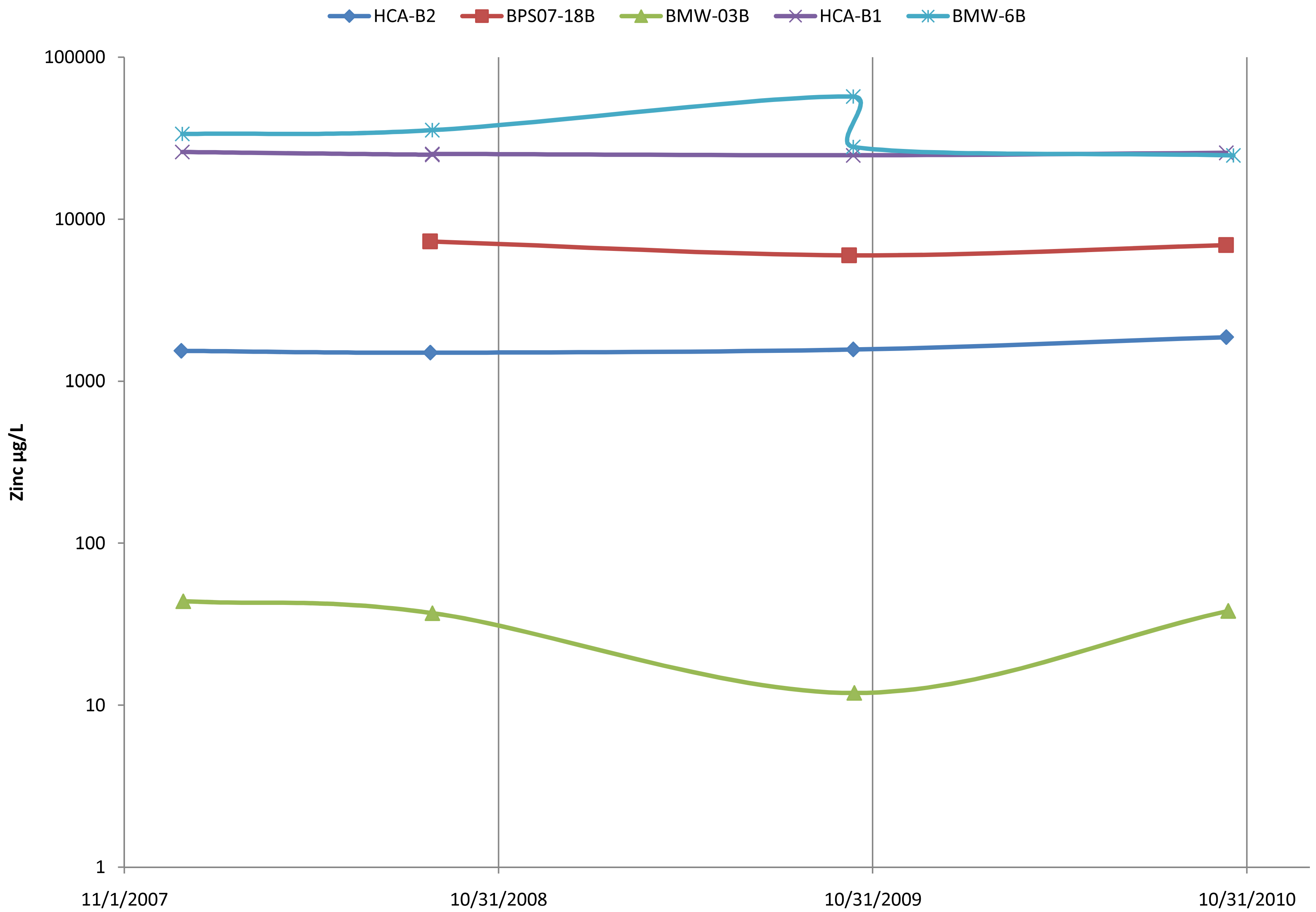


Figure 3-20: Geologic Cross-Section in Metro Storm Drain Area

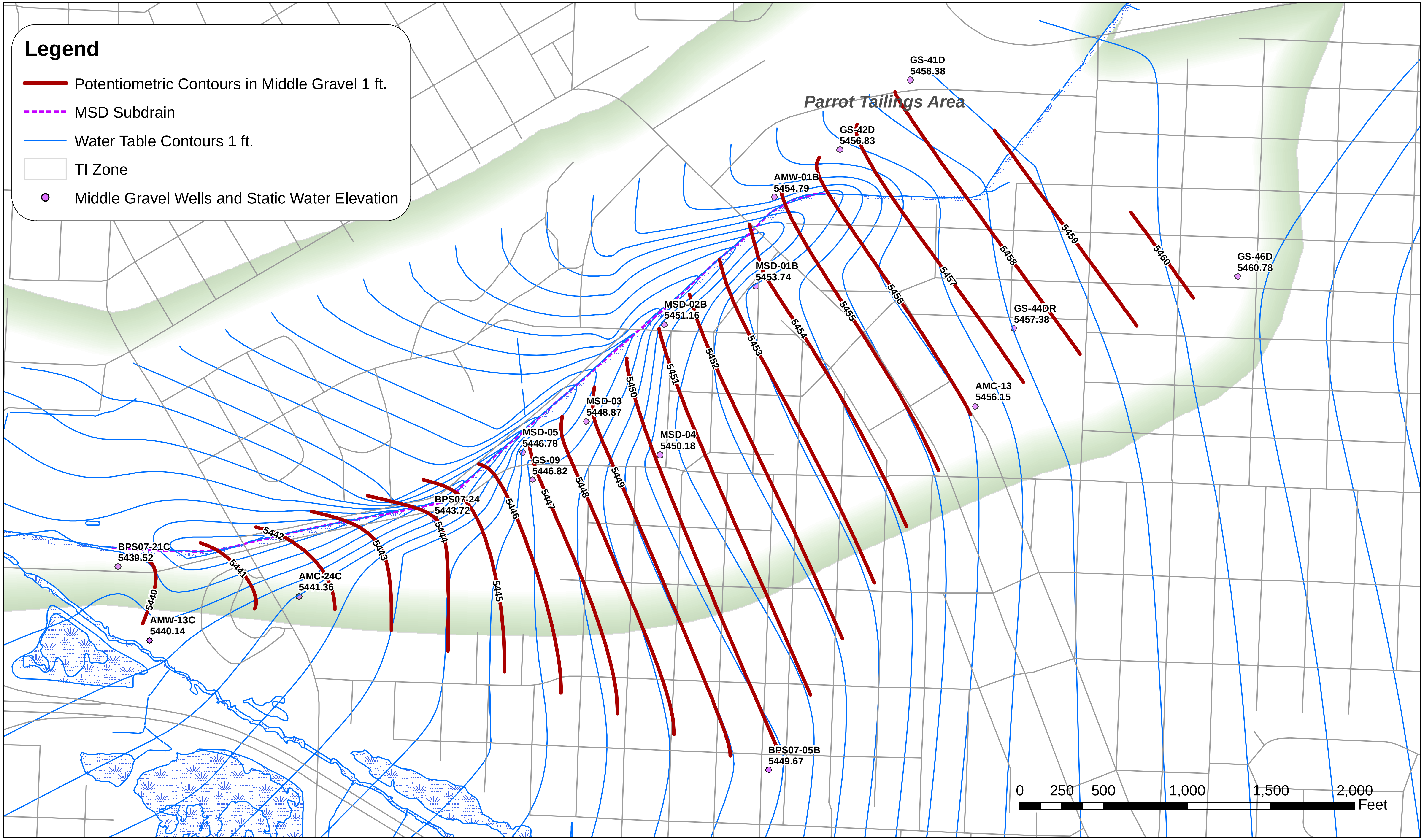


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Figure 3-21
Middle Gravel Potentiometric Surface October 2010
Butte Priority Soils Operable Unit

Figure 3-22: Spatial Trends for Copper and Zinc within Selected Middle Gravel Wells

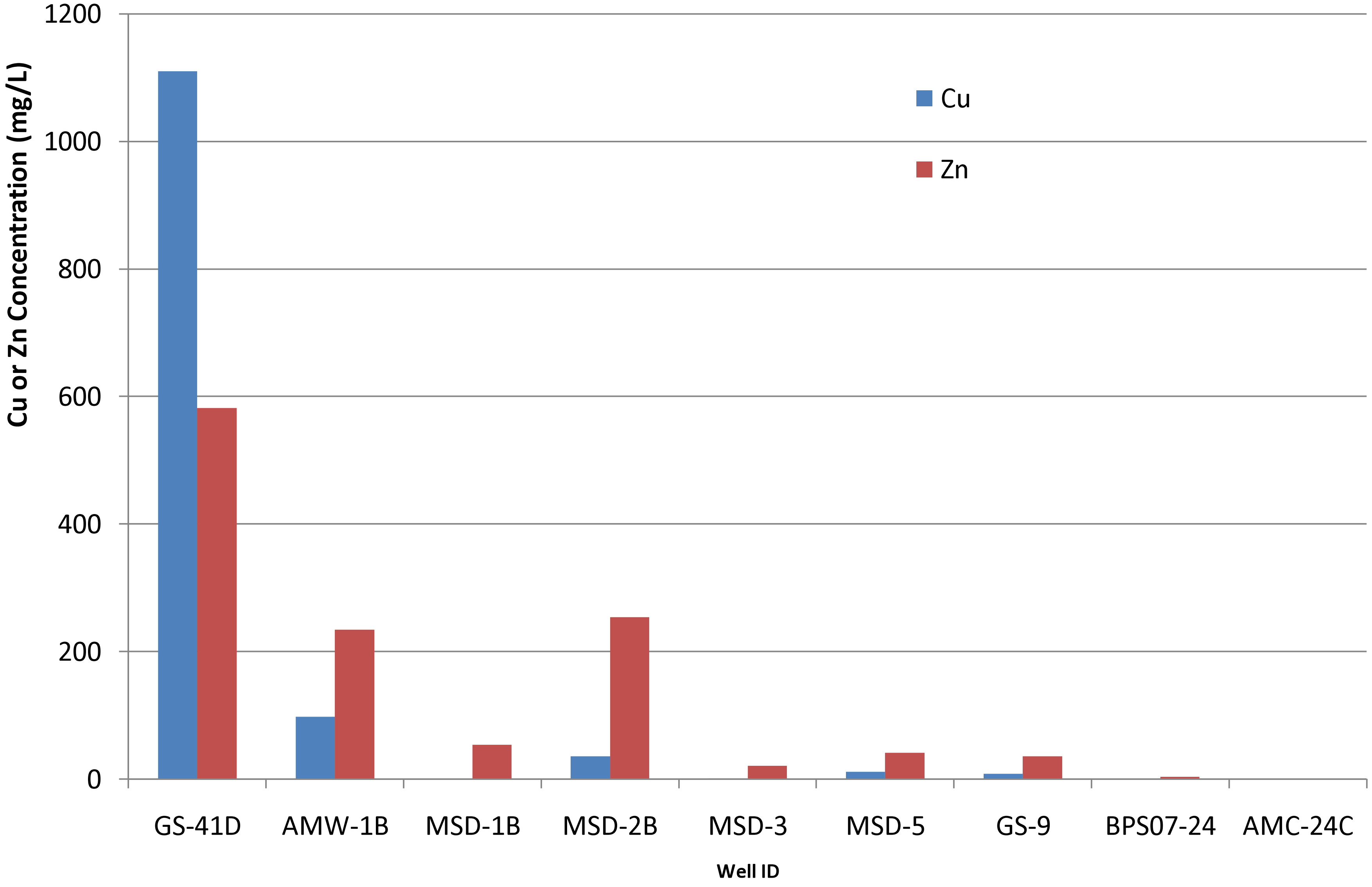


Figure 3-23: Spatial Trends for Copper within Selected Middle Gravel Wells (Jul-August 2004)

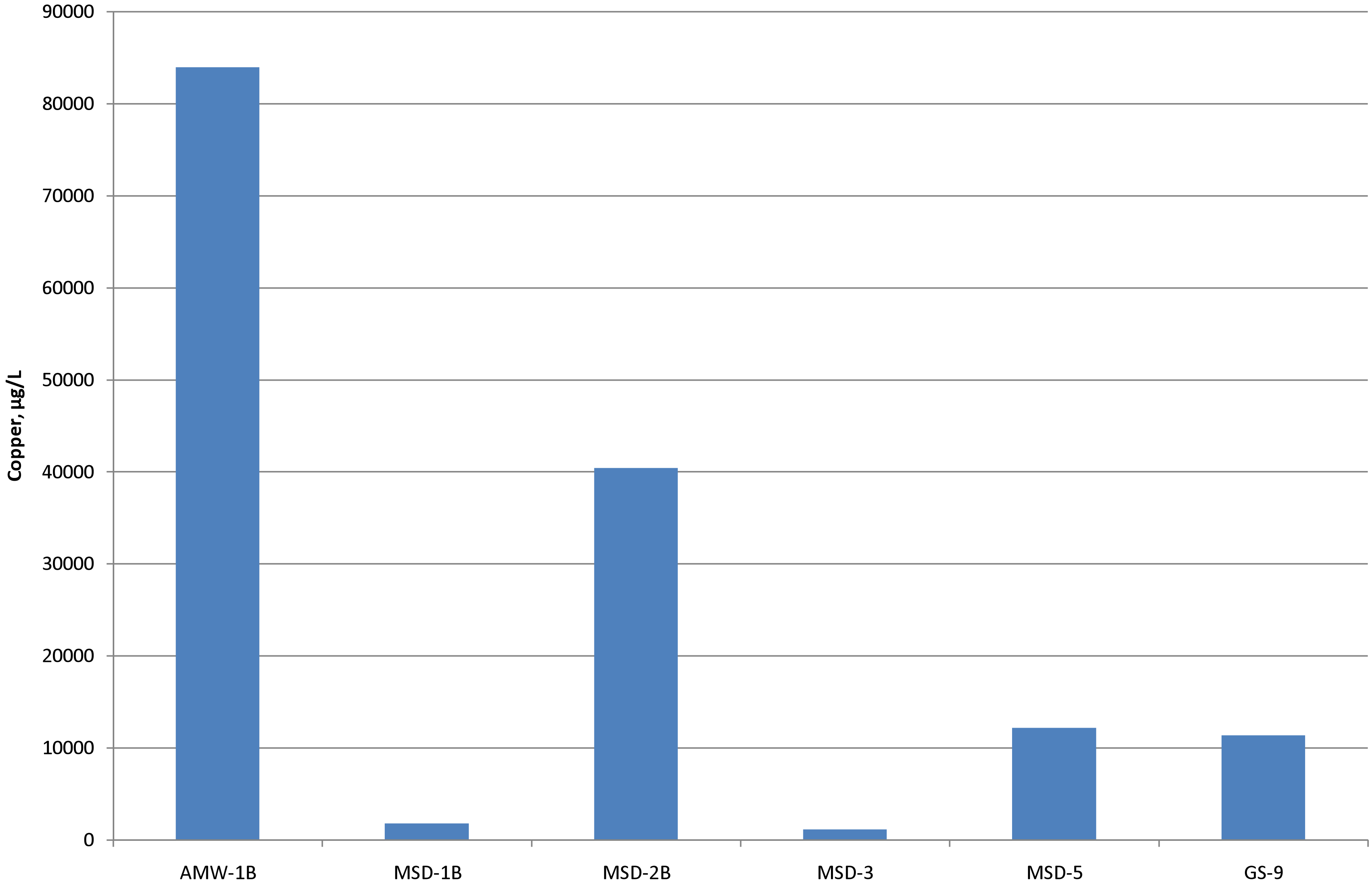
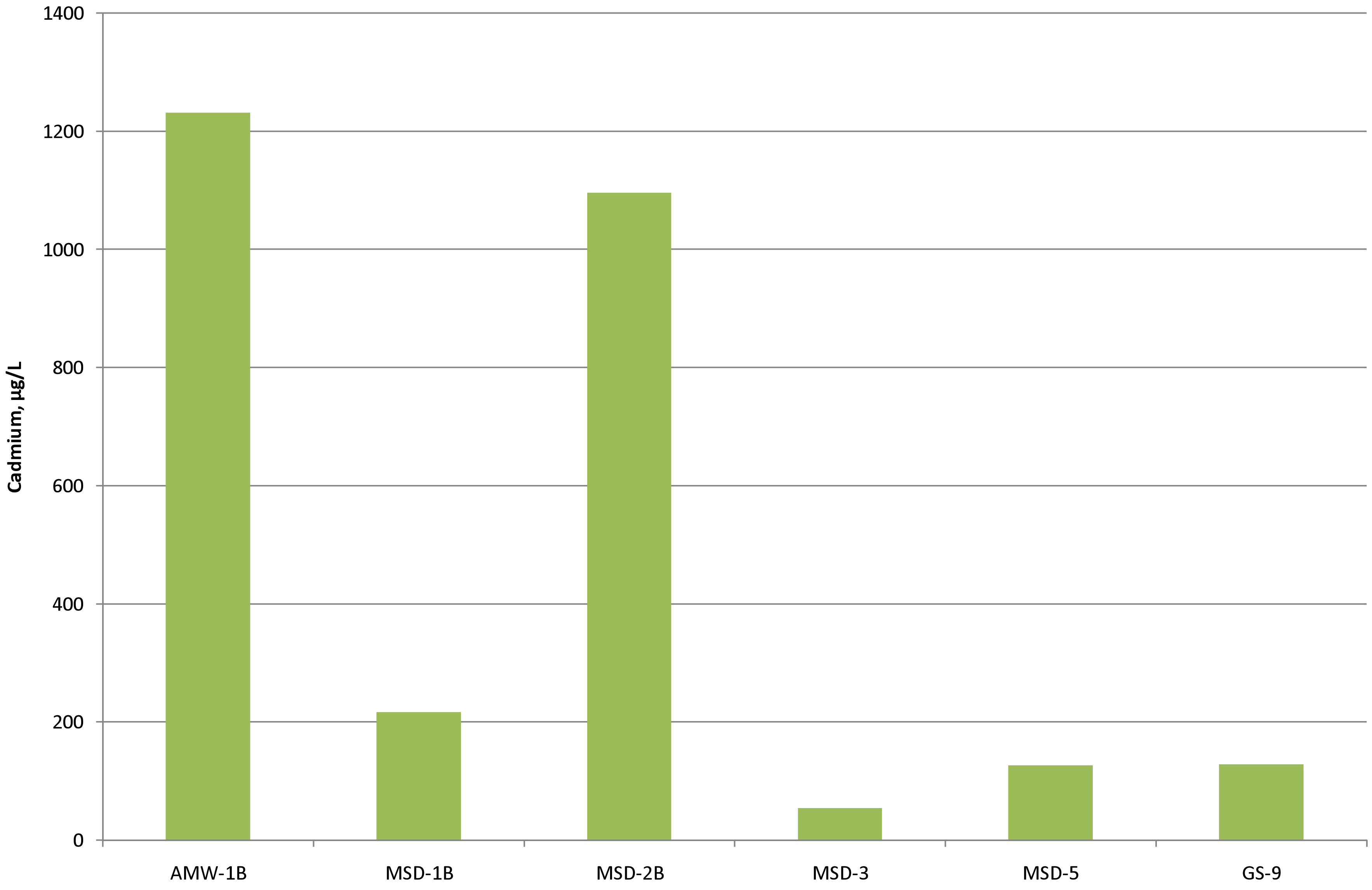


Figure 3-24: Spatial Trends for Cadmium within Selected Middle Gravel Wells (July - August 2004)



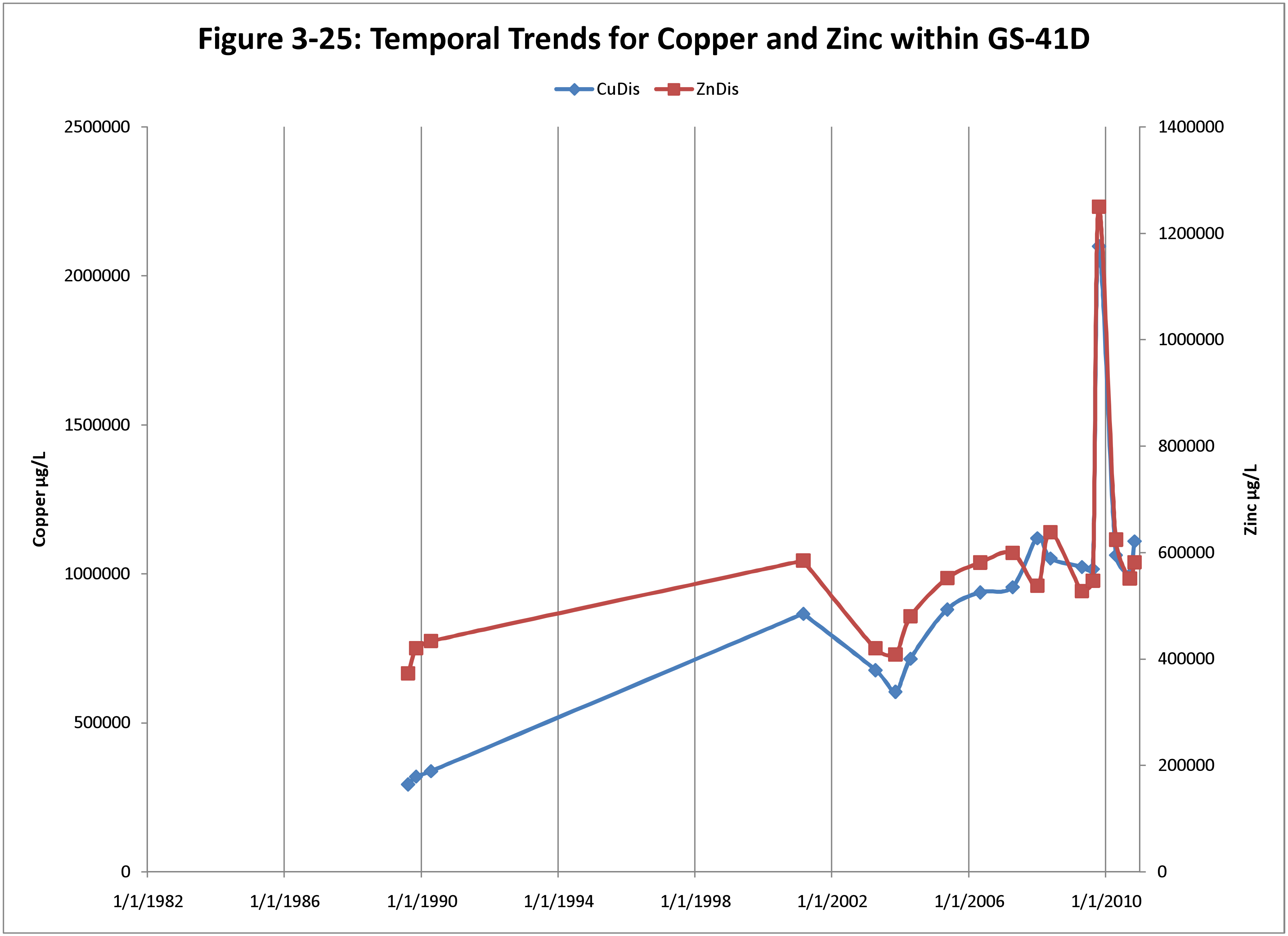
Figure 3-25: Temporal Trends for Copper and Zinc within GS-41D
CuDis
ZnDis
Copper µg/L
Zinc µg/L
2500000
2000000
1500000
1000000
500000
0
1400000
1200000
1000000
800000
600000
400000
200000
0
1/1/1982
1/1/1986
1/1/1990
1/1/1994
1/1/1998
1/1/2002
1/1/2006
1/1/2010

Figure 3-26: Temporal Trends for Copper and Zinc within Well GS-41S

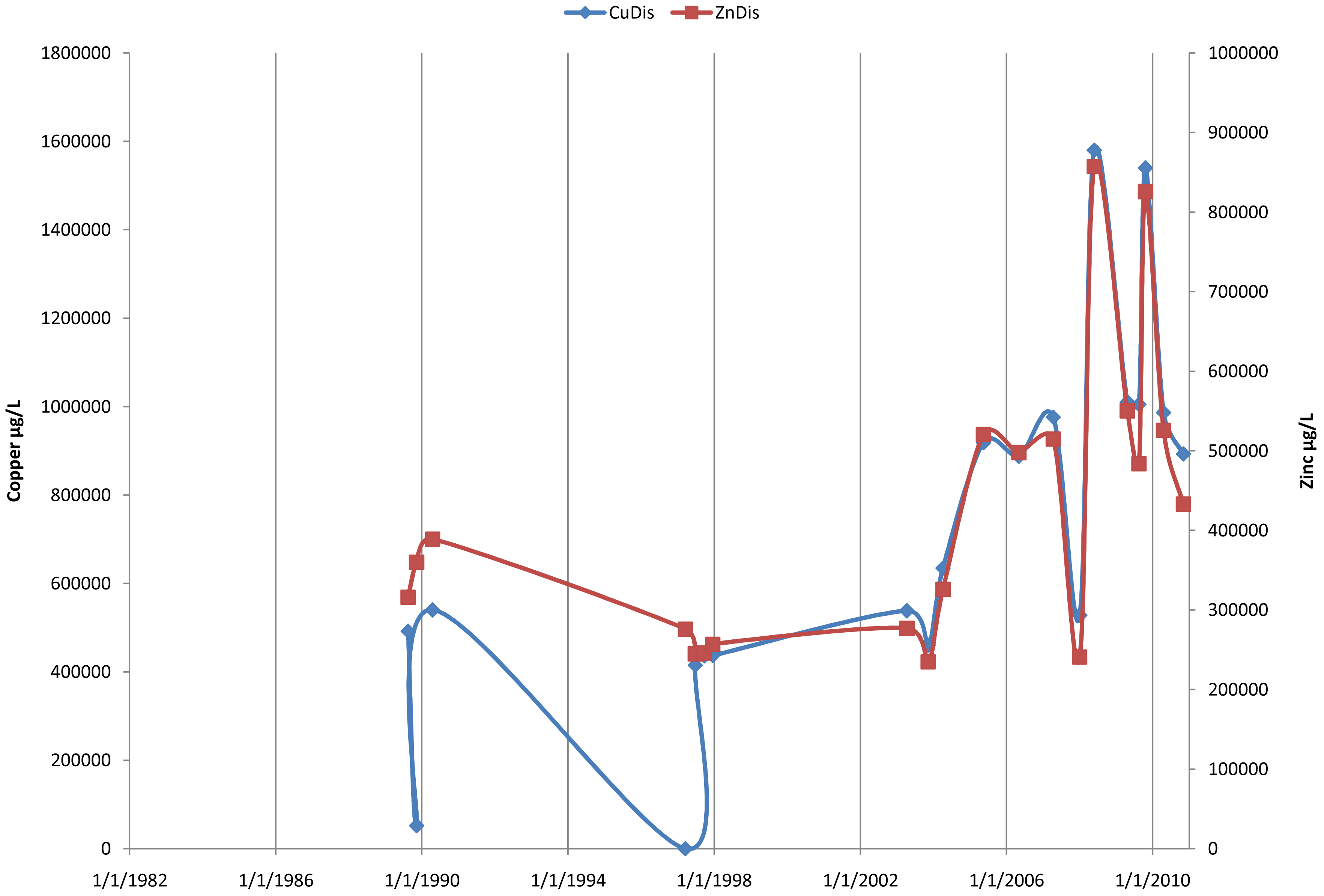


Figure 3-27: Temporal Trends for Copper and Zinc within Well AMW-01B

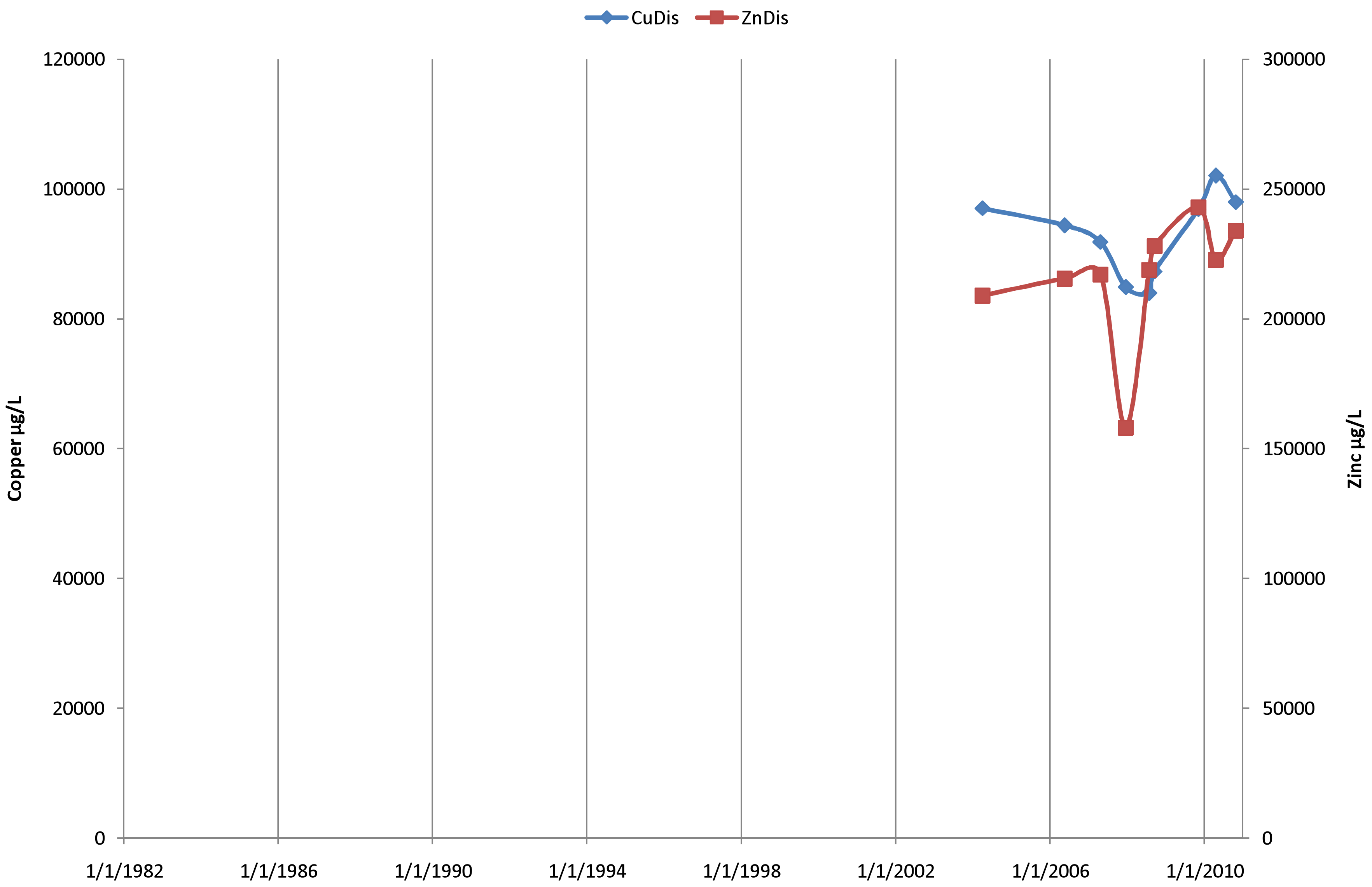


Figure 3-28: Temporal Trends for Copper and Zinc within Well MSD-01B

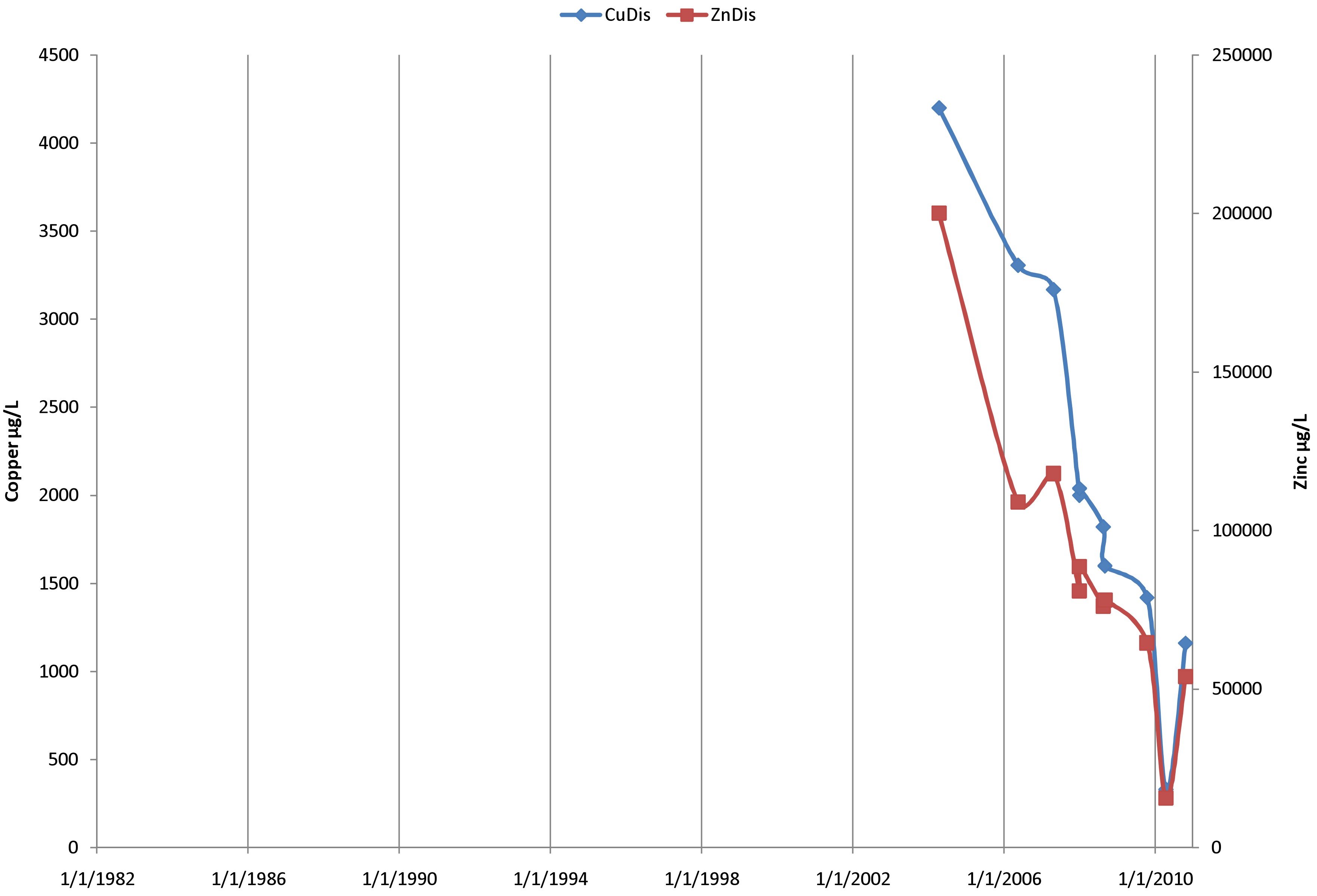


Figure 3-29: Temporal Trend for Copper and Zinc within Well MSD-02B

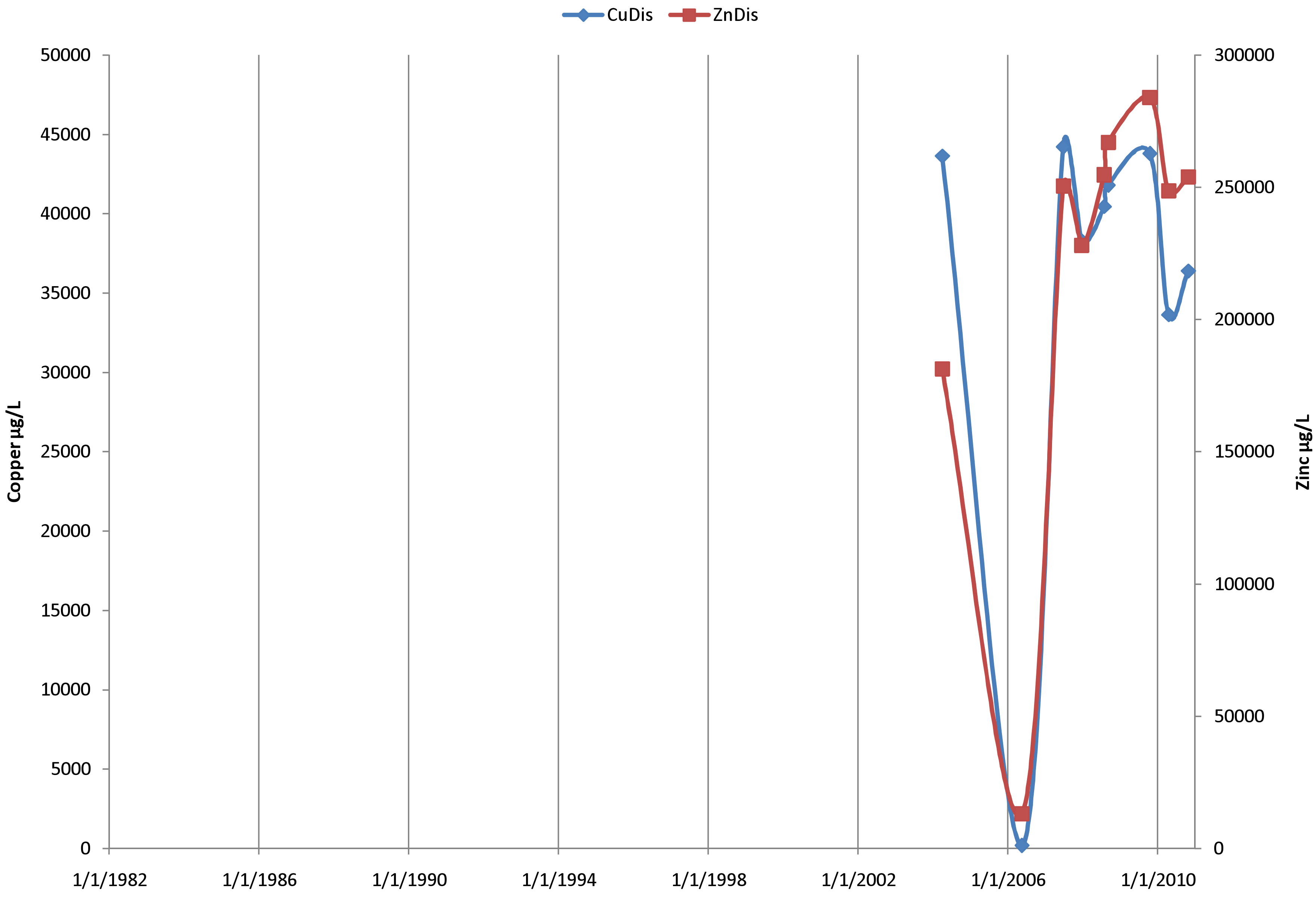


Figure 3-30: Temporal Trends for Copper and Zinc within Well MSD-03

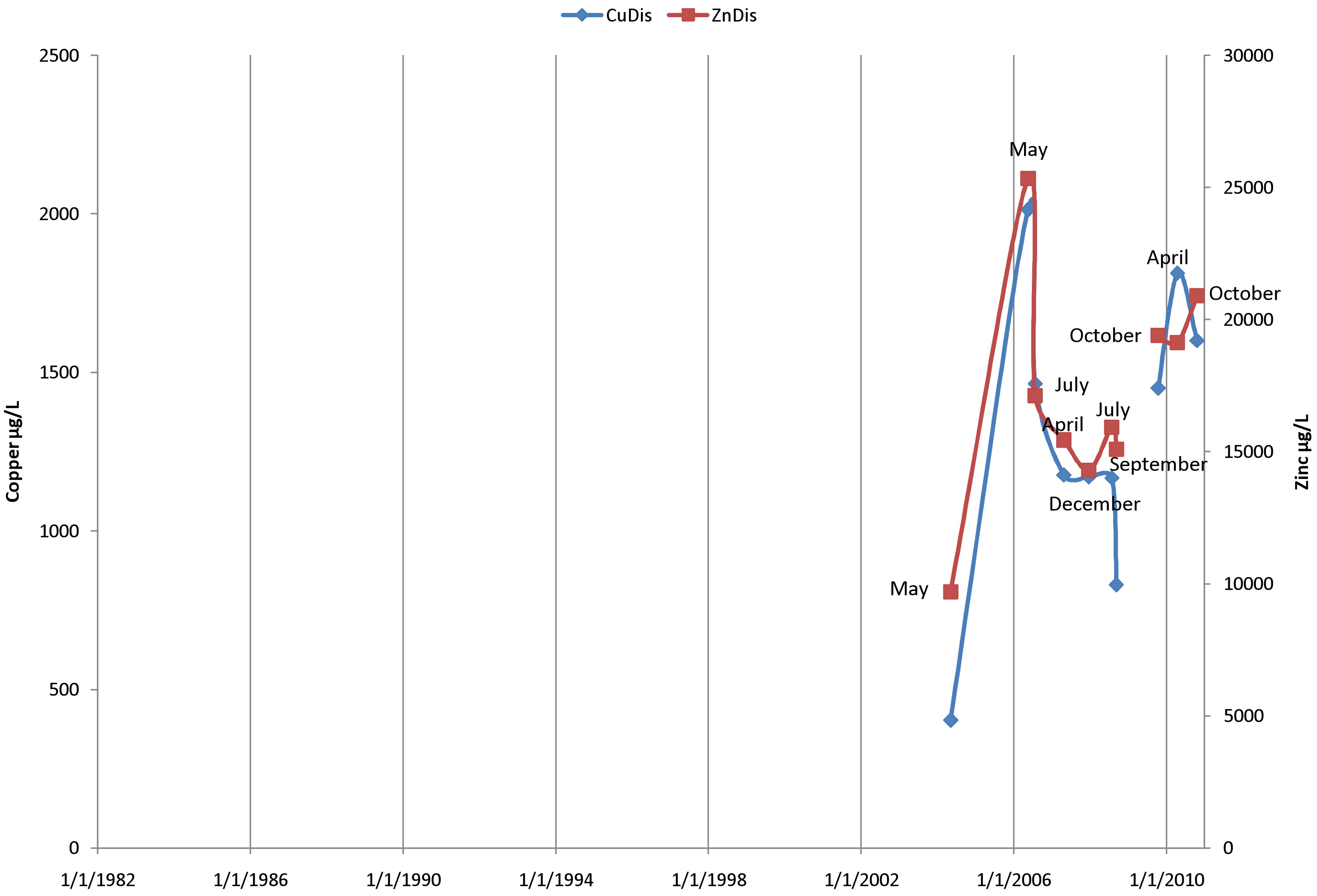


Figure 3-31: Temporal Trends for Copper and Zinc within Well MSD-05

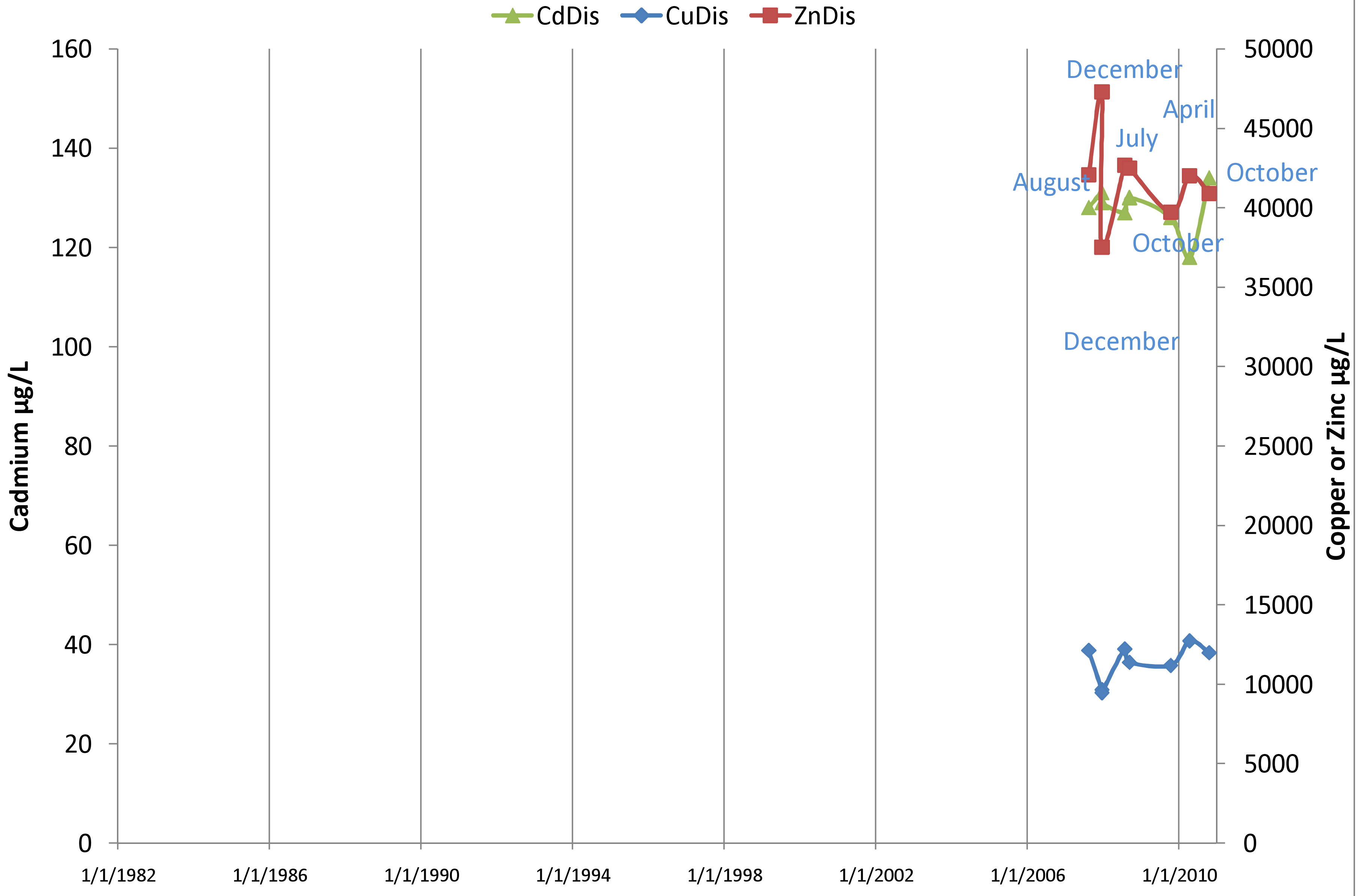


Figure 3-32: Temporal Trend for Copper and Zinc within WellGS-09

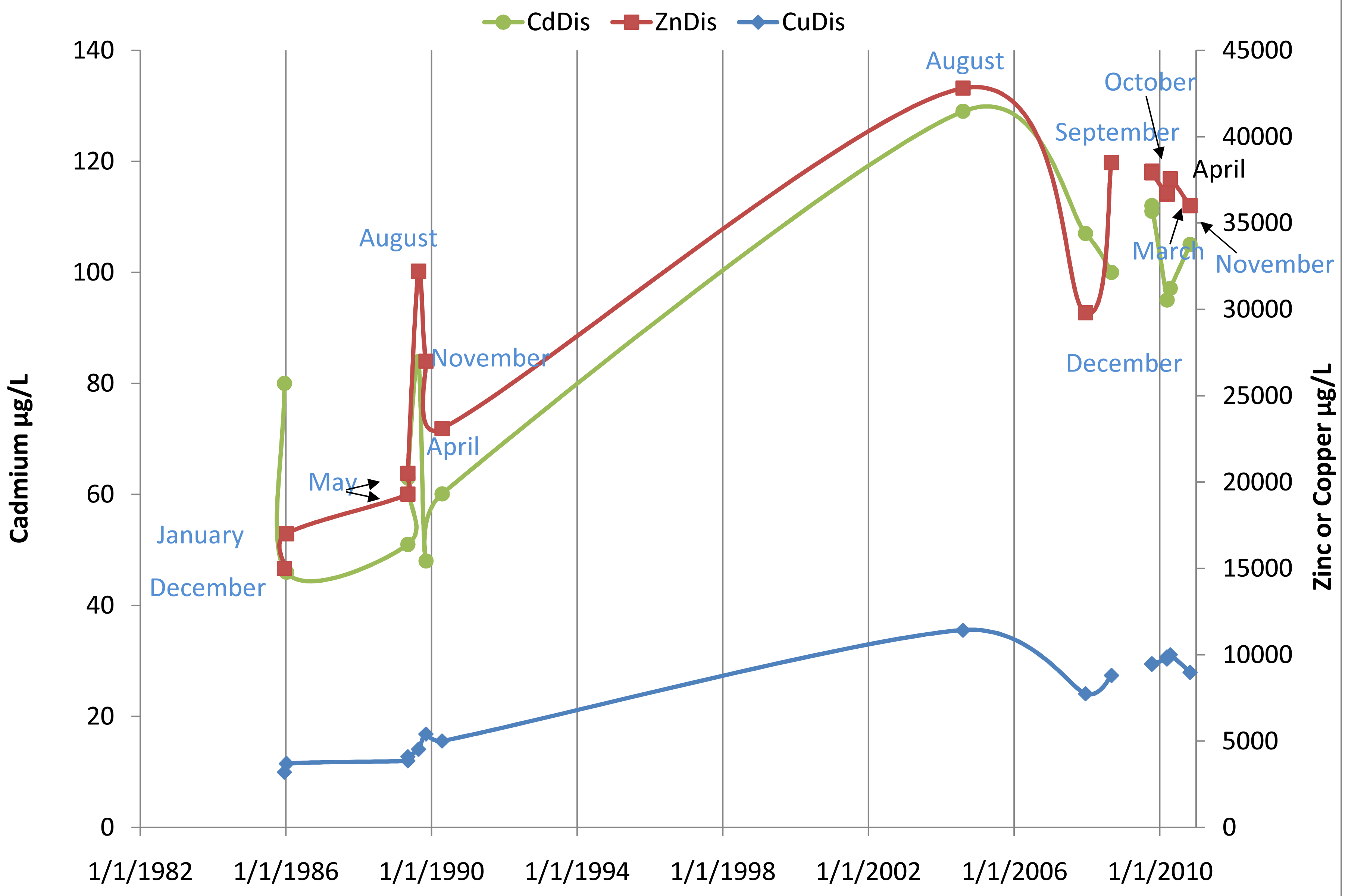
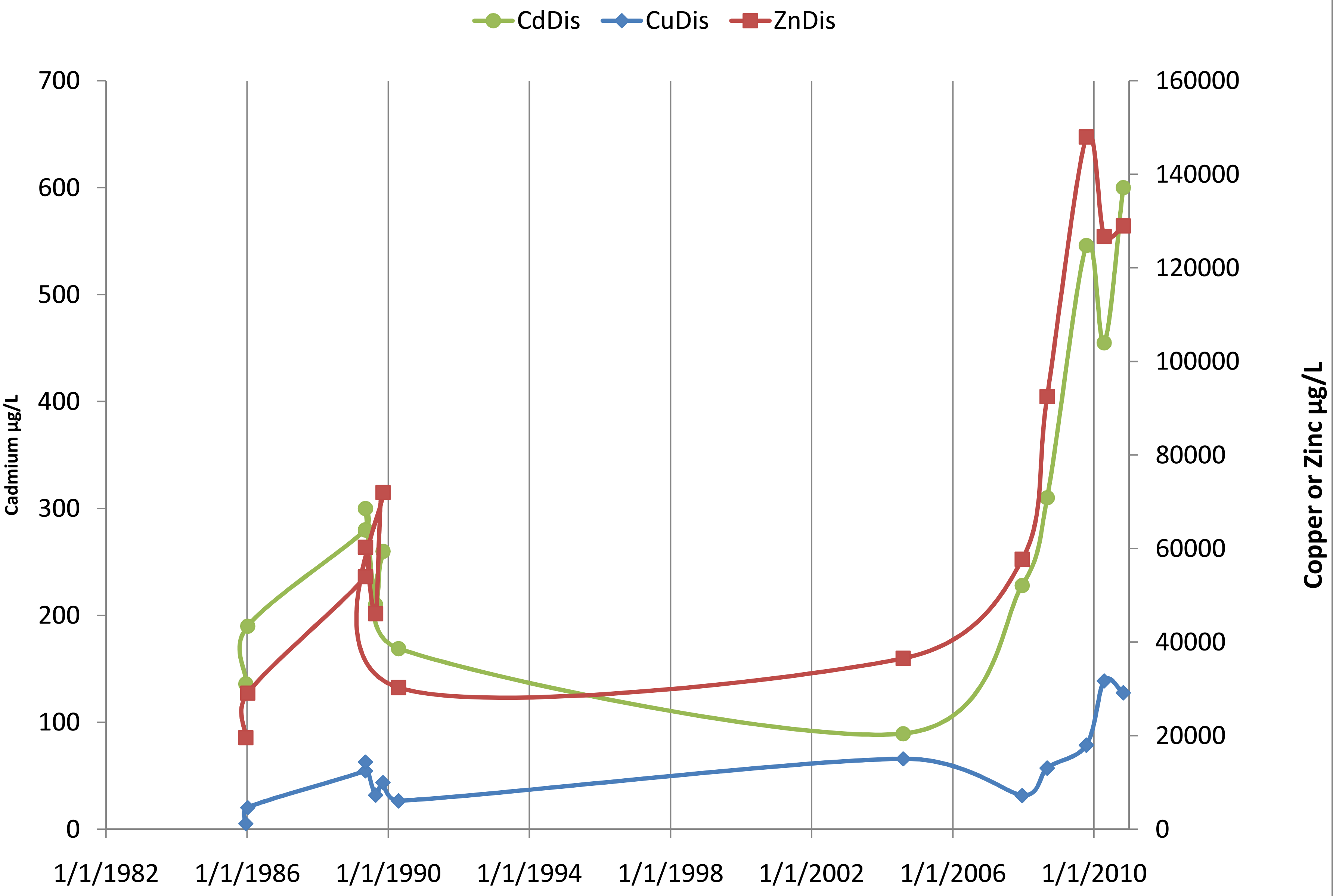


Figure 3-33: Temporal Trends for Copper and Zinc wtihin Well GS-11



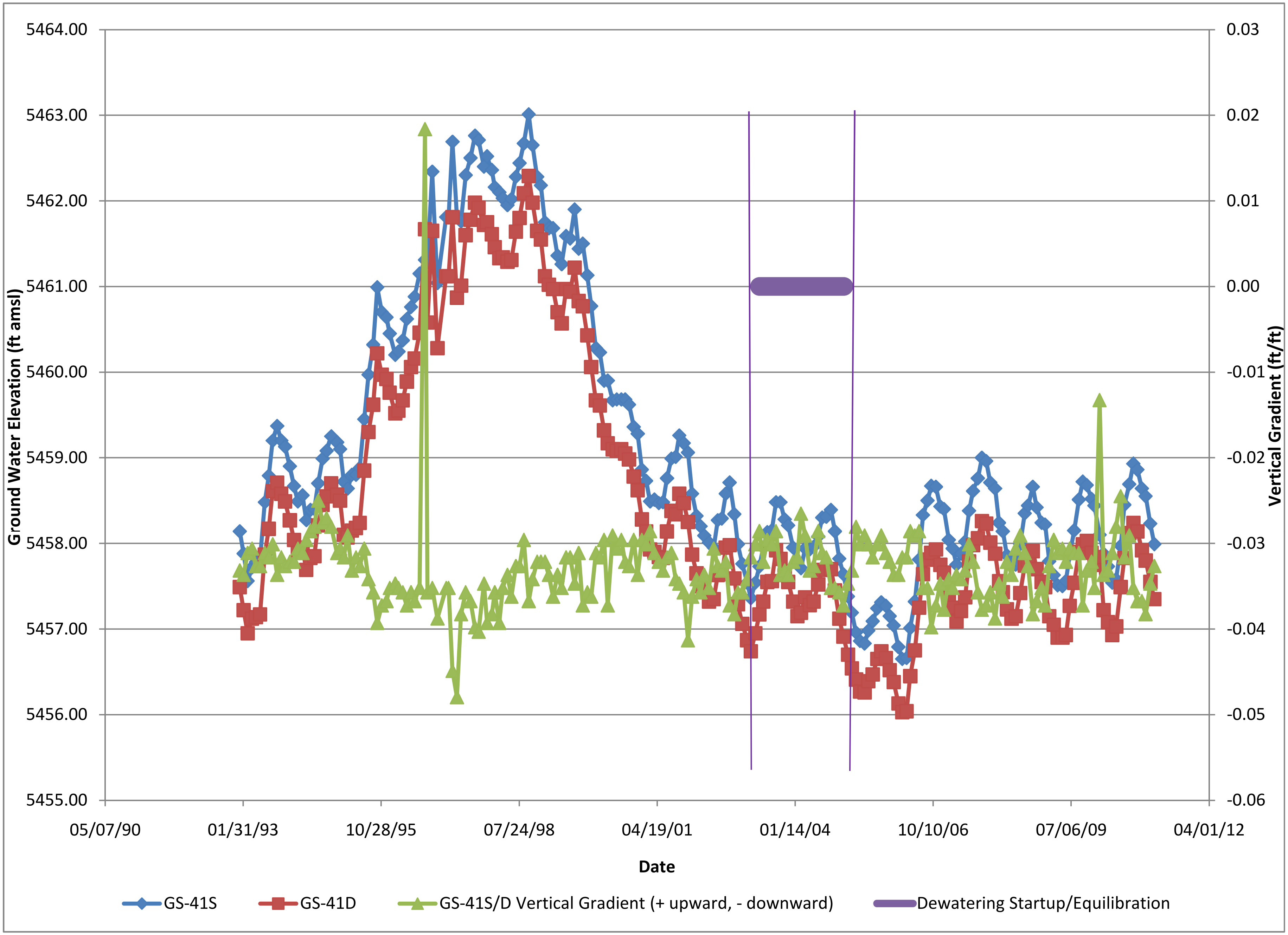


Figure 3- 34
GW-41 S/D Vertical Gradient

Butte Priority Soils Operable Unit

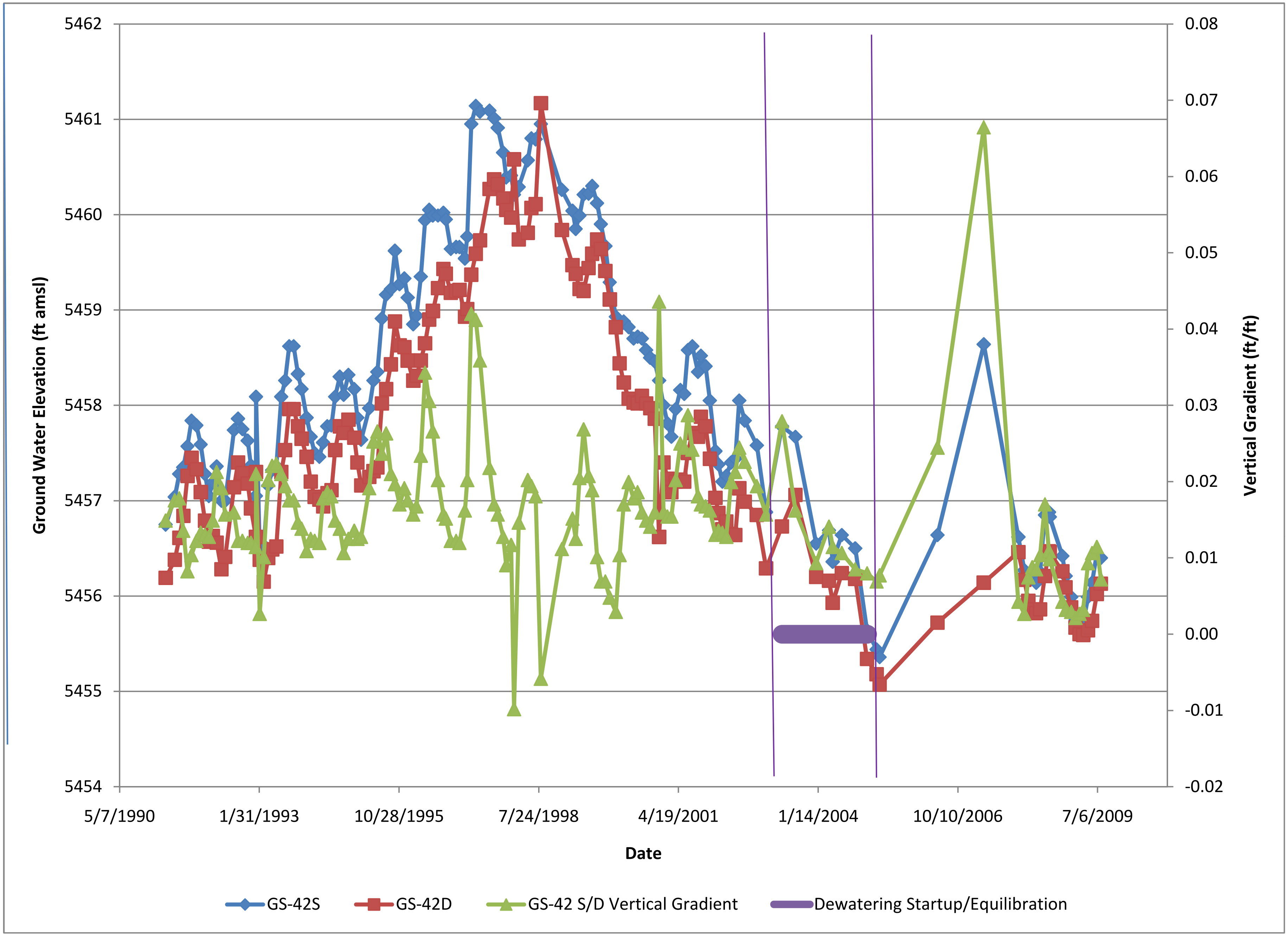


Figure 3-35
GS 42 S/D Vertical Gradient

Butte Priority Soils Operable Unit

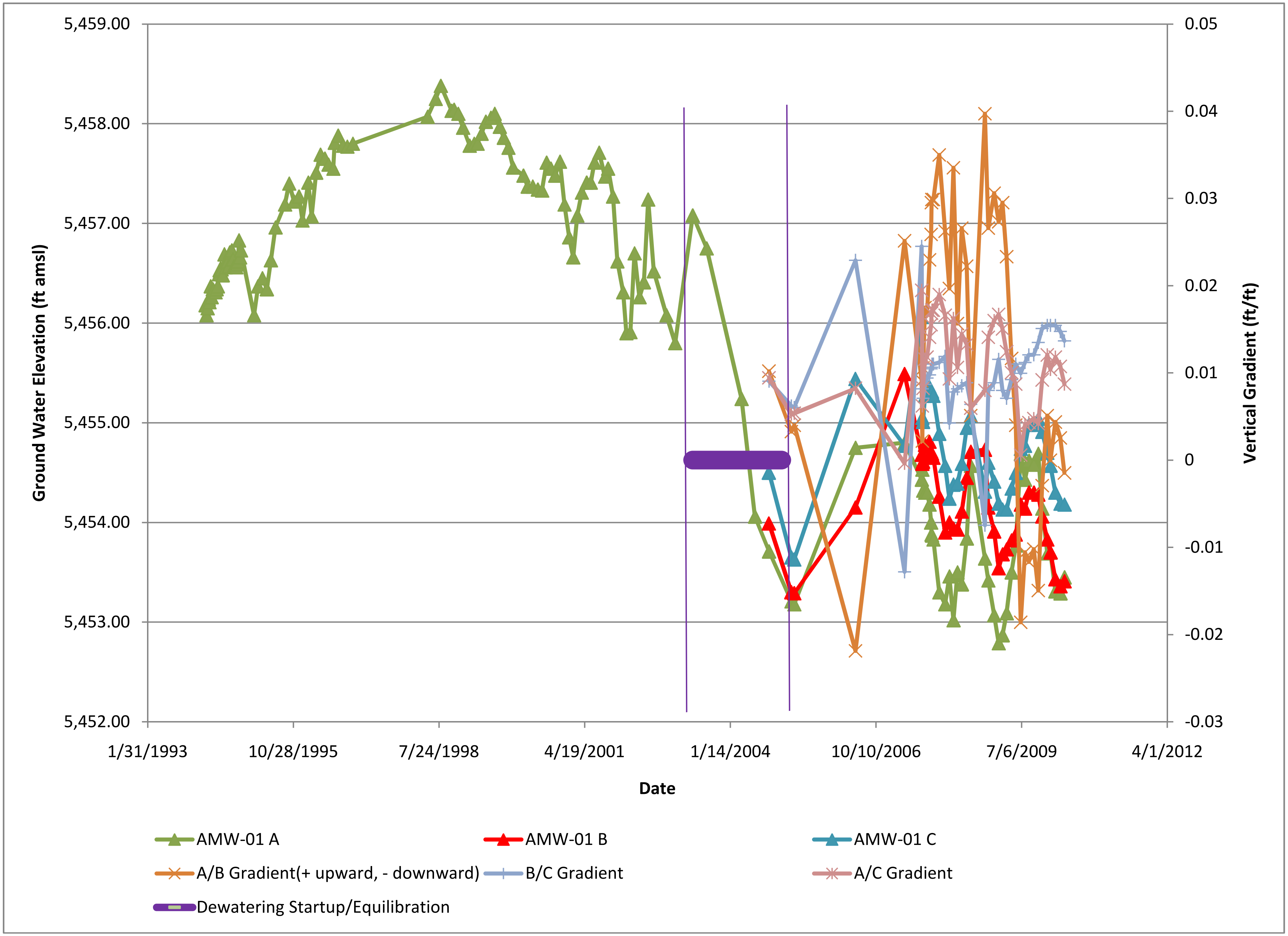


Figure 3-36
AMW-1 A,B,C Vertical Gradient

Butte Priority Soils Operable Unit

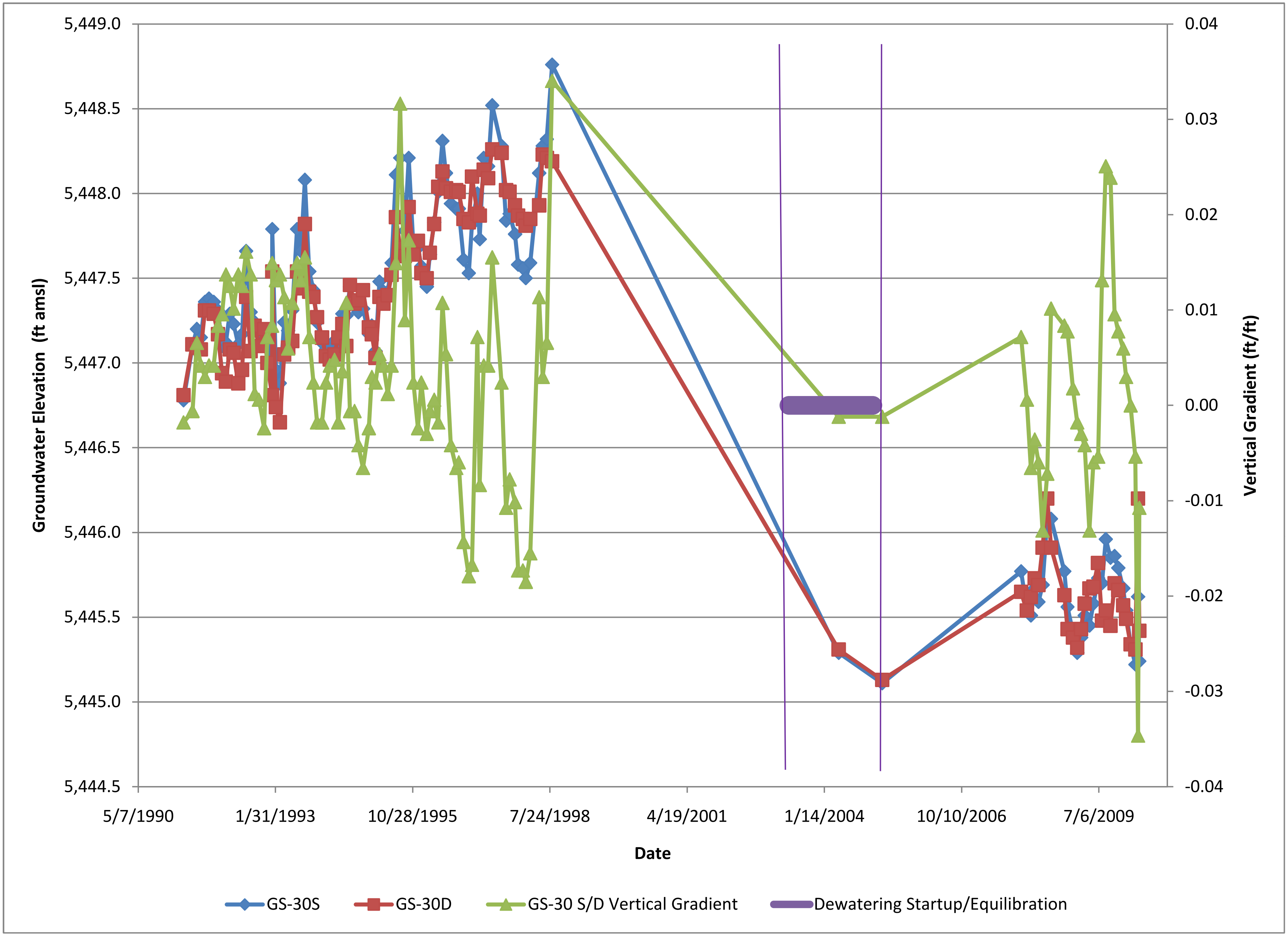


Figure 3-37
GS-30 S/D Vertical Gradient

Butte Priority Soils Operable Unit

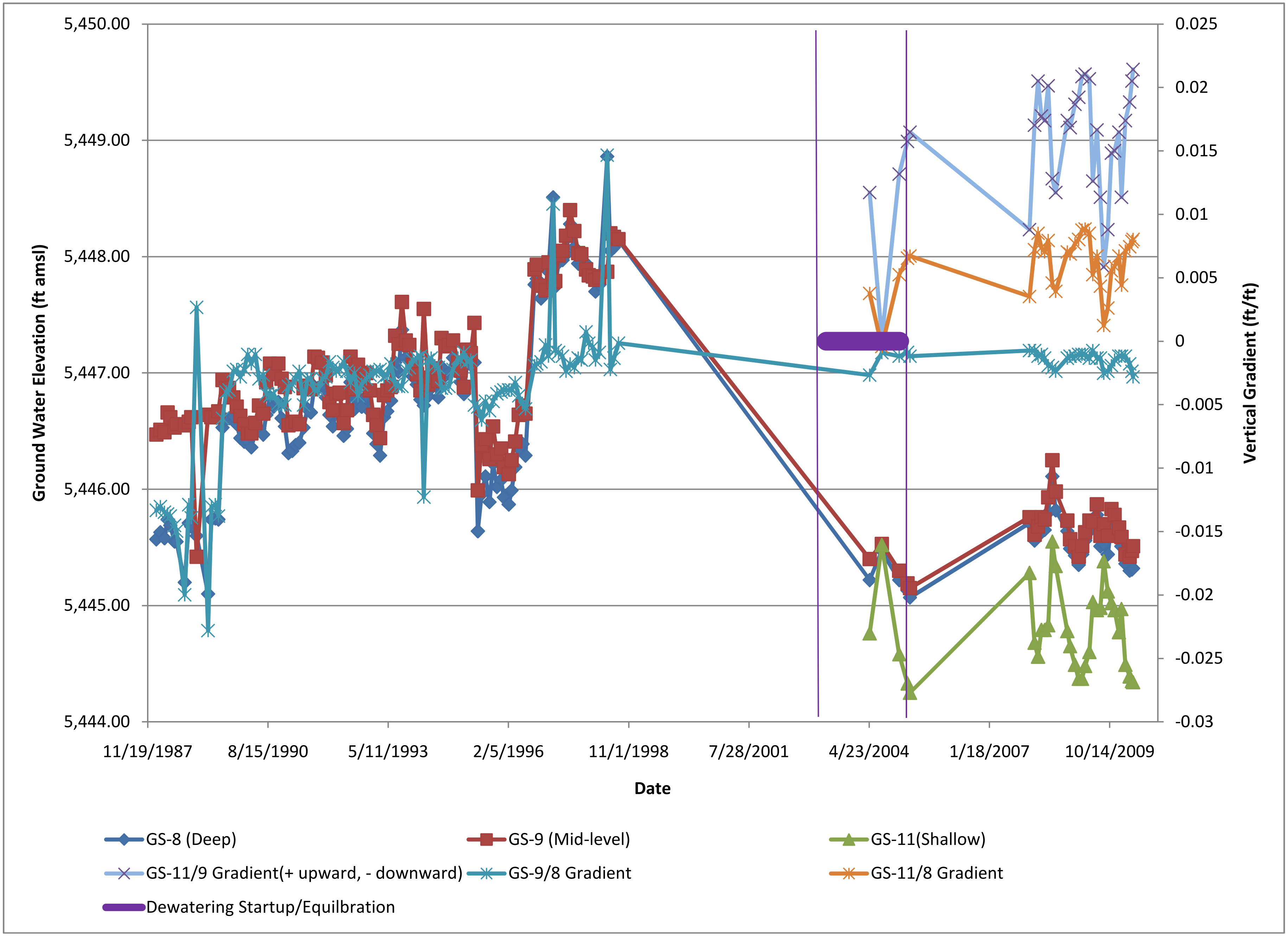


Figure 3-38
GS-8, 9,11 Vertical Gradient

Butte Priority Soils Operable Unit

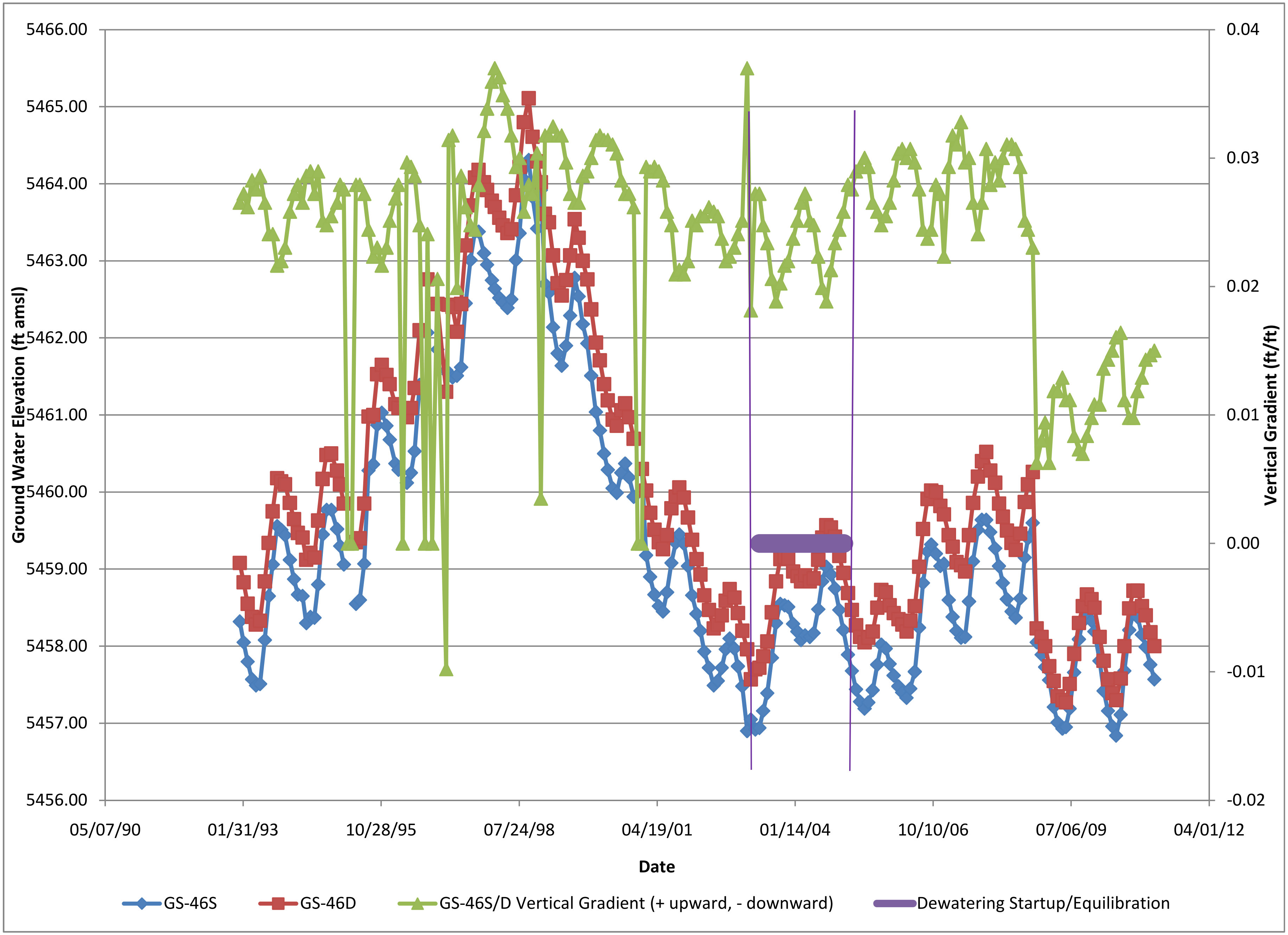
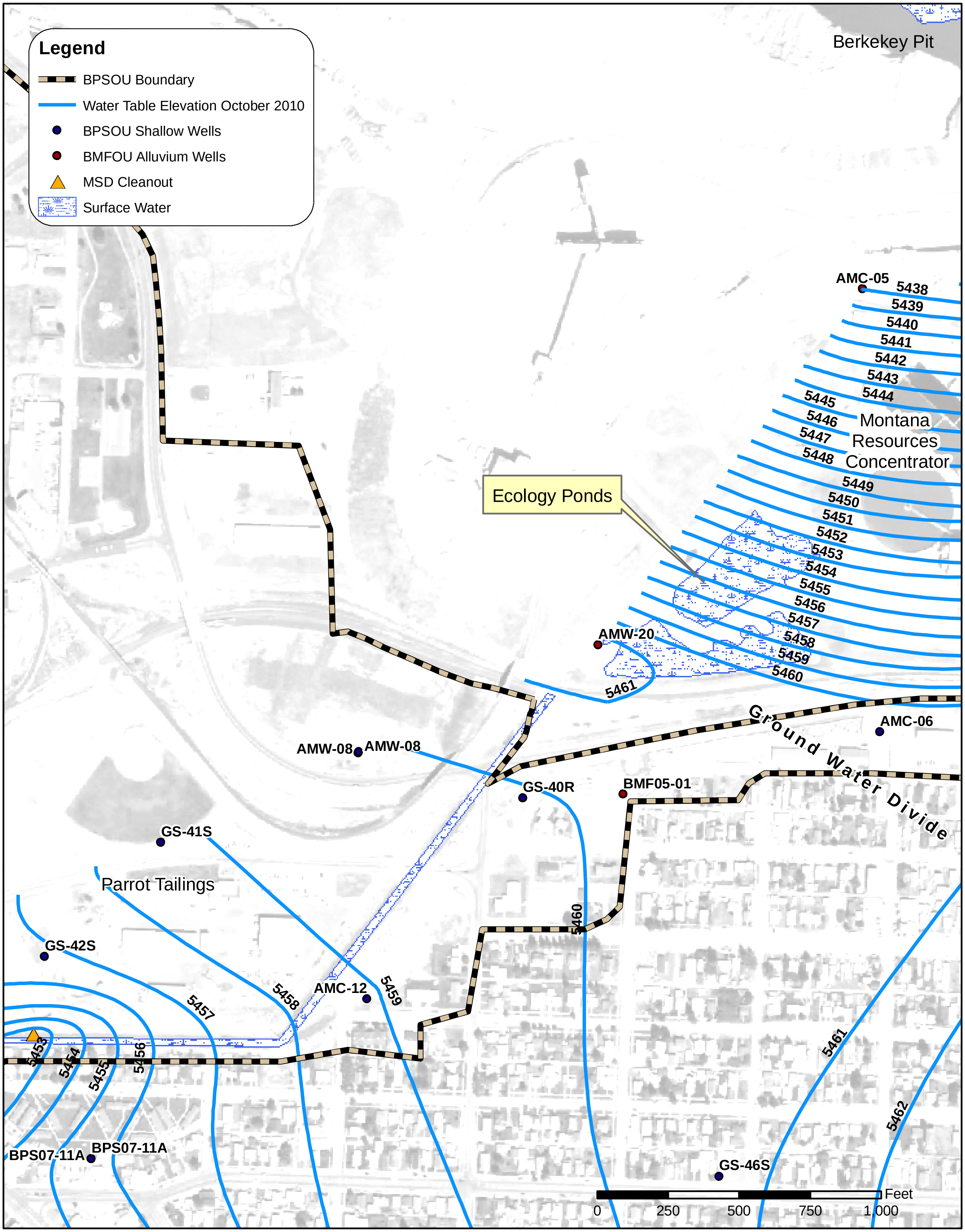


Figure 3-39

GW-46 S/D Vertical Gradient

Butte Priority Soils Operable Unit



Z:\gis\Public\Butte\Water_Table\MXD\WL_Parrot_Oct10.mxd

Figure 3-40

Water Table Elevations near the Parrot Tailings October 2010

Butte Priority Soils Operable Unit

Figure 3-41
Long-Term Water Elevations Along Cross Section in Parrot Tailings Area

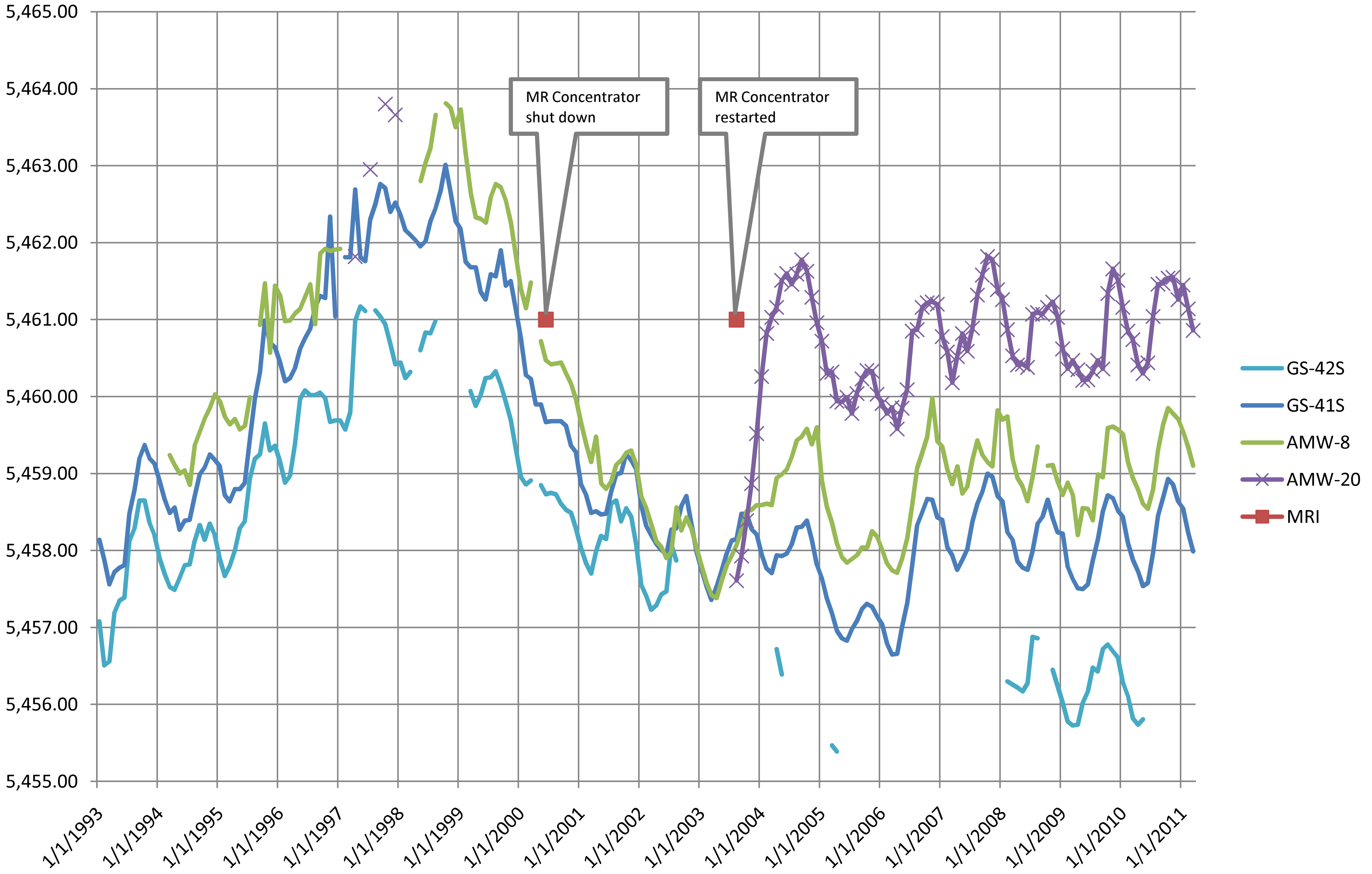


Figure 3-42
Water Table Elevation Differences between AMW-08 and GS-41S

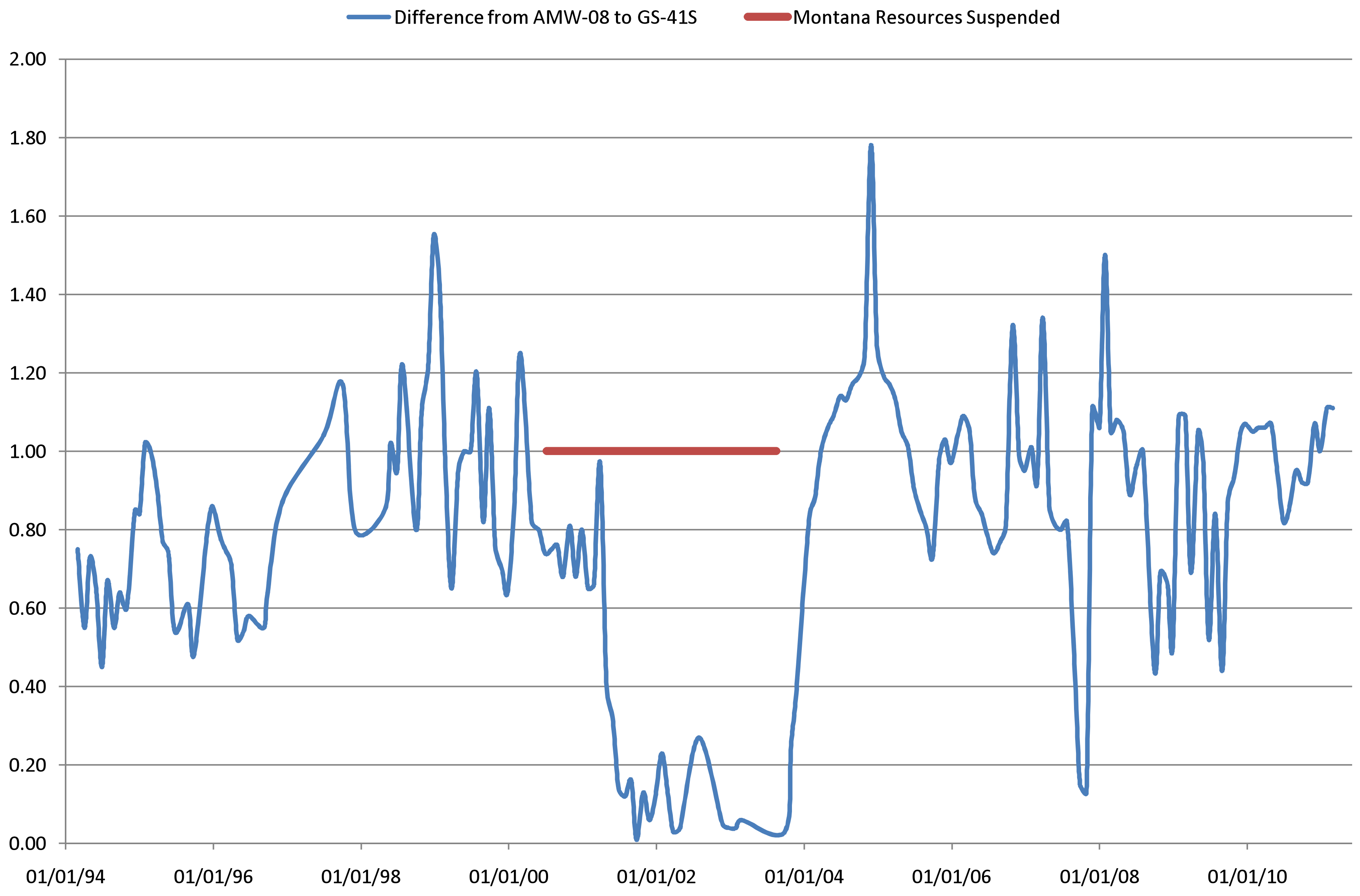
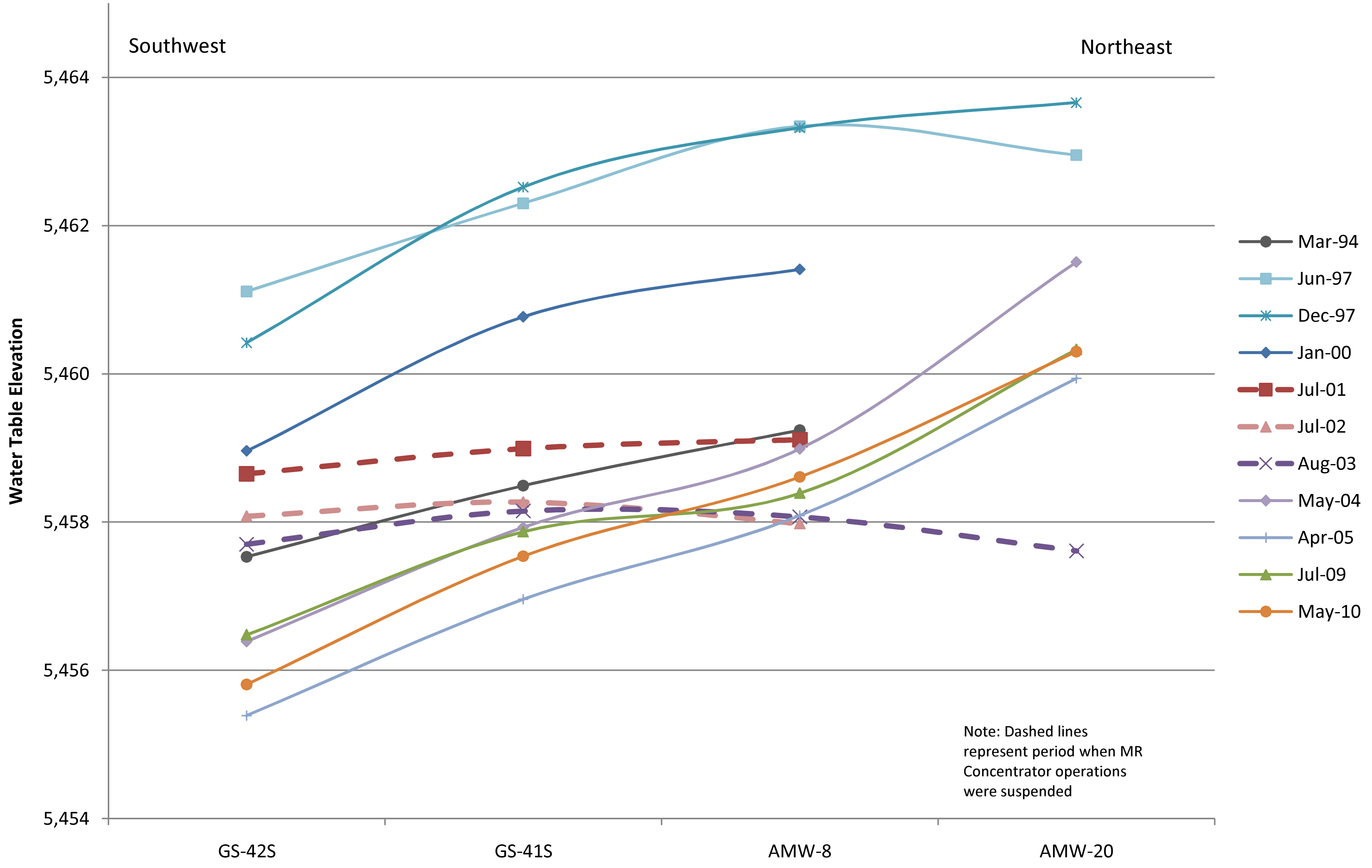


Figure 3-43
Water Table Elevations Along Cross Section Through Parrot Tailings



Note: Dashed lines represent period when MR Concentrator operations were suspended

Appendix A
Data Analysis

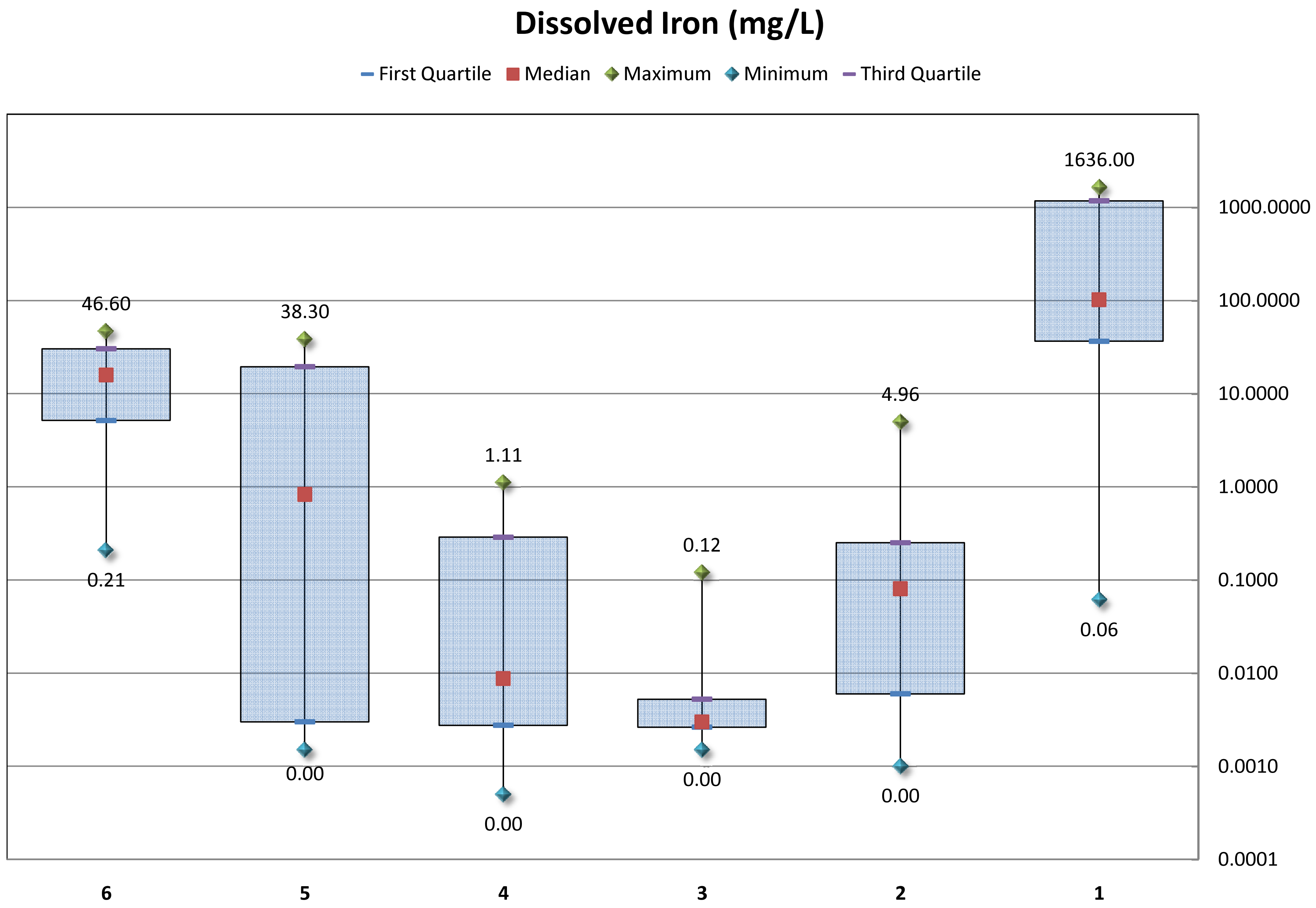


Figure 2

Box and Whisker Plot for Iron, April and August 2010 Data.

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Butte Priority Soils Operable Unit
Silver Bow Creek/Butte Area NPL Site

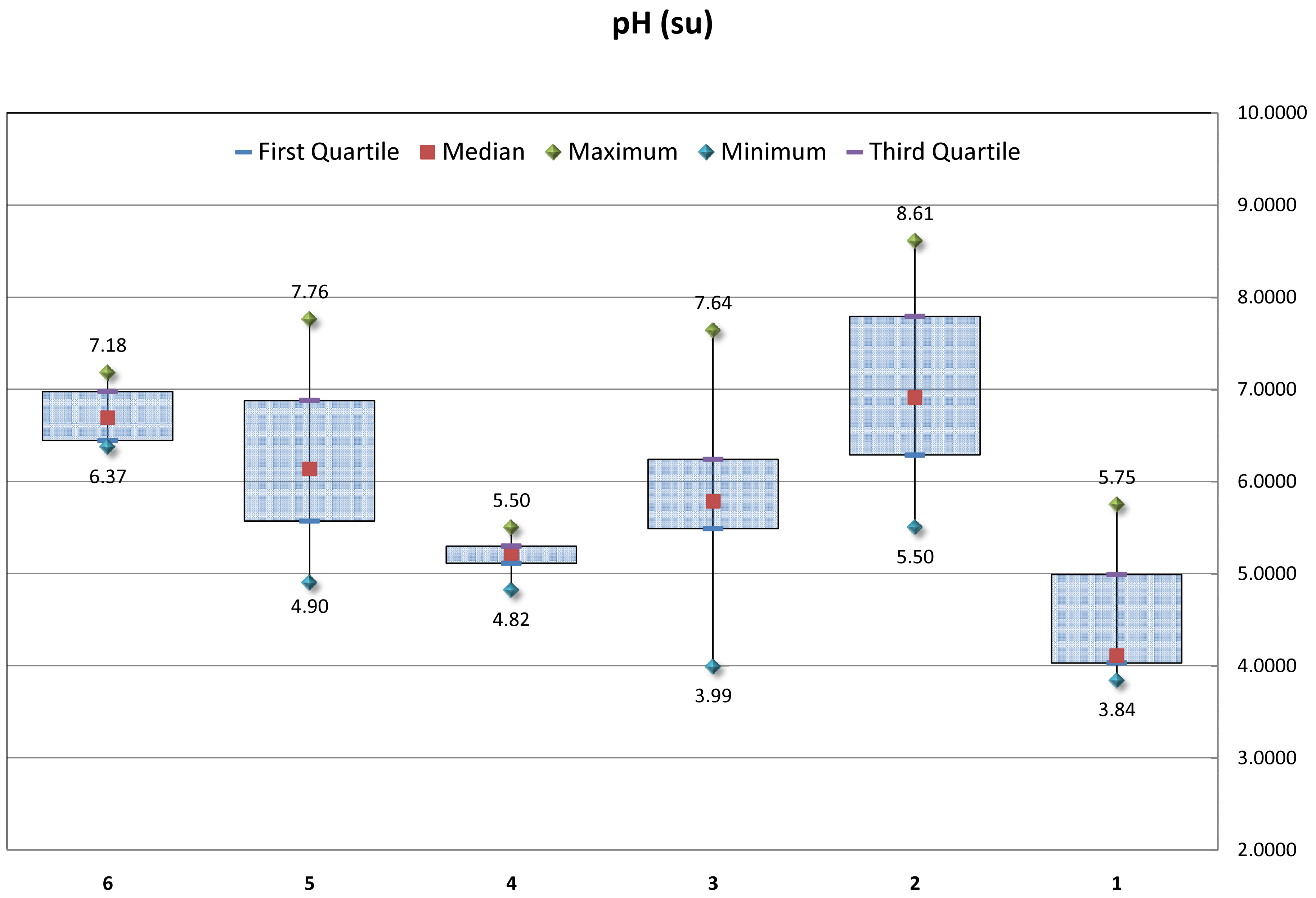

Figure 3
Box and Whisker Plot for pH, April and August 2010 Data.

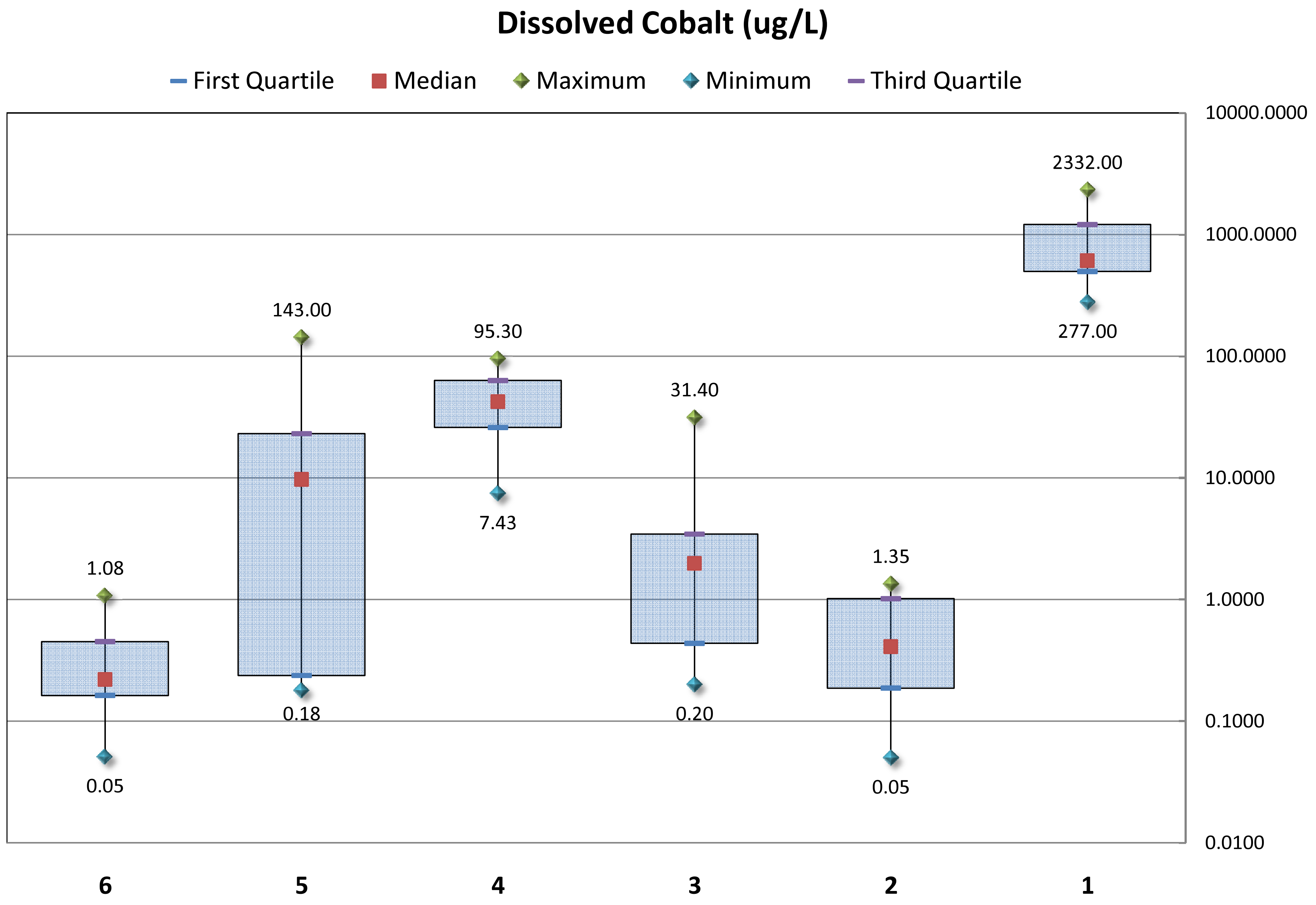

Figure 4
Box and Whisker Plot for Cobalt, April and August 2010 Data.

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Silver Bow Creek/Butte Area NPL Site

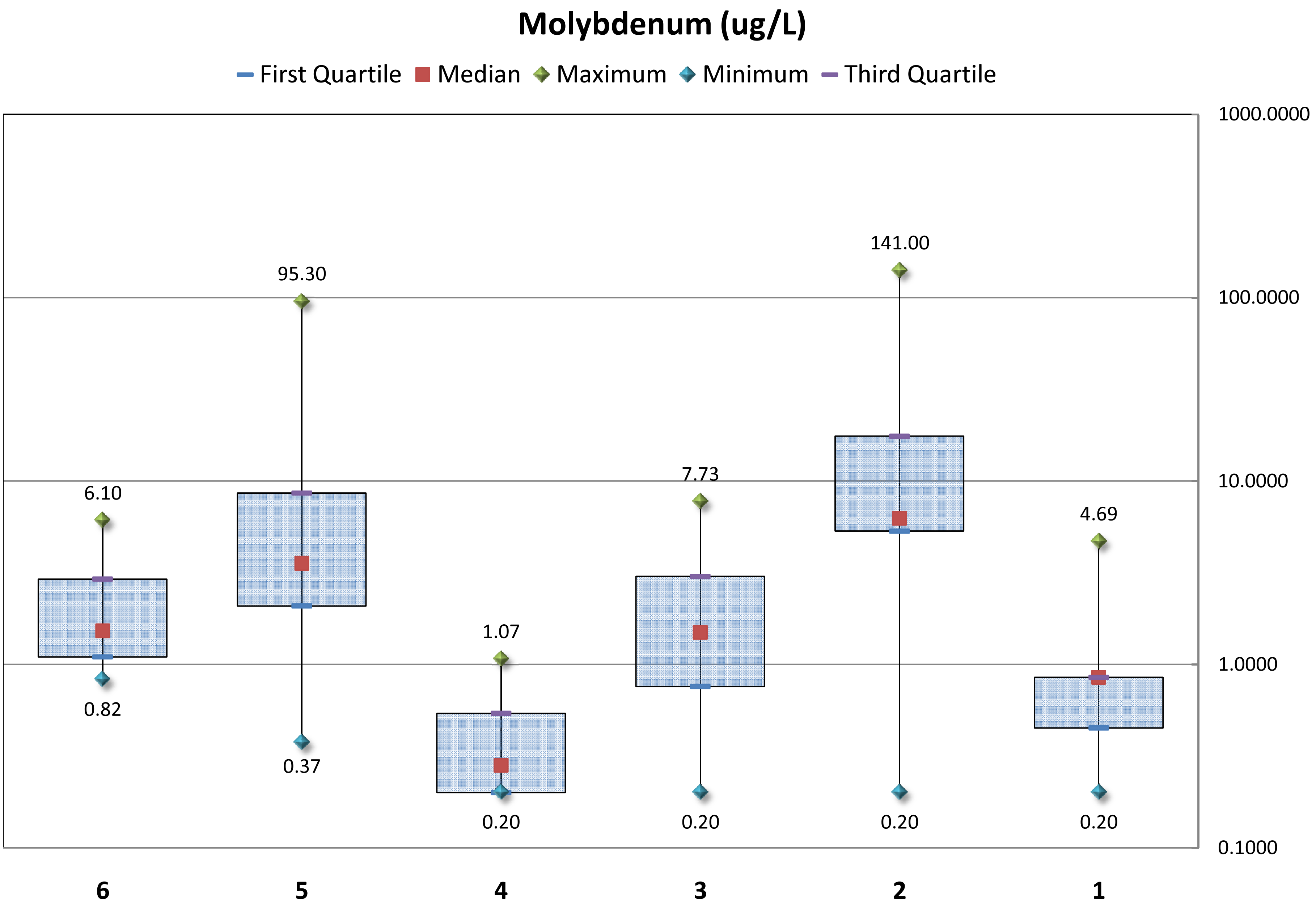


Figure 5
Box and Whisker Plot for Molybdenum, April and August 2010 Data.

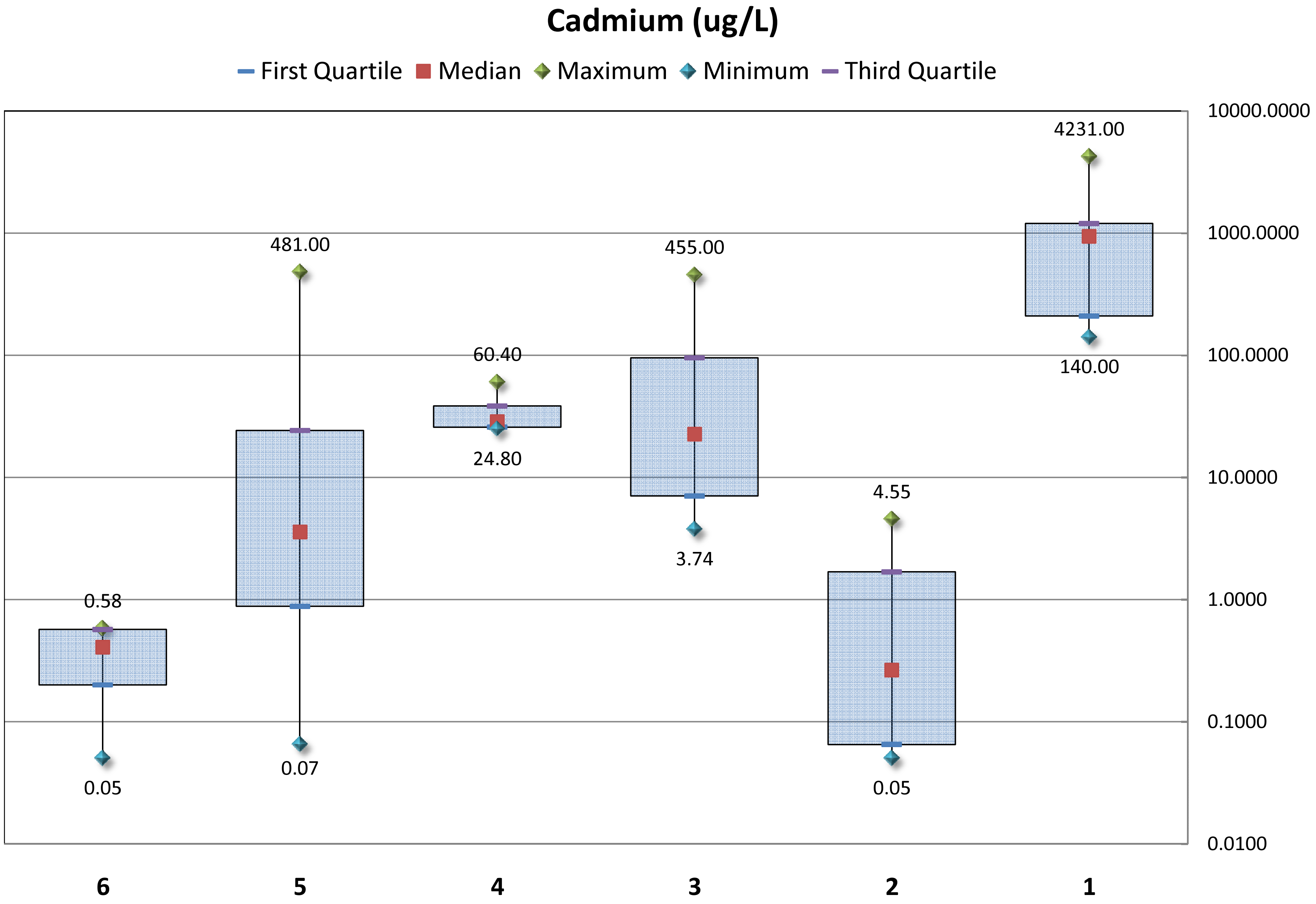
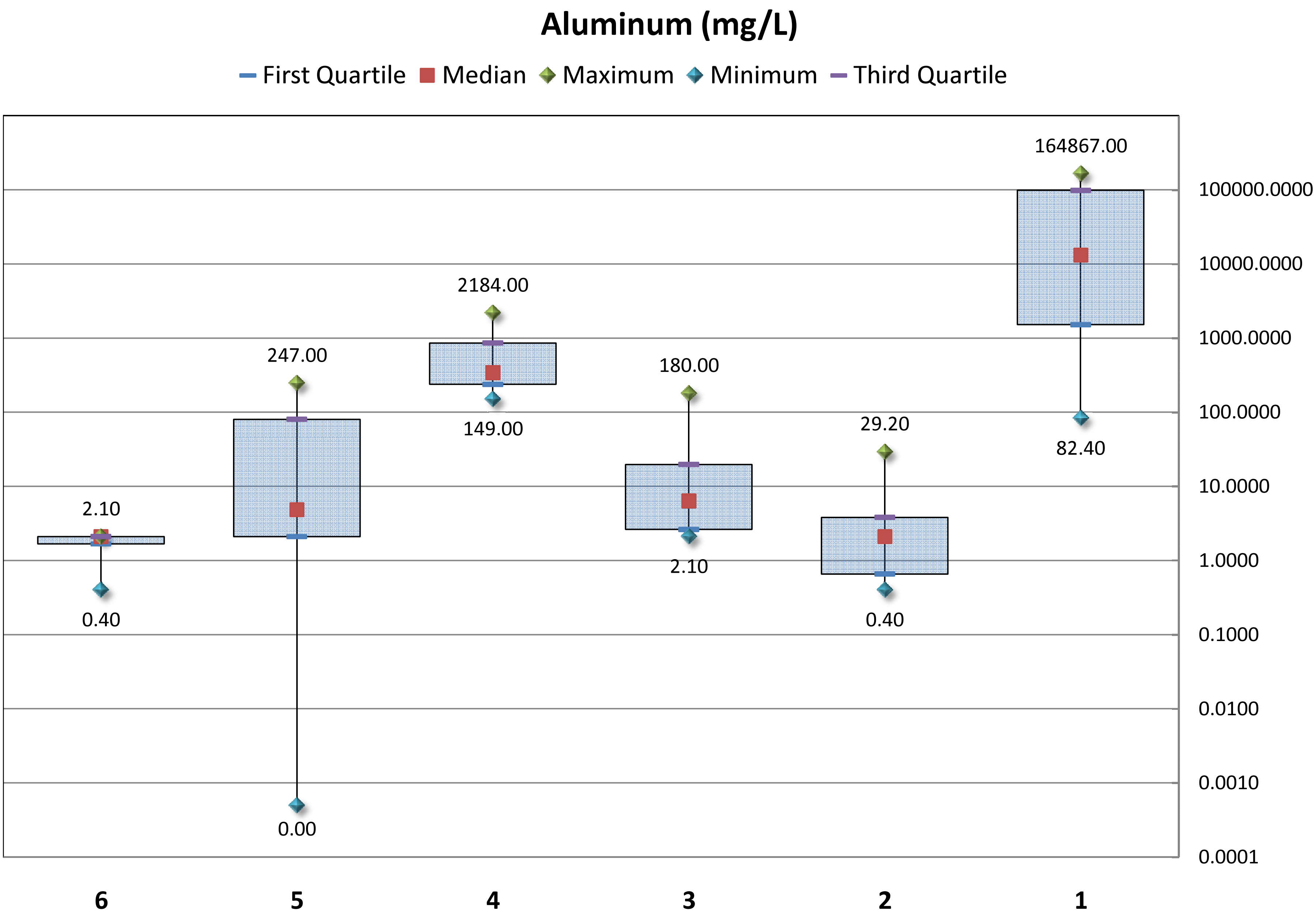


Figure 6

Box and Whisker Plot for Cadmium, April and August 2010 Data.



Ground Water Characterization Report
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Figure 7
Box and Whisker Plot for Aluminum, April and August 2010 Data.

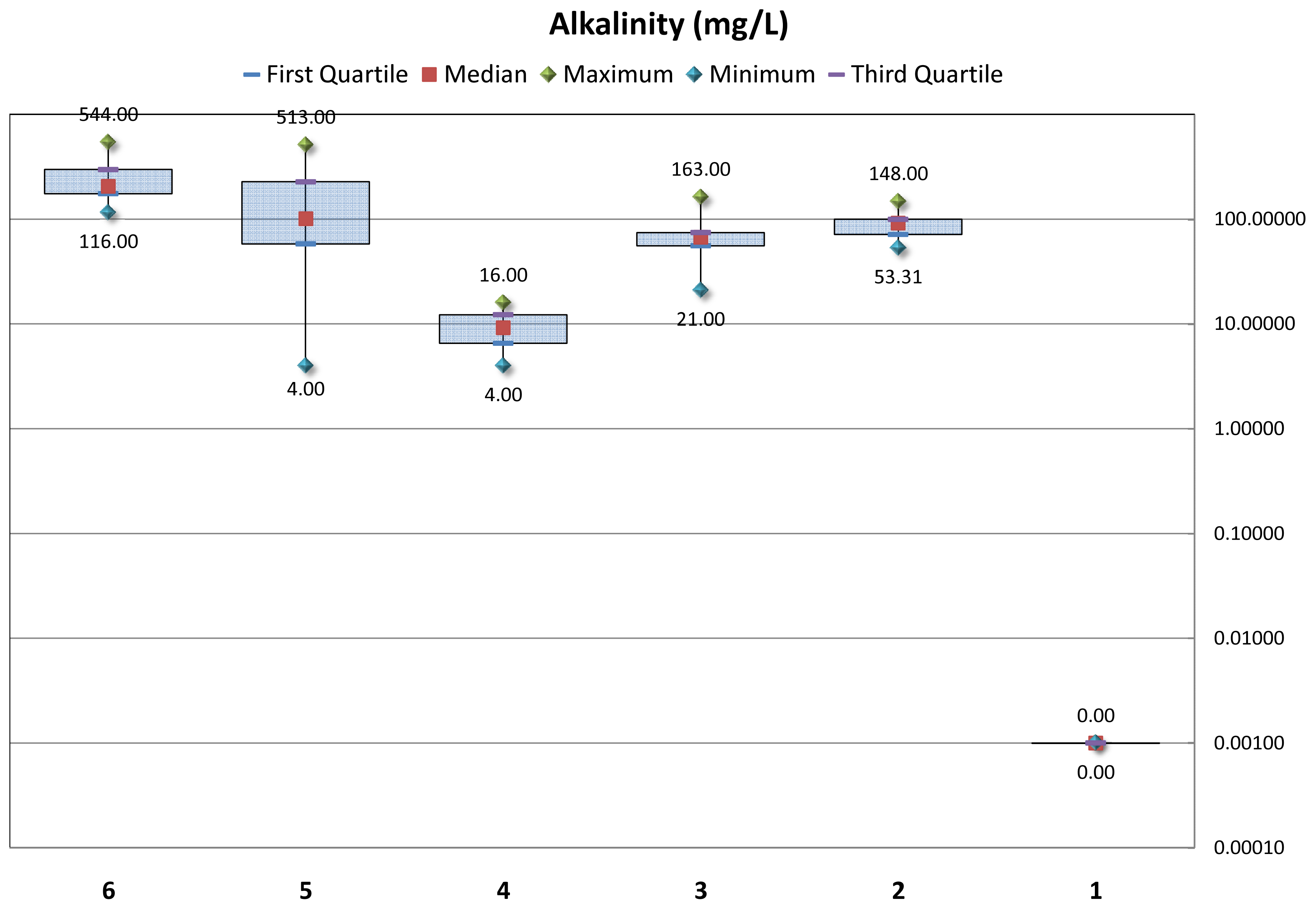

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Figure 8
Box and Whisker Plot for Alkalinity, April and August 2010 Data.

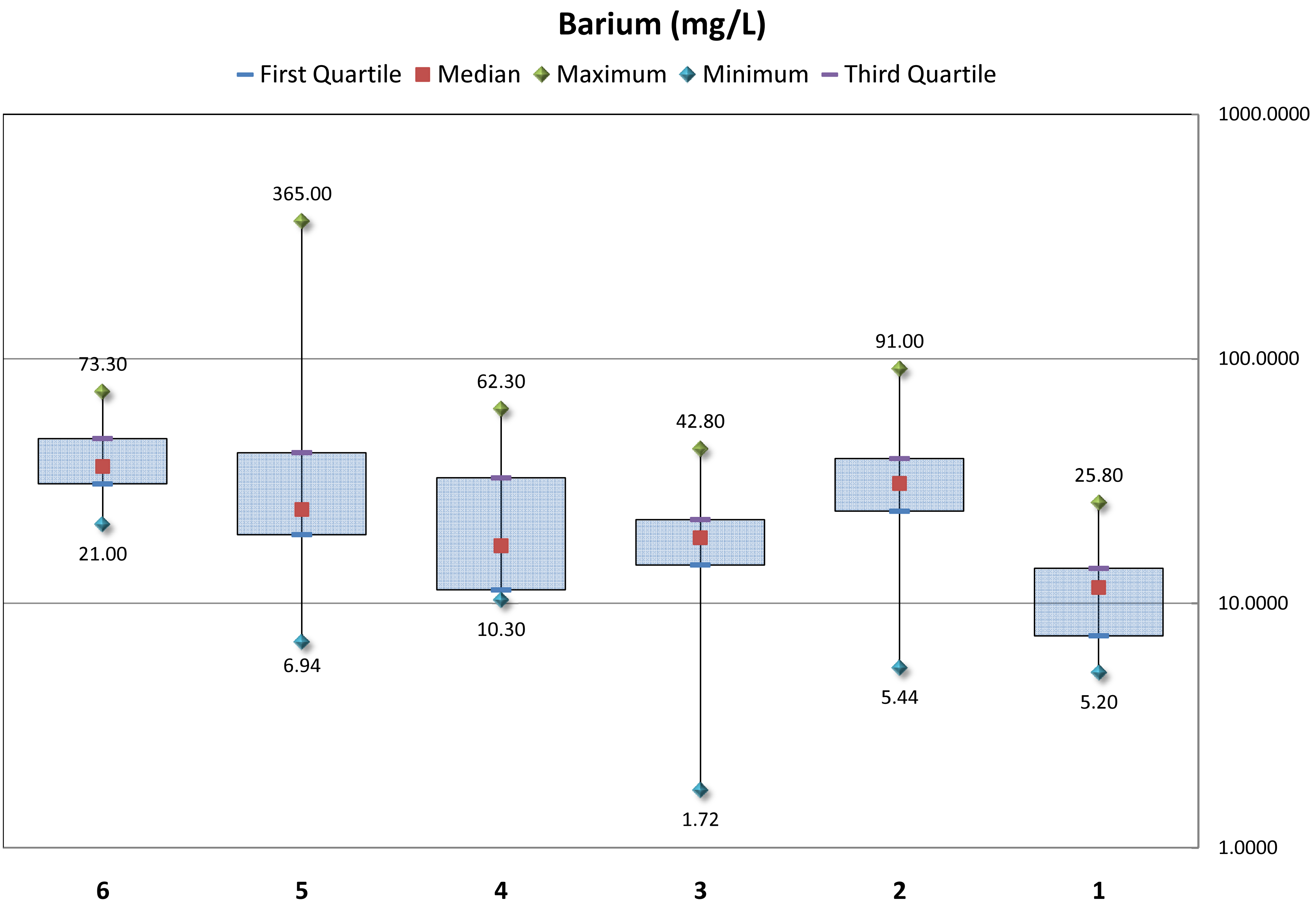

Figure 9

Box and Whisker Plot for Barium, April and August 2010 Data.

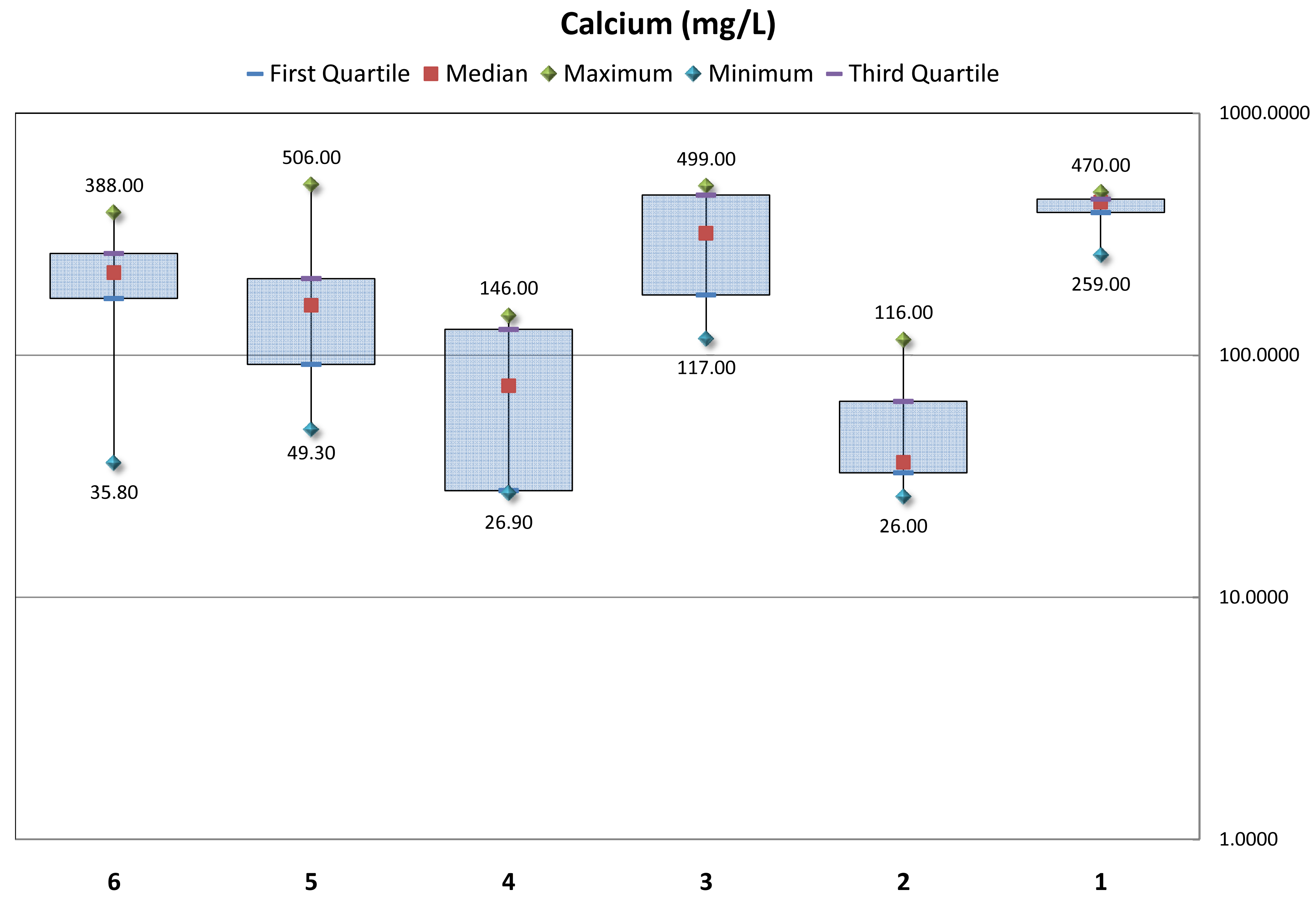

Figure 10
Box and Whisker Plot for Calcium, April and August 2010 Data.

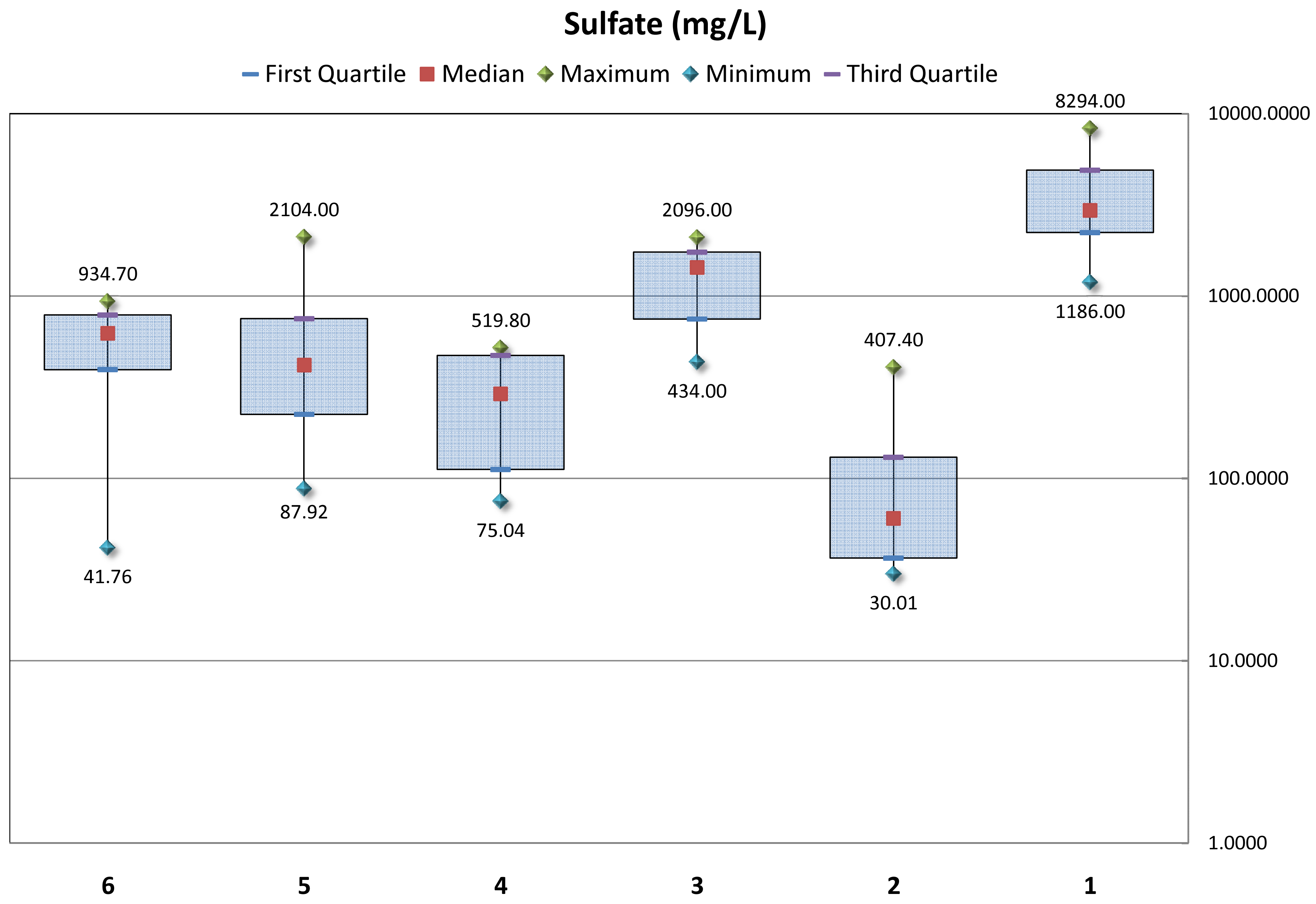

Figure 11

Box and Whisker Plot for Sulfate, April and August 2010 Data.

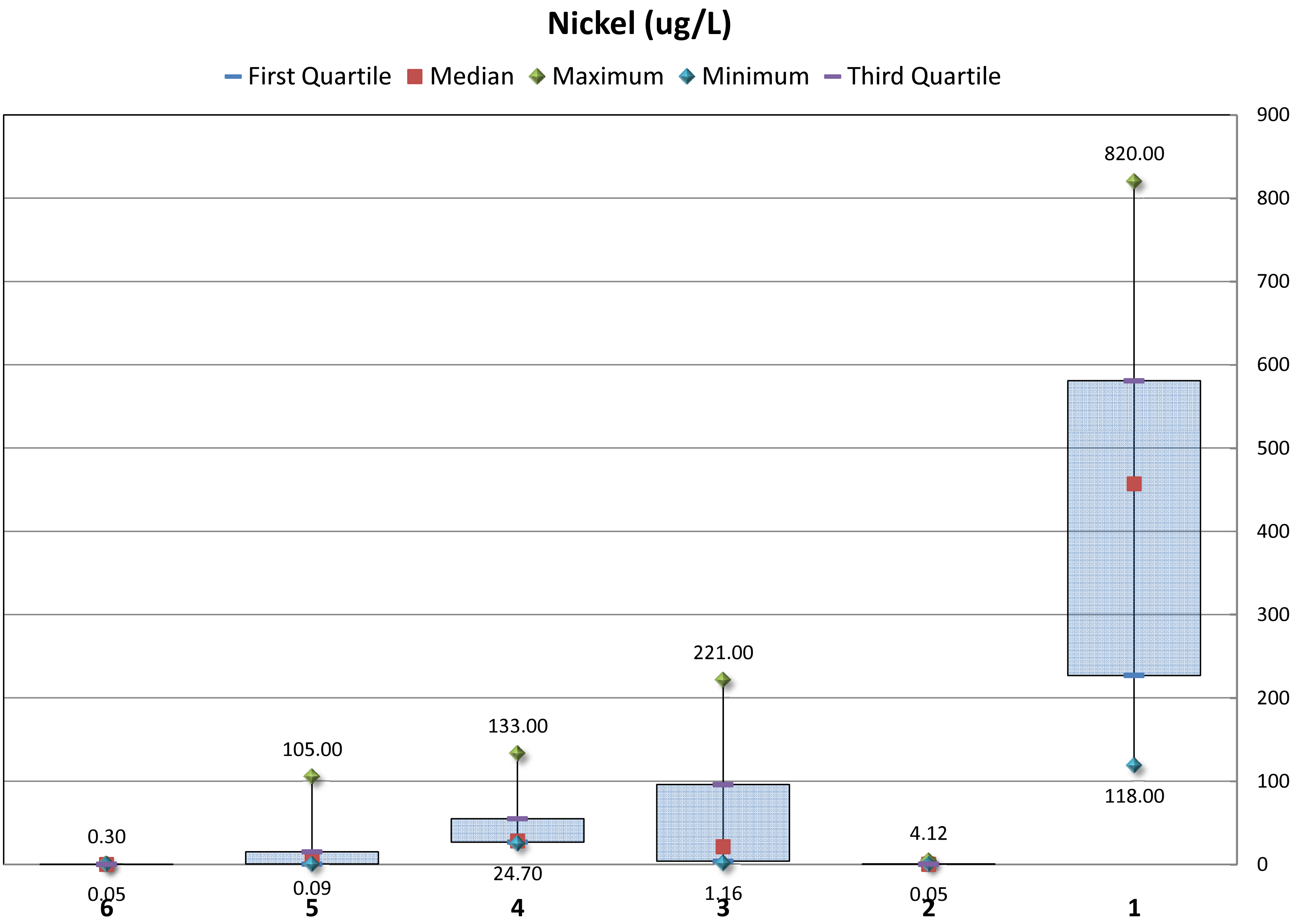

Figure 12

Box and Whisker Plot for Nickel, April and August 2010 Data.

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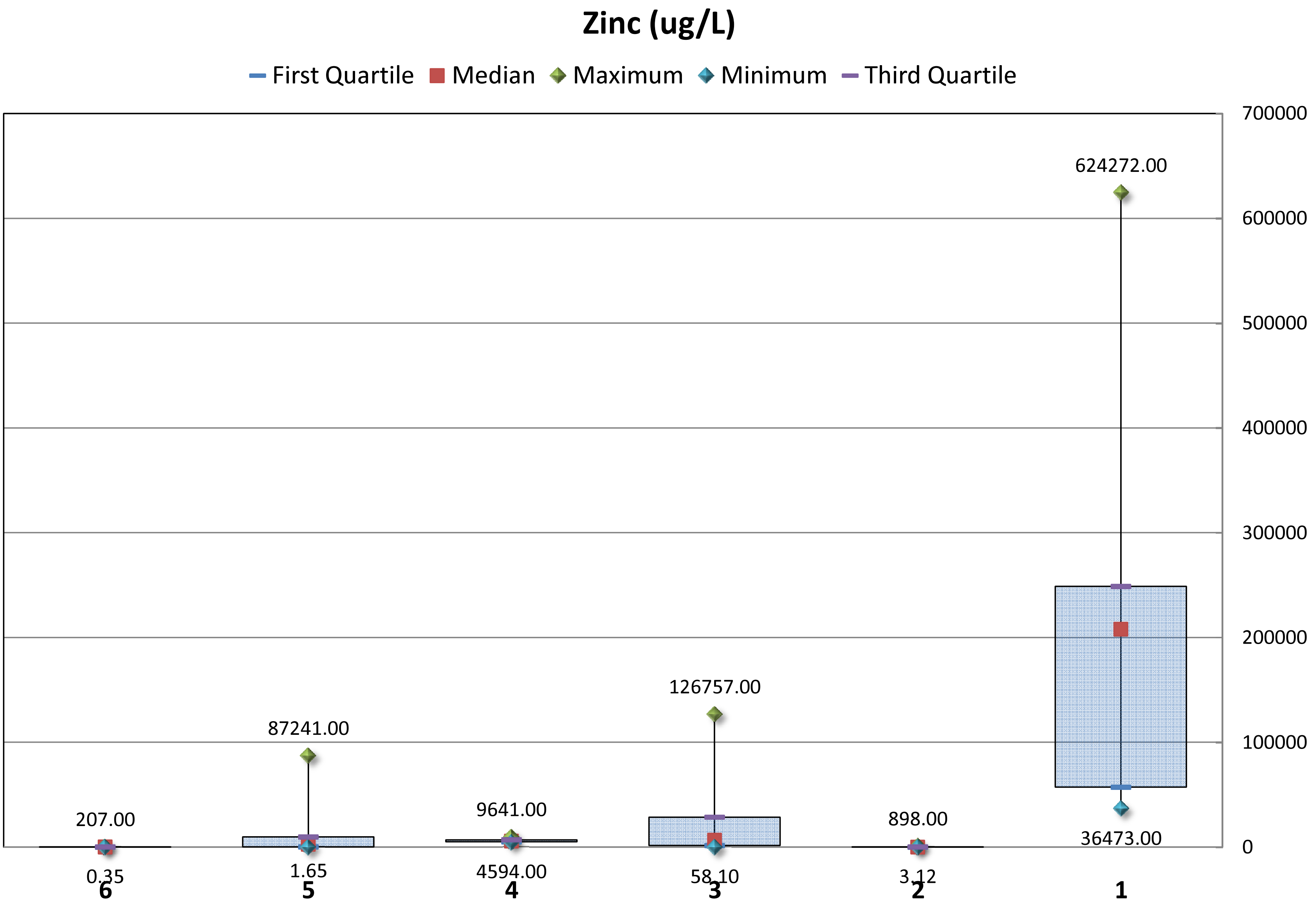

Figure 13
Box and Whisker Plot for Zinc, April and August 2010 Data.

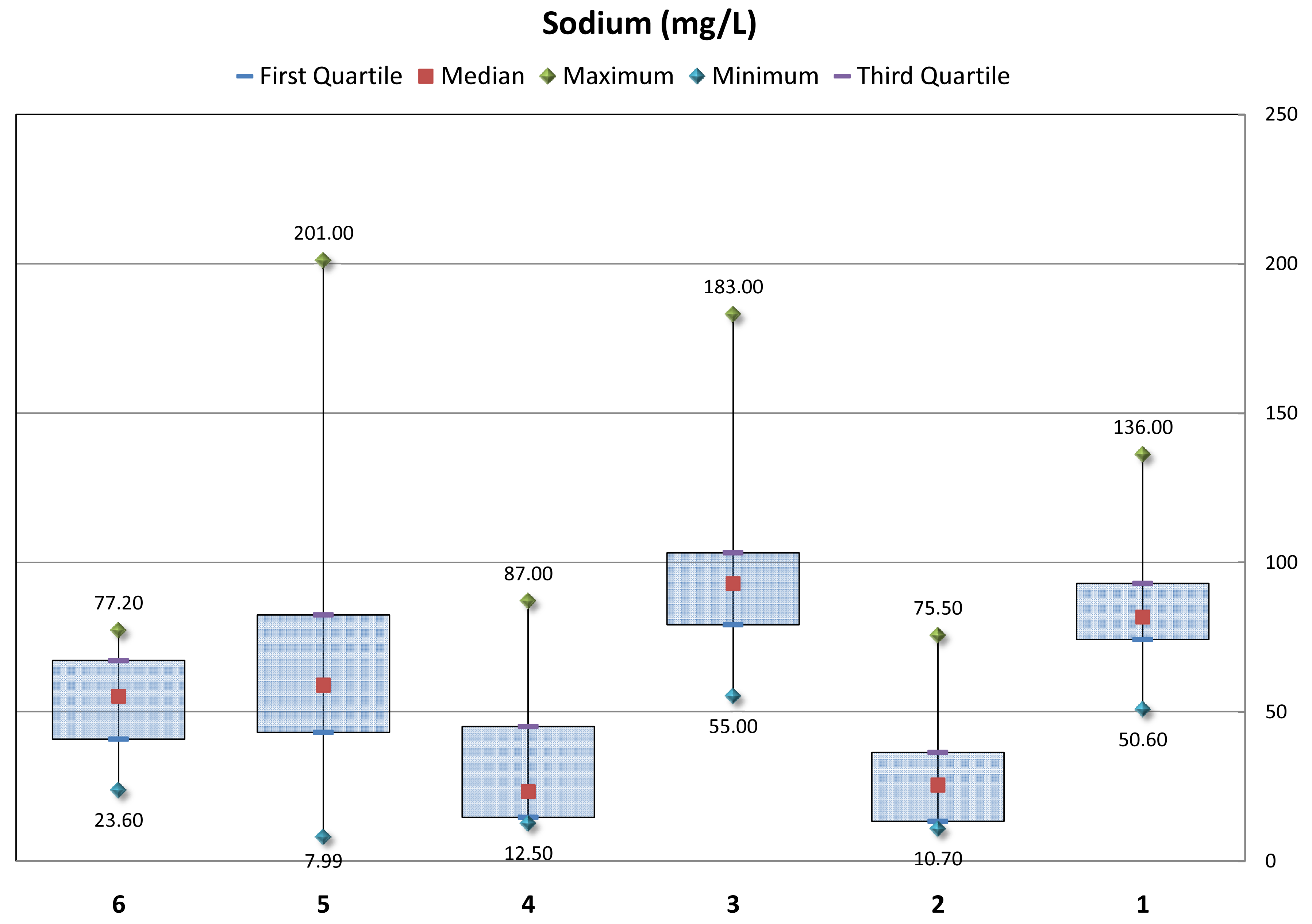

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Figure 14
Box and Whisker Plot for Sodium, April and August 2010 Data.

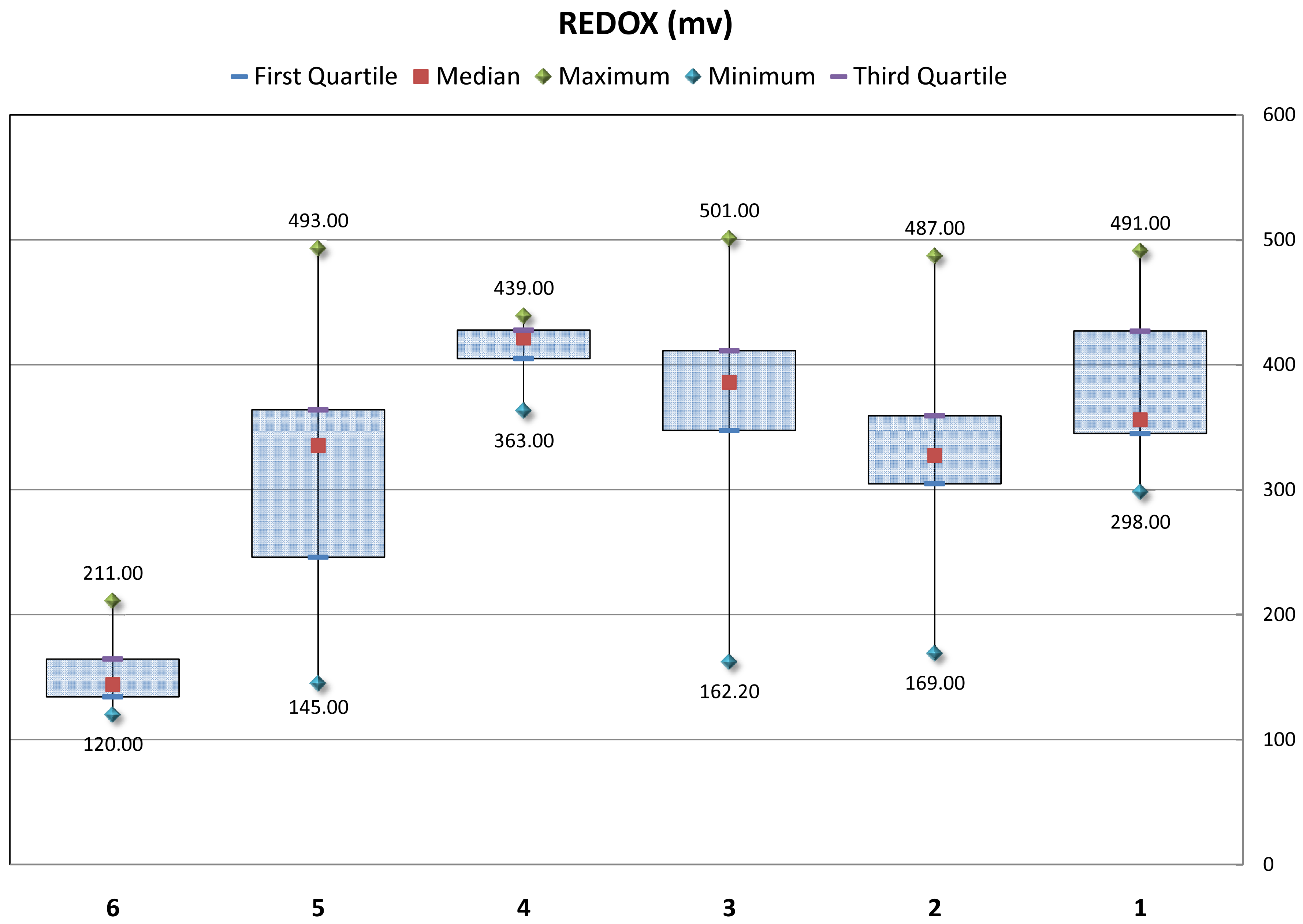

Figure 15
Box and Whisker Plot for REDOX, April and August 2010 Data.

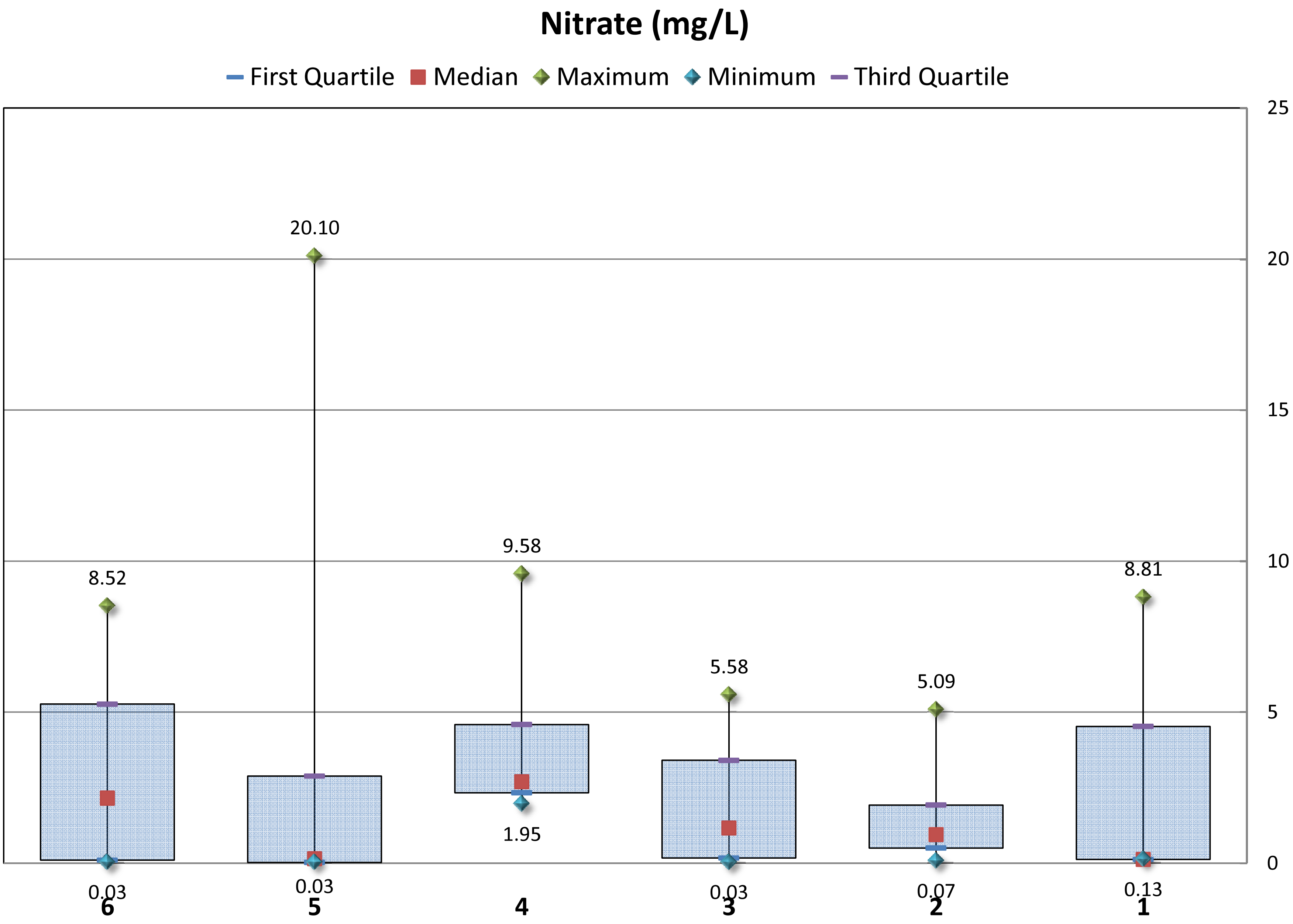

Figure 16
Box and Whisker Plot for Nitrate, April and August 2010 Data.

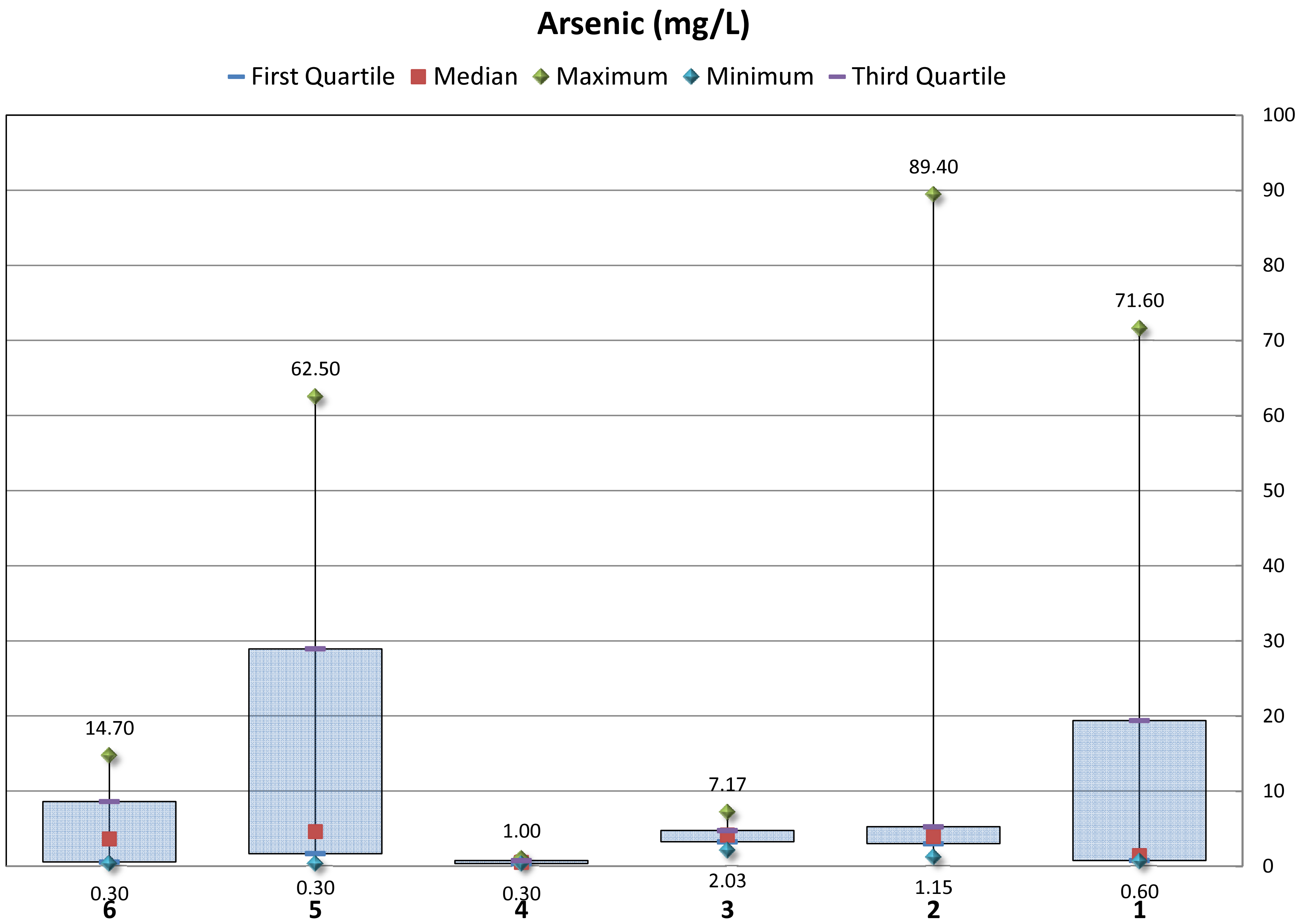

Figure 17

Box and Whisker Plot for Arsenic, April and August 2010 Data.

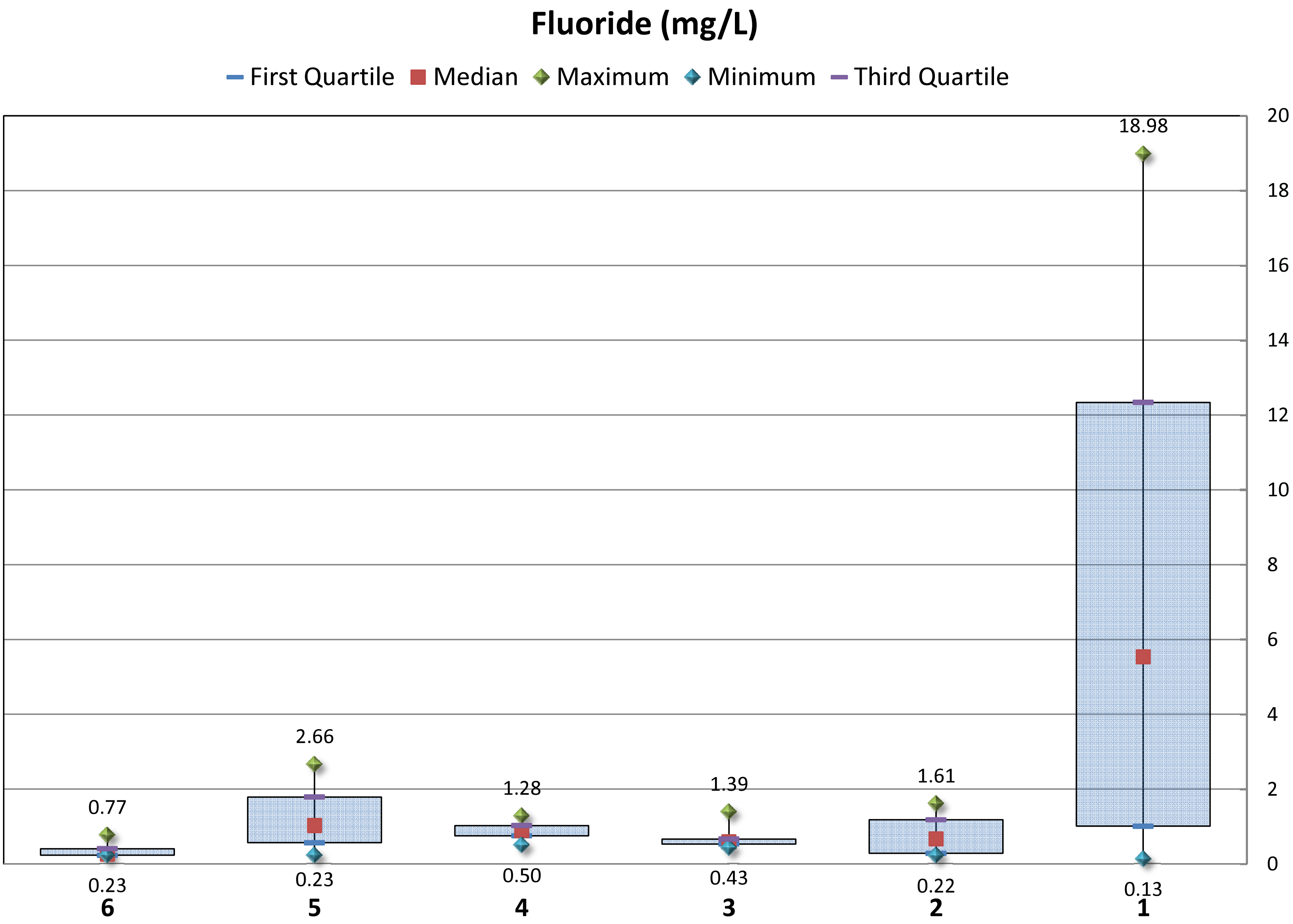

Figure 18

Box and Whisker Plot for Fluoride, April and August 2010 Data.

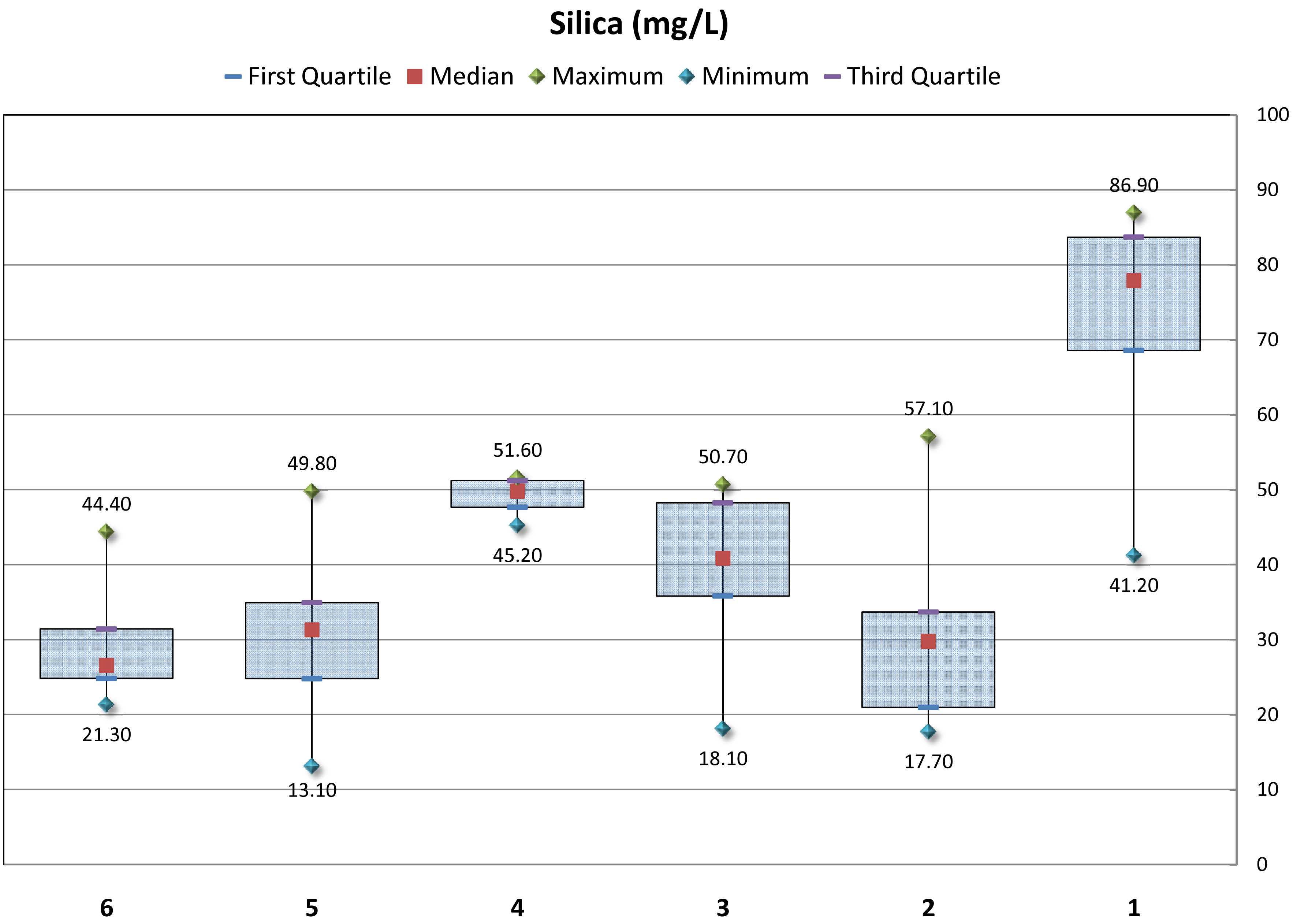

Figure 19
Box and Whisker Plot for Silica, April and August 2010 Data.

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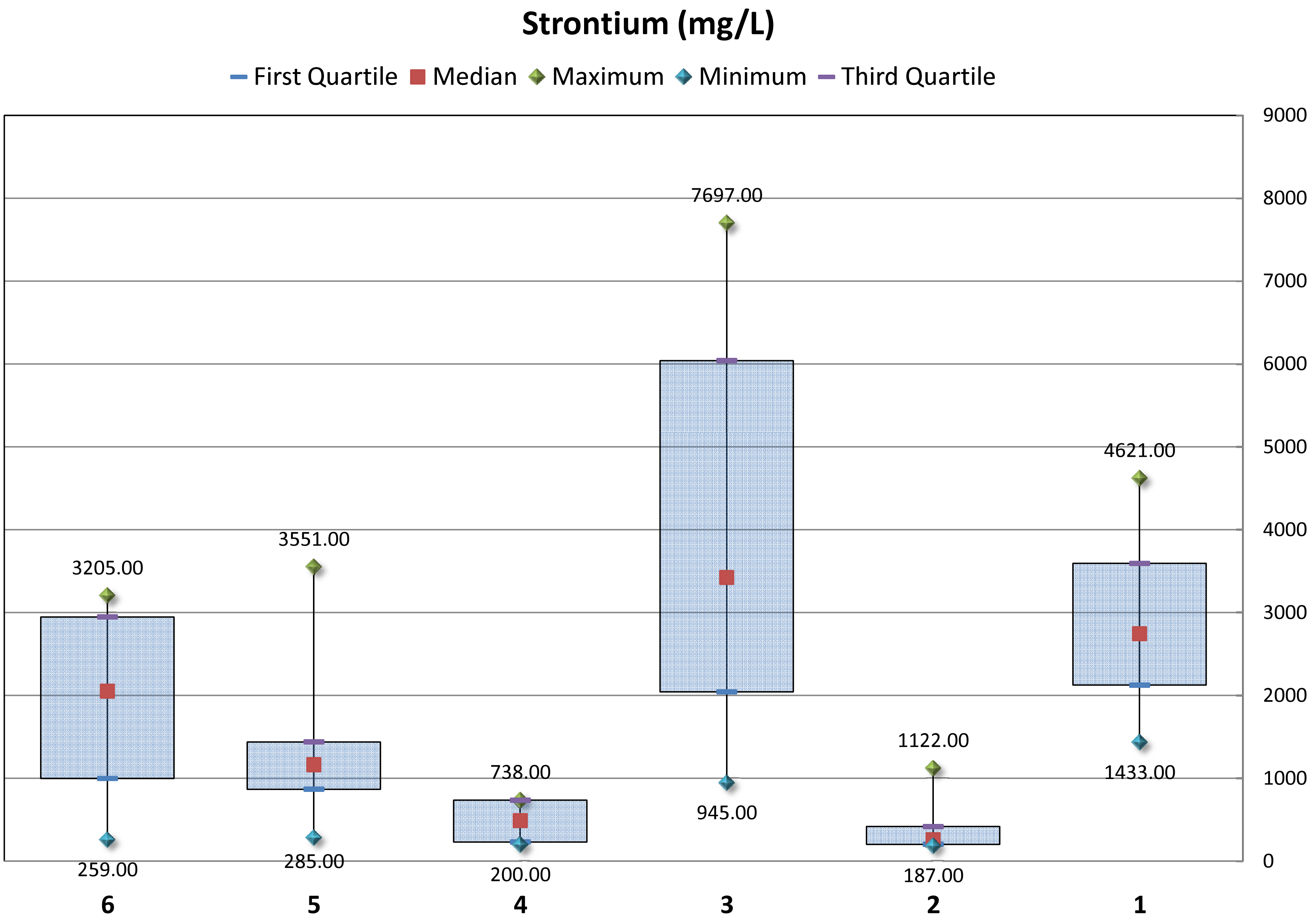

Figure 20
Box and Whisker Plot for Strontium, April and August 2010 Data.

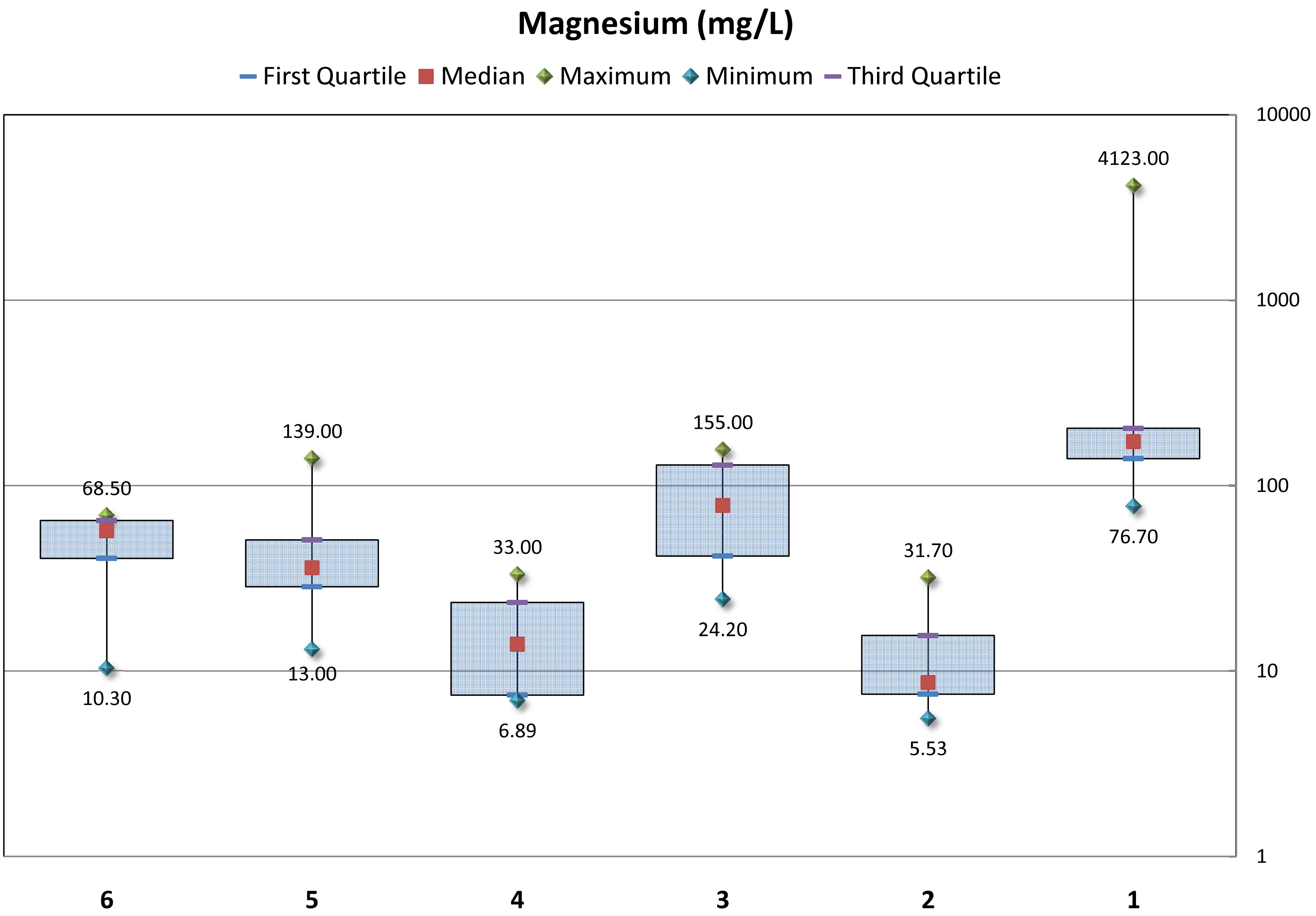

Figure 21
Box and Whisker Plot for Magnesium, April and August 2010 Data.

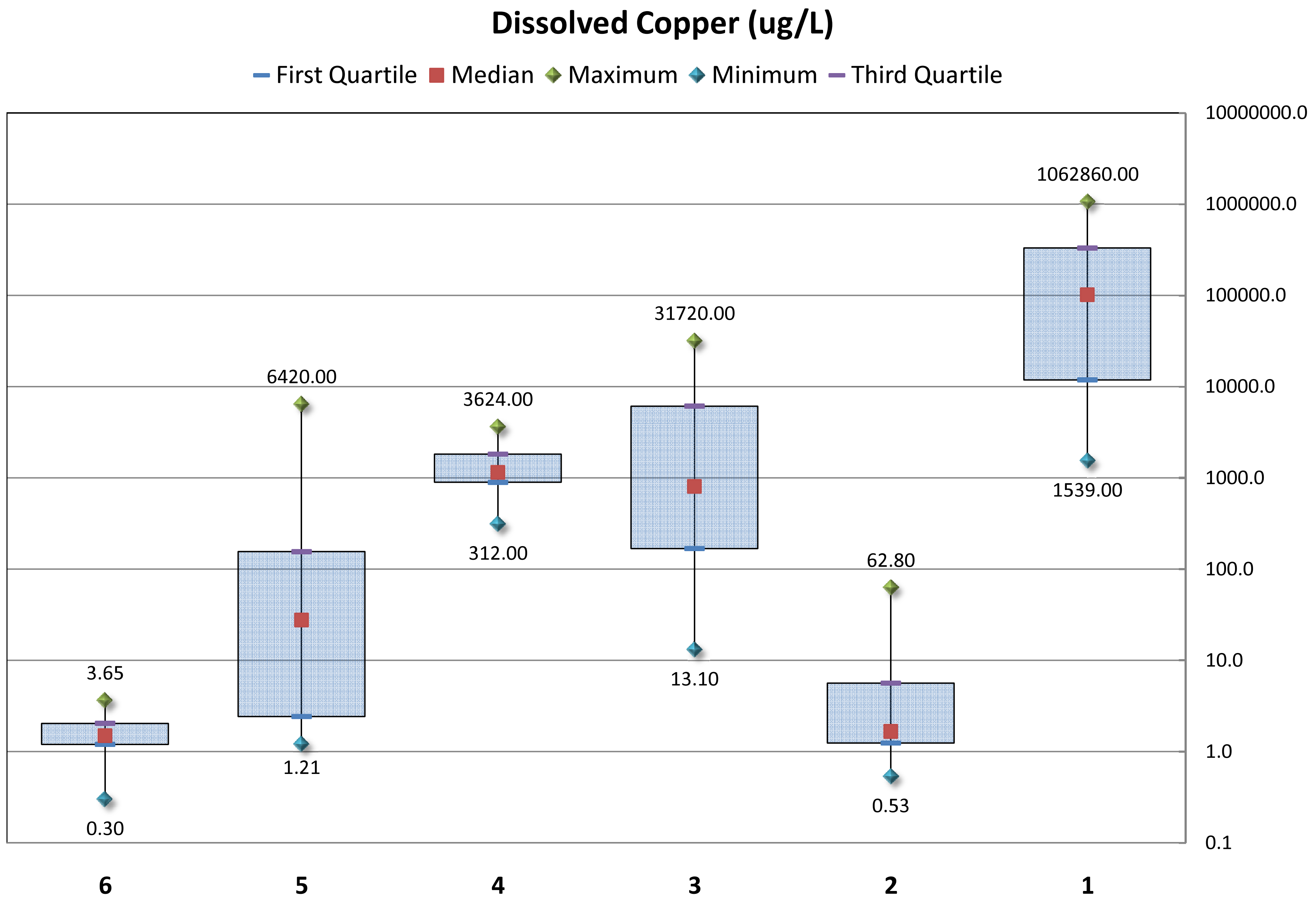

Figure 22

Box and Whisker Plot for Copper, April and August 2010 Data.