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Investigation of the hydrogeology and geochemistry of a floodplain aquifer system impacted by mine tailings Silver Bow Creek Montana

Devin Tremayne Shay
The University of Montana

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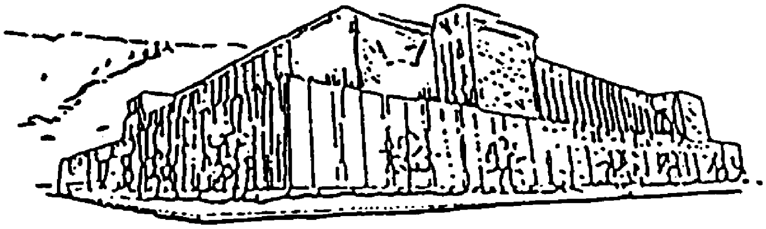

An Investigation of the Hydrogeology and Geochemistry of a Floodplain Aquifer System Impacted by Mine Tailings, Silver Bow Creek, Montana

by

Devin Tremayne Shay
B.A., Hamilton College, 1994

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Silver Bow Creek has transported millions of tons of mining and smelting wastes downstream from Butte, Montana over the last century. These wastes are deposited continuously along the floodplain of the creek, and are a secondary source of heavy metals to the creek and the adjacent shallow alluvial aquifer. Over 60 borings and 100 test pits were used to determine the stratigraphy of floodplain sediments along a 610-meter stretch of the creek at the Miles Crossing research site. Sediment samples were returned to the laboratory to undergo a weak acid digest procedure to determine the concentration of easily soluble metals in the sediments. A groundwater monitoring program was implemented to quantify seasonal and storm-induced fluctuations in stream stage and water table using over 60 piezometers, 10 staff gauges, and continuous recorders in both a well on the floodplain and a stilling well in the creek. Groundwater was sampled in 13 piezometers to determine the spatial variability in groundwater chemistry. Three sites were chosen for detailed instrumentation consisting of multi-level samplers, suction lysimeters, and tensiometers to examine the controls on groundwater chemistry.

Stratigraphic and chemical studies identified 5 distinct floodplain sedimentary units, all of which contained high concentrations of easily soluble metals, including original floodplain materials. Average concentrations of easily soluble metals for all samples are As = 229 ppm, Cd = 6.25 ppm, Cu = 1350 ppm, Fe = 5540 ppm, Mn = 850 ppm, Pb = 725 ppm, and Zn = 1350 ppm. Water table fluctuations of up to 80 cm, controlled by seasonal and storm-induced stream stage changes, result in a volume change of saturated metals-impacted sediments from 1400 m^3 to 4800 m^3. Dissolved metals in floodplain groundwater varied from below detection limits to Cu = 80.7 ppm, Fe = 42.8 ppm, Mn = 86.5 ppm, Zn = 152 ppm. In general, higher concentrations of dissolved metals in groundwater corresponded to areas where sediments enriched in easily soluble metals were saturated. Several mechanisms controlling the release of metals to the groundwater have been hypothesized, including water table fluctuations and extension of the capillary fringe into metal-impacted sediments. Soil moisture and vadose zone water chemistry data illustrate that the majority of vadose zone water deeper than 40 cm below land surface is not frequently replenished and contains high concentrations of dissolved metals. Data from multi-level samplers indicate that as groundwater pH increases with depth, dissolved metals decrease. As a result, highest concentrations of dissolved metals were found within 1-meter of the water table, close to areas of groundwater and capillary fringe saturated metals-rich sediments. Proper characterization of mining-impacted floodplains should therefore involve groundwater sampling plans that include collection of samples near the water table. Remediation schemes must address the role of the fluctuating water table and capillary fringe when attempting to mitigate the release of metals to floodplain groundwater systems and streams.

Acknowledgments

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Table of Contents

List of Tables

List of Figures

Introduction

The interaction of floodplain alluvial aquifers and their associated stream channels has been receiving growing attention in recent years (Castro and Hornberger, 1991; Harvey and Bencala, 1993; Henry, *et. al.*, 1994; Wroblicky, *et. al.*, 1994). The identification of this environment, known as the hyporheic zone, as an important area of nutrient transport in aquatic ecosystems has been illustrated by several researchers (Grimm and Fisher, 1984; Triska, *et. al.*, 1989; Triska, Duff, and Avanzino, 1993). In addition, the surface water/groundwater interaction zone has been shown to be very important to the biologic health of the river system (Williams and Hynes, 1974; Coleman and Hynes, 1980; Hynes, 1983; Stanford and Ward, 1988; Gregory, *et. al.*, 1991). Despite the importance of this environment to the health of the aquatic ecosystem, the impact of pollutants and their transport in areas of surface water/groundwater interaction has received only limited attention (Day and Briggs, 1988; McKnight and Bencala, 1990).

The historic mining and milling of sulfide ores in the Rocky Mountains resulted in environmental damage to many aquatic ecosystems (Moore and Luoma, 1990). The release of mining wastes to river systems and their floodplains has created a secondary source of heavy metals to surface water and groundwater systems. Consequences of such contamination include the loss of agricultural productivity, negative impacts on river system biota, and degradation of surface water and groundwater quality (Moore and Luoma, 1990; Moore, Luoma, and Peters, 1991). In Montana alone, 5-7% of stream systems have been impacted by mining activity (Moore and Luoma, 1990).

Silver Bow Creek, a headwater stream of the Clark Fork River, and its floodplain, have been impacted by gold, silver, and copper mining from the Boulder Batholith near the headwaters in Butte, Montana (Figure 1). Mining activity began in the vicinity of Butte in 1864 with placer operations aimed at finding gold located along Silver Bow Creek. By the late 1870's, underground hardrock mining of veins for silver dominated mining activity, six ore processing mills were in operation along Silver Bow Creek by 1885 (Freeman, 1900). As silver played out during the late 1880's, mining activity focused on copper. During the milling of Butte ores, wastes were deposited into tailings ponds adjacent to, or directly into Silver Bow Creek (MDEQ, 1995). By 1910, the majority of the ore mined in Butte was being processed at the Washoe Smelter in Anaconda, Montana. However, between 1878 and 1925, an estimated 10 million tons of smelting and milling wastes were deposited directly into Silver Bow Creek (Moore and Luoma, 1990). In addition to this direct deposition, large floods occurring around the turn of the century entrained and deposited tailings and mill wastes downstream of Butte, along the floodplain of the creek. The largest of these floods occurred in 1908 (CH2M Hill, 1989).

Studies on the environmental impacts of mining on Silver Bow Creek and its floodplain began 1982 (EPA, 1982). In 1983, the Silver Bow Creek/Butte Area Site was put on the National Priorities List (NPL) under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The inclusion of downstream contamination along the Clark Fork River and the Milltown Dam by CERCLA makes the upper 200 kilometers of the Clark Fork Valley the largest complex of Superfund sites in the country. In November of 1995, the Remedial Investigation (RI) for Silver Bow Creek and its floodplain (termed the Streamside Tailings Operable Unit) was completed with the release of the Record of Decision (ROD) (MDEQ, 1995). The ROD for Silver Bow Creek is the first outline for cleanup of a site within the Upper Clark Fork complex of Superfund sites.

Since its inclusion on the NPL, many general large-scale studies of the Silver Bow Creek system have attempted to characterize the hydrogeology of the area and metals chemistry in the sediments, surface water, and the adjacent floodplain aquifer (MultiTech, 1987; CH2M Hill, 1987, 1989.; ARCO, 1995). In addition, several site-specific investigations have been performed along the Clark Fork River with the objective of addressing the geochemistry of metals-contaminated floodplain systems. Brooks and Moore (1989) studied a portion of the Clark Fork River floodplain with the intent of identifying the distribution of metals in the floodplain sediments and how those metals are transferred to the groundwater and vadose zone water. Nimick and Moore (1991) examined the concentrations of water soluble metals in floodplain sediments and effervescent crusts formed at the surface of fluvially-deposited tailings. Detailed investigations along Silver Bow Creek are confined to work conducted over the last 4 years by researchers from the University of Montana (Benner, 1994; Smart, 1995; Lucy, 1995; Nagorski, 1997) concentrating on the Miles Crossing study site (Figure 1), and also investigations along Silver Bow Creek at the Rocker site (Keystone Environmental Resources, 1992; Schafer and Associates, 1993).

The main source of metals contamination along Silver Bow Creek are fluvially-deposited, tailings-rich sediments located on the floodplain of the creek. The contaminants of concern have been identified as As, Cd, Cu, Fe, Mg, Mn, Pb, and Zn (MDEQ, 1995). The floodplain groundwater system is characterized as low pH and metal-rich. The surface water is near neutral with relatively low concentrations of metals (Nagorski, 1997). Surface water is occasionally enriched with metals during rainfall and snowmelt events (Benner, 1994).

The majority of metals are released to the stream/alluvial aquifer system through the oxidation of sulfide minerals present in the mining derived sediment. When oxygenated water comes into contact with sulfide minerals in tailings, the sulfides are oxidized, releasing sulfate, hydrogen ions, and metal ions to the water (Nordstrom, 1982). Acidic, metal-rich water produced in the vadose zone of the floodplain through the oxidation of sulfides may either recharge the local groundwater, or migrate to the surface during the dry summer months where it evaporates and leaves behind a sulfate and metal-rich crust (Nimick and Moore, 1991; Lucy, 1996). Another avenue for metals to enter the creek is through interaction with groundwater. Benner (1994) and Smart (1995) identified a zone of groundwater/surface water interaction at the Miles Crossing site where the creek received input from groundwater along one bank and recharged the contaminated floodplain sediment along the opposite bank.

The principal mechanism influencing the release of metals from the floodplain sediments to the shallow floodplain aquifer of the Silver Bow Creek system is relatively poorly understood. One potential pathway of metals to the groundwater is downward migration through the vadose zone. Lucy (1995) studied the chemistry of water and sediments in the vadose zone at the Miles Crossing site. The results of her work illustrate an upper vadose zone (0-87 cm) with extremely contaminated pore water (pH = 3.1, Cd = 8.06 ppm, Cu = 1963 ppm, Mn = 1551 ppm, Zn = 2703 ppm, SO_4=15230 ppm; AL-48 on 7/14/94). The vadose zone is only recharged by infiltrating water down to a depth of approximately 40 cm. Below this depth, the vadose zone receives very little input from infiltrating water, and no recharge of groundwater by vadose zone water was observed during the summer and fall. An important mechanism releasing metals to the floodplain groundwater may be the presence of tailings below the water table and/or the capillary fringe during all or part of the year. Brooks and Moore (1989) found that spring snowmelt at a study site located on the Clark Fork River induced the water table to move into contaminated sediments, thereby mobilizing metals at that location. The importance of this mechanism has been noted by researchers in Canada conducting studies at a uranium tailings impacted site (Gillham, 1984; Abdul and Gillham, 1984; Blowes and Gillham, 1988). Downgradient migration of contaminated groundwater may account for high metals concentrations where the water table is not in direct contact with tailings. Any of these processes, or a combination thereof, could account for the release of metals to the groundwater of the Silver Bow Creek system.

Project Goals and Objectives

This study undertakes the task of examining the Miles Crossing site on a larger scale than in previous work (Benner, 1994; Smart, 1995; Lucy, 1995) The purpose of this study is to determine the mechanisms through which metals are released from the overlying floodplain tailings and impacted sediments to the floodplain groundwater. Specific objectives were to:

1. Define the floodplain stratigraphy.
2. Establish the concentration of water soluble metals in floodplain sediments.
3. Determine the seasonal variation of the water table within the floodplain sediments.

4. Correlate groundwater chemistry with the location and fluctuation of the water table, chemistry of the local sediments, chemistry and flow of vadose zone water, and flow system of the floodplain aquifer.

Site Description

The study site is located at Miles Crossing of Silver Bow Creek, 20 kilometers west of Butte, Montana. The site encompasses approximately 0.2 km^2, through which a 610 meter channel of Silver Bow Creek is found (Figure 1).

The headwaters of Silver Bow Creek occur at the confluence of Blacktail Creek and the Butte Metro storm drain. From there, the creek flows to Warm Springs, 37 kilometers downstream, where it enters the Warm Springs Ponds. Discharge from the ponds, Warm Springs Creek, and Mill-Willow Bypass form the headwaters of the Clark Fork River.

The Miles Crossing site consists of a 400-meter wide, roughly east-west trending section of floodplain bordered to the north and south by bedrock. Bedrock in the area consists of Eocene volcanic flows and welded tuffs that are members of the Lowland Creek Volcanics. The floodplain is composed of clay, sands and gravels, and mine and mill wastes transported downstream from Butte. Silver Bow Creek enters the valley from a broad floodplain known as Ramsay Flats. The creek runs westward for 1.8 kilometers through the valley until it enters Durant Canyon to the west (Figure 2).

The climate is semi-arid, with cool, dry summers and cold winters. Average annual precipitation reported by NOAA (1994) for Butte was 30.7 cm for the years 1961-1990. The bulk of the precipitation occurs during May and June each year. Highest flows in Silver Bow Creek occur during those months, with the record being 12.7 m^3/s, in June of 1995, and the average being 2.74 m^3/s for the years 1994 and 1995 (USGS Streamflow Data, 1996).

Groundwater in the vicinity of the site exists as a shallow, unconfined aquifer (Smart, 1995). Depth to groundwater at the site averages approximately 1.3 meters below land surface. Aquifer material is mainly coarse sand and gravel, with some areas containing saturated fine sands, silts, and clays. The aquifer is bounded on the bottom by green clay that has been interpreted as a weathered volcanic tuff (Smart, 1995). This clay varies from 2-3 meters below land surface. The floodplain aquifer has been shown to be in intimate connection with Silver Bow Creek (Benner, 1994; Smart, 1995). Groundwater flow direction is approximately parallel to the east-west trending floodplain (Figure 3).

Methods

Stratigraphy and chemistry of floodplain sediments

The first step in this study was to establish the stratigraphy of the Miles Crossing site. Efforts were focused on differentiating between tailings and pre-mining floodplain sediments. Over 75 boreholes were constructed at the site using a 5-cm bore hand auger (Figures 4 and 5). The auger bucket was screwed into the ground until full, or until a change in sediment character was detected while augering. The character of the sediments was noted and recorded, including the color, grain size, organic content, and moisture content (see Appendix A for logs of all boreholes). All samples were placed in gallon-sized ziplock plastic freezer bags, labeled, and returned to the laboratory. In addition, over 100 test pits were hand dug, varying in depth from several centimeters to 1.5 meters. Stratigraphy was carefully examined and logged in these test pits, and sediment samples were collected and bagged (see Appendix B for test pit data summary).

Selected sediment samples were analyzed to determine the concentration of easily soluble heavy metals using a weak acid digest developed for this study. The extraction method is similar to USGS Method I-5485-85 for determination of acid-soluble metals, except that organic matter was not destroyed and the acid used was weaker (Fishman and Friedman, 1989). Several grams of sample were extracted from a bag and oven dried in a glass beaker overnight at 70 degrees celsius. After drying, the sample was placed in a dessicator for cooling. Once at room temperature, each sample was weighed on an analytical balance to exactly 0.50 grams and placed in a centrifuge tube, to which was pipetted 30 mL of 1 M hydrochloric acid. The samples were then shaken on the shaker table for 1 hour, removed, and centrifuged for 30 minutes at approximately 3000 rpm. Supernatant was decanted off, and analyzed on the Inductively Coupled Argon Plasma Emission Spectrophotometer (ICAPES) for Al, As, B, Ca, Cd, Co, Cr, Cu, Fe, Mg, Mn, Mo, Na, Ni, P, Pb, S, Si, Sr, Ti, and Zn in the analytical laboratory of the Department of Geology at the University of Montana. Detection limits are presented in Appendix I. Quality assurance/quality control for sediment digests was accomplished using procedural duplicates, laboratory duplicates, laboratory blanks, and USGS Standards (Appendix C).

Development of piezometer network

Previous investigators at Miles Crossing (Benner, 1994; Smart 1995) had established a network of approximately 50 hand-driven piezometers at the site. Thirty-six new hand-driven piezometers were installed in selected auger holes in conjunction with the stratigraphic study to establish a more complete network of piezometers to monitor water levels, and to collect groundwater samples (Figure 4). Each piezometer was constructed of 3.18 cm inside diameter schedule 80 PVC pipe glued via a coupler to a 30.5 cm long PVC drive tip of which 15 cm was slotted with 20-slot screen (Figure 6). After being placed in the bore hole, the piezometer was then driven into the ground using a fence post driver until excessive resistance was met. The hole was backfilled 15 cm with either silica sand or the materials removed from the bottom of the hole. The remainder of the hole was backfilled with materials removed during augering. Each hole was filled with about 3 cm of bentonite clay, then topped of with local sediment, and compacted. Each piezometer was developed using a surge block. After surge blocking development, the piezometer was bailed to remove any sediment. Elevation above mean sea level of all piezometers was surveyed in to the nearest 0.3 cm.

Determination of the potentiometric surface

Existing and newly constructed piezometers were used to measure the water table position at approximately 50 points. To record stream stage, steel fence posts were hand-driven into the creek bed at 10 locations, and a previously installed stilling well at the Miles Crossing bridge was also used (Figure 4). Elevation above mean sea level was surveyed in to the nearest 0.3 cm for each measuring point. Water levels in piezometers and at staff gauges were measured to the nearest 0.3 cm using an electric tape at least once a month during the 17-month study period. During the winter of 1995-96, ice jams destroyed all of the fence post measuring points, so these were not included in data past the December 1995 round of measurements. Stevens' continuous water level recorders were installed in April of 1996 in the stream stilling well and a 15.25 cm diameter well on the floodplain (Figure 4).

Continuous water level measurements were recorded from April 1996 until September of 1996 at these points. Data were plotted on a site map and contoured for each measurement date.

Water Quality Monitoring

A groundwater sampling program was developed to characterize water quality and its relationship to stratigraphic, spatial, and temporal variation. Twelve piezometers were selected for sampling based on their location in the floodplain. In addition, 3 sites were chosen for instrumentation with multi-level samplers (Figure 4). Each multi-level sampler was constructed of a center piece of 2-cm PVC, surrounded by 4 different lengths of polyethelyene tubing, staggered at 23 cm intervals from the base (Figure 7). Each piece of tubing, and the center conduit had the bottom 8 cm perforated with 0.5 cm diameter drill holes, and were covered with a fine nylon screen mesh held in place by rubber bands. A boring was made with a hand auger, and then a length of 5-cm steel pipe with a center steel drive rod was set in the hole and driven to the desired depth. The center rod was then pulled from the hole and the multi-level sampler installed. As the 5-cm steel pipe was pulled out, the hole collapsed around the instrument. Each sampling tube was then pumped with a peristaltic pump for several minutes for development.

Sampling of water from piezometers and multi-level samplers involved first pumping the piezometer or sampling tube for several minutes with a peristaltic pump to purge water from the instrument. A volume of water was then collected in a plastic container, from which pH, dissolved oxygen, and conductivity were measured. An Orion electrode was used to measure pH. An Orion dissolved oxygen meter was used to measure dissolved oxygen, and a Hach conductivity meter was used to measure conductivity. Samples were then pumped through a 0.45 micron filter into 2-50 mL sample bottles. One sample was acidified using trace metal grade nitric acid and labeled for cation analysis. The other sample was left unacidified and labeled for anion analysis. Between the sampling of different tubes or piezometers, each instrument that came into contact with the sample was purged and rinsed with deionized water. Samples were placed on ice and returned to the laboratory for analysis. Anion analysis was completed within 24 hours on the Ion Chromatograph in the University of Montana's analytical lab. Each sample for anion analysis had to be run undiluted, and also diluted 100 times to be properly analyzed for sulfate. Cations were analyzed within 3 months on the ICAPES. Quality assurance/quality control procedures were followed by taking deionized water blanks and a duplicate sample every 10 samples. Quality assurance/quality control in the lab was quantified using laboratory duplicates, spikes, and USGS Standards (Appendix C).

Vadose zone monitoring

In addition to the installation of multi-level samplers, suction lysimeters and tensiometers were installed at 2 of the 3 detailed sites to sample vadose zone water chemistry and collect soil moisture data. Site 1 was instrumented with 3 handbuilt suction lysimeters set at depths of 51 cm, 84 cm, and 121 cm, and 4-Soilmoisture Equipment Corporation Jet Fill tensiometers, set at depths of 122 cm, 61 cm, 37 cm, and 15 cm. Site 2 was instrumented with 1 suction lysimeter set at 86 cm, and 6 tensiometers set at 15 cm, 30 cm, 46 cm, 87 cm, 120 cm, and 141 cm. Lysimeters were constructed by epoxying a Soil Moisture Corporation 5 cm long porous ceramic cup to the desired length of PVC pipe. The top of the PVC was fitted with a rubber stopper into which 2 pieces of glass tubing were inserted. To one piece of glass tubing, a length of tygon tubing was attached that reached the bottom of the ceramic cup, to be used for removal of sample from the lysimeter. Each glass tube also had a short length of tygon tubing attached to the top, one for attachment to a peristaltic pump, and the other for attachment to a vacuum pump.

Suction lysimeters were installed by augering a hole to the desired depth, then filling the bottom of the hole with a slurry of Soil Moisture Corporation silica flour and deionized water. The lysimeter was then set in the slurry, and the hole was backfilled partially with silica sand, then bentonite clay. The rest of the hole was backfilled with sediment removed during augering, and sealed with approximately 3 cm of bentonite clay at the surface. Tensiometers were installed by coring a hole of the same diameter as the tensiometer, but slightly shorter in length than the instrument. The bottom of the hole was then loosened up slightly with the coring device, and the tensiometer was then placed in the hole, with the porous cup being pressed into the loosened sediment for a tight fit. Sediment removed from the top 3 cm around the tensiometer and backfilled with bentonite, then covered back up with the removed sediment.

Sampling of suction lysimeters followed the same procedure outlined above for sampling of piezometers and multi-level samplers, except that the instrument was not purged by pumping. After each sampling, the lysimeters were evacuated to 60 centibars of suction to be ready for the next sampling round. Tensiometer gauges were read during water quality sampling rounds, and also when water levels were measured.

Results

Floodplain stratigraphy

The floodplain stratigraphy is spatially variable and is likely the result of a complex stream history of flooding, erosion, aggradation, channel meandering, and deposition. For the purpose of mapping, the study area has been divided into two areas: the present channelized area, and the floodplain bench above the current channelized area (Figure 8). Deposits within the current channelized area are reworked on a yearly basis, and thus are a complex mixture of mining derived sediments, native materials, and reworked floodplain sediments (Appendix B). Stratigraphy of the upper floodplain bench is more regular, thus general relationships between units have been identified. Based on observations from borings and test pits, 5 distinct stratigraphic units have been identified (Table 1; Figure 9). These units are described below.

Unit 1

Overlying most of the site is a fine sand and silt deposit (Figure 10; Appendix D), that is generally brown to tan in color, and often shows an orange and gray mottling. This unit has been interpreted as an overbank deposit of mill tailings. This unit ranges in thickness from a few centimeters to over 1 meter. Vegetation occurs sporadically on the surface above this unit. Some areas of the deposit are devoid entirely of vegetation, where in others, some grasses and willows can be found growing. Effervescent copper sulfate crusts form during the summer on the surface of this unit (Lucy, 1996).

Unit 2

In areas near the stream channel, or near unoccupied older channels, a red sand unit has been identified below the fine sand and silt unit. The sand varies from medium to coarse grained (Figure 11; Appendix D), and appears to be similar to the feldspar quartz mica composition typical of weathered or mined Boulder Batholith found upstream in Butte. Thickness of the deposits vary from several centimeters to over 1 meter. This unit has been interpreted as a high energy deposit because of its proximity to the stream channel and older channels. Its origin has been hypothesized to be placer mining wastes carried downstream, as it is dissimilar to the volcanic bedrock found in the immediate area (Smart, 1995).

Unit 3

Where the red sands are absent beneath the fine sand and silt unit, a fine silt and clay deposit is found. The unit is dark brown to gray in color. Occasionally it is mixed with small amounts of sand. Thickness of this unit rarely exceeds 1 meter. A developed soil horizon may sometimes be found within the unit, as can organic material such as root material. This unit has been interpreted as mill tailings mixed with other sediments due to the variability of the metals concentrations in different samples.

Unit 4

Below all of the above units is found a gray sand unit. This unit is generally continuous over the entire site. Grain size is highly variable (Figure 12; Appendix D), ranging from clayey silt to coarse sand, with most of the unit comprised of a medium sand sized fraction. Root mottling is apparent in areas of this deposit. This unit has been interpreted to be original floodplain deposits.

Unit 5

Beneath the gray sand unit is coarse sand and gravel that comprises the majority of the floodplain aquifer material. Detailed description of this unit is difficult due to the inability to obtain representative samples. The unit was too coarse to auger through or retrieve a sample from using the 5-cm bore hand auger. Drilling data have shown this unit to be 2 to 4 meters thick. Underlying this unit is a green clay that has been interpreted as a weathered volcanic tuff (Smart, 1995). Thickness of this unit has not been determined in this study, however, drilling data from other studies have found it to be at least 21 feet thick at this site (Canonie, 1992).

Sediment chemistry

The concentrations of HCl-extractable metals in the floodplain materials also exhibited a great deal of heterogeneity. Although there is variability in the data set, by grouping the samples together based on the physical description, the units can be distinguished based on metals chemistry. The differing units are compared using the average concentration of the metals (Table 1), and also the high and low values observed. Figure 13 shows a comparison of the average concentration of each of the metals for the different units, and the range of values observed. The results of the weak acid digest for samples of each unit is located in Appendix E.

Sediment chemistry data show the fine sand and silt unit, or the overbank deposited mill tailings, to consistently contain the highest concentration of easily soluble metals, with the exception of Cd, Mg, Mn, and Zn. The fine silt and clay unit is highest in easily soluble Cd, Mg, and Zn. Soluble Mn is highest in the gray sands of the original floodplain. The plot of the average concentrations of soluble metals illustrates that the gray sands, which are interpreted as original floodplain materials, are enriched in easily soluble metals, to levels comparable to the mill tailings deposits.

Variability in the sediment geochemistry data has been analyzed through the calculation of the ratios of the different contaminant metals to Ti, which is not a contaminant in the system. From the plot of average metals concentrations in the sediments (Figure 13), it can be seen that Ti concentrations are approximately the same for each unit. The ratios of Ti to the different contaminant metals (Figure 14) shows some interesting results. The concentrations of easily soluble metals for the red sand, and the fine sand and silt units are statistically very similar, while the gray sand and the fine silt and clay units show a high degree of variability.

Variation in the potentiometric surface

Data from 24 rounds of water level measurements taken over the course of 16 months illustrate a potentiometric surface that varies according to seasonal and storm-induced effects (see Appendix F). Stream stage fluctuated 0.6 meters over the course of the study. Water levels in wells varied over a vertical distance of 0.8 meters. Variations in stream stage appeared to control the water table at this site, as it does at the Ramsay Flats and Rocker sites upstream (Schafer and Associates, 1993). The floodplain water table was highest when spring snowmelt was coupled with a rain event and creek stage was raised. Daily fluctuations in stream stage and the floodplain water table were noted at the two locations of the continuous water level recorders (Figure 15). These changes occur on the order of 1-3 centimeters. The dampening factor between the stream stage fluctuation and the groundwater fluctuation appears to be approximately 0.3. The observed lag time between high flow in the stream and high water table next to the stream is approximately 16 hours.

Fluctuation in the water table results in a significant change in the amount of saturated tailings and impacted sediments. Figure 16 is a site map that shows the amount of saturated tailings and impacted sediments during the lowest water levels recorded, in August of 1996. Figure 17 shows the same map during the highest water levels recorded, in May of 1995. The estimated volume of saturated tailings changes from 1400 m^3 to 4800 m^3 between low and high water (Table 2).

Vadose zone water content and chemistry

In general, the tensiometers illustrate that over the summer months, the upward gradient in the vadose zone increases in strength (Appendix G) Similar trends were evident in the summer of 1994, as illustrated in the study done by Lucy (1996). Very little relative soil moisture changes are seen below a depth of 30 cm. However, soil moisture changes dramatically in the upper 30 cm over the course of the summer (Figure 18). This change is likely due to the limited summer precipitation and the low humidity of the region.

Water samples were taken from the vadose zone using suction lysimeters. The results of the chemical analysis of these samples are reported in Appendix H. At Site 1, the lysimeter at the 51 cm depth sampled water in contact with the fine silt and clay unit; the other two lysimeters sampled water in contact with the gray sand unit. On the June 20 sampling date, all 3 lysimeters were functioning properly, allowing a vertical profile of water chemistry to be seen. Water sampled from the deepest lysimeter had a pH of 6.4, and the highest concentrations of Cu, Mn, and Zn (Table 3). At a depth of 84 cm, dissolved metals concentrations decreased, and then continued to decrease at a depth of 51 cm. Dissolved metals concentrations were significantly higher at the deepest sampling point in comparison with the shallowest point, despite the lower pH of the shallower water (pH = 5.3). Sulfate concentrations decreased with depth from 4418 mg/L to 575 mg/L. On the August 7 sampling date, only the lysimeters at 84 cm and 121 cm were functioning (Table 4). The pH had changed at both points, increasing at the 84 cm depth to 7.0, and decreasing at the 121 cm depth to 5.1. Dissolved metals concentrations at the 121 cm depth remained relatively constant, with the exception of copper, which decreased to 6.1 mg/L. Sulfate concentration increased dramatically to 2175 mg/L at this point. In contrast, dissolved Cu, Mn, and Zn all decreased at the 84 cm depth, while SO_4 concentration remained stable.

Vadose zone water chemistry at Site 2 is different than that found at Site 1 (Figure 19). The vadose zone at this site is characterized by approximately 30 cm of fine sand and silt mill tailings, underlain by red sands. In general, dissolved metals and sulfate concentrations were significantly greater at Site 2 (Table 5). Dissolved Fe, Cd, and Pb were also present in the water at Site 2, whereas they had been below detection limits or just above detection at Site 1. Between the June and August sampling dates, all dissolved metals concentrations increased at Site 2 (Table 6).

Groundwater chemistry

The first two sampling rounds for groundwater chemistry involved sampling selected shallow piezometers across the site. The data from these sampling rounds prove groundwater to be spatially variable in dissolved metals concentration, conductivity, and pH (Figure 20) (see Appendix I for complete water chemistry data). Values of groundwater pH ranged from 3.2 to 6.3. Conductivity of groundwater ranged from 0.44 to 2.82 mS/cm. The highest dissolved metals concentrations were observed at the southwest portion of the site, at piezometers D-3, D-4, and D-5 (Table 7). High concentrations of dissolved metals were also observed in the middle of the site at piezometer D-21 (Table 7). Lowest observed dissolved metals occurred at the easternmost portion of the site at piezometer D-52 (Table 7). However, there is no regular increase in dissolved metals concentration as groundwater flows east to west across the site. Lower groundwater pH generally corresponded to higher amounts of dissolved metals when compared to groundwater of a more neutral pH (Figure 21). Dissolved oxygen in the groundwater remained relatively regular across the site, with values generally around 1.2 mg/L.

Installation and sampling of multi-level samplers was undertaken to examine the vertical variation in groundwater chemistry. Of the three instrumented sites, groundwater at Site 3 was highest in dissolved metals and sulfate, and conductivity. However, pH, which was typically around 4 at this location, is not the lowest at the site. During the course of the study, groundwater at this location was in constant contact with 8 to 15 cm of the fine silt and clay unit (Figure 22), which has been shown to contain elevated concentrations of soluble metals. The remainder of the groundwater was in contact with the gray sand unit, or the sand and gravel unit. Groundwater chemistry at the site showed little variation over the course of the summer (Table 8).

Groundwater at Site 1 was in constant contact with the gray sand unit, and the sand and gravel unit, providing the opportunity to sample water not in direct contact with tailings (Figure 22). The pH of the shallow groundwater fluctuated vertically between 4.0 and 4.5, but no measurable corresponding change in dissolved metals concentration was seen accompanying the pH change. In general, dissolved metals concentrations remained stable through the sampled vertical area. Although the pH of the groundwater was approximately the same as at Site 3, dissolved metals concentrations were much lower (Table 9). Over the course of the summer, metal concentrations in groundwater did not change significantly at this site.

At Site 2, shallow groundwater was in direct contact with the red sands unit during the sampling period (Figure 23). However, the water table declined slightly over the summer by 6 cm. Dissolved metals decreased significantly over the summer. For instance, dissolved Zn, Cu, and Mn in the uppermost sampling port decreased from 59.1 mg/L, 42.4 mg/L, and 36.2 mg/L, respectively, on the June sampling date, to 29.3 mg/L, 21.8 mg/L, and 10.4 mg/L, on the August sampling date. This decrease occurred despite the fact the the pH of the groundwater sampled in this port remained relatively constant, between 3.2 and 3.4. The other 3 sampling ports followed the same trend. The vertical variation in groundwater chemistry is perhaps the most interesting. Data from the uppermost port, within a few centimeters of the water table, is significantly different from the water quality data collected from the lowest port, only 69 cm deeper. The groundwater just below the water table at this site had a pH of approximately 3, and high concentrations of dissolved metals (Cu = 27.8, Fe = 7.0, Mn = 14.9, Zn = 32.9 mg/L). Water sampled from progressively deeper ports increased gradually in pH to approximately 6, and dissolved metals concentrations decreased dramatically (Cu = 1.05, Fe = 0.11, Mn = 9.3, Zn = 7.4 mg/L). This vertical trend was reproduced at each sampling date (Appendix I).

Discussion

Fluvial deposition of tailings in a floodplain environment has created a highly variable system of stratigraphy, sediment geochemistry, groundwater chemistry, and vadose zone water chemistry at the Miles Crossing site. The influence that each of these four components exerts on the metals geochemistry of the system creates a high degree of complexity. The system is marked by spatial variation in metals concentration in both the sediment and groundwater. Understanding how metals are released to such a system requires a detailed examination of each of the important components, and a careful consideration of how these components may interact with and affect each other.

The complexity of the floodplain stratigraphy observed at the Miles Crossing site is a function of fluvial processes (Figure 24). Major floods around the turn of the century would have caused the creek to overflow its banks and carve new channels in the floodplain. As the stream gained energy, the floodplain was being eroded. With the subsidence of flooding came the deposition of entrained sediments in the newly carved channels. Deposition of tailings-rich sediment contaminated the floodplain, thereby restricting the growth of vegetation. The lack of vegetation would make the floodplain highly erodable. Floods since the turn of the century would have caused the stream to top its banks and fill the old channels with more sediment, as well as carving channels into the easily erodable floodplain. It is likely that the tailings sediment carried by the separate flood events had different sources upstream, such as different tailings impoundments, resulting the different stratigraphic units found today at the site. The tailings would also mix with other sediments as they were transported and deposited downstream. The end result is a complex stratigraphy with variation in the chemistry of the sediments.

The chemical reaction controlling the release of metals to mining-impacted systems is the oxidation of sulfide minerals found in the sediments (Nordstrom, 1982; Wunderly, et. al., 1996). With sulfide oxidation comes the generation of acid and the release of metals. The drop in pH that accompanies the generation of acid causes more metals to enter the dissolved phase as the cation adsorption capacity decreases (Filipek, et. al., 1987). There are two environments where the oxidation of sulfides is occurring in the floodplain of Silver Bow Creek. Highly oxygenated water in the vadose zone interacts directly with tailings and contaminated sediments to lead to sulfide oxidation. In addition, the fluctuation of the floodplain water table creates a constantly changing environment near the water table and capillary fringe, as sulfide minerals in the sediments are exposed to different oxidation-reduction conditions that accompany the saturation-desaturation process. The results of the oxidation of sulfides in these two locations are high metals concentrations in the vadose zone water, and also in the shallow groundwater.

Knowledge of the stratigraphy and geochemistry of the sediments at the site is essential to being able to understand the spatial variability in groundwater and the vadose zone water chemistry. Areas where tailings and metals-impacted original floodplain sediments are exposed to an oxidizing environment will generate the highest concentrations of dissolved metals. This study has defined the floodplain stratigraphy in a detailed physical and chemical manner that has not been conducted in previous investigations. In light of this, the floodplain stratigraphy defined in other studies for the Miles Crossing site has proven to be inaccurate. Tailings thickness maps of the Miles Crossing site created by Titan Environmental (MDEQ, 1995) for the Superfund Remedial Investigation underestimate the extent and thickness of tailings. In addition, this study has found through the examination of readily soluble metals in sediments, that original floodplain materials have elevated levels of metals, especially Fe, Mn, and Zn. The impact of metals on original floodplain materials has led to the conclusion that at this site, the thickness of heavy metal contaminated sediments is best defined by the depth to the sand and gravel unit at the site. Given such a definition, a new tailings/impacted sediment thickness map has been created for the site (Figure 25). This map illustrates that the average thickness of contaminated material at the site is approximately 1.4 meters, which translates to a volume of 280,000 m^3 over the entire site.

The chemistry of the vadose zone water, as sampled from June through August 1996, indicates that no direct relationship exists between readily soluble metals in the sediments and dissolved metals concentrations in the pore water (Figure 26). In the study of the pore water chemistry conducted by Lucy (1996), low-pH water with high levels of dissolved metals was found where the vadose zone is composed primarily of the red sands unit. This observation is supported by the results of pore water sampling at Site 2 in this study. In contrast, where pore water is in contact with the gray sand unit, such as at Site 1, dissolved metal concentrations are significantly lower, and pH is more neutral. Weak acid digests performed on the gray sand unit illustrate that the average readily soluble metal concentrations are greater for the gray sand than they are for the red sands for most metals, with the exception of As and Fe. However, the high degree of variability in the concentrations of metals in the extract from the gray sands, as seen in the ratios of the contaminant metals to Ti (Figure 14), suggest the possibility that the gray sands at Site 1 may be less impacted than other deposits of the gray sand.

The nested set of lysimeters at Site 1 allowed the opportunity to sample water at the same locality in contact with two different sedimentary units. The lysimeter finished at 51 cm sampled water in contact with the fine silt and clay unit. This sedimentary unit has higher average concentrations of soluble metals than the gray sand unit. Despite this difference, pore water at the 51 cm depth was 7 to 30 times less concentrated in dissolved Cu, Mn, and Zn than the pore water sampled from the gray sands unit. These data suggest that sediment geochemistry is not the main controlling factor on vadose zone water chemistry.

The apparent lack of the sediment geochemistry control on the vadose zone water chemistry can be attributed to the physical controlling mechanisms occurring in the vadose zone. In her detailed study of the vadose zone at the Miles Crossing site, Lucy (1996) found that water in the uppermost portion of the vadose zone was low in dissolved metals and relatively neutral in pH. This water chemistry has been attributed to recharge of this water through precipitation and infiltration in the upper portion of the vadose zone. In the portion of the vadose zone below the upper recharged zone, water has a longer residence time and has thus been found to be low in pH and high in dissolved metals. This deep vadose zone water, or capillary fringe water, would only be mobilized during a large infiltration event in early spring, or a rise in the water table. Data from lysimeters at Site 1 supports the conclusions of Lucy's study, that the uppermost vadose zone water, despite sedimentary controls, is not as contaminated as water from deeper in the vadose zone.

The control of sediment geochemistry on water chemistry is, however, seen in groundwater quality data. Results of the piezometer sampling program show the highest levels of dissolved metals at D-3, D-4, and D-5, where groundwater is in perpetual contact with the fine silt and clay unit. At D-21 (Figure 4), where dissolved metals are also high, groundwater is in contact with the red sands unit. At piezometers P-10, D-13, D-14 and D-52, where groundwater is in contact with original floodplain deposits, pH is approximately 6.0, dissolved Cd and Cu are below detection limits, and Zn is found in concentrations at least 10 times lower than the most contaminated groundwater. Piezometer D-13 is an exception in the case of Zn, where concentrations are 3 times lower. Groundwater from all four of the aforementioned piezometers did, however, have significant concentrations of dissolved Fe and Mn. Metals concentrations in groundwater sampled from D-55 were below detection limits, despite the fact that it is in contact with the fine silt and clay unit. The low dissolved metals concentrations in this piezometer are attributed to dilution of groundwater with stream water, due to the proximity of the piezometer to the stream. Regional groundwater flow likely creates a "flow-through" system with the stream at this location, as it moves east to west through the stream. A similar dilution process was observed at the western end of the site by Benner and others (1995).

Water quality data from the multi-level sampling devices further illustrates the control of the sediments in contact with the groundwater on groundwater chemistry. At Site 3, which is within several feet of piezometer D-4, groundwater is in contact with the fine silt and clay unit. Water drawn from the multi-level sampler had a similar amount of dissolved metals in comparison to the piezometers sampled in close proximity to it (Table 10).

The amounts of dissolved metals did not change significantly within the depth sampled by the multi-level sampler, despite the fact that the sampling ports were retrieving water in contact with the gray sands. This fact would suggest that groundwater is not only degraded where it is in contact with sediments that have high concentrations of readily soluble metals, but also in areas below this contact where the aquifer material is composed of original floodplain deposits. In contrast to Site 3 is Site 1, where groundwater is also in contact with the gray sands, but has no contact with impacted mining-derived sediments. Groundwater at Site 3 is identical in pH to Site 1, but dissolved metals and sulfate are 3-10 times lower. The vertical change of dissolved metals concentrations from this multi-level sampler is erratic, and can not be associated with the observed changes in pH at the different ports. However, these vertical changes, despite their erratic nature, are reproduced for all three sampling dates. The reproducibility of the data suggests that small-scale changes in sediment geochemistry are responsible for the chemical differences observed with depth, as this is one controlling factor that could cause chemistry changes to reoccur on such a local level.

The results of groundwater sampling at Site 2 illustrate a changing chemistry profile with depth (Figure 23). This profile shows that dissolved metals concentrations decrease significantly over a depth of 70 cm from the water table. Oxidation of sulfide minerals near the water table is likely responsible for the elevated concentrations of dissolved metals found near the top of the aquifer. Dissolved oxygen measurements from the lower sampling ports, which show little to no dissolved oxygen, suggests a reducing environment exists there, where metals will stay primarily in the solid phase. This profile of groundwater chemistry illustrates that the most contaminated groundwater found in the shallow aquifer is near the water table. As depth increases in the aquifer, pH increases to more neutral values and dissolved metals concentrations drastically decrease. This profile is not seen in data from other multi-level samplers at the site, but this may be the result of the samplers not penetrating deep enough into the aquifer. At the other two sites, the sediments near the water table are finer-grained than the coarse sands found with depth at Site 2. It could be suggested that the coarse grained sediments at Site 2 allow for more rapid transport and dilution in the shallow groundwater, as velocities would be expected to be higher in the coarser material than in the finer sands found at Sites 1 and 3. The dilution and rapid transport would make the transition zone between shallow, contaminated groundwater and deeper, less contaminated groundwater appear at a depth closer to the water table. Support for this argument can be found in water quality data from piezometers that penetrate deeper into the aquifer. Piezometer P-10 sampled water from the deepest point measured in the study, approximately 2.4 meters from the surface, and 1.2 meters below the water table. Dissolved metals were all below detection limits in this piezometer, except for Fe, Mn, and Zn, and the amount of dissolved Zn at this point was the lowest amount measured across the entire site. At piezometer

D-52, the sampling point is approximately 1.5 meters below the water table. Again, the only dissolved metals present are Fe, Mn, and Zn, and dissolved Zn is the second smallest concentration measured at the site. Values of groundwater pH in both of these instances were near 6. Sampling done at D-55 illustrates exactly the same trends in metals concentrations as D-52 and P-10, with dissolved Zn being the third lowest concentration measured at the site. Sample depth at this piezometer is approximately 1.2 meters below the water table. Other piezometers sampled at the site are shallower and sample water within the upper 1 meter of the aquifer. All of the groundwater samples from these piezometers have higher concentrations of dissolved metals, and pH values between 4 and 4.5. Based on this chemistry data, it appears that the greatest groundwater contamination is generally found within the upper 1 meter of the aquifer across the entire site.

Attempting to predict the success of certain remedial measures taken at the site, or to simply address the problem of why the groundwater is contaminated in the floodplain aquifer necessitates an understanding of the mechanism or mechanisms releasing metals to the groundwater (Figure 27). One hypothesis is that pore water that is highly acidic and contains high levels of dissolved metals is recharging the aquifer at the site. Results of this study and the study done by Lucy (1996) indicate that during the periods that soil moisture was monitored in each study, gradients in the upper 40 cm of the vadose zone were upward, which would restrict the infiltration of precipitation to the water table. The fine-grained nature of most of the surface sediments would also prevent infiltration. During the winter months, a uniform frozen layer was discovered across the site at a depth of approximately 15 cm. Thickness of this layer was never determined due to the inability to penetrate the frozen ground with a shovel or hand-auger. This frozen layer would prevent any downward migration of snowmelt or precipitation during the winter months. What remains is a small window of opportunity each year, during the months of April and May, where the potential for recharge from the surface may occur. At the Ramsay Flats research site along Silver Bow Creek, where surficial deposits are also fine-grained, water balance calculations predict 1.8 cm of recharge per year (Schafer and Associates, 1993). This value for recharge was determined to be within the margin of error of the calculation, suggesting the possibility that there may be no recharge to the groundwater at all in areas such as this (Schafer and Associates, 1993). If recharge was the main mechanism for metals release, we would expect to see an improvement in water quality as the months progressed from the spring melt. There is no temporal variation in water chemistry seen at any sampling point, suggesting that recharge is most likely not the main mechanism for the release of metals to the groundwater. The only exception to these data is from the multi-level sampler at Site 2, where dissolved metals concentrations did decrease over the summer. The sandy nature of the vadose zone at this location may allow more infiltration to occur, so recharge may be a more important mechanism here than at other locations at the site. Studies of sandy floodplain materials along Silver Bow Creek at the Rocker site suggest that infiltration of precipitation is more prevalent in sandy materials than it is in the finer-grained deposits found across most of the Miles Crossing and Ramsay Flats sites (Schafer and Associates, 1993).

The seasonal fluctuations in the water table have also been hypothesized as a mechanism that releases metals to the groundwater. The stage-induced seasonal variation in the water table has been documented in this study to be up to 0.8 meter at this site. Stream stage has also been shown to control the water table at the Ramsay Flats, Rocker, and Opportunity sites along Silver Bow Creek (Schafer and Associates, 1993). As the water table fluctuates, it moves into and out of tailings and impacted sediments in certain locations. Data from the multi-level sampler at Site 3, as well as piezometers D-3, D-4, and D-5, illustrate that where groundwater is in contact with sediments that have been characterized to have high concentrations of readily soluble metals, groundwater has high concentrations of dissolved metals. Contact with the gray sand unit may also cause groundwater degradation in areas where metals are concentrated in this unit. The changing redox front that occurs with the saturation and desaturation of sediments as the water table fluctuates would allow for the oxidation of sulfides in different sediments. These seasonally contacted sediments may be more concentrated in readily soluble metals, thus releasing metals to the system.

As the water table fluctuates, we would also expect to see changes in the extension of the capillary fringe, which may also be responsible for the release of metals to the groundwater. During the summer months, when the water table is generally in sandy sediments, the capillary fringe may only be several centimeters high. During high water in the spring, as the water table moves into finer-grained material such a silts and clays, the capillary fringe would likely extend significantly higher, perhaps a meter, into these sediments. Consideration of the extension of the capillary fringe when calculating the extent of saturated impacted sediments dramatically changes the estimate of the volume of these sediments. Using a 0.5-meter rise in the capillary fringe as a conservative estimate for grain size equal to very fine sand (Fetter, 1994), a volume estimate of the amount of impacted sediments saturated during high water increases to approximately 7600 m^3 if we assume the same area of saturated sediments used in Table 2. However, using this area results in a conservative estimate, as it would be expected that the capillary fringe would rise into contaminated sediments in other areas of the floodplain. In the sandy sediments of the Rocker site, the capillary fringe was measured to be 35-40 cm thick. However, in the fine-grained sediments of the Ramsay Flats site, the capillary fringe was measured to be 1.5-3.0 meters, in some instances extending to land surface (Schafer and Associates, 1993). The fine-grained materials at the site, such as the fine silt and clay unit, are high in easily soluble metals, so it is expected that metals will go into solution in the capillary fringe water. Atmospheric contact in the capillary zone means that there will be oxygen available for the oxidation of the sulfide minerals. The metals-rich capillary fringe water could easily mix with the shallow groundwater as the water table fluctuates, providing a significant load of dissolved metals to the groundwater.

Conclusions

This study examined the impacts of fluvially deposited mining-derived sediments on a floodplain groundwater system. A detailed analysis of floodplain stratigraphy and geochemistry has shown tailings deposition and its effects to be more extensive than previously thought. There are high concentrations of readily soluble metals in floodplain sediments, including original floodplain materials. Seasonal and storm-induced stream stage changes result in water table fluctuations are likely the predominant mechanism releasing metals to the groundwater. Dissolved metals have impacted groundwater quality, especially in the uppermost 1 meter of the aquifer.

The complexity of the floodplain stratigraphy is the result of deposition that occurred with multiple flooding events, and the action of the creek as it cut through the floodplain. The irregularity of the floodplain sediment deposition is also reflected in the variability of the concentrations of metals in the sediments. Despite the heterogeneity of the mining-impacted floodplain, 5 distinct stratigraphic units were identified at the Miles Crossing site, based on physical characteristics, as well as chemistry. Chemical variation exhibited within 2 of the 5 units suggests that metal mobility has played an important role in sediment geochemistry.

Water quality data for both the vadose zone and the groundwater illustrates a system marked by a great degree of spatial variation. Vertical changes in dissolved metals concentration in the vadose zone water have been attributed to the limited infiltration of fresh water below the upper 30-50 cm of the floodplain. Deeper vadose zone water, or capillary fringe water, is characterized by lower pH and higher amounts of dissolved metals as the result of sulfide oxidation and a slow natural downward percolation of this water. If percolation of the vadose zone water was an important mechanism transporting metals to the groundwater, the low flux rate would most likely limit the impact of vadose water on floodplain groundwater. It appears a more dominant mechanism controlling the release and transport of metals to the groundwater system is the varying water table and capillary fringe. Deep vadose zone water, or capillary fringe water, contains some of the highest dissolved metals concentrations found at the site. A rise in the water table would mix the groundwater with the poor-quality capillary fringe water. In places where groundwater is in perpetual contact with sediments high in readily soluble metals, dissolved metals concentrations in the groundwater are high. Clearly impacted groundwater extends approximately 1 meter below the water table over most of the floodplain. Elevated concentrations of dissolved metals are present to a greater depth in the aquifer, but in low concentrations. This study has, in effect, defined a zone of metals contamination within the uppermost 1 meter of the aquifer.

Spring snow melt and storm-induced stage changes exert control over the position of the water table. The water table fluctuates up to 1 meter at the site. With such fluctuations comes changes in the volume of saturated tailings and impacted sediments. As groundwater contact with contaminated materials has been shown to be the most important mechanism controlling release of metals at the site, it is important to address the change in water level as a factor in the degree of groundwater contamination.

Identification of the zone of greatest groundwater contamination within the upper 1 meter of the aquifer has certain implications for future work at the Miles Crossing site, and the entire Streamside Tailings Operable Unit. In reference to groundwater/surface water interaction, it is this upper meter of the aquifer that would have the most influence on the creek. Stream water mixes with this water in the hyporheic zone, and it is this water that loads the creek with contaminants. Characterization of this upper zone through groundwater sampling schemes is therefore extremely important for understanding and quantifying the amount of metals entering the creek. Sampling schemes that are intended to characterize the groundwater quality must be carefully planned out to sample water near the water table in order to characterize the entire system, rather than just a single well point within the sand and gravel aquifer. Results of this study indicate that single point measurements may not appropriately define whole-aquifer chemistry.

The results of this study also have implications for planned remediation strategies at Silver Bow Creek. Current remedial plans involve the plowing of lime amendments into the upper portion of the floodplain. The lime will supposedly raise the system pH and thus limit the mobility of metals through the vadose zone to the groundwater. This study implies that recharge of the water table through the vadose zone may only be significant over the coarse-grained portion of the floodplain, a small percent of the area. In addition, recharge through the vadose zone is likely confined to a short period of time occurring after the ground thaws, and before the arid summer. From this study, it appears that groundwater and the capillary fringe in seasonal or continual contact with contaminated materials controls the amounts of dissolved metals in the floodplain groundwater. Water table fluctuations seasonally change the amount of saturated tailings and heavy metals impacted sediments at the site, as well as mix the groundwater with capillary fringe water, shown to contain high concentrations of dissolved metals. It is therefore necessary to address the tailings stratigraphy and the temporal and spatial position of the water table when considering the ultimate remediation strategies for tailings-impacted floodplains.

Table 1: Descriptions of floodplain deposits at the Miles Crossing site.
Unit 1: Fine sands and silts Overbank deposited tailings covering the majority of the surface of the site. Generally brown to tan in color with yellow, orange, and gray mottling. Sparsely vegetated. Metal sulfate crusts form on this unit during dry periods. Uniformity coefficient = 3.3; d_{50} = 0.1 mm.
Unit 2: Red sands Medium to coarse grained sand found in proximity to the channel of the creek. Also found near ephemeral channels occupied during flood events, and older flood channels. Red staining throughout. Uniformity coefficient = 3.4; d_{50} = 0.33 mm for medium sand. Coarse sand is subrounded to rounded; uniformity coefficient = 4; d_{50} = 1.4 mm. Mineralogy is dominated by quartz and feldspar.
Unit 3: Fine silt and clay Generally fine silt to clay size grains, occasionally mixed with fine to medium sand. Very poor sorting. Old soil horizons may be found within this unit containing root material. Found beneath Unit 1 where Unit 2 is absent.
Unit 4: Gray sand Generally found as a medium sand, but grain size varies from silt to coarse sand. Root mottling apparent in some samples. Found underlying Units 2 and 3. Interpreted as original floodplain deposits. Subrounded to rounded grains. Uniformity coefficient = 1.7; d_{50} = 0.96 mm. Mineralogy is dominated by quartz and feldspar.
Unit 5: Gravels Grain size varies from coarse sand to cobbles. Comprises most of the floodplain aquifer material.

Table 2: Calculation of the amount of tailings/impacted sediments saturated by groundwater, August and May, 1996.

Surface Area (square meters)	**Saturated Thickness (meters)**		**Volume (cubic meters)**	
	Aug' 96	May ' 96	Aug '96	May '96
Gray sands:				
2800	0.3	0.9	840	2520
1200	0	0.5	0	600
250	0	0.6	0	150
Red sands:				
200	0.6	0.9	120	180
10	0.3	0.8	3	8
55	0.5	0.8	28	44
150	0	0.2	0	30
Dark brown/gray silt and clay:				
120	0.4	0.8	48	96
200	0.1	0.5	20	100
750	0.4	0.7	300	525
800	0	0.7	0	560
			Totals 1359	Totals 4813

Table 3: Vadose zone water chemistry, site 1, 6/20/96.

all values reported in ppm			
	LS-1	**LS-3**	**LS-2**
depth	121 cm	84 cm	51 cm
unit	gray sand	gray sand	f. silt and clay
pH	6.4	5.3	not measured
sulfate	575	4410	not measured
Cd	0.301	0.062	0.022
Cu	23.5	2.70	1.30
Fe	< .015	0.175	0.033
Mn	33.1	4.39	1.40
Zn	61.8	8.57	3.68

Table 4: Comparison of vadose zone water at site 1, 6/20/96 and 8/7/96.

all values reported in ppm						
	LS-1			**LS-3**		
depth	121 cm			84 cm		
unit	gray sand			gray sand		
date	6/20/96	8/7/96		6/20/96	8/7/96	
pH	6.4	5.1		5.3	7.0	
sulfate	575	2180		4410	4820	
Cd	0.301	0.155		0.062	0.136	
Cu	23.5	6.10		2.70	0.693	
Fe	< .015	0.087		0.175	0.084	
Mn	33.1	28.3		4.39	0.102	
Zn	61.8	62.6		8.57	0.729	

Table 5:						
Comparison of vadose zone water quality, sites 1 and 2, 6/20/96.						
all values reported in ppm						
	LS-1				**AL-85**	
depth	121 cm				84 cm	
unit	gray sand				red sand	
pH	6.4				2.9	
sulfate	575				6550	
As	< .06				0.109	
Cd	0.301				2.63	
Cu	23.5				546	
Fe	< .015				63.5	
Mn	33.1				245	
Pb	< .075				0.271	
Zn	61.8				670	

Table 6:

Comparison of vadose zone water quality at site 2, 6/20/96 and 8/7/96.

all values reported in ppm

		AL-85			
depth		84 cm			
unit		red sand			
date	6/20/96		8/7/96		
pH	2.9		not measured		
sulfate	6550		not measured		
Cd	2.63		3.36		
Cu	546		688		
Fe	63.5		73.2		
Mn	245		321		
Pb	0.271		0.370		
Zn	670		818		

Table 7: Comparison of water quality data from selected piezometers, 6/6/96.

all values reported in ppm

Piezometer	pH	Cd	Cu	Fe	Mn	Zn
D-3	3.6	0.389	59.2	19.9	64.0	95.3
D-4	3.7	0.372	64.2	27.8	56.3	99.1
D-5	3.7	1.39	40.4	35.7	104	113
D-13	5.7	< .009	< .006	19.2	47.6	33.6
D-14	6.0	< .009	< .006	27.5	35.3	10.3
D-21	4.1	0.480	67.5	24.4	45.9	99.0
D-52	6.0	< .009	< .006	42.8	8.67	4.76
P-10	5.7	< .009	< .006	13.3	24.5	3.79

Table 8: Comparison of water quality at D-4 and D-26, June - August, 1996.

all values reported in ppm

Piezometer	date	pH	cond. (mS/cm)	Sulfate	Al	Cd	Cu	Fe	Mn	Zn
D-4	6/6/96	3.7	2.34		26.6	0.372	64.2	27.8	56.3	99.1
	6/20/96	4.1	2.44	1550	24.8	0.362	60.8	27.2	55.2	96.0
	7/17/96	4.3	2.40	1730	29.0	0.395	67.2	29.6	61.5	105
	8/7/96	4.1	2.44	1700	29.6	0.374	69.2	26.8	59.5	101
D-26	6/6/96	3.7	1.22		7.93	0.192	7.24	0.550	12.8	30.5
	6/20/96	3.7	1.12	525	6.22	0.166	6.12	0.494	11.0	26.0
	7/17/96	3.9	1.14	648	6.58	0.169	6.34	0.556	11.3	26.9
	8/7/96	3.9	1.21	639	7.18	0.187	7.10	0.765	12.2	29.5

Table 9: Comparison of water quality at multi-level samplers 1 and 3, 6/20/96.

all values reported in ppm

Sample Port	depth to port (m)	pH	Sulfate	Cd	Cu	Fe	Mn	Zn
MLS-1								
S1-5	2.16	4.3	760	0.233	9.53	8.40	18.9	43.7
S1-1	1.93	4.0	575	0.168	7.48	0.165	11.3	28.1
S1-2	1.70	4.5	722	0.165	10.5	0.066	10.8	29.5
S1-3	1.47	4.1	579	0.161	9.83	15.4	10.8	28.7
MLS-3								
S3-5	2.16	4.2	1530	0.442	78.4	20.7	56.2	114
S3-1	1.93	4.3	1530	0.455	80.7	17.7	56.9	116

Table 10: Water quality data, MLS-3 and D-4, 8/7/96.					
all values reported in ppm					
		D-4			**MLS3-5**
pH		4.1			4.1
Conductivity (mS/cm)		2.44			2.32
SO4		1700			1570
Al		29.6			23.6
As		< 0.06			< 0.06
Ca		242			230
Cd		0.374			0.425
Cu		69.2			76
Fe		26.8			19.8
Mg		66.1			58.1
Mn		59.5			56.4
Na		96.3			92.5
Pb		< 0.075			< 0.075
S		546			511
Si		48.7			50.2
Zn		101			112

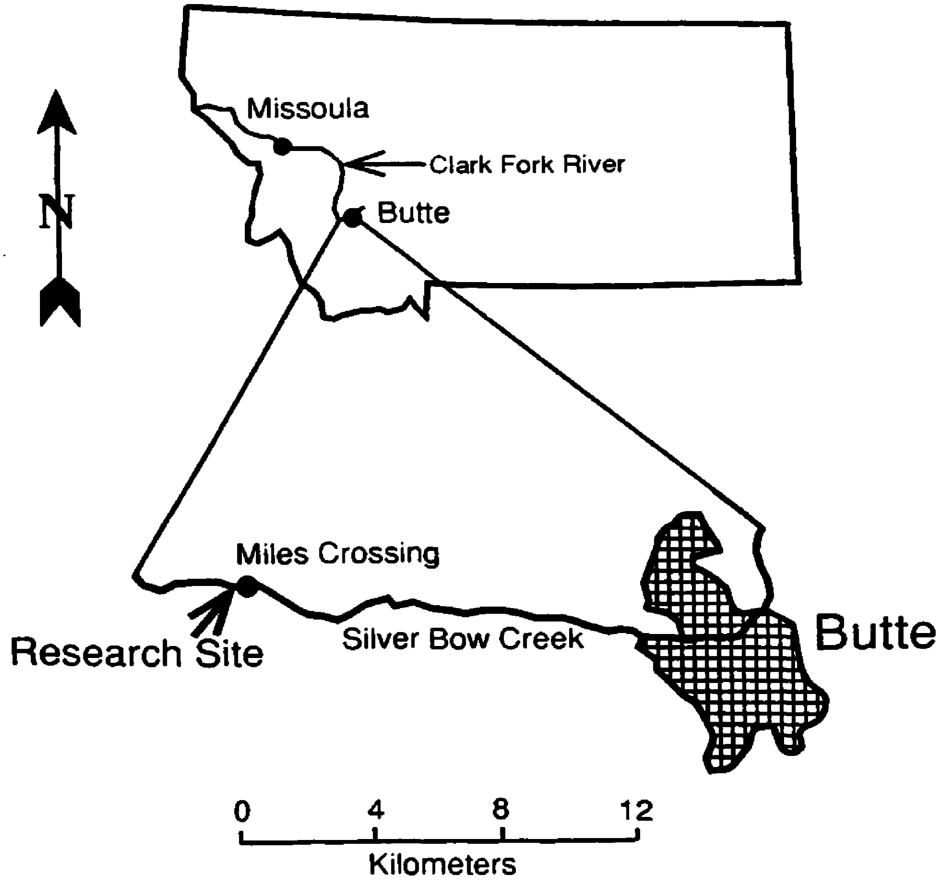


Figure 1 - Location Map

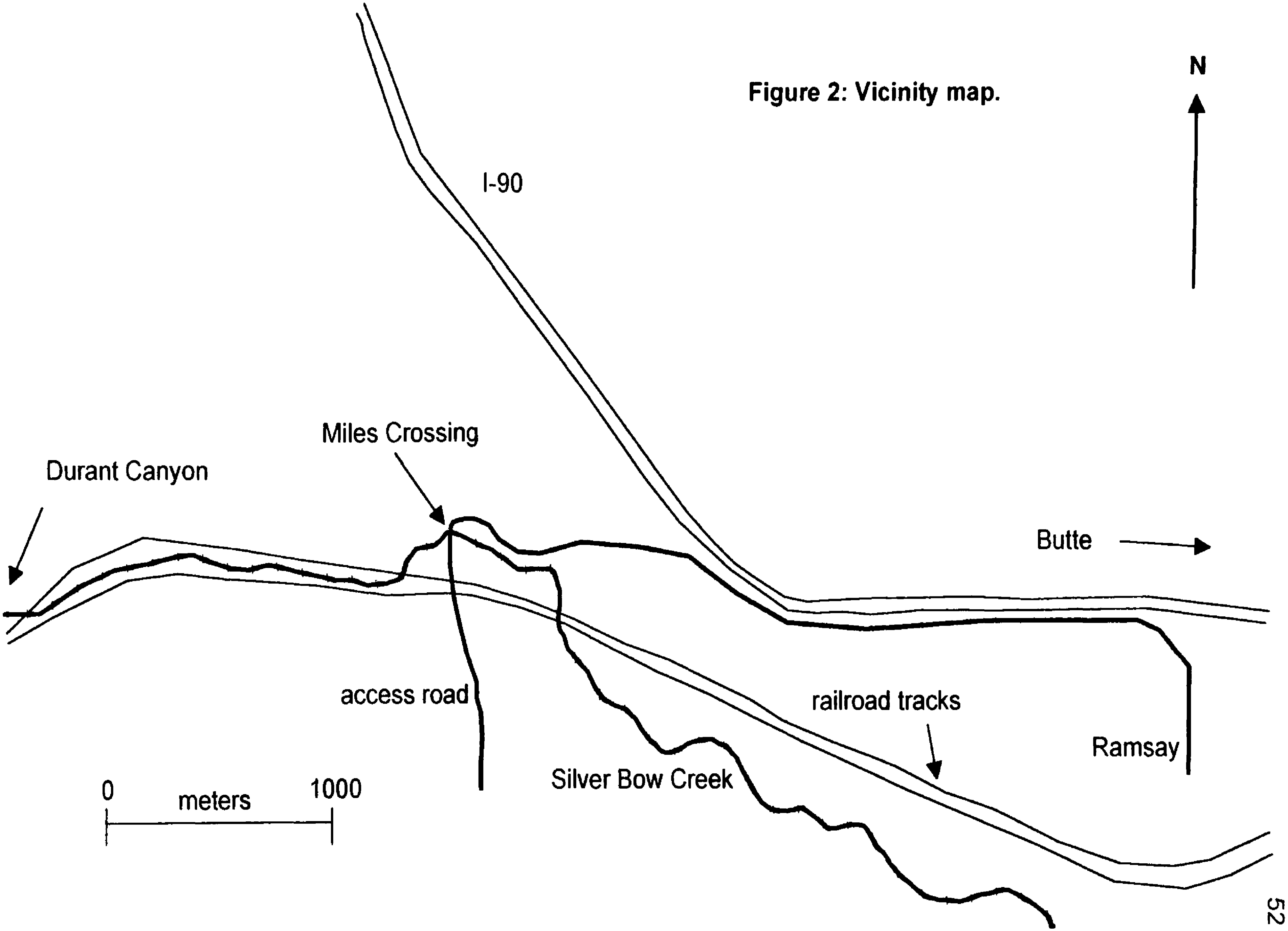
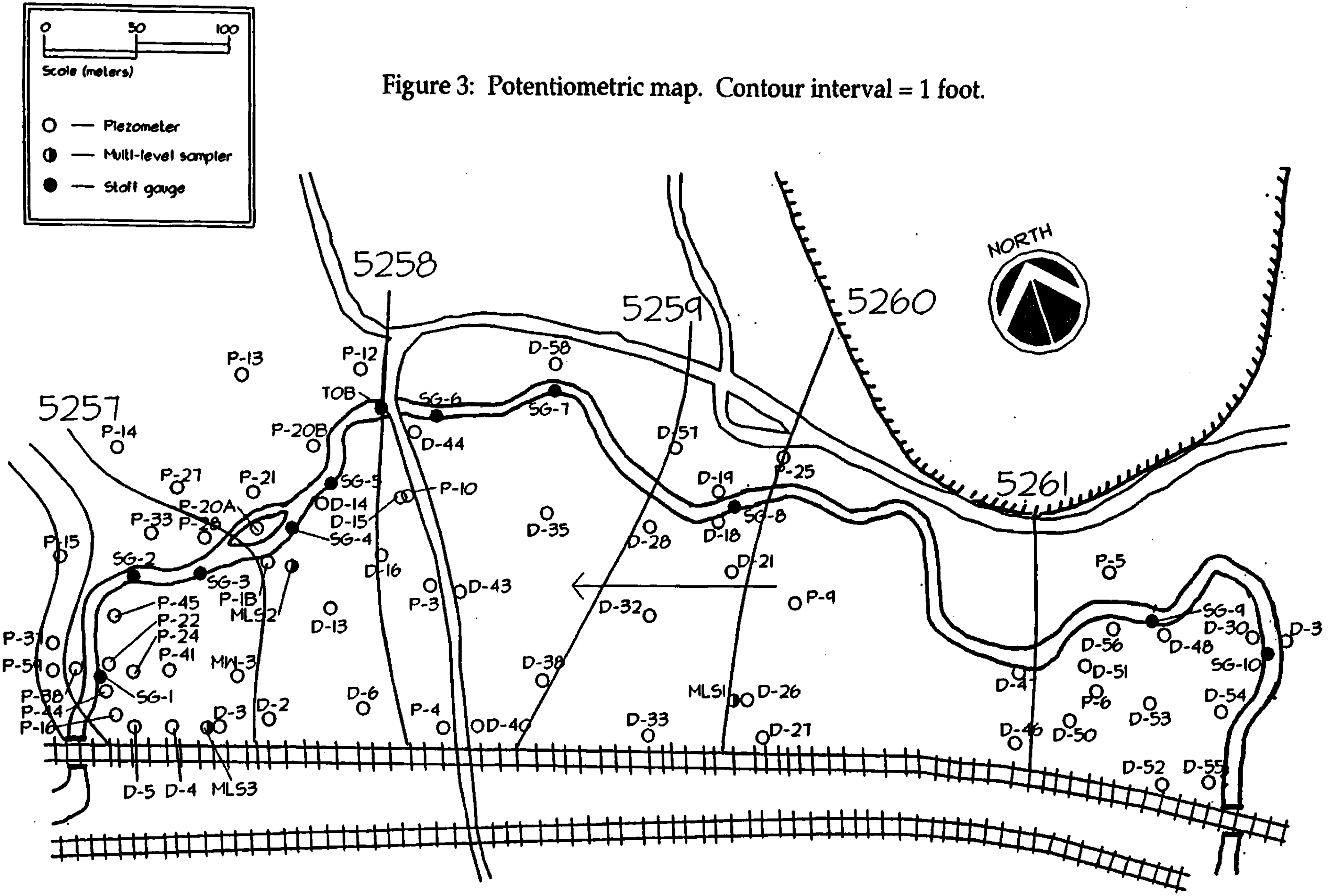


Figure 2: Vicinity map.

Figure 3: Potentiometric map. Contour interval = 1 foot.



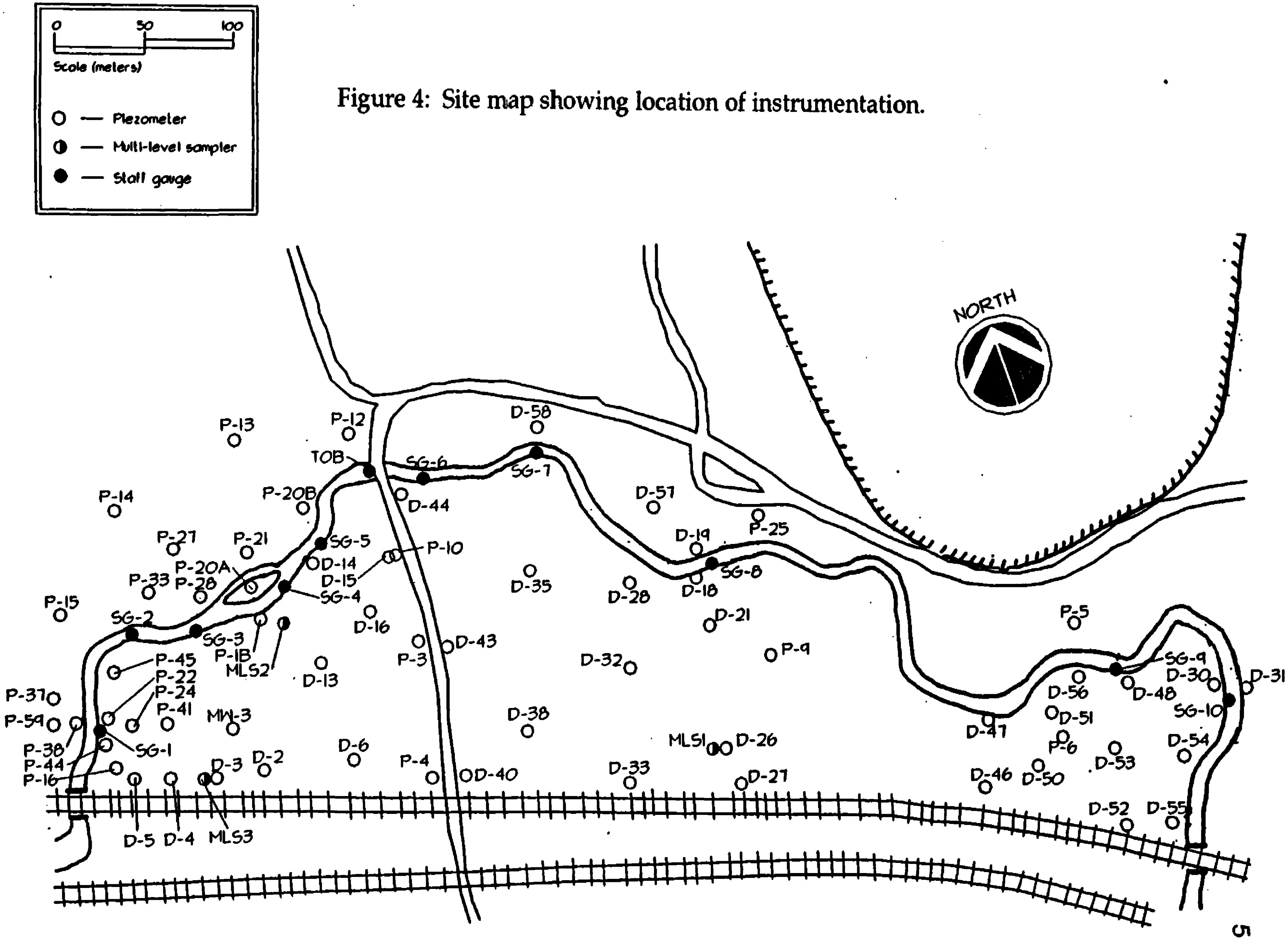


Figure 4: Site map showing location of instrumentation.

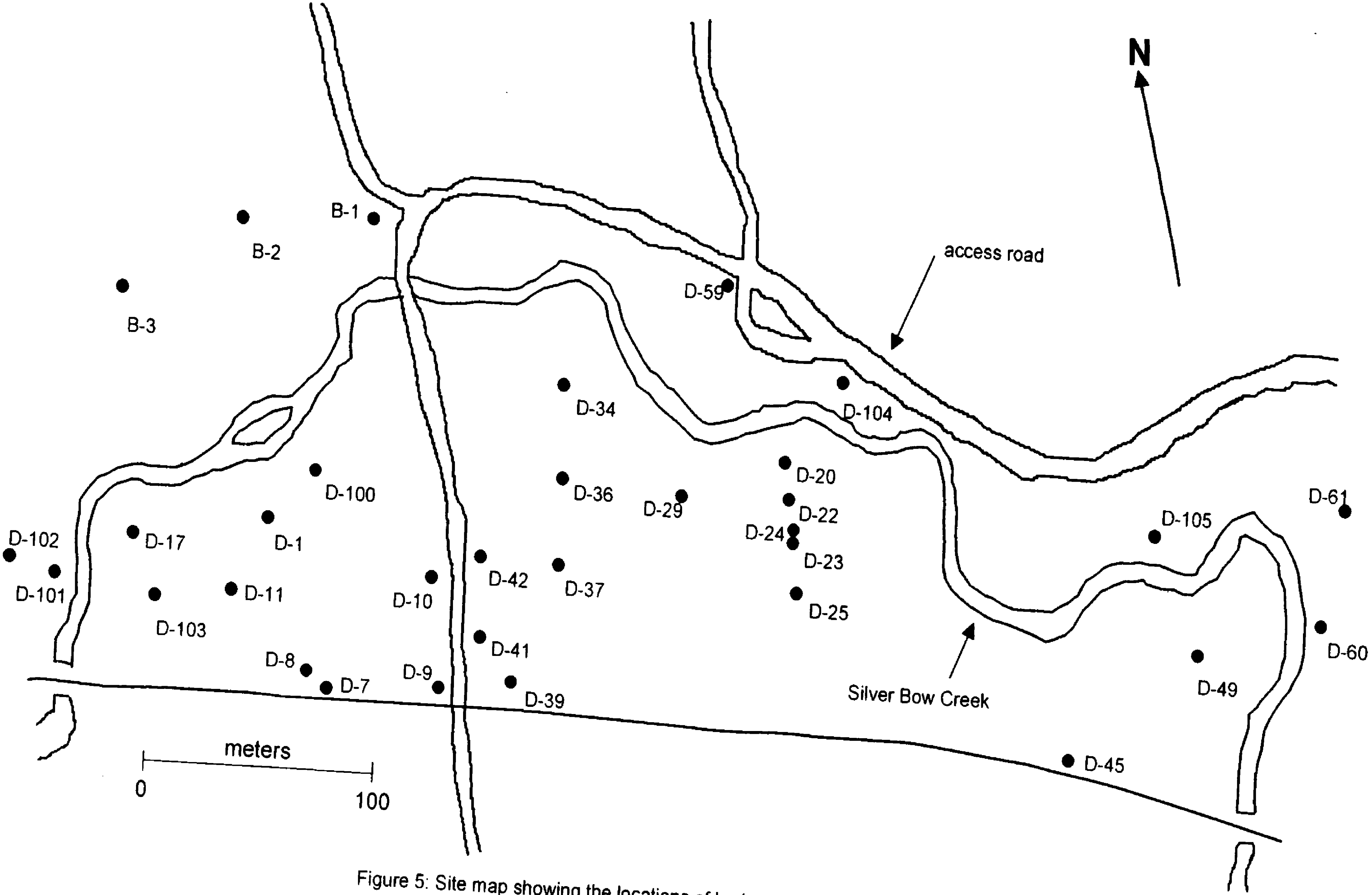


Figure 5: Site map showing the locations of borings where wells were not installed.

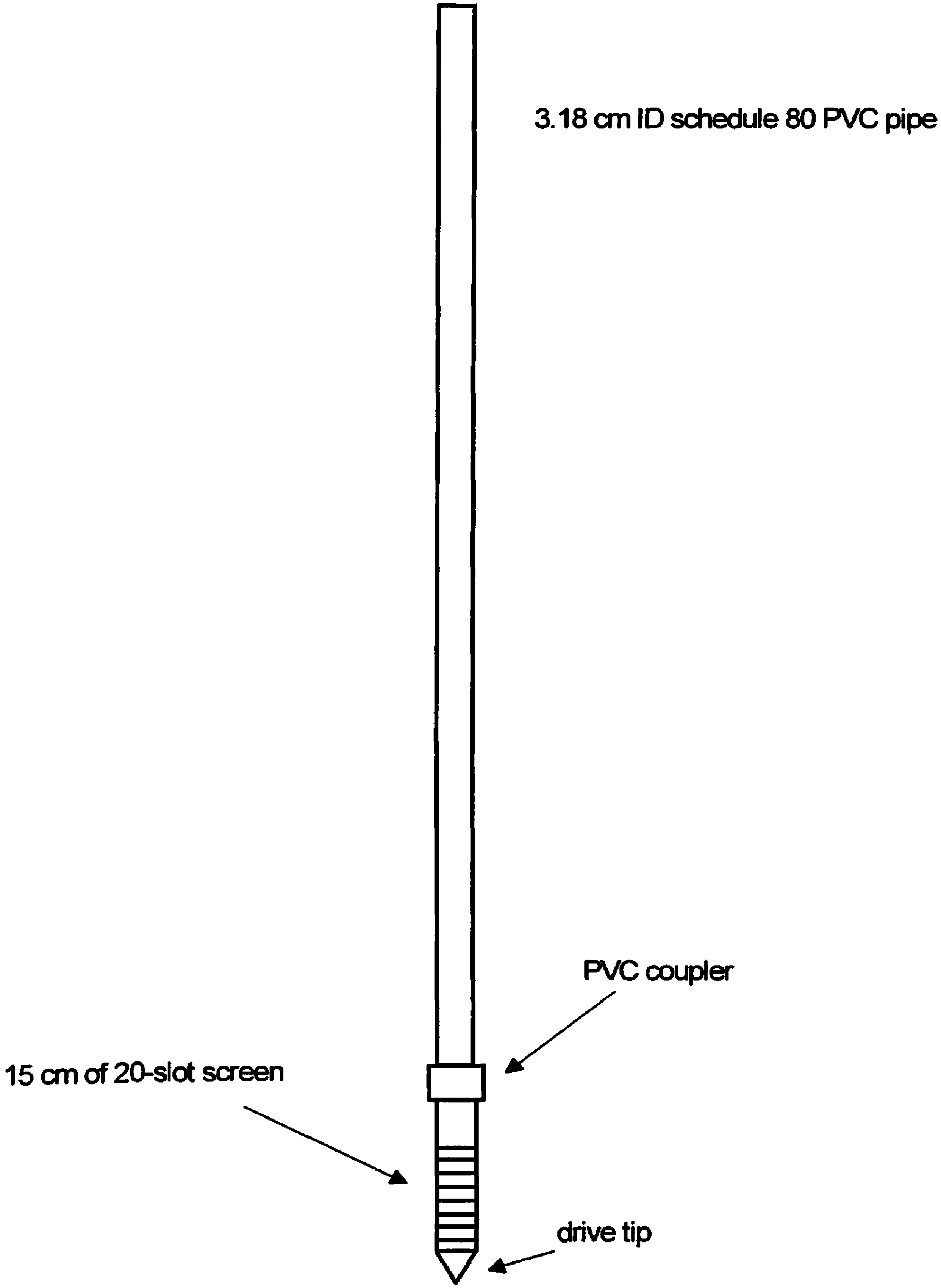


Figure 6: Piezometer construction.

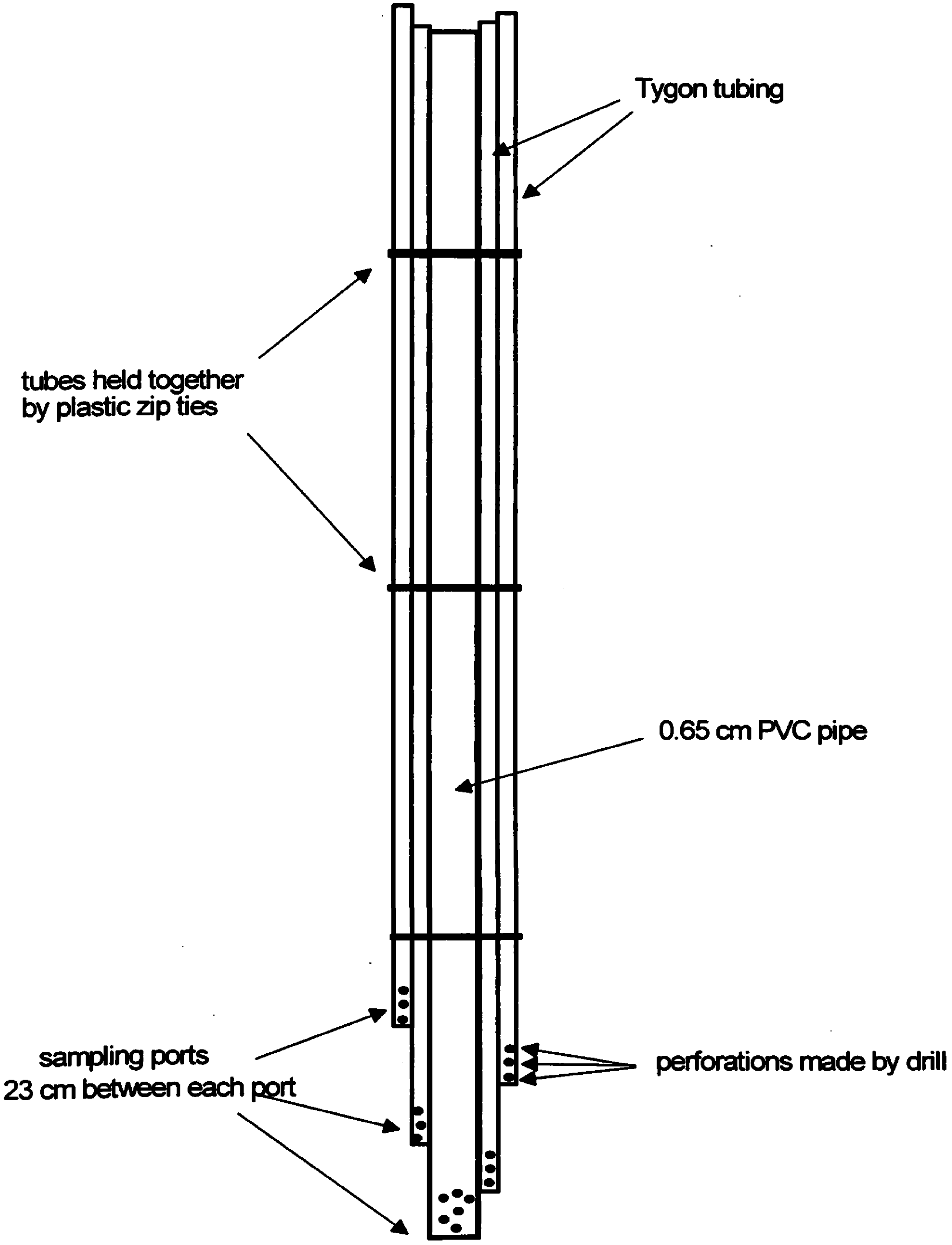


Figure 7: Multi-level sampler construction.

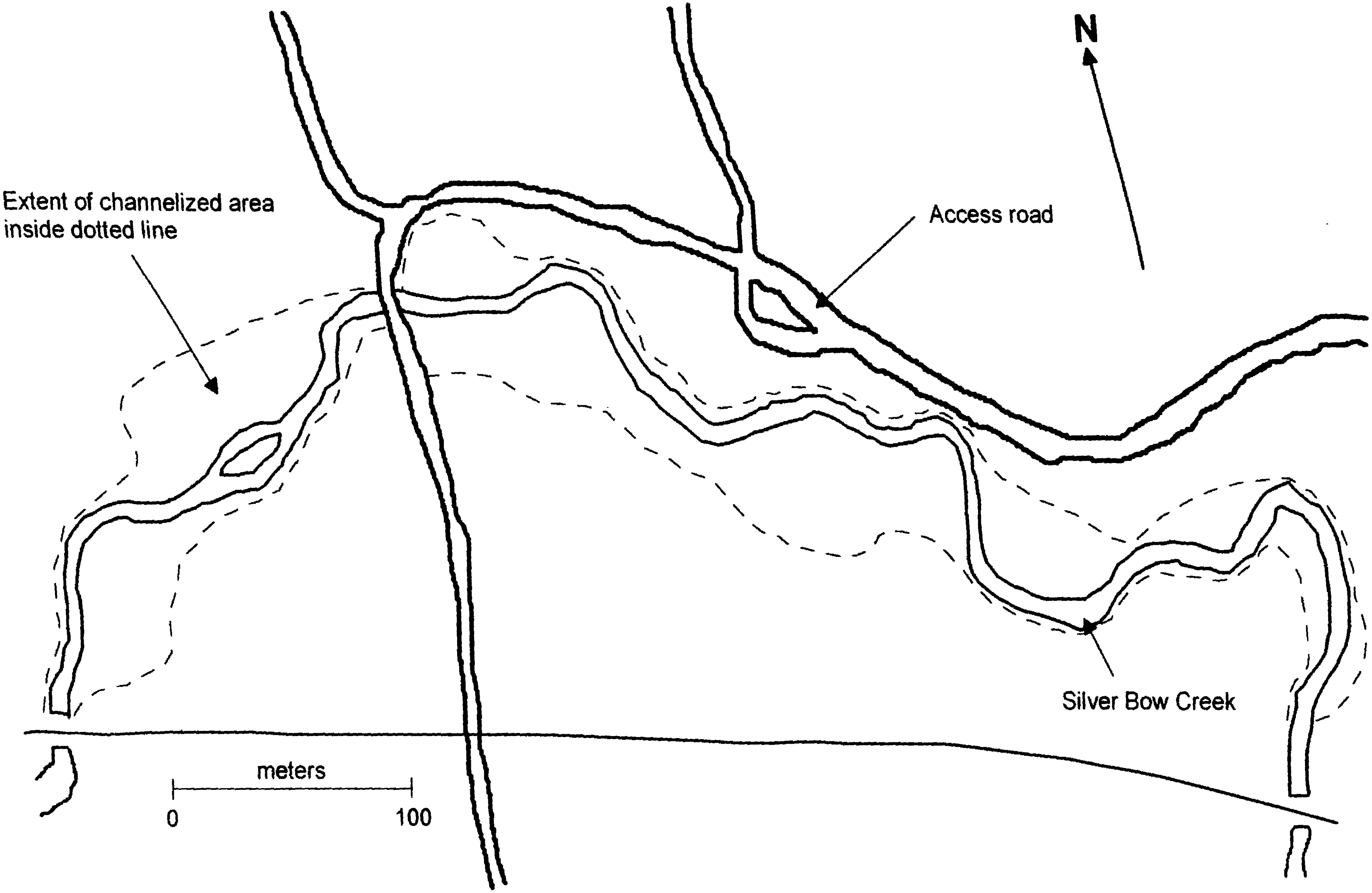


Figure 8: Site map showing the division between the upper floodplain bench and the present channelized area.

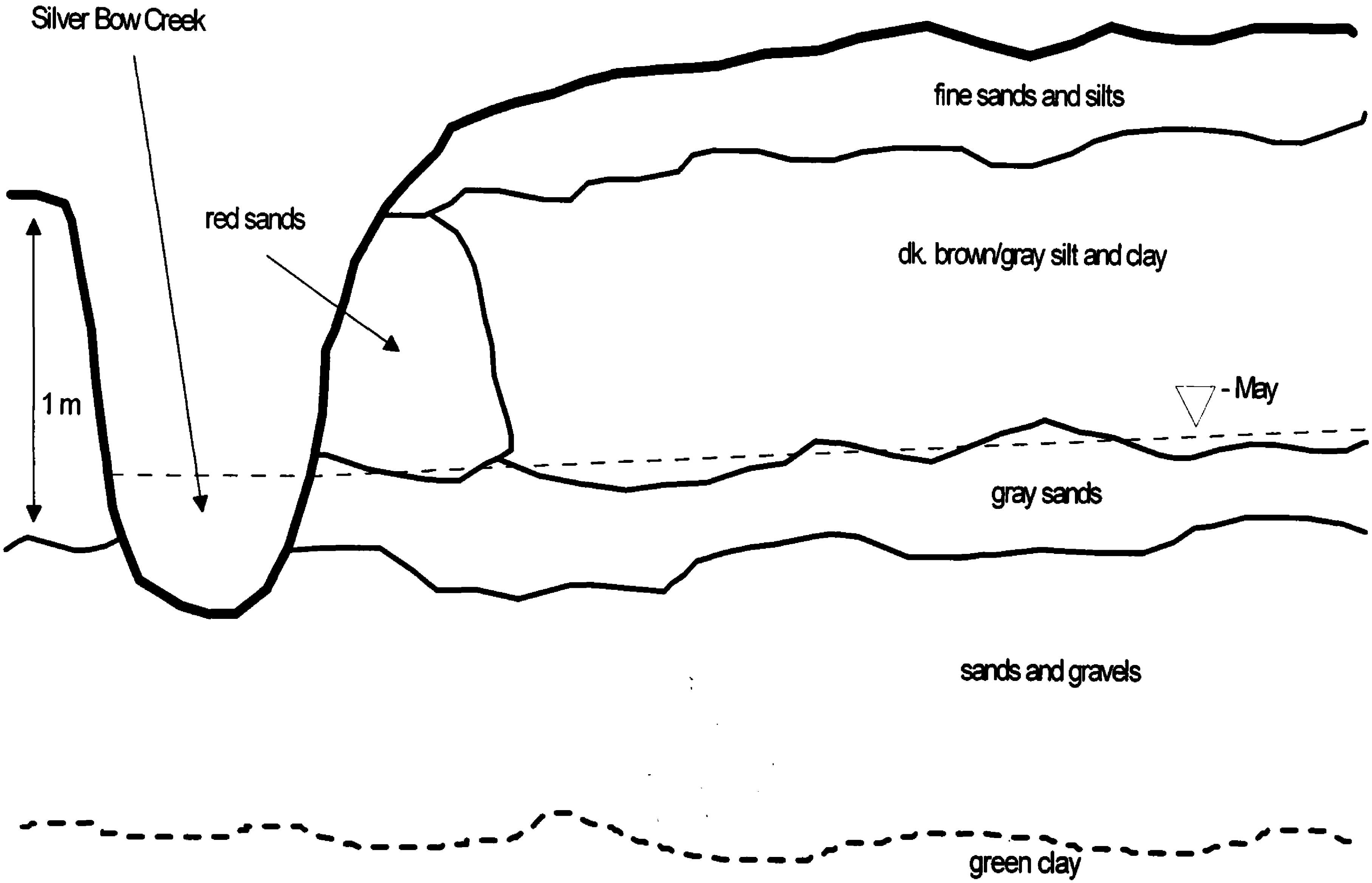


Figure 9: Schematic diagram illustrating the general stratigraphic relationships seen at the site.

Figure 10: Grain size distribution for the fine sand and silt unit.

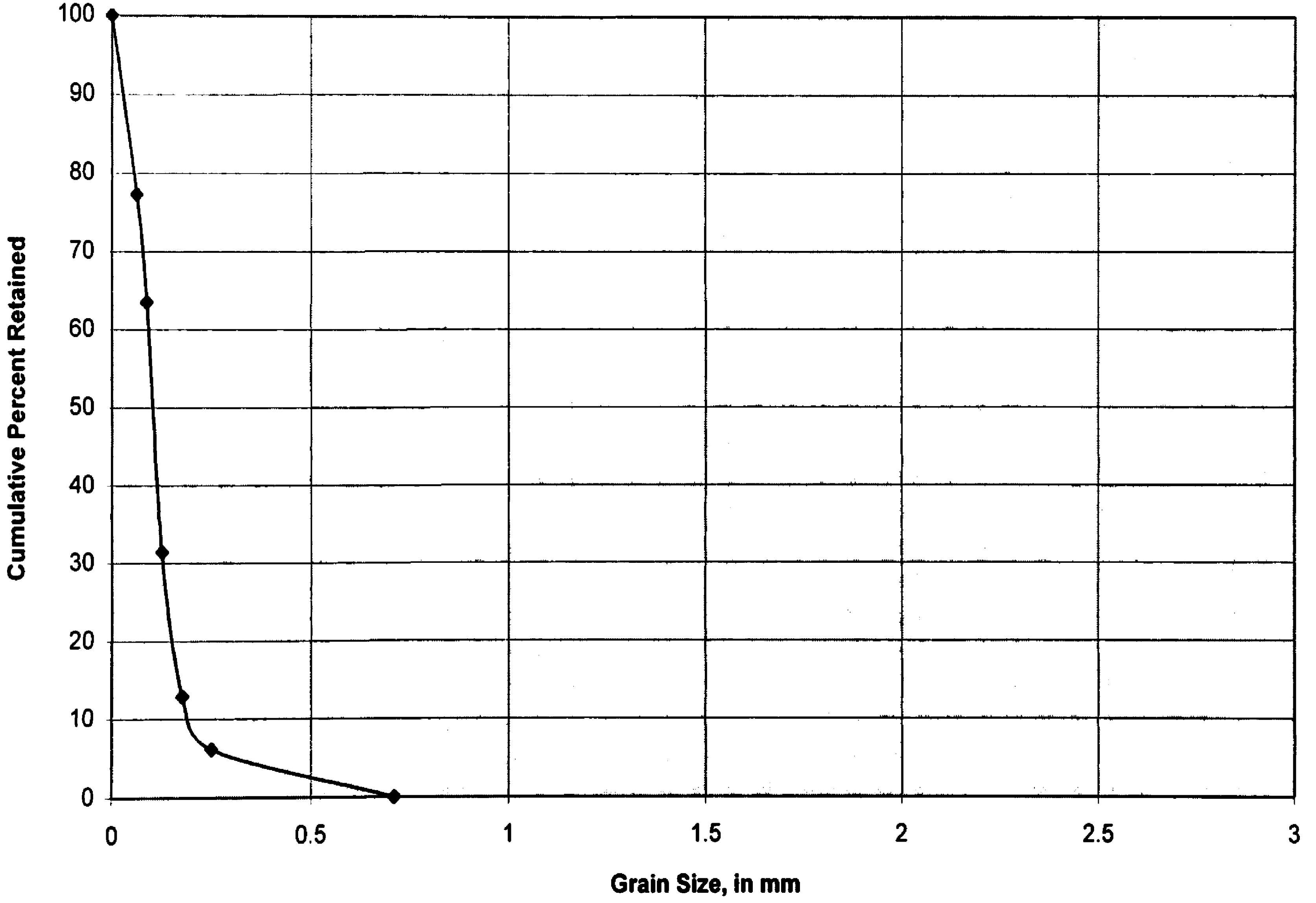


Figure 11a: Grain size distribution for the red sand unit.

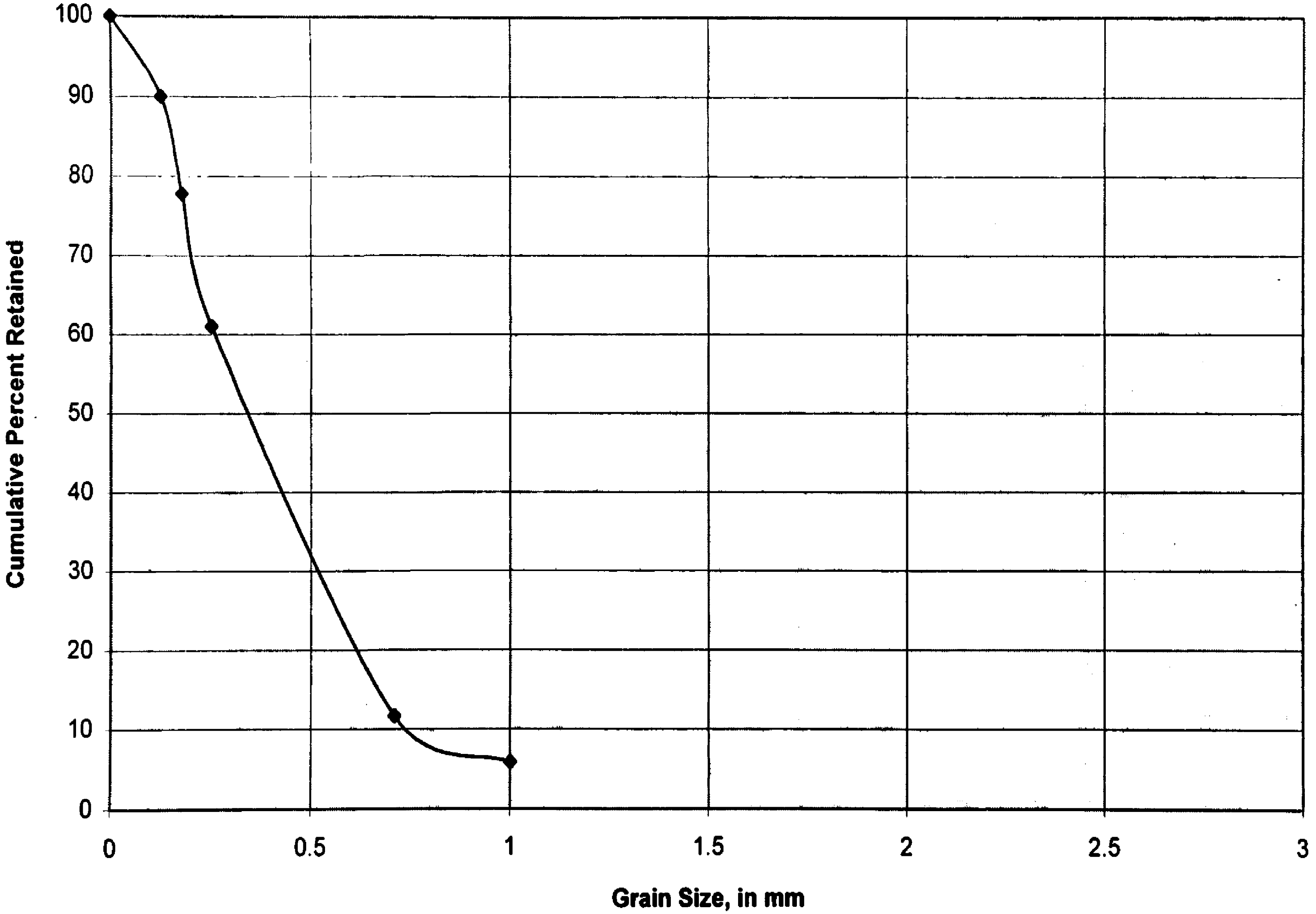


Figure 11b: Grain size distribution for the coarse red sand unit.

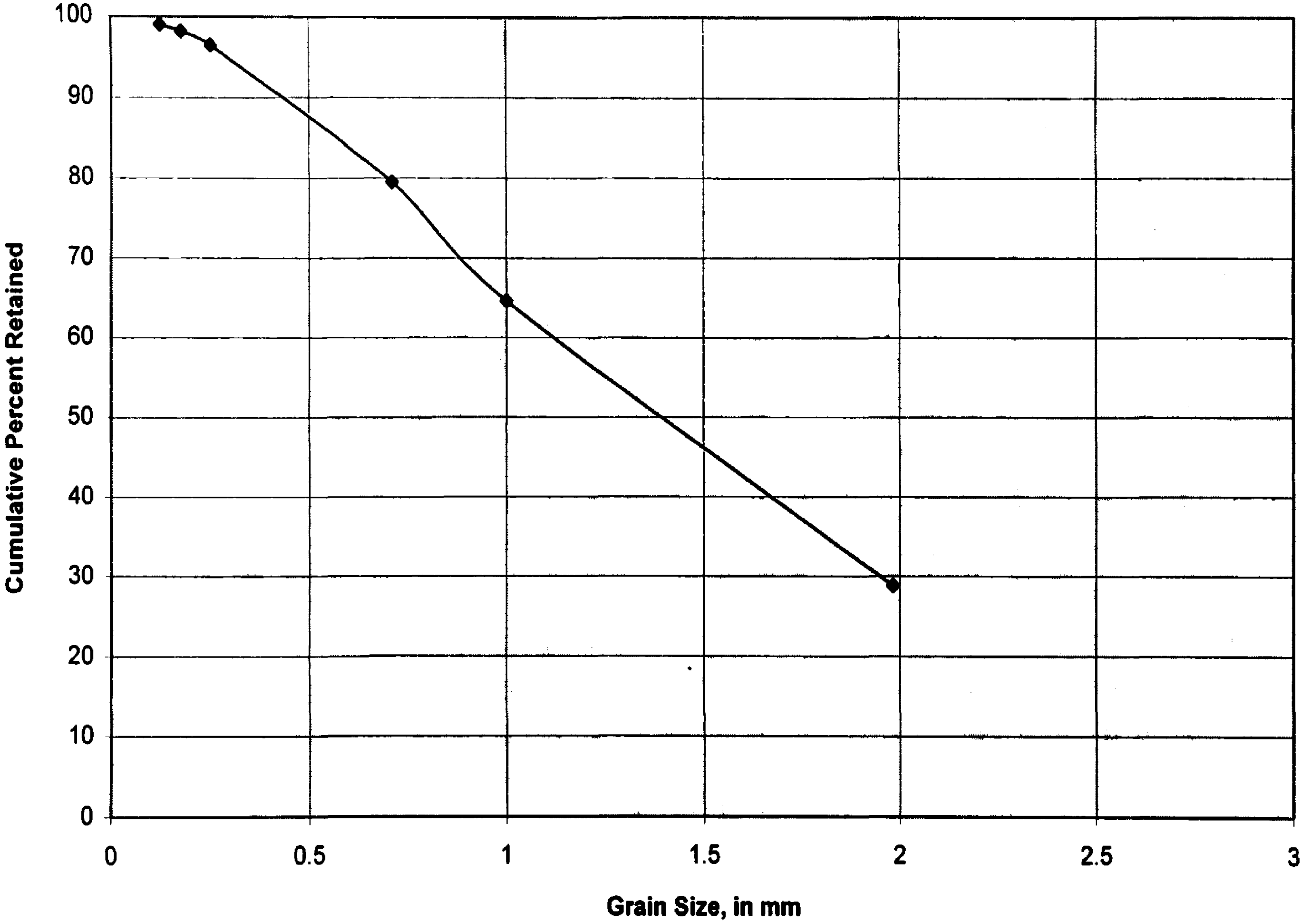


Figure 12: Grain size distribution for the gray sand unit.

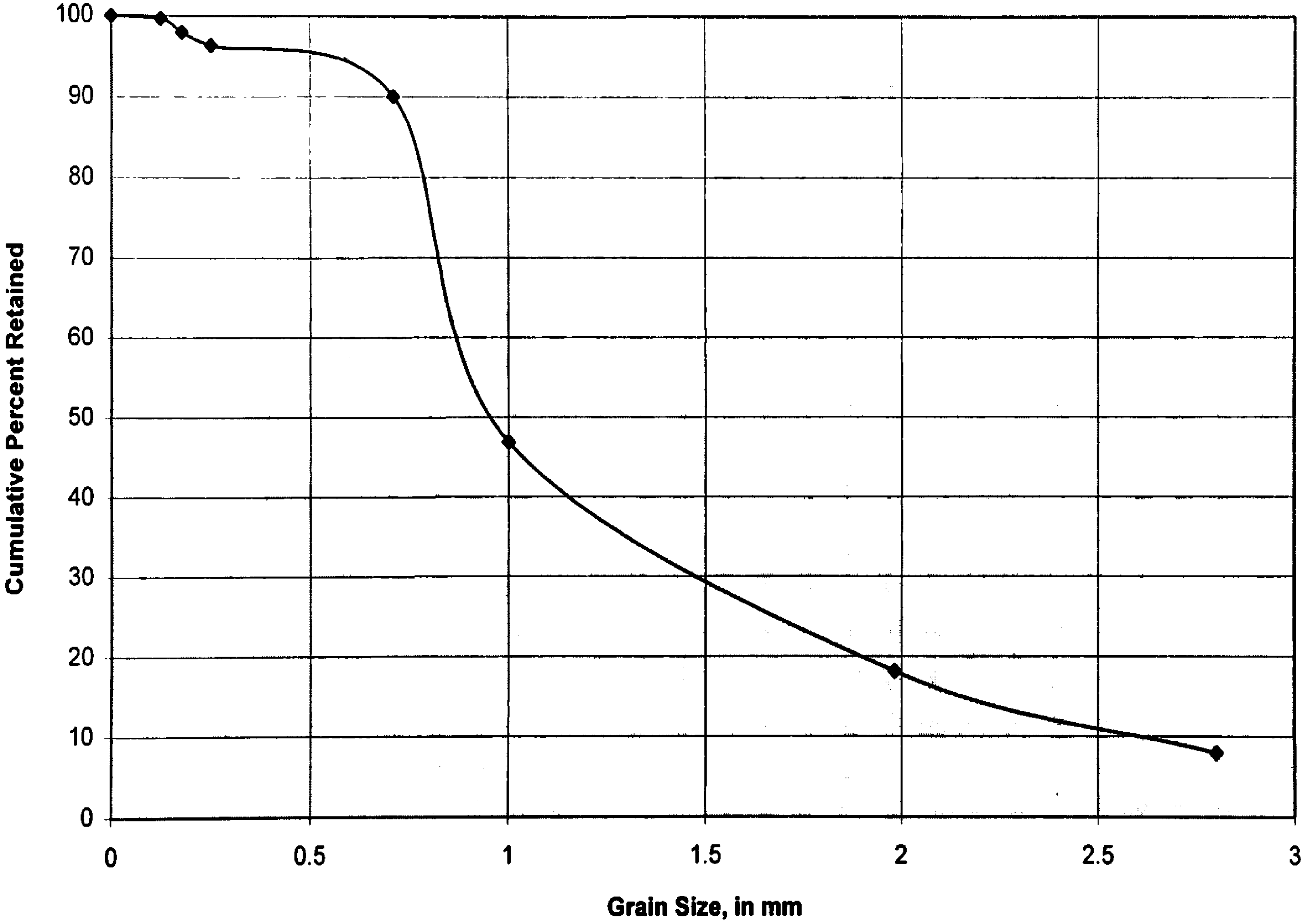
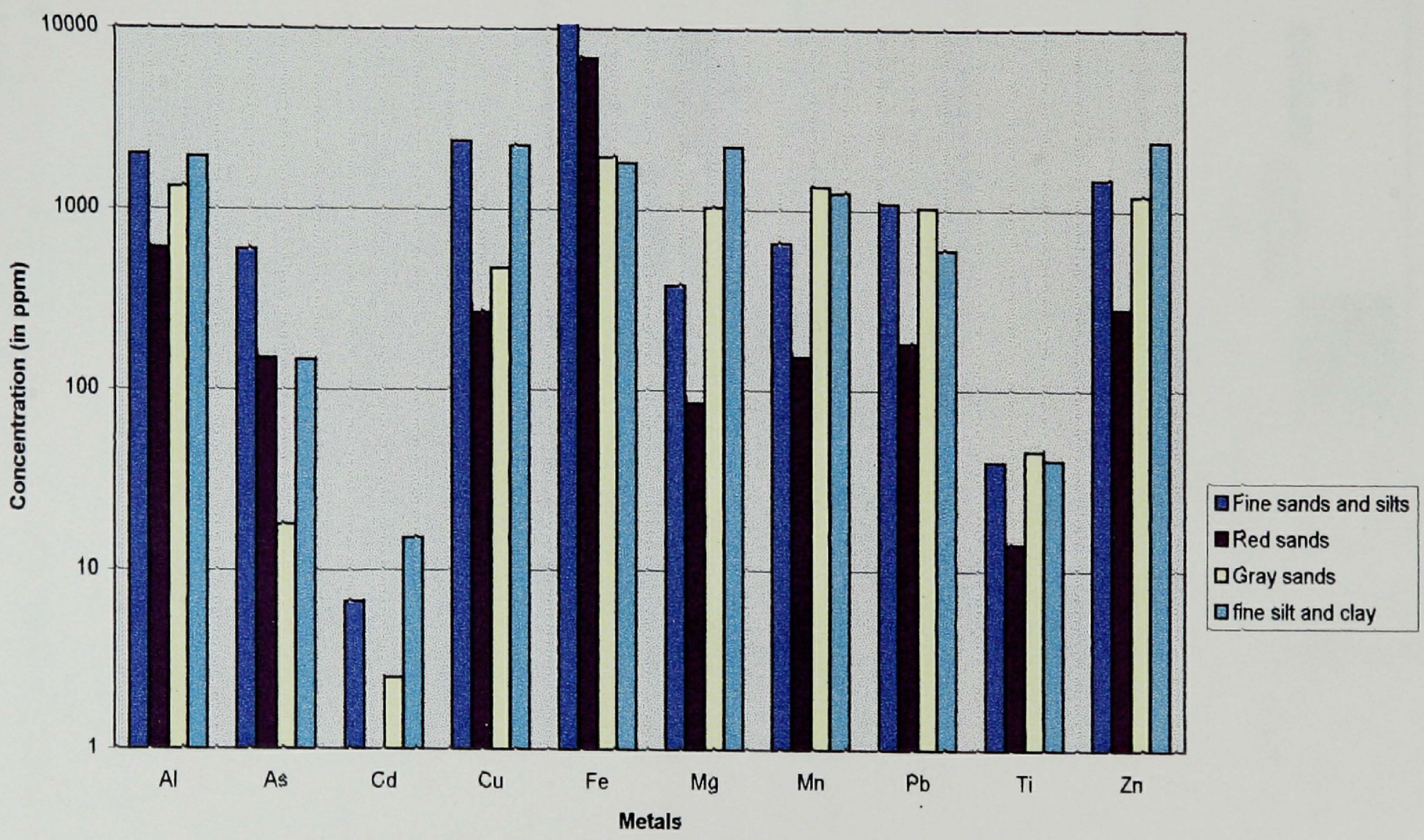


Figure 13: Average concentration of metals in sedimentary units.



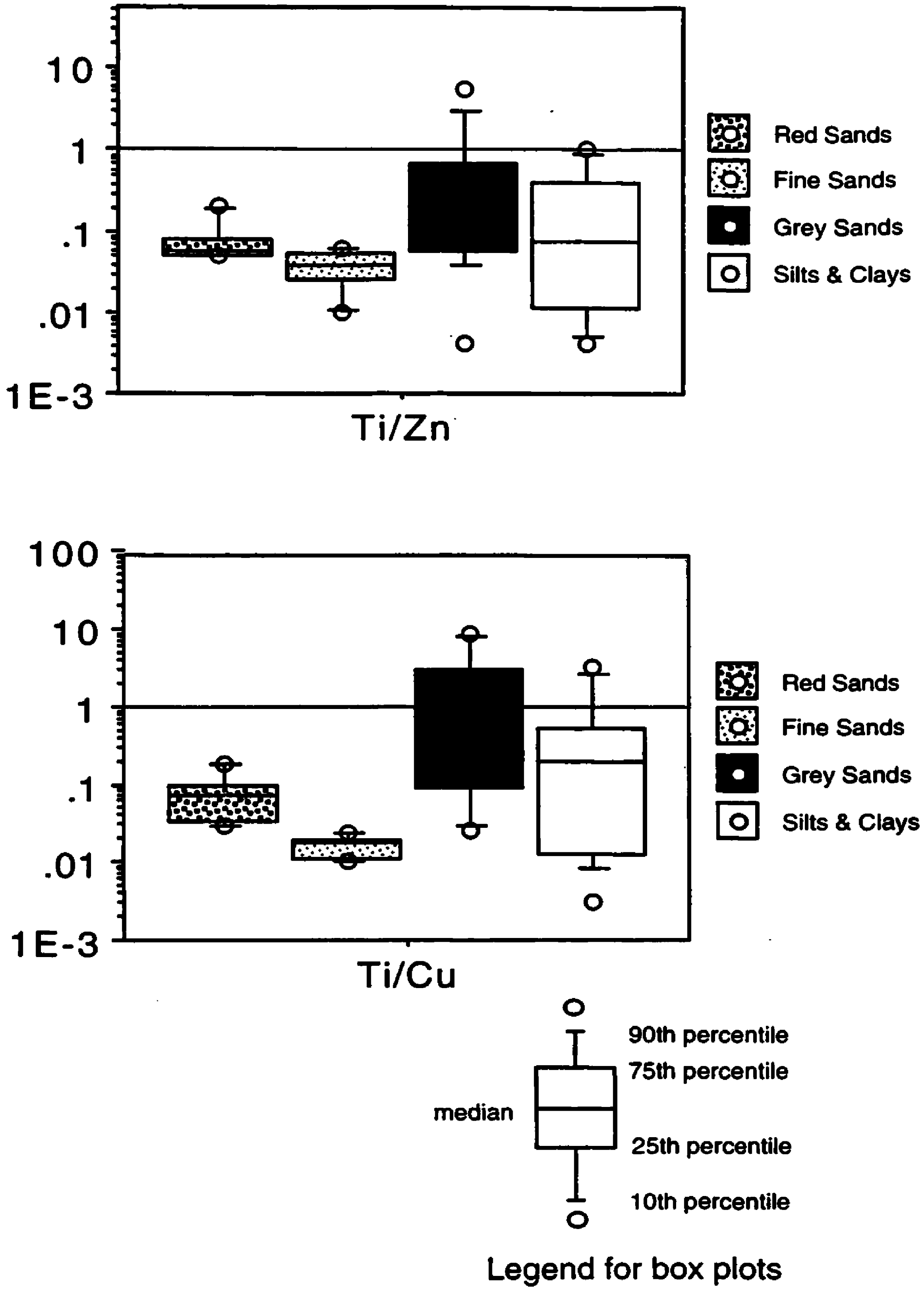
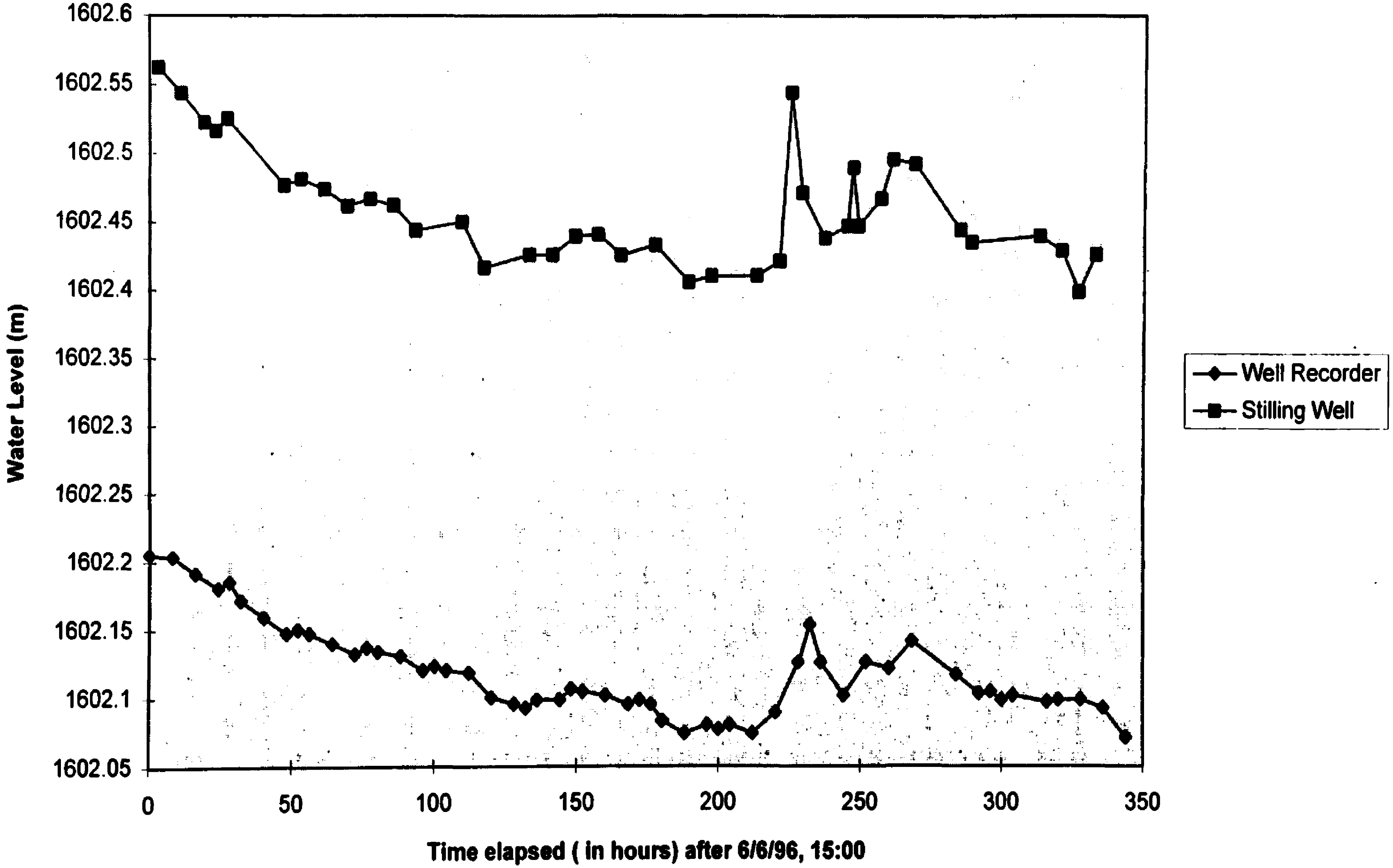


Figure 14: Box plots of Ti/Zn and Ti/Cu ratios from the weak acid digest results for each of the stratigraphic units.

Figure 15: Continuous water level recorder data.



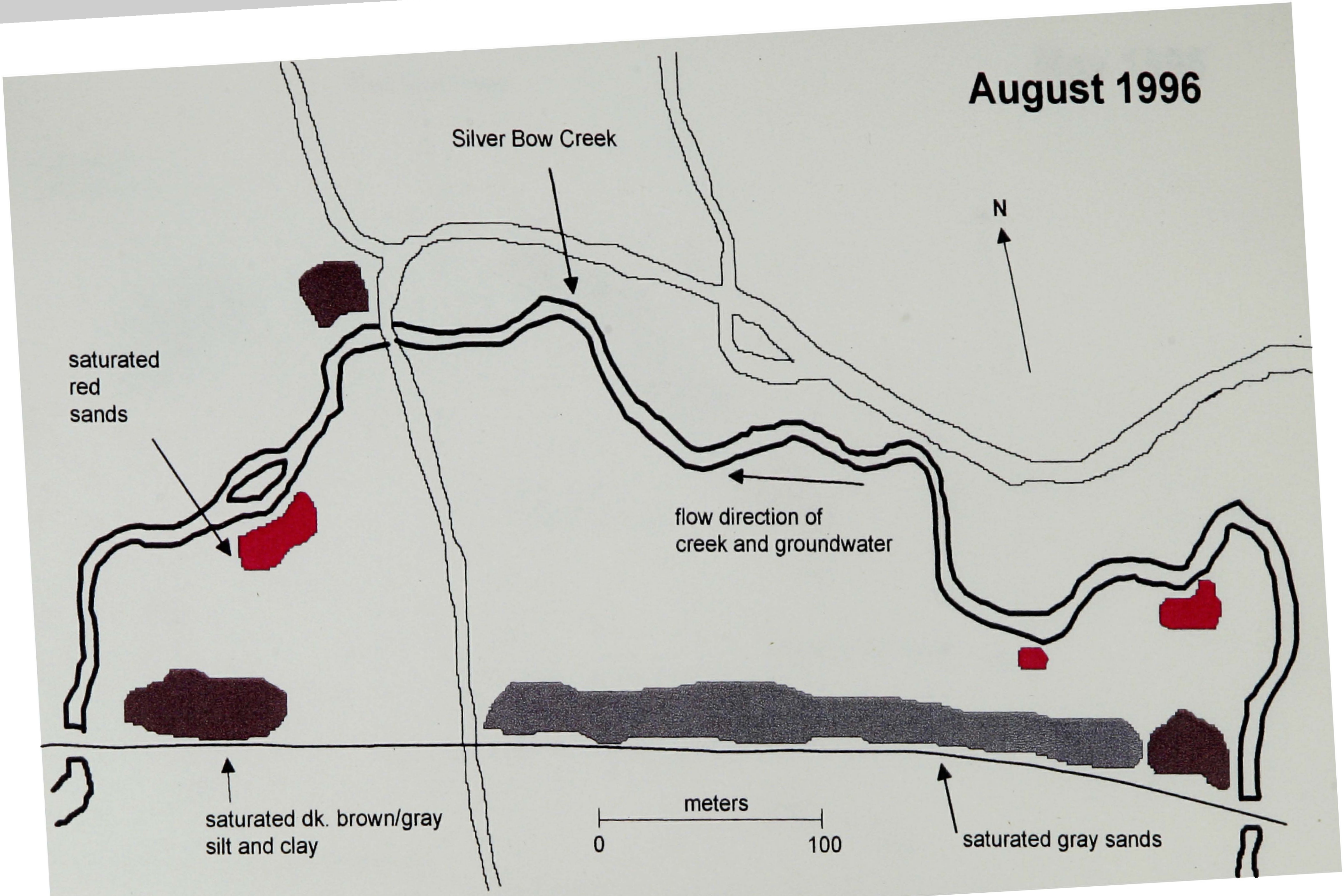


Figure 16: Location and extent of saturated tailings in August, 1996.

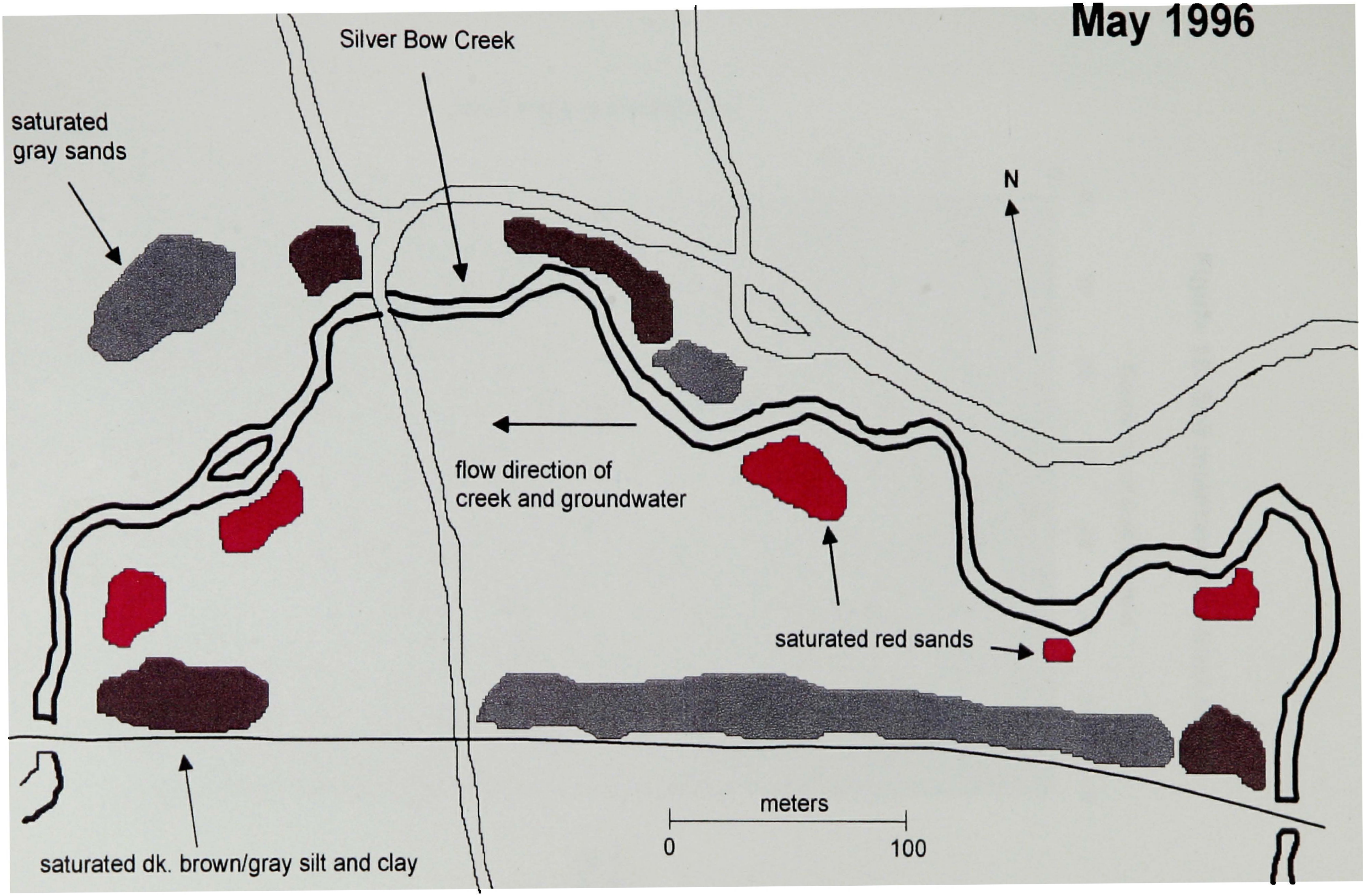


Figure 17: Location and extent of saturated tailings in May, 1996.

Figure 18: Soil moisture data from Site 2.

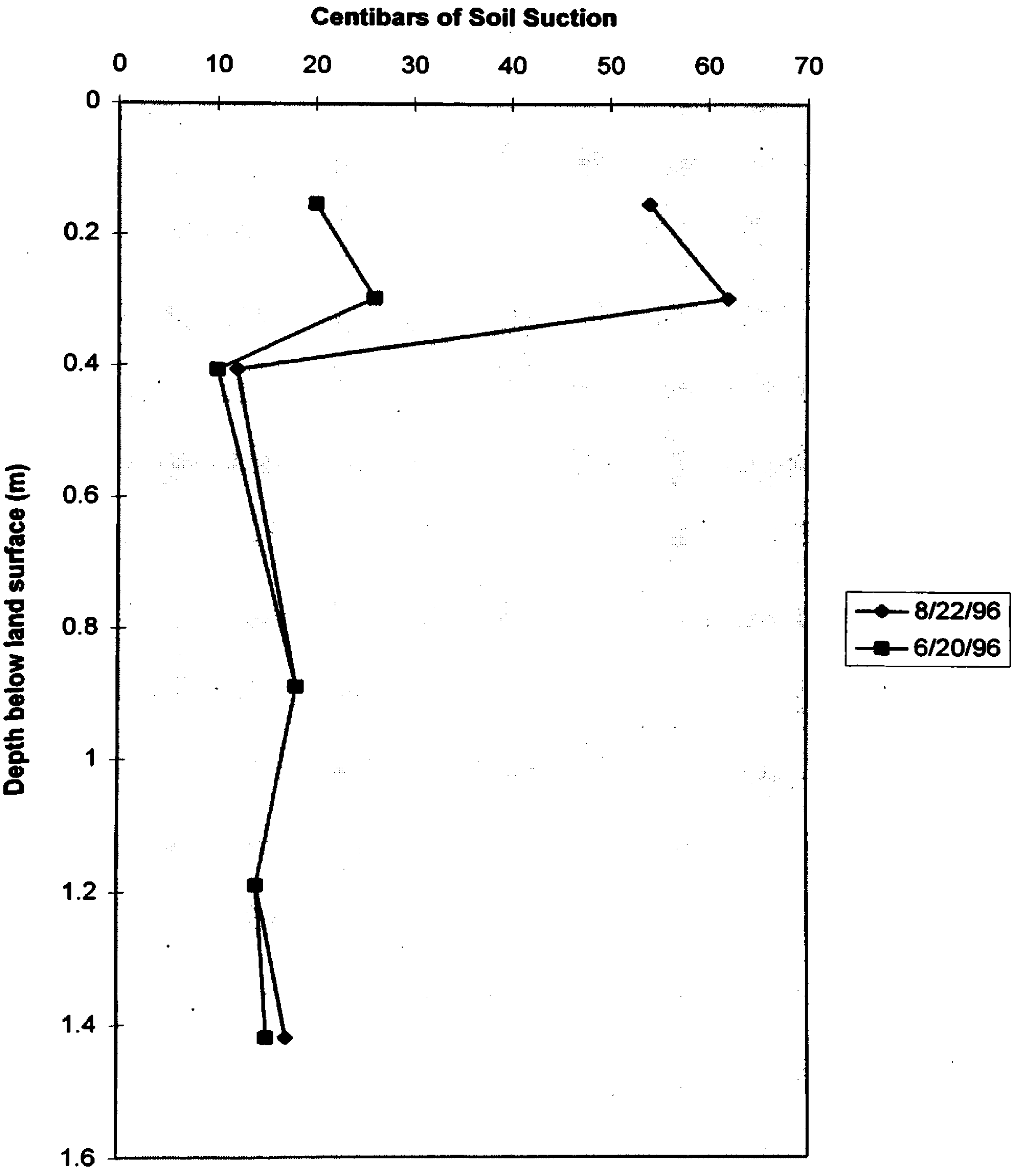
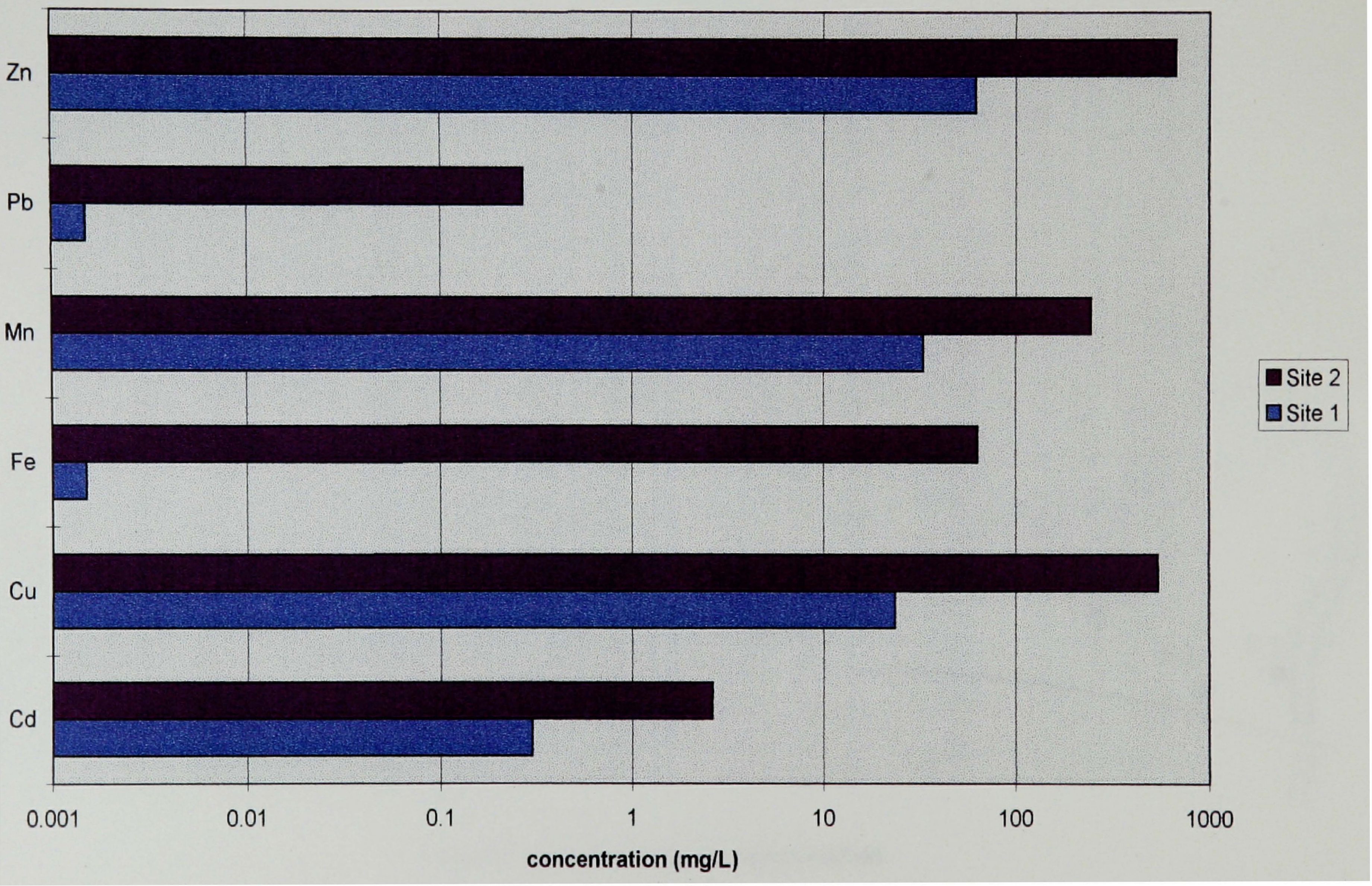


Figure 19: Comparison of dissolved metals concentrations in pore water at Sites 1 and 2, 6/20/96.



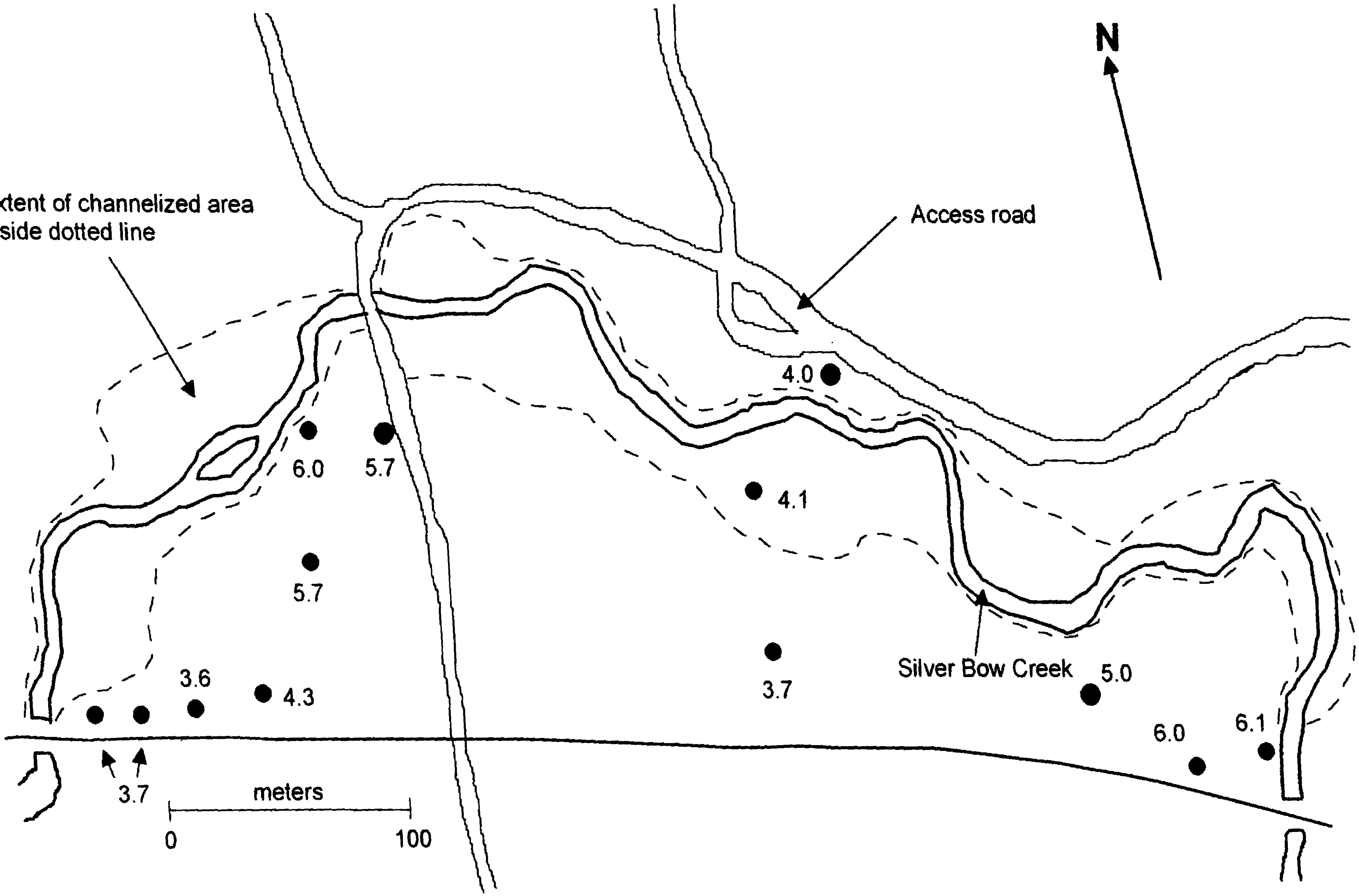
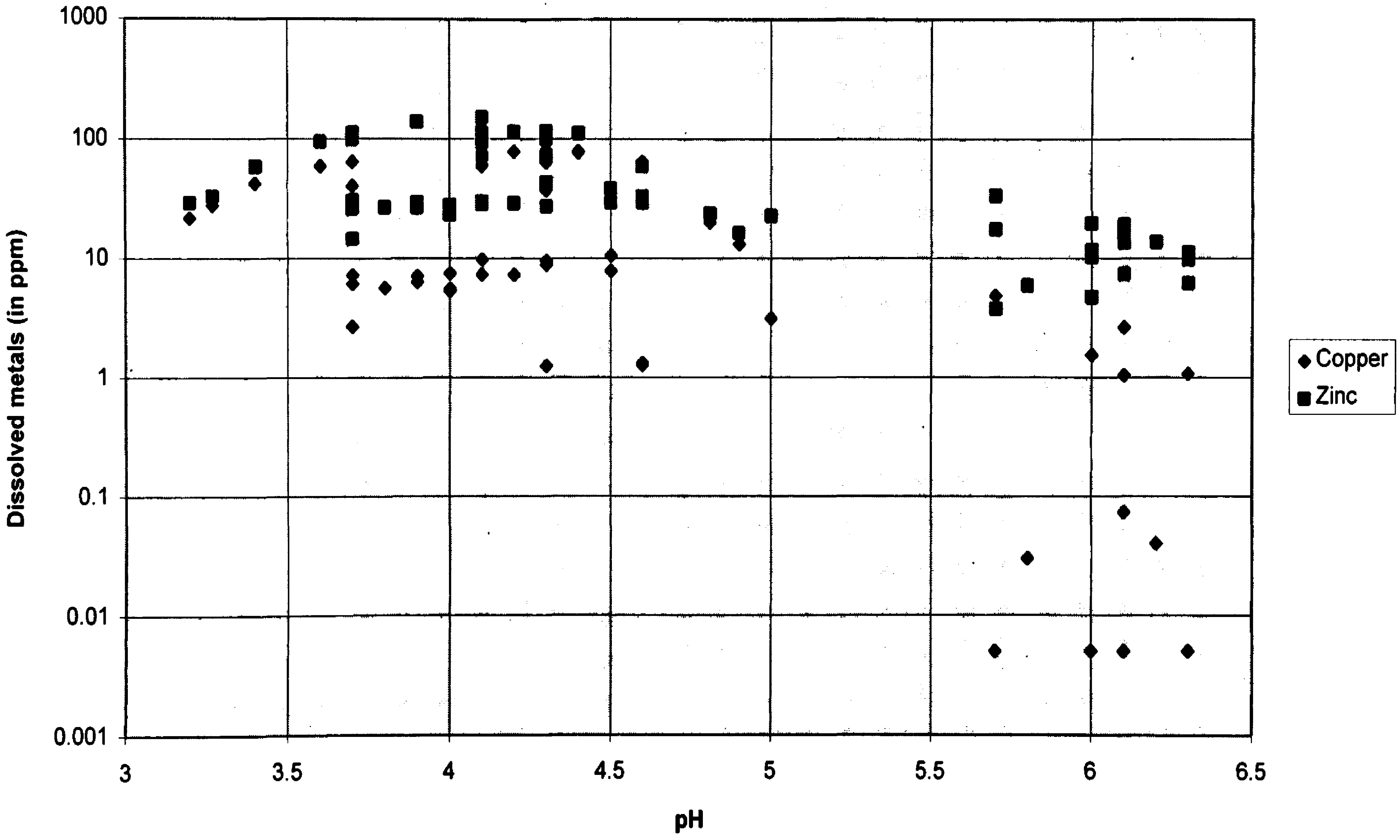


Figure 20: Groundwater pH as measured on 6/6/96.

Figure 21: Plot of pH vs. dissolved Cu and Zn for all groundwater samples taken in this study.



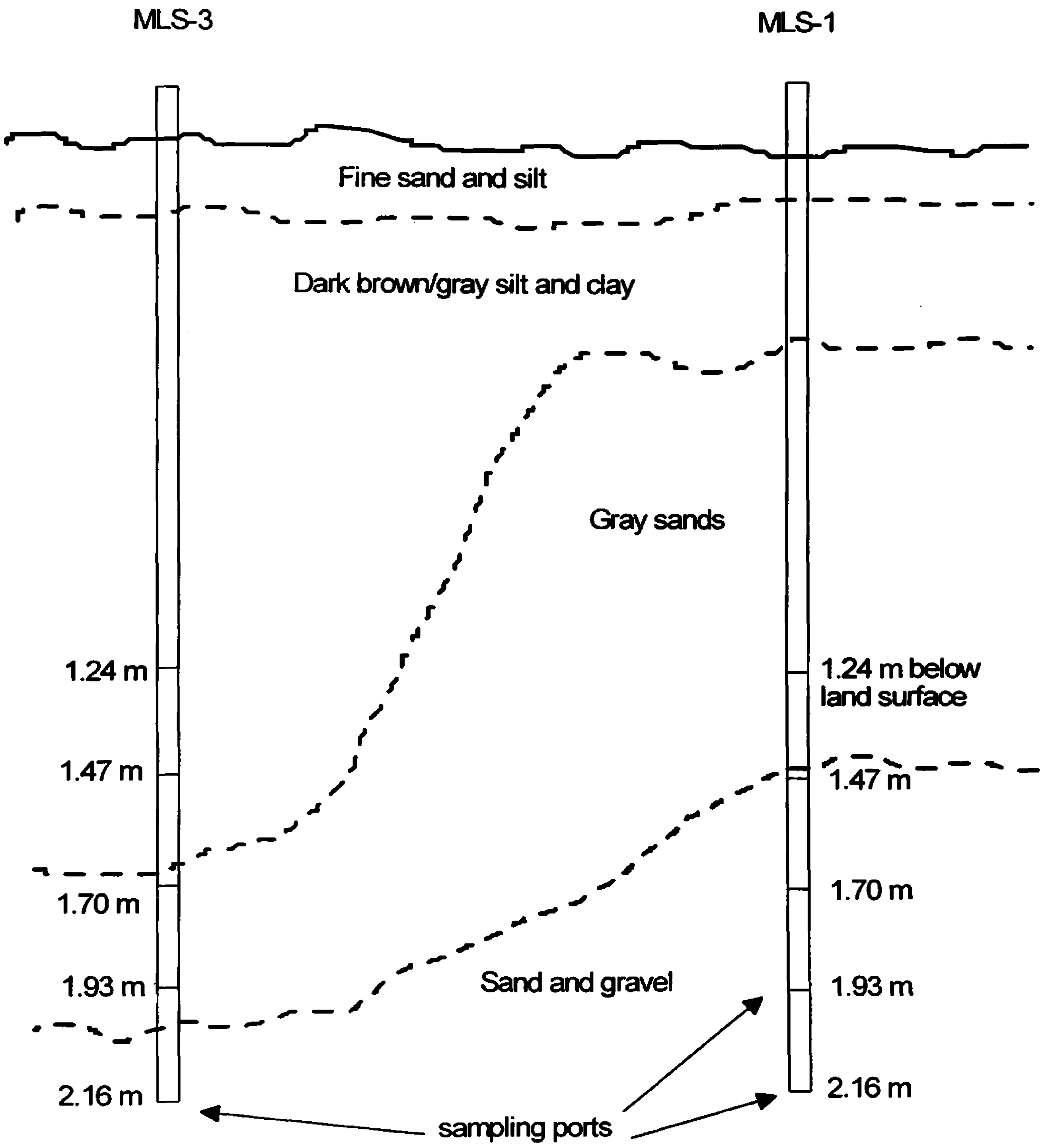


Figure 22: Schematic of multi-level samplers MLS-1 and MLS-3.

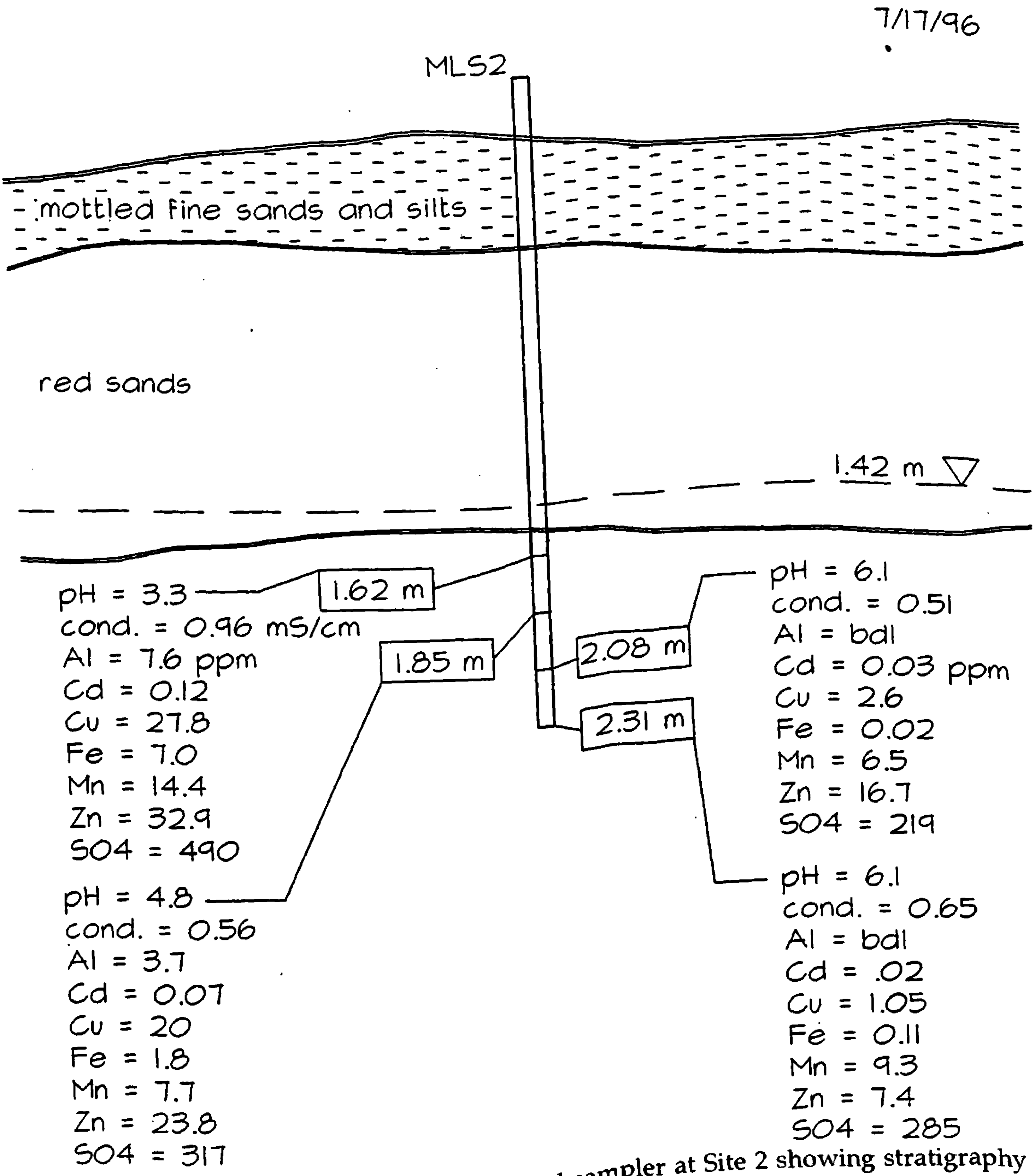


Figure 23: Diagram of the multi-level sampler at Site 2 showing stratigraphy and water quality data for 7/17/96.

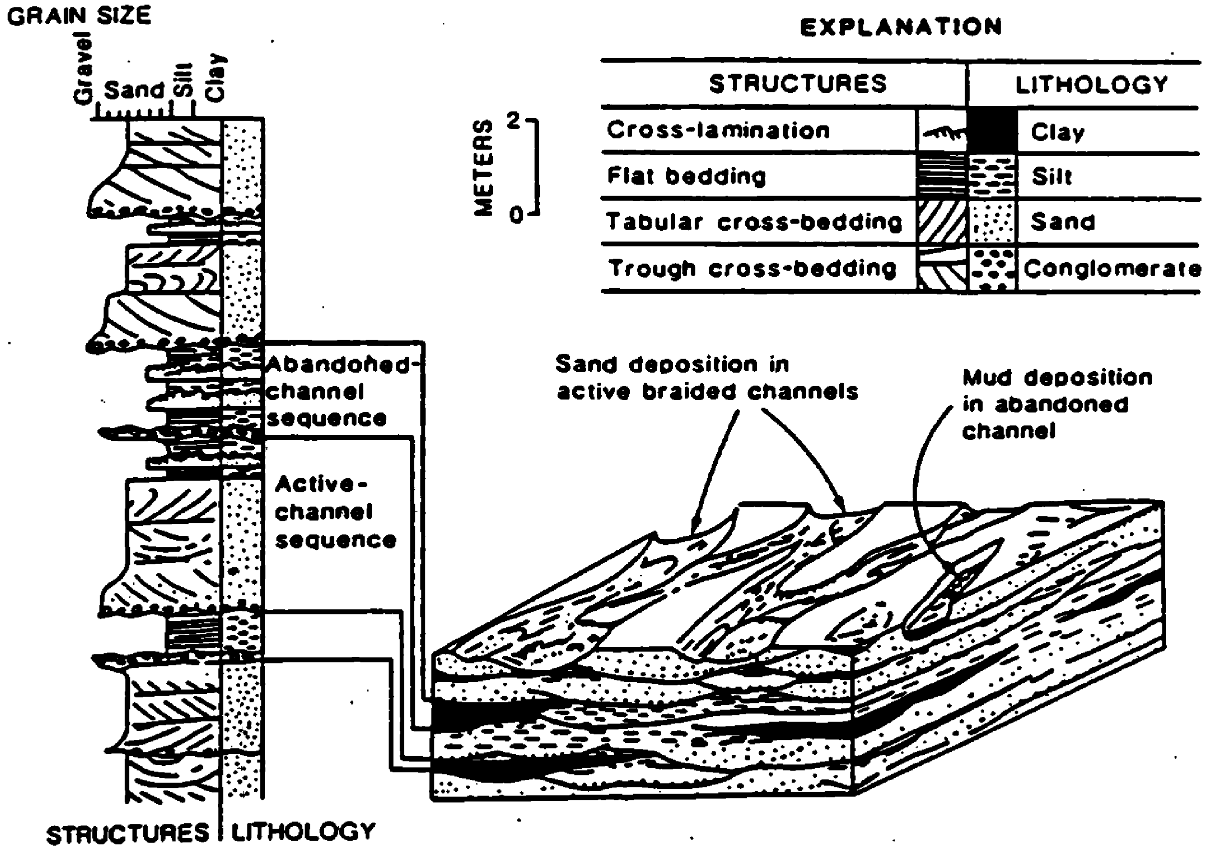


Figure 24: Fluvial facies diagram illustrating the depositional complexity associated with flooding events at Silver Bow Creek (from Rosenshein, 1988).

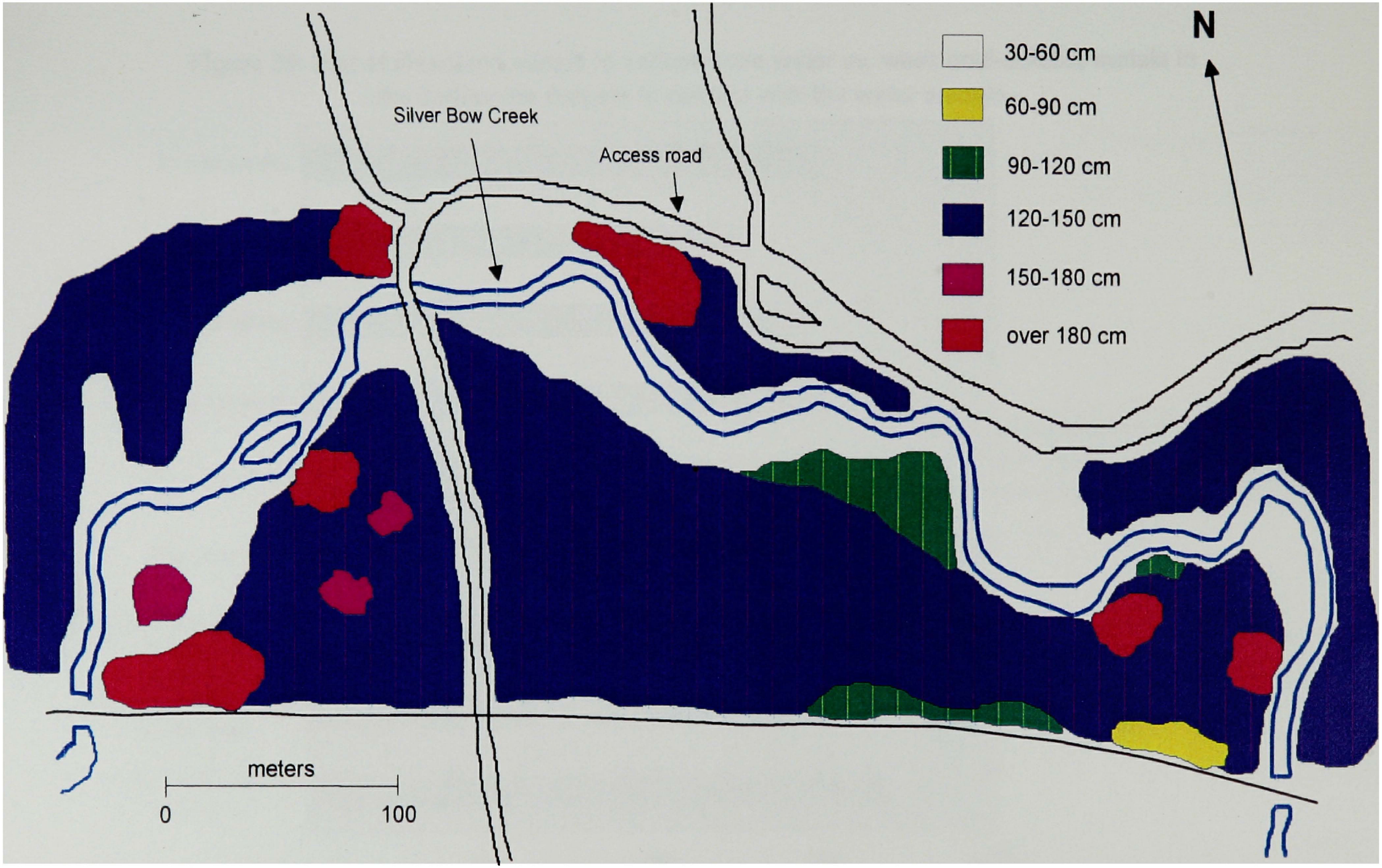
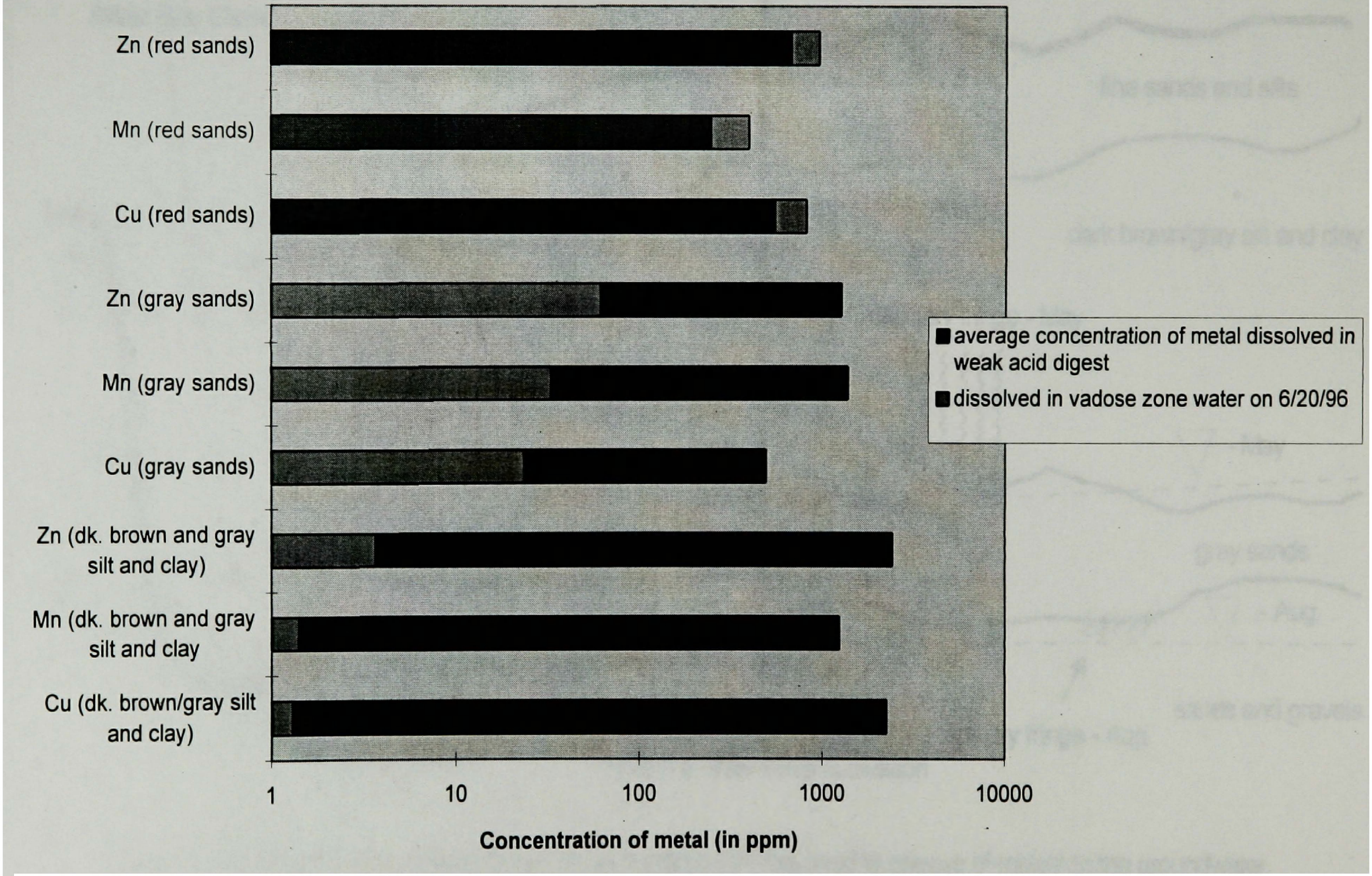


Figure 25: Site map delineating tailings/impacted sediment thickness.

Figure 26: Plot of dissolved metals in vadose zone water vs. weak acid-soluble metals in the sediments that are in contact with the water sample.



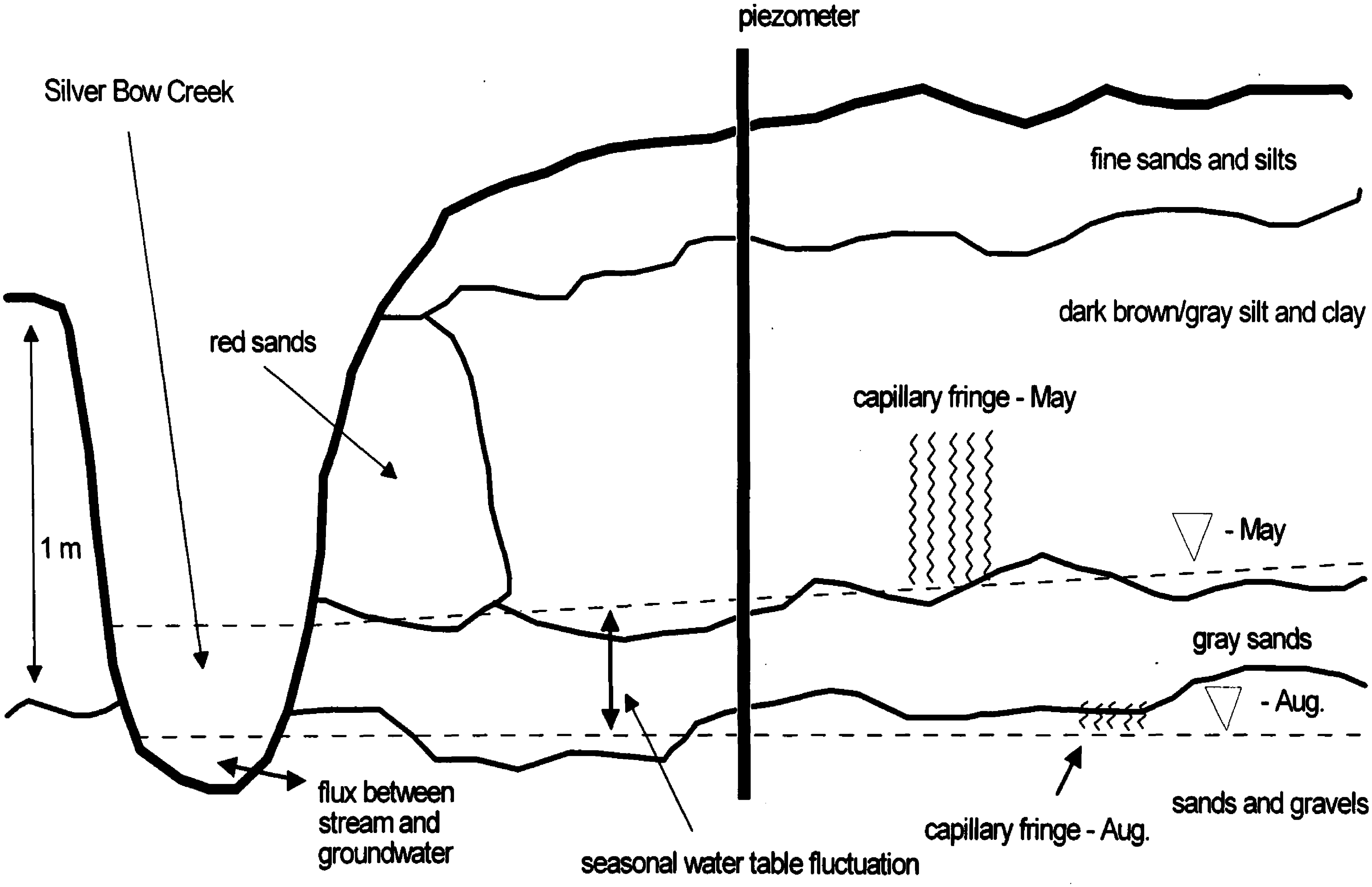


Figure 27: Schematic diagram illustrating the mechanisms that may lead to release of metals to the groundwater.

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Appendix A: Borehole Stratigraphic Logs

D-1:

0-15 cm - Silt and clay, brown, some Fe-staining, occasional layer of fine sand, tan.

15-37 cm - increasing content of fine sand, tan.

37-119 cm - Sand, fine to medium, tan and red, coarsening downwards.

D-2:

0-55 cm - Silt and clay, dark brown, moist, some organics. Occasional layer of fine sand, tan.

55-104 cm - Sand, silt and clay, dark gray, occasional small pebble.

104- 143 cm - Clay, dark gray, grading into clay and silt with some fine sand.

143-149 cm - Sand, medium, gray.

D-3:

0-37 cm - Silt with some fine sand, brown, grading into clay, brown, with some Fe-staining.

37-119 cm - Sand, fine to medium, tan and red, coarsening downwards to coarse sand, red, with small gravel. Occasional interbeds of clay and silt, 1-2 cm thick, brown and gray.

D-4:

0-30 cm - Silt and fine sand, tan.

30-165 cm - Clay, dark brown, moist.

165 cm - Fine sand, gray.

D-5:

0-158 cm - Silt with some clay, dark brown, moist. Increasing content of fine sand downwards.

158-198 cm - Sand, gray, coarsening downwards from fine to coarse.

D-6:

0-49 cm - Silt with some clay and fine sand, brown and dark gray.

49 cm - encountered railroad bed material.

D-7:

0-122 cm - Silt and fine sand, mottled orange, gray, and tan coloration.
122 cm - Coarse sand, orange.

D-8:

0-30 cm - Silt, brown and orange.
30-55 cm - Silt and clay, dark brown to black, with lots of organics.
55-91 cm - Same, but no more organics, grading into fine sand.
91-131 cm - Sand, gray, coarsening downwards to coarse sand.

D-9:

0-76 cm - Sand, orange, medium grained.
76-85 cm - Clay, gray to black, wet.
85-91 cm - Silt and sand, brown.
91-110 cm - Clay, dark gray, wet, some organics.
110 cm - Coarse sand and fine gravel, gray, with some orange staining.

D-10:

0-46 cm - Silt with some clay, mottled brown, dark brown, and orange coloration.
46-64 cm - Sand, medium, red.
64 cm - Sand, fine, gray.

D-11:

0-104 cm - Silt, brown, with some fine sand interbeds, 1-2 cm thick.
104-152 cm - Sand, gray, coarsening downwards.

D-12:

0-10 cm - Silt, mottled brown, red and gray. Organics present in form of root hairs.
10-104 cm - Silt and clay, dark gray, some sand grains present.
104-158 cm - Sand, gray, coarsening downwards, some interbeds of clay and silt, 1-2 cm thick.

D-13:

0-73 cm - Silt, mottled brown, tan, gray and orange coloration.
73-91 cm - Fine sand, silt and clay, gray.
91-116 cm - Silt and clay, dark brown to gray, organics present.

D-14:

0-30 cm - Silt, mottled brown, tan, gray and orange coloration.
30-60 cm - Clay, gray.
60-79 cm - Sand, fine to medium grained, brown.
79-116 cm - Silt and clay, dark brown to gray.
116-140 cm - Sand, gray, fine to medium grained.

D-15:

0-67 cm - Fine sand and silt, mottled brown, tan, and orange coloration.
67-100 cm - Silt and clay, gray, with some fine sand.
100-122 cm - Sand, gray, coarsening downwards.

D-16:

0-64 cm - Fine sand and silt, tan, with some orange mottling.
64-134 cm - Silt and clay, dark brown to gray.
134-168 - Fine sand, gray.

D-17:

0-40 cm - Coarse sand and fine gravel, red and tan.

D-18: No log, well driven into edge of creek.

D-19: No log, well driven into edge of creek.

D-20:

0-15 cm - Fine to medium sand, light brown.
15-46 cm - Coarse sand, red and orange.
46 cm - Silt and clay, gray, coarsening into fine sand, gray.

D-21:

0-46 cm - Silt, mottled brown, tan, orange, gray coloration.
46-107 cm - Sand, red, coarsening downwards from fine to coarse.
107 cm - Coarse sand, gray.

D-22:

0-25 cm - Silt, mottled brown, tan, orange, gray coloration.
25-128 cm - Fine sand, silt, and clay, brown, high organic content.

D-23:

0-13 cm - Silt, mottled brown, tan, orange, gray coloration.
13-76 cm - Fine sand, silt, and clay, dark brown to gray color, some organics.

D-24:

0-13 cm - Silt, mottled brown, tan, orange, gray coloration.
13-76 cm - Fine sand, silt, and clay, dark brown to gray color.
76-85 cm - Sand and gravel, brown.

D-25:

0-10 cm - Silt, brown to light brown, organics present.
10-91 cm - Silt and clay, dark brown to gray color.
91-107 cm - Fine sand, silt and clay, brown, coarsening into gravel.

D-26:

0-23 cm - Silt, mottled brown, tan, and gray coloration.
23-70 cm - Silt and clay, dark brown to gray, high organic content.
70-122 cm - Sand, fine to medium, gray.
122 cm - Sand, orange.

D-27:

0-13 cm - Silt, brown.
13-104 cm - interbedded red sands, gray clays, tan and brown silt, and tan, orange and gray sands.
104-116 cm - Sands, gray, coarsening downwards to gravel.

D-28:

0-30 cm - Fine sand, brown, with some orange discoloration.
30-82 cm - Silt and clay, dark brown, high organic content.
82-171 cm - Silt, clay, and sand, tan, coarsening downwards to sand. Gravels encountered at 171 cm. Some red grains present.

D-29:

0-30 cm - Fine sand and silt, tan, high organic content.
30-140 cm - Silt and clay, dark brown to gray, some organics, some sand layers present near 140 cm.
140-152 cm - Fine sand, red stained, grading into coarse sand and gravel.

D-30: No log, well driven into edge of creek.

D-31: No log, well driven into edge of creek.

D-32:

0-25 cm - Silt, mottled brown, tan, orange coloration, some organics.
25-79 cm - Silt and fine sand, dark brown to gray, some red coloring.

D-33:

0-10 cm - Silt and fine sand, brown and gray.
10-33 cm - Sand, red.
33-70 cm - Silt and fine sand, mottled coloration.
70-134 cm - Silt and clay, gray, with interbedded fine sands, gray, some organics. Gravel encountered at 134 cm.

D-34:

0-48 cm - Fine sands, brown, orange, tan.
48-73 cm - Silt and clay, dark brown to gray, with some fine sand.
73-122 cm - Clay, light gray, with some fine sand and silt fraction.
122-140 cm - Fine to medium sand, tan, with red staining.
140 cm - Sand, gray, with some red staining. Gravel encountered.

D-35:

0-30 cm - Fine sand and silt, brown and tan.

30-67 - Silt and clay, dark brown to gray, with some fine sand.

67-146 - Silt and clay, light gray, with some fine to coarse sand fraction.

146-149 - Medium sand, gray and orange stained. Gravel encountered at 149 cm.

D-36:

0-18 cm - Silt, mottled tan, brown, orange coloration.

18-85 cm - Silt and clay, dark brown to gray, high organic content decreasing at 46 cm.

85-101 cm - Fine to medium sand. brown, with some silt and clay. Gravel encountered at 101 cm.

D-37:

0-20 cm - Silt, mottled tan, brown, orange coloration.

20-128 cm - Silt and clay, dark brown to gray, high organic content decreasing at 40 cm.

128-131 cm - Fine sand, brown. Gravel encountered at 131 cm.

D-38:

0-33 cm - Silt and fine sand, mottled tan, brown, orange, gray coloration.

33-149 cm - Silt and clay, dark brown to gray.

149 cm - Sand, gray.

D-39:

0-15 cm - Silt, brown.

15-46 cm - Fine to medium sand, red.

46-55 cm - Silt and clay, dark brown to gray.

55-73 cm - Sand, gray, with some red staining. Gravel encountered at 73 cm.

D-40:

0-18 cm - Silt, brown.

18-36 cm - Fine to medium sand, tan and orange.

36-113 cm - Silt and clay, dark brown to gray, mixed with orange and red sand. Becoming more uniform silt and clay at 91 cm.

113-122 cm - Sand, gray, coarsening downwards. Gravel encountered at 122 cm.

D-41:

0-53 cm - Silt, mottled tan, red, brown, gray coloration.

53-101 cm - Silt and clay, dark brown to gray, mixed with some red sand.

D-42:

0-18 cm - Silt and fine sand, tan and brown.

18-49 cm - Clay, gray.

49-98 cm - Clay, light brown, mixed with some fine sand and organics.

98-134 cm - Same, but now with increasing fraction of coarse sand, grading into sand. Gravel encountered at 134 cm.

D-43:

0-60 cm - Silt, mottled brown, tan, orange, gray coloration.

60-73 cm - Silt and clay, dark brown to gray.

73-140 cm - Clay, light brown, mixing with sand downwards. Encountered gravel at 140 cm.

D-44:

0-60 cm - Silt, mottled brown, tan, and orange coloration. Lens of fine sand, tan and orange at 30 cm.

60-88 cm - Coarse sand, orange.

88-128 - Fine sand and silt, gray. Gravel encountered at 128 cm.

D-45:

0-15 cm - Silt, mottled brown, tan, red and gray coloration.
15-25 cm - Medium sand, tan and red.
25-76 cm - Sands, mixture of fine to coarse textured, red and gray.
76-128 - Sand, gray, coarsening downwards to coarse sand and fine gravel. Large gravel encountered at 128 cm.

D-46:

0-43 cm - Silt, mottled brown, tan, gray, red coloration.
43-61 cm - Silt and sand, dark brown to gray.
61-122 cm - Clay and silt, dark brown to gray, some fine sand, high organic content, some dark red staining.
122-152 cm - fine sand, gray, coarsening downwards. Gravel encountered at 152 cm.

D-47:

0-18 cm - Silt, brown.
18-67 cm - Silt and clay, dark brown to gray, high organic content.
67-91 cm - Medium sand, gray and red.
91-122 cm - Coarse sand, orange. Gravel encountered at 122 cm.

D-48:

0-41 cm - Silt, Mottled brown, tan, red, and gray.
41-152 cm - Medium sand, orange.

D-49:

0-28 cm - Silt, brown.
28-155 cm - Silt and clay, dark brown to gray.
155 cm - Gray sand encountered. Some orange staining.

D-50:

0-23 cm - Silt, mottled brown, tan, orange, gray coloration.

23-30 cm - Fine to medium sand, tan and orange.

30-46 cm - Silt and clay, gray. Upper 15 cm mixed with organics and some sand. Coarsening downwards to coarse sand at 137 cm. Gravel encountered at 140 cm.

D-51:

0-20 cm - Silt and fine sand, tan and brown. High organic content.

20-152 cm - Silt and clay, dark brown to gray.

152-183 cm - Sand, gray, coarsening to gravel at 183 cm.

D-52:

0-28 cm - Medium to coarse sand, red and orange.

28-79 cm - Sand, gray, coarsening downwards.

D-53:

0-23 cm - Silt and fine sand, brown and tan.

23-137 cm - Coarse sand, red and orange.

137-152 cm - Clay, gray, grading into coarse sand, gray. Encountered gravel at 152 cm.

D-54:

0-20 cm - Silt and fine sand, mottled tan, brown, orange coloration.

20-122 cm - Silt and clay, dark brown to gray, some areas of mixing with sands.

122-183 cm - Sand, gray, coarsening downwards, some red staining. Gravel encountered at 183 cm.

D-55:

0-41 cm - Interbedded silt and sand layers, mottled coloration.

41-122 cm - Silt and clay, dark brown to gray, some organics, some red staining.

122-131 cm - Clay, gray, coarsening into coarse sand.

D-56:

0-43 cm - Silt and fine sand, mottled tan, orange, brown, gray coloration.

43-110 cm - Medium sand, orange.

110 cm - Sand and gravel, gray.

D-57:

0-104 cm - Silt and fine sand, mottled brown and orange coloration.

104-131 cm - Fine sand, gray, coarsening downwards to coarse sand and fine gravel.

D-58:

0-91 cm - Silt and fine sand, mottled brown, tan, and orange coloration.

91-183 cm - Medium sand, tan, coarsening downwards.

183 cm - Encountered silt, gray.

D-59:

0-28 cm - Silt and fine sand, brown.

28-110 cm - Silt and fine sand, dark brown, organics present in upper 30 cm.

110-155 cm - Medium sand, brown, coarsening downwards. Gravel encountered at 155 cm.

D-60:

0-137 cm - Fine sand, silt, and clay, irregular, mottled appearance.

137-152 cm - Sand, gray. Orange discoloration coinciding with the water table at 152 cm.

D-61:

0-85 cm - Silt and fine sand, mottled coloration.

85-122 cm - Medium sand, brown and gray mixed.

122 cm - Coarse sand and gravel encountered.

D-100:

0-30 cm - Silt and fine sand, mottled coloration.
30-152 cm - Fine to medium sand, red.

D-101:

0-36 cm - Silt and fine sand, mottled coloration.
36-41 cm - Medium to coarse sand, red.
41-86 cm - Fine sand, silt, and clay, gray.
86 cm - Medium to coarse sand, gray.

D-102:

0-15 cm - Fine sand and silt, tan.
15-112 cm - Silt, clay, and fine sand, dark brown to gray.
112-152 cm - Fine sand, gray, coarsening downwards.

D-103:

0-61 cm - Silt and fine sand, mottled coloration.
61-152 cm - Fine to medium sand, red.

D-104:

0-23 cm - Silt and fine sand, brown, some organics.
23-61 cm - Silt and clay, dark brown to gray.
61-152 cm - Medium sand, gray, mixed with some clay.
152 cm - Sand and gravel.

D-105:

0-15 cm - Silt and fine sand, mottled coloration.
15-60 cm - Silt and clay, dark brown to gray.
60-137 cm - Medium sand, gray, mixed with some clay.
137 cm - Sand and gravel.

B-1:

0-28 cm - Silt and fine sand, mottled coloration.
28-91 cm - Silt and clay, dark brown to gray, with some organics.
91-177 cm - Clay, gray, with increasing fraction of sand downwards.
177-192 cm - Fine sand, silt, and clay, with some small gravel, mottled brown, orange, and tan.
192 cm - Coarse sand and gravel encountered.

B-2:

0-36 cm - Silt and fine sand, brown, orange, and tan.
36-91 cm - Fine sand, brown.
91-146 cm - Silt, gray, changing to coarse sand at 113 cm, then to fine sand at 119 cm.

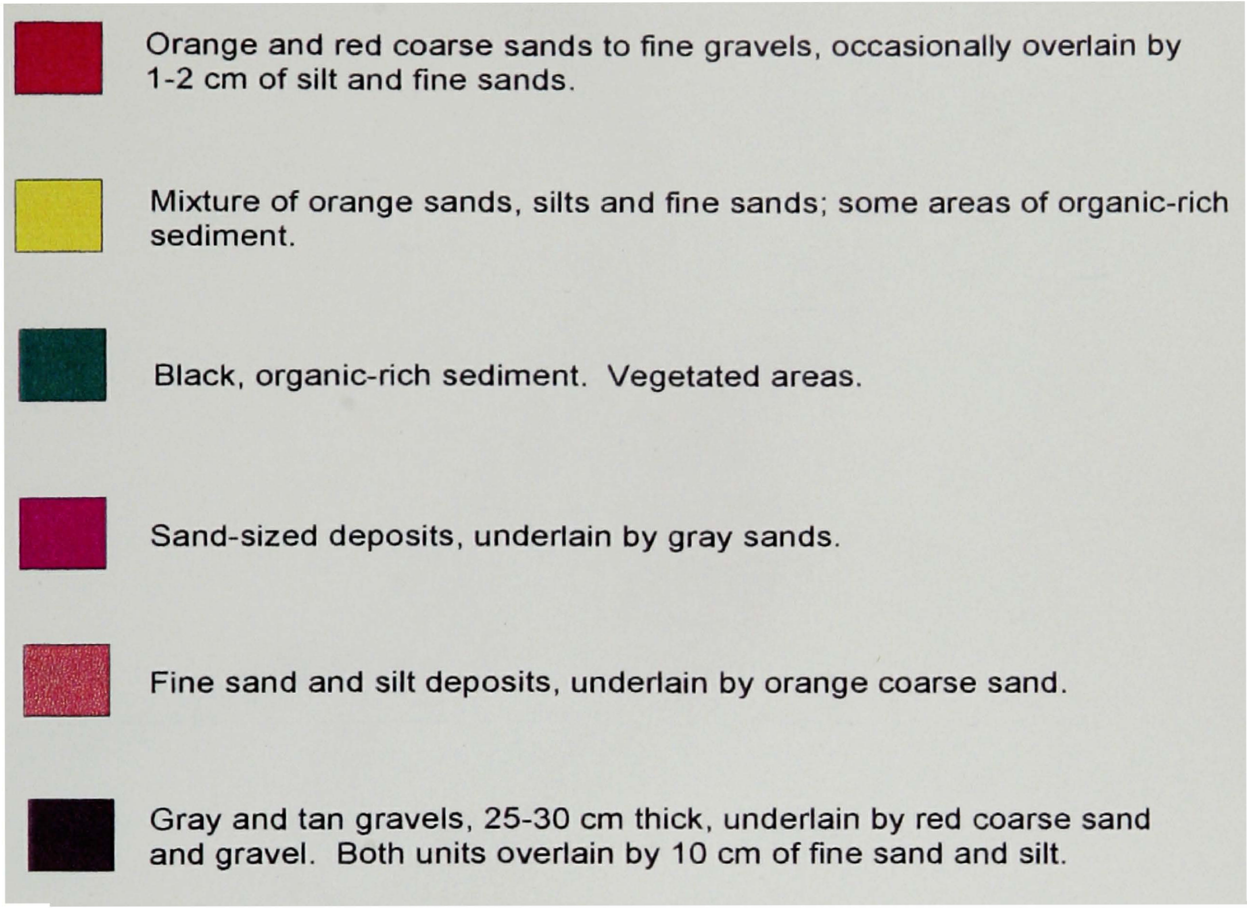
B-3:

0-25 cm - Fine sand and silt, brown and tan coloration.
25-149 cm - Silt and clay, dark brown to gray. Some fine sand and organics between 25 and 61 cm.
149-162 cm - Medium to coarse sand, gray.

Appendix B: Test Pit Data

Test pits were hand-dug with a shovel in the current channelized area of the stream to determine the nature of the deposits within this area. Over 100 pits were excavated in this area, usually 30-60 cm deep. The area between the west railroad bridge and the Miles Crossing bridge was characterized using approximately 50 pits. Approximately 50 pits were located between the Miles Crossing bridge and 200 meters upstream of the bridge. Fifteen pits were excavated at the easternmost portion of the site near the east railroad bridge. Six units were identified for mapping and are described in the key to the map.

Key to sediments mapped by test pit



🟥	Orange and red coarse sands to fine gravels, occasionally overlain by 1-2 cm of silt and fine sands.
🟨	Mixture of orange sands, silts and fine sands; some areas of organic-rich sediment.
🟩	Black, organic-rich sediment. Vegetated areas.
🟪	Sand-sized deposits, underlain by gray sands.
▨	Fine sand and silt deposits, underlain by orange coarse sand.
⬛	Gray and tan gravels, 25-30 cm thick, underlain by red coarse sand and gravel. Both units overlain by 10 cm of fine sand and silt.


N
Access road
Silver Bow Creek
meters
0
100

Appendix C: Quality Assurance/Quality Control Data

Appendix C: Quality Assurance/Quality Control Data.

Sediments (all values reported in ppm)

			Al	As	Ca
detection limit			0.03	0.06	0.055
sample		**date**			
USGS T-107		9/25/95	0.250	bdl	12.9
USGS T-107		9/25/95	0.248	bdl	12.3
BLANK		9/25/95	bdl	bdl	bdl
BLANK		9/25/95	bdl	bdl	bdl
D-21@1'	p. dup	9/25/95	3290	514	1030
D-21@1'	p. dup	9/25/95	3430	606	1050
D-100@3.4'	p. dup	9/10/96	448	195	451
D-100@3.4'	p. dup	9/10/96	436	178	522
B-1@3'	p. dup	9/10/96	2190	5.60	
B-1@3'	p. dup	9/10/96	2150	6.30	
D-57@4.3	p. dup	9/25/95	386	bdl	1210
D-57@4.3	p. dup	9/25/95	502	bdl	1530
D-23@5"	p. dup	9/25/95	1630	568	7140
D-23@5"	p. dup	9/25/95	1820	624	4890
D-20@6"	p. dup	9/25/95	1050	140	720
D-20@6"	p. dup	9/25/95	1130	149	578
D-25@3'	p. dup	9/25/95	1950	bdl	2810
D-25@3'	p. dup	9/25/95	1870	bdl	2740
D-24@2.8'	p. dup	9/25/95	1460	7.08	16200
D-24@2.8'	p. dup	9/25/95	708	16.6	9660
D-101@7"	lab dup	9/10/96	2030	595	6110
D-101@7"	lab dup	9/10/96	1880	551	6220

Appendix C, continued.

Sediments (all values reported in ppm)

	Cd	Cu	Fe	Mg	Mn	Na	Ni
detection limit	0.009	0.006	0.015	0.1	0.006	0.1	0.009
sample							
USGS T-107	0.017	0.028	0.055	2.26	0.052	23	0.027
USGS T-107	0.015	0.030	0.059	2.16	0.050	24	0.031
BLANK	bdl	bdl	bdl	bdl	bdl	bdl	bdl
BLANK	bdl	bdl	bdl	bdl	bdl	bdl	bdl
D-21@1'	18.8	3660	14400	187	922	57.5	bdl
D-21@1'	18.5	3700	16100	201	938	58.5	bdl
D-100@3.4'	bdl	128	6130	68.5	94.1		bdl
D-100@3.4'	bdl	118	6230	51.2	63.2		bdl
B-1@3'	0.630	17.0	686	4450	291		2.53
B-1@3'	0.630	17.0	652	4450	277		2.39
D-57@4.3	1.60	4.33	774	197	120	74.4	bdl
D-57@4.3	2.26	5.48	714	235	131	88.2	bdl
D-23@5"	1.67	1090	11900	152	204	64.2	bdl
D-23@5"	1.60	1220	13400	151	192	64.2	bdl
D-20@6"	bdl	120	11000	50.7	36.9	20.1	bdl
D-20@6"	bdl	124	11500	35.1	65.3	13.1	bdl
D-25@3'	bdl	9.55	618	1900	39.3	4770	bdl
D-25@3'	bdl	7.90	596	1840	38.5	4720	bdl
D-24@2.8'	bdl	16.3	606	2260	131	2450	bdl
D-24@2.8'	0.890	58.6	732	990	122	1160	1.32
D-101@7"	7.30	3140	10100	742	1180		4.02
D-101@7"	7.40	2840	10000	652	1180		3.67

Appendix C, continued.

Sediments (all values reported in ppm)

	Pb	Si	Ti	Zn
detection limit	0.075	0.05	0.006	0.006
sample				
USGS T-107	bdl	4.20	bdl	0.089
USGS T-107	bdl	4.00	bdl	0.097
BLANK	bdl	bdl	bdl	bdl
BLANK	bdl	bdl	bdl	bdl
D-21@1'	732	888	40.1	3840
D-21@1'	648	966	41.4	3900
D-100@3.4'	258	355	10.9	140
D-100@3.4'	208	491	7.28	151
B-1@3'	14.5	3450	27.1	11.4
B-1@3'	12.7	3400	24.3	11.1
D-57@4.3	7.14	323	13.8	202
D-57@4.3	6.72	406	19.9	242
D-23@5"	1120	792	27.5	441
D-23@5"	1200	816	30.9	445
D-20@6"	96.0	470	23.4	86.9
D-20@6"	79.2	606	18.0	114
D-25@3'	11.1	1840	41.5	12.5
D-25@3'	11.3	1680	39.0	11.8
D-24@2.8'	11.1	1780	22.8	116
D-24@2.8'	29.0	996	14.5	240
D-101@7"	1670	1800	56.3	1720
D-101@7"	1520	1640	52.4	1690

Appendix C, continued.

Water (all values reported in ppm)

			Al	**As**	**B**
detection limit			0.03	0.06	0.075
sample		**date**			
USGS T-121		9/10/96	bdl	bdl	0.096
USGS T-121		9/10/96	bdl	bdl	0.100
USGS T-121		9/10/96	bdl	bdl	0.099
USGS T-121		9/10/96	bdl	bdl	0.096
DI BLANK		6/6/96	bdl	bdl	bdl
DI BLANK		6/20/96	bdl	bdl	bdl
MLS1-5C	lab dup.	7/17/96	5.04	bdl	bdl
MLS1-5C	lab dup.	7/17/96	4.90	bdl	bdl
MLS2-5C	lab dup.	8/7/96	bdl	bdl	0.079
MLS2-5C	lab dup.	8/7/96	bdl	bdl	0.087
P-10	lab dup.	6/6/96	0.061	bdl	bdl
P-10	lab dup.	6/6/96	bdl	bdl	bdl
MLS3-5C	lab dup.	8/7/96	23.6	bdl	0.109
MLS3-5C	lab dup.	8/7/96	23.9	bdl	0.112
D-4	lab dup.	7/17/96	29.0	bdl	0.114
D-4	lab dup.	7/17/96	27.7	bdl	0.107
P-25	field dup.	6/6/96	8.71	bdl	0.082
P-25	field dup.	6/6/96	9.09	bdl	0.085
D-26	field dup.	6/20/96	6.22	bdl	bdl
D-26	field dup.	6/20/96	6.22	bdl	bdl
D-4	field dup.	6/20/96	24.8	0.062	0.094
D-4	field dup.	6/20/96	24.4	bdl	0.092
D-4	field dup.	7/17/96	29.0	bdl	0.114
D-4	field dup.	7/17/96	27.9	bdl	0.108
MLS3-5C	field dup.	8/7/96	23.9	bdl	0.112
MLS3-5C	field dup.	8/7/96	23.9	bdl	0.108

Appendix C, continued.

Water (all values reported in ppm)

	Ca	Cd	Cr	Cu	Fe	K	Mg
detection limit	0.055	0.009	0.009	0.006	0.015	0.3	0.1
sample							
USGS T-121	5.66	bdl	0.018	bdl	0.164	0.340	1.31
USGS T-121	5.77	bdl	0.020	bdl	0.161	0.660	1.31
USGS T-121	6.18	bdl	0.019	bdl	0.170	0.450	1.29
USGS T-121	5.90	bdl	0.018	bdl	0.163	0.510	1.31
DI BLANK	0.400	bdl	bdl	0.007	bdl	bdl	bdl
DI BLANK	0.103	bdl	bdl	0.010	bdl	0.445	bdl
MLS1-5C	148	0.199	bdl	8.10	8.51	10.3	32.2
MLS1-5C	156	0.208	bdl	7.82	8.60	9.79	31.8
MLS2-5C	54.9	0.015	bdl	1.13	0.025	8.09	12.0
MLS2-5C	56.2	0.015	bdl	1.08	0.039	8.13	11.6
P-10	194	bdl	bdl	bdl	13.7	8.99	43.5
P-10	187	bdl	bdl	bdl	13.3	8.28	42.5
MLS3-5C	230	0.425	bdl	76.0	19.8	8.23	58.1
MLS3-5C	230	0.421	bdl	76.8	19.8	8.12	58.3
D-4	254	0.395	bdl	67.2	29.6	8.75	65.2
D-4	256	0.394	bdl	63.8	29.4	7.86	62.6
P-25	135	0.145	bdl	5.35	0.290	5.30	29.2
P-25	140	0.152	bdl	5.54	0.100	5.63	30.2
D-26	116	0.166	bdl	6.12	0.490	7.24	21.5
D-26	117	0.166	bdl	6.15	0.470	6.86	21.5
D-4	225	0.362	bdl	60.8	27.2	7.40	57.9
D-4	220	0.351	bdl	59.1	26.9	7.19	56.5
D-4	254	0.395	bdl	67.2	29.6	8.75	65.2
D-4	237	0.367	bdl	65.2	27.8	8.20	63.0
MLS3-5C	230	0.421	bdl	76.8	19.8	8.12	58.3
MLS3-5C	238	0.435	bdl	75.9	20.3	8.05	57.9

Appendix C, continued.

Water (all values reported in ppm)

	Mn	Mo	Na	Ni	Pb	Si	Sr
detection limit	0.006	0.009	0.1	0.009	0.075	0.05	0.01
sample							
USGS T-121	0.031	0.010	0.096	bdl	bdl	2.44	0.046
USGS T-121	0.032	0.010	0.100	bdl	bdl	2.44	0.045
USGS T-121	0.033	0.010	0.099	bdl	bdl	2.38	0.048
USGS T-121	0.031	0.010	0.096	bdl	bdl	2.39	0.045
DI BLANK	0.010	bdl	bdl	bdl	bdl	0.134	bdl
DI BLANK	0.009	bdl	bdl	bdl	bdl	0.158	
MLS1-5C	16.6	bdl	46.2	0.071	bdl	39.9	0.958
MLS1-5C	16.9	bdl	45.1	0.076	bdl	39.5	1.00
MLS2-5C	6.41	bdl	29.4	bdl	bdl	17.9	0.346
MLS2-5C	6.38	bdl	30.2	bdl	bdl	17.6	0.348
P-10	25.1	bdl	141	0.037	bdl	28.8	1.08
P-10	24.5	bdl	109	0.041	bdl	27.7	1.06
MLS3-5C	56.4	bdl	92.5	0.130	bdl	50.2	1.20
MLS3-5C	56.9	bdl	89.6	0.130	bdl	50.2	1.20
D-4	61.5	bdl	91.7	0.130	0.081	48.1	1.28
D-4	60.3	bdl	84.7	0.130	0.077	47.0	1.29
P-25	13.3	bdl	42.0	0.059	bdl	30.2	0.710
P-25	13.9	bdl	44.5	0.061	bdl	30.0	0.740
D-26	11.0	bdl	39.7	0.048	bdl	39.3	0.733
D-26	11.0	bdl	37.5	0.046	bdl	39.3	0.739
D-4	55.2	bdl	81.9	0.120	bdl	44.9	1.14
D-4	53.8	bdl	79.3	0.116	bdl	43.8	1.12
D-4	61.5	bdl	91.7	0.127	0.081	48.1	1.19
D-4	58.1	bdl	86.7	0.117	0.087	45.9	1.29
MLS3-5C	56.9	bdl	89.6	0.127	bdl	50.2	1.20
MLS3-5C	57.8	bdl	92.5	0.134	bdl	50.7	1.25

Appendix C, continued.

Water (all values reported in ppm)

	Zn
detection limit	0.006
sample	
USGS T-121	0.016
USGS T-121	0.016
USGS T-121	0.018
USGS T-121	0.018
DI BLANK	0.026
DI BLANK	0.025
MLS1-5C	37.6
MLS1-5C	38.3
MLS2-5C	6.31
MLS2-5C	6.21
P-10	4.03
P-10	3.79
MLS3-5C	112
MLS3-5C	111
D-4	105
D-4	104
P-25	23.2
P-25	24.1
D-26	26.0
D-26	26.2
D-4	96.0
D-4	93.5
D-4	100
D-4	104
MLS3-5C	111
MLS3-5C	113

Appendix C, continued.							
Spike Analysis Data							
Sample Name	MLS1-5C 7/17/96			ANALYSIS DATE:			EXPECTED
% dilution	80.0			SPIKE DATE:			READING
	READING BEFORE SPIKE ADDITION (mg/L)	READING AFTER SPIKE ADDITION (mg/L)	SPIKE ADDITION (mg/L)	SAMPLE ANLY IN SPIKED SAMPLE	EXPECTED READING (mg/L)	% THAT SPIKE IS OF SAMPLE ANALYTE	SPIKE % RECOVER
Al3082	5.04	5.15	1	4.032	5.032	24.8	102.34
As1890	0.031	0.628	0.5	0.025	0.525	2016.1	119.66
B_2497	0.0671	0.0955	0	0.054	0.054		177.91
Ca3158	148.4	173	50	118.720	168.720	42.1	102.54
Cd2265	0.1986	0.1565	0	0.159	0.159		98.50
Co2286	0.0759	0.062	0	0.061	0.061		102.11
Cr2677	-0.0089	-0.0113	0	-0.007	-0.007		158.71
Cu3247	8.097	8.633	2	6.478	8.478	30.9	101.83
Fe2399	8.512	29.5	20.5	6.810	27.310	301.0	108.02
K_7664	10.26	19.16	10	8.208	18.208	121.8	105.23
Mg2936	32.21	36.56	10	25.768	35.768	38.8	102.21
Mn2605	16.57	24.24	11	13.256	24.256	83.0	99.93
Mo2020	-0.0329	0.4779	0.5	-0.026	0.474	-1899.7	100.89
Na5895	46.17	89.2	50	36.936	86.936	135.4	102.60
Ni2316	0.0709	0.0522	0	0.057	0.057		92.03
P_1782	-0.1231	2.756	2.5	-0.098	2.402	-2538.6	114.76
Pb2203	0.0302	0.5991	0.5	0.024	0.524	2069.5	114.30
S_1820	238.9	194.6	0	191.120	191.120		101.82
Se1960	0.0316	0.0214	0	0.025	0.025		84.65
Si2124	39.94	55.1	20	31.952	51.952	62.6	106.06
Sr3464	0.9579	1.863	0	0.766	0.766		243.11
Ti3361	-0.0082	-0.0112	0	-0.007	-0.007		170.73
Zn2138	37.64	35.83	6	30.112	36.112	19.9	99.22

Appendix C, continued.

Spike Analysis Data

Sample Name	MLS2-5C 8/7/96			ANALYSIS DATE:			EXPECTED
% dilution	80.0			SPIKE DATE:			READING
	READING BEFORE SPIKE ADDITION (mg/L)	READING AFTER SPIKE ADDITION (mg/L)	SPIKE ADDITION (mg/L)	SAMPLE ANLY IN SPIKED SAMPLE	EXPECTED READING (mg/L)	% THAT SPIKE IS OF SAMPLE ANALYTE	SPIKE % RECOVER
Al3082	0.013	1.13	1	0.010	1.010	9615.4	111.84
As1890	0.022	0.591	0.5	0.018	0.518	2840.9	114.18
B_2497	0.0785	0.1018	0	0.063	0.063		162.10
Ca3158	54.94	99.71	50	43.952	93.952	113.8	106.13
Cd2265	0.0146	0.0123	0	0.012	0.012		105.31
Co2286	0.0045	0.0046	0	0.004	0.004		127.78
Cr2677	-0.0052	-0.0032	0	-0.004	-0.004		76.92
Cu3247	1.127	2.962	2	0.902	2.902	221.8	102.08
Fe2399	0.0247	22.99	20.5	0.020	20.520	103744.9	112.04
K_7664	8.089	17.29	10	6.471	16.471	154.5	104.97
Mg2936	11.99	19.61	10	9.592	19.592	104.3	100.09
Mn2605	6.406	16.36	11	5.125	16.125	214.6	101.46
Mo2020	-0.0055	0.5026	0.5	-0.004	0.496	-11363.6	101.41
Na5895	29.42	74.48	50	23.536	73.536	212.4	101.28
Ni2316	0.0026	-0.0058	0	0.002	0.002		-278.85
P_1782	-0.0187	2.752	2.5	-0.015	2.485	-16711.2	110.74
Pb2203	0.0265	0.5949	0.5	0.021	0.521	2358.5	114.14
S_1820	54.47	42.53	0	43.576	43.576		97.60
Se1960	-0.0024	0.0031	0	-0.002	-0.002		-161.46
Si2124	17.85	36.66	20	14.280	34.280	140.1	106.94
Sr3464	0.3456	1.37	1	0.276	1.276	361.7	107.33
Ti3361	-0.0028	-0.0064	0	-0.002	-0.002		285.71
Zn2138	6.314	11.41	6	5.051	11.051	118.8	103.25

Appendix C, continued.

Spike Analysis Data

Sample Name	P-10 6/6/96			ANALYSIS DATE:			EXPECTED
% dilution	80.0			SPIKE DATE:			READING
	READING BEFORE SPIKE ADDITION (mg/L)	READING AFTER SPIKE ADDITION (mg/L)	SPIKE ADDITION (mg/L)	SAMPLE ANLY IN SPIKED SAMPLE	EXPECTED READING (mg/L)	% THAT SPIKE IS OF SAMPLE ANALYTE	SPIKE % RECOVER
Al3082	0.061	1.19	1	0.049	1.049	2049.2	113.46
As1890	0.036	0.618	0.5	0.029	0.529	1736.1	116.87
B_2497	0.0604	0.0905	0	0.048	0.048		187.29
Ca3158	193.7	209.7	50	154.960	204.960	32.3	102.31
Cd2265	-0.0005	0.0005	0	0.000	0.000		-125.00
Co2286	0.0472	0.0386	0	0.038	0.038		102.22
Cr2677	0.0082	0.0002	0	0.007	0.007		3.05
Cu3247	0.0003	2.123	2	0.000	2.000	833333.3	106.14
Fe2399	13.69	33.46	20.5	10.952	31.452	187.2	106.38
K_7664	8.985	18.47	10	7.188	17.188	139.1	107.46
Mg2936	43.48	46.76	10	34.784	44.784	28.7	104.41
Mn2605	25.09	31.04	11	20.072	31.072	54.8	99.90
Mo2020	-0.0098	0.4974	0.5	-0.008	0.492	-6377.6	101.06
Na5895	140.5	181.1	50	112.400	162.400	44.5	111.51
Ni2316	0.0366	0.0289	0	0.029	0.029		98.70
P_1782	0.043	2.845	2.5	0.034	2.534	7267.4	112.26
Pb2203	0.0254	0.5934	0.5	0.020	0.520	2460.6	114.05
S_1820	321.4	266.6	0	257.120	257.120		103.69
Se1960	0.0084	0.0228	0	0.007	0.007		339.29
Si2124	28.8	46.41	20	23.040	43.040	86.8	107.83
Sr3464	1.078	1.95	1	0.862	1.862	116.0	104.70
Ti3361	-0.0129	-0.0168	0	-0.010	-0.010		162.79
Zn2138	4.027	9.848	6	3.222	9.222	186.2	106.79

Appendix C, continued.

Spike Analysis Data

Sample Name	J-20			ANALYSIS DATE:			EXPECTED
% dilution	80.0			SPIKE DATE:			READING
	READING BEFORE SPIKE ADDITION (mg/L)	READING AFTER SPIKE ADDITION (mg/L)	SPIKE ADDITION (mg/L)	SAMPLE ANLY IN SPIKED SAMPLE	EXPECTED READING (mg/L)	% THAT SPIKE IS OF SAMPLE ANALYTE	SPIKE % RECOVER
Al3082	33.8	28	1	27.040	28.040	3.7	99.86
As1890	9.92	8.48	0.5	7.936	8.436	6.3	100.52
B_2497	0.0575	0.089	0	0.046	0.046		193.48
Ca3158	101.8	136.3	50	81.440	131.440	61.4	103.70
Cd2265	0.1216	0.0979	0	0.097	0.097		100.64
Co2286	0.0367	0.0305	0	0.029	0.029		103.88
Cr2677	-0.0768	-0.0609	0	-0.061	-0.061		99.12
Cu3247	52.26	43.22	2	41.808	43.808	4.8	98.66
Fe2399	169	156.6	20.5	135.200	155.700	15.2	100.58
K_7664	16.93	23.98	10	13.544	23.544	73.8	101.85
Mg2936	12.37	20.16	10	9.896	19.896	101.1	101.33
Mn2605	19.7	26.05	11	15.760	26.760	69.8	97.35
Mo2020	0.0299	0.5204	0.5	0.024	0.524	2090.3	99.33
Na5895	5.591	55.5	50	4.473	54.473	1117.9	101.89
Ni2316	0.0672	0.0491	0	0.054	0.054		91.33
P_1782	16.17	15.62	2.5	12.936	15.436	19.3	101.19
Pb2203	24.87	20.36	0.5	19.896	20.396	2.5	99.82
S_1820	80.29	63.65	0	64.232	64.232		99.09
Se1960	0.0597	0.0475	0	0.048	0.048		99.46
Si2124	29.91	45.78	20	23.928	43.928	83.6	104.22
Sr3464	0.8876	1.772	1	0.710	1.710	140.8	103.62
Ti3361	0.9379	0.7427	0	0.750	0.750		98.98
Zn2138	28.73	29.08	6	22.984	28.984	26.1	100.33

Appendix C, continued.

Spike Analysis Data

Sample Name	AL-85C 7/17/96			ANALYSIS DATE:			EXPECTED
% dilution	80.0			SPIKE DATE:			READING
	READING BEFORE SPIKE ADDITION (mg/L)	READING AFTER SPIKE ADDITION (mg/L)	SPIKE ADDITION (mg/L)	SAMPLE ANLY IN SPIKED SAMPLE	EXPECTED READING (mg/L)	% THAT SPIKE IS OF SAMPLE ANALYTE	SPIKE % RECOVER
Al3082	134	105	1	107.200	108.200	0.9	97.04
As1890	0.055	0.621	0.5	0.044	0.544	1136.4	114.15
B_2497	0.0097	0.0473	0	0.008	0.008		609.54
Ca3158	104.4	137	50	83.520	133.520	59.9	102.61
Cd2265	0.9428	0.7267	0	0.754	0.754		96.35
Co2286	0.1391	0.1082	0	0.111	0.111		97.23
Cr2677	0.0048	0.0069	0	0.004	0.004		179.69
Cu3247	190.9	154.4	2	152.720	154.720	1.3	99.79
Fe2399	22.49	39.59	20.5	17.992	38.492	113.9	102.85
K_7664	0.1496	10.64	10	0.120	10.120	8355.6	105.14
Mg2936	26.93	30.75	10	21.544	31.544	46.4	97.48
Mn2605	104.1	76.44	11	83.280	94.280	13.2	81.08
Mo2020	-0.1577	0.3625	0.5	-0.126	0.374	-396.3	96.97
Na5895	6.761	55.31	50	5.409	55.409	924.4	99.82
Ni2316	-0.0978	-0.0952	0	-0.078	-0.078		121.68
P_1782	-0.4322	2.409	2.5	-0.346	2.154	-723.0	111.83
Pb2203	0.1147	0.6521	0.5	0.092	0.592	544.9	110.20
S_1820	694.7	543.3	0	555.760	555.760		97.76
Se1960	-0.0569	-0.0072	0	-0.046	-0.046		15.82
Si2124	18.52	37.18	20	14.816	34.816	135.0	106.79
Sr3464	0.1053	1.156	1	0.084	1.084	1187.1	106.62
Ti3361	-0.0096	-0.0107	0	-0.008	-0.008		139.32
Zn2138	215.3	183.7	6	172.240	178.240	3.5	103.06

Appendix D: Grain Size Analysis Data

Appendix D: Grain Size Analysis Data

Red Sand - D-48@61 cm

Sieve Size (mm)	Cumulative Weight Retained (g)	Cumulative % Retained
1.00	6.26	5.84
0.71	12.50	11.66
0.25	65.46	61.05
0.177	83.41	77.79
0.125	96.54	90.04
pan	106.50	99.33

Gray Sand - D-40@122 cm

Sieve Size (mm)	Cumulative Weight Retained (g)	Cumulative % Retained
2.80	8.51	7.95
1.981	19.42	18.13
1.00	50.19	46.86
0.71	52.08	48.62
0.25	96.42	90.02
0.177	103.19	96.34
0.125	104.93	97.96
pan	106.75	99.66

Coarse Red Sand - D-100@152 cm

Sieve Size (mm)	Cumulative Weight Retained (g)	Cumulative % Retained
1.981	33.81	28.87
1.00	75.70	64.63
0.71	93.13	79.52
0.25	113.04	96.52
0.177	115	98.19
0.125	115.95	99.00
pan	116.94	99.85

Fine Sand and Silt - D-40@55 cm

Sieve Size (mm)	Cumulative Weight Retained (g)	Cumulative % Retained
0.71	0.13	0.002
0.25	3.49	6.13
0.177	7.32	12.86
0.125	17.89	31.43
0.088	36.15	63.51
0.0625	44.00	77.30
pan	56.00	98.38

Appendix E: Summary of Weak Acid Digest Results

Appendix E: Summary of data from weak acid digest procedure.

Description of Materials		**Metals concentration, in ppm**					
		Al	As	Cd	Cu	Fe	Mg
detection limit		0.03	0.06	0.009	0.006	0.015	0.1
fine sands, silts; brown, tan, orange mottled							
D-15@ 1'		600	119	1.36	554	4080	193
D-23@ 5"		1630	624	1.59	1220	13400	151
D-25@ 2"		1710	726	2.89	3600	11700	272
D-21@ 1'		3290	514	18.8	3660	14400	187
D-21@ 1'	duplicate	3430	606	18.5	3700	16100	201
B-3@ 5"		1280	319	3.67	1630	8640	396
D-102@3"		1150	1410	3.59	2410	11200	988
D-101@7"		1880	551	7.37	2840	10000	652
D-100@6"		3470	520	6.09	2200	14600	407
B-1@ 5"		1640	624	3.34	2150	10400	370
Range	high	3470	1410	18.8	3700	16100	988
	low	600	119	1.36	554	4080	151
Average		2000	601	6.72	2400	11500	382
red / orange sands							
D-48@ 2'		606	219	2.35	429	7020	99.0
D-21@2.4'		278	222	3.04	380	5880	47.0
D-100@3.	duplicate	448	195	< 0.54	128	6130	68.5
D-100@3.4'		436	178	< 0.54	118	6230	51.2
D-100@1.8'		792	152	1.19	598	6680	107
D-100@5'		666	63.0	< 0.54	154	4630	32.6
D-101@15"		518	19.3	1.52	221	7470	238
D-20@ 6"		1130	149	< 0.54	124	11500	35.1
Range	high	1130	222	3.04	598	11500	238
	low	278	19.3	< 0.54	118	4630	35.1
Average		609	150	1.01	269	6940.00	84.8

Appendix E, continued.

Description of Materials		Metals concentration, in ppm					
		Al	As	Cd	Cu	Fe	Mg
detection limit		0.03	0.06	0.009	0.006	0.015	0.1
grey sands, silts and clays							
D-2@ 4.8'		328	< 4.2	< 0.6	19.0	373	209
D-57@4.3'		386	< 4.2	2.26	5.48	714	235
D-57@3.4'		1160	< 4.2	< 0.6	8.34	6120	424
D-20@1.6'		1640	< 4.2	1.32	2730	530	96.0
D-101@32"		1480	5.10	4.28	773	1040	637
D-101@1.7'		1770	4.90	6.10	1160	689	818
D-101@3.4'		319	< 3.6	0.680	35.4	1050	95.7
D-102@4.7'		2190	< 3.6	< 0.54	45.1	1620	651
B-2@3'		1760	169	18.5	1790	8270	448
B-1@3'		2190	5.60	0.630	17.0	686	4450
B-1@3'	duplicate	2150	6.30	0.630	17.0	652	4450
B-1@3.9'		1520	< 3.6	< 0.54	6.70	924	1070
B-3@5.2'		397	< 3.6	< 0.54	1.07	763	255
B-2@4.2'		1270	54.8	0.970	26.0	4080	582
Range	high	2190	169	2.26	2730	8270	4450
	low	319	< 3.6	< 0.54	1.07	373	95.7
Average		1330.00	17.6	2.53	474	1970	1030
dark brown / grey silt and clay							
D-16@2.1'		1250	< 4.2	< 0.6	12.3	870	1470
D-12@1'		1390	4.32	25.8	5430	779	1030
D-13@3.4'		1600	7.80	< 0.6	44.4	2560	924
D-38@1.8'		2270	5.04	40.9	2890	870	3000
D-22@ 1'		1750	1760	29.9	14200	9540	1780
D-23@1.5'		2110	8.52	0.792	96.5	1570	4620
D-25@ 6"		2540	25.3	1.88	151	660	3230
D-59@15"		2540	13.1	52.0	3430	810	1280
B-3@2.4'		2810	11.1	1.12	27.5	1130	6400
B-3@1.2'		1970	72.6	28.5	2110	1660	1200
B-3@4'		1850	< 3.6	0.560	11.3	973	1660
B-1@1.75'		1940	54.1	18.9	305	1610	1300
D-102@10"		1360	81.0	4.80	2920	1450	1060
D-102@2.8'		1940	4.50	1.57	63.8	1040	2480
Range	high	2810	1760	52.0	14200	9540	6400
	low	1250	< 3.6	< 0.6	11.3	660	924
Average		1950	147	14.8	2260	1820	2250

Appendix E, continued.

Description of Materials

		Mn	Pb	Ti	Zn
detection limit		0.006	0.075	0.006	0.006
fine sands, silts; brown, tan, orange mottled					
D-15@ 1'		366	212		366
D-23@ 5"		192	1200	27.5	445
D-25@ 2"		560	1320	37.3	1010
D-21@ 1'		922	732	40.1	3840
D-21@ 1'	duplicate	938	648	41.4	3900
B-3@ 5"		595	729	29.4	871
D-102@3"		598	2300	38.9	763
D-101@7"		1180	1520	52.4	1690
D-100@6"		767	1350	52.2	1250
B-1@ 5"		429	854	39.8	702
Range	high	1180	2300	52.4	3900
	low	192	212	27.5	366
Average		655	1100	39.9	1480.00
red / orange sands					
D-48@ 2'		259	292		447
D-21@2.4'		150	159		575
D-100@3.	duplicate	94.1	258	10.9	140
D-100@3.4'		63.2	208	7.28	151
D-100@1.8'		239	283	17.4	323
D-100@5'		88.8	151	5.23	86.6
D-101@15"		267	21.2	21.2	433
D-20@ 6"		65.3	79.2	23.4	113
Range	high	267	292	23.4	575
	low	63.2	21.2	5.23	86.6
Average		153	181	14.2	284

Appendix E, continued.

Description of Materials

		Mn	Pb	Ti	Zn
detection limit		0.006	0.075	0.006	0.006
grey sands, silts and clays					
D-2@ 4.8'		79.7	< 6		108
D-57@4.3'		131	6.72	13.8	242
D-57@3.4'		168	9.78	65.6	1060
D-20@1.6'		63.9	14.8	84.0	414
D-101@32"		734	7.60	62.5	1160
D-101@1.7'		1160	9.45	109	1660
D-101@3.4'		70.3	< 4.5	10.5	121
D-102@4.7'		212	10.4	68.1	416
B-2@3'		14400	12000	45.0	10400
B-1@3'		291	14.5	27.1	11.4
B-1@3'	duplicate	277	12.7	24.3	11.1
B-1@3.9'		172	6.50	29.1	5.40
B-3@5.2'		46.8	5.10	9.54	147
B-2@4.2'		1090	225	54.4	1200
Range	high	14400	12000	109	10400
	low	46.8	< 4.5	9.54	5.40
Average		1350	1030	46.4	1210
dark brown / grey silt and clay					
D-16@2.1'		179	7.32		11.4
D-12@1'		643	8.88		1590
D-13@3.4'		445.9	21.0		533
D-38@1.8'		1070	27.6		5330
D-22@ 1'		4120	5170	35.5	6000
D-23@1.5'		722	9.66	52.4	553
D-25@ 6"		290	45.5	35.4	304
D-59@15"		2550	67.8	42.9	11600
B-3@2.4'		139	22.3	51.2	67.1
B-3@1.2'		4640	1280	46.3	3150
B-3@4'		262	14.6	37.5	37.8
B-1@1.75'		1440	1410	44.2	4070
D-102@10"		746	319	36.8	649
D-102@2.8'		152	15.3	32.4	80.7
Range	high	4640	5170	32.4	11600
	low	139	7.32	52.4	11.4
Average		1240	601	41.5	2430

Appendix F: Water Level Data

Appendix F: Water level data.

Well #	*Elevation (TOC) (m)*	*Water level (m above m.s.l.)*		
		5/9/95	**5/15/95**	**5/22/95**
P-1	1603.79		1602.34	1602.28
P-1B	1603.64	1602.29		
P-3	1603.84	1602.62	1602.73	1602.62
P-4	1603.82	1602.68	1602.74	1602.61
P-5	1604.85	1603.34	1603.44	1603.45
P-6	1604.59	1603.61	1603.64	1603.50
P-8	1603.32	1602.94		
P-9	1604.54	1603.18	1603.29	1603.14
P-10	1603.89	1602.56	1602.65	1602.57
P-12	1603.91	1602.31	1602.50	1602.40
P-13	1603.52	1602.51		
P-14	1603.78	1602.19	1602.35	1602.28
P-15	1602.92	1601.49	1601.60	1601.56
P-16	1602.94	1601.92	1602.02	1601.93
P-18	1603.76	1602.26	1602.34	1602.27
P-19	1603.75	1602.23	1602.32	1602.27
P-20A	1602.63			
P-20B	1603.27	1602.42	1602.47	1602.40
P-21	1603.31	1602.40	1602.45	1602.37
P-22	1602.57	1602.06	1602.10	1602.01
P-23	1603.49	1602.05	1602.10	1602.02
P-24	1603.16	1602.07	1602.13	1602.05
P-25	1604.56	1602.82	1602.94	1602.86
P-27	1602.85	1602.27	1602.33	1602.25
P-28	1603.10	1602.56	1602.59	
P-29	1602.94	1602.47		1602.44
P-30	1603.82	1602.21		
P-31	1603.80	1602.16		
P-33	1603.67	1602.15		
P-34	1603.65	1602.11	1602.15	1602.16
P-35	1603.10	1601.33		
P-36	1603.09	1601.25		
P-37	1603.04	1601.38	1601.49	1601.43
P-38	1602.59	1601.92	1602.00	1601.89
P-39	1603.89	1602.30	1602.36	1602.32
P-41	1603.50	1602.12	1602.19	1602.11
P-42	1603.79	1602.16	1602.24	1602.16
P-44	1602.95	1602.03	1602.07	1601.98
P-45	1602.53	1602.13	1602.18	1602.11
P-59	1602.57		1601.60	1601.51
P-60	1603.75	1602.07	1602.12	1602.04
MW-1	1603.81	1602.19		
MW-2	1603.86	1602.27		
MW-3	1603.59	1602.18	1602.26	1602.18

Appendix F, continued.

Well #	*Elevation (TOC) (m)*	*Water level (m above m.s.l.)*		
		5/9/95	**5/15/95**	**5/22/95**
D-2	1603.70			
D-3	1603.49			
D-4	1603.53			
D-5	1603.35			
D-6	1603.83			
D-13	1603.78			
D-14	1603.84			
D-15	1603.67			
D-16	1604.06			
D-18	1603.28			
D-19	1603.76			
D-21	1604.17			
D-26	1604.86			
D-27	1604.06			
D-28	1604.35			
D-30	1604.27			
D-31	1604.35			
D-32	1604.56			
D-33	1603.96			
D-35	1604.19			
D-38	1604.01			
D-43	1604.21			
D-44	1604.02			
D-46	1604.86			
D-47	1604.53			
D-48	1604.97			
D-50	1605.40			
D-51	1605.45			
D-52	1604.74			
D-53	1605.22			
D-54	1605.46			
D-55	1605.19			
D-56	1605.10			
D-57	1604.21			
D-58	1603.94			
SG-1	1603.08			
SG-2	1602.75			
SG-3	1602.78			
SG-4	1603.22			
SG-5	1602.97			
SG-6	1603.62			
SG-7	1603.58			
SG-8	1603.62			
SG-9	1604.29			
SG-10	1604.40			
TOB	1605.22	1602.57	1602.59	1602.53

Appendix F, continued.

Well #	***Water level (m above m.s.l.)***				
	5/30/95	**6/6/95**	**6/12/95**	**6/23/95**	**7/6/95**
P-1	1602.21	1602.52	1602.40	1602.30	1602.19
P-1B					
P-3	1602.54	1602.79	1602.81	1602.63	1602.51
P-4	1602.50	1602.84	1602.74	1602.54	1602.37
P-5	1603.38	1603.46	1603.64	1603.50	
P-6	1603.41	1603.88	1603.66	1603.48	1603.32
P-8	1602.84				
P-9	1603.06	1603.32	1603.32	1603.13	1603.00
P-10		1602.74	1602.74	1602.59	
P-12	1602.33	1602.55	1602.55	1602.43	1602.30
P-13					
P-14	1602.23	1602.42	1602.42	1602.32	1602.20
P-15	1601.52	1601.70	1601.71	1601.59	1601.49
P-16	1601.82		1602.10	1601.94	
P-18	1602.20	1602.49			
P-19	1602.20	1602.29	1602.40		
P-20A					
P-20B	1602.32			1602.44	1602.31
P-21	1602.29			1602.31	1602.21
P-22	1601.92		1602.17	1602.03	1601.89
P-23	1601.93		1602.18	1602.04	
P-24	1601.96	1602.37	1602.20	1602.07	1601.93
P-25	1602.80	1603.04	1603.05	1602.90	
P-27	1602.18		1602.40		
P-28			1602.66	1602.46	1602.34
P-29	1602.36				
P-30					
P-31					
P-33					
P-34	1602.17	1602.18	1602.21	1602.16	1602.17
P-35					
P-36					
P-37	1601.39	1601.61	1601.59	1601.48	1601.37
P-38	1601.81		1602.08	1601.92	1601.77
P-39	1602.27	1602.46	1602.44	1602.36	1602.24
P-41	1602.03	1602.35	1602.25	1602.13	
P-42	1602.08	1602.32			
P-44	1601.89		1602.15	1602.00	
P-45	1602.01				
P-59		1601.76	1601.69	1601.52	
P-60	1601.95	1602.37			
MW-1					
MW-2					
MW-3	1602.10	1602.33	1602.33	1602.19	1602.07

Appendix F, continued.

Well #	*Water level (m above m.s.l.)*				
	5/30/95	**6/6/95**	**6/12/95**	**6/23/95**	**7/6/95**
D-2				1602.25	1602.13
D-3				1602.19	1602.06
D-4				1602.12	1601.99
D-5				1601.89	1601.74
D-6				1602.42	1602.28
D-13				1602.38	1602.25
D-14				1602.35	1602.24
D-15				1602.55	
D-16				1602.43	1602.31
D-18				1602.94	1602.82
D-19					1602.87
D-21				1602.95	1602.84
D-26				1603.15	1602.97
D-27				1603.17	1603.10
D-28				1602.67	1602.71
D-30					
D-31					
D-32					1602.64
D-33					1602.85
D-35					1602.56
D-38					1602.61
D-43					1602.58
D-44					1602.38
D-46					
D-47					
D-48					
D-50					
D-51					
D-52					
D-53					
D-54					
D-55					
D-56					
D-57					
D-58					
SG-1					
SG-2					
SG-3					
SG-4					
SG-5					
SG-6					
SG-7					
SG-8					
SG-9					
SG-10					
TOB	1602.47	1602.74	1602.65	1602.56	1602.45

Appendix F, continued.

Well #	***Water level (m above m.s.l.)***				
	7/12/95	**8/15/95**	**8/24/95**	**8/31/95**	**10/20/95**
P-1	1602.32	1602.05	1602.04	1602.03	1602.06
P-1B					
P-3	1602.76	1602.36	1602.32		1602.32
P-4	1602.74	1602.26	1602.20	1602.16	1602.18
P-5		1603.22	1603.21	1603.19	1603.24
P-6	1603.63				1603.08
P-8					
P-9	1603.20	1602.81		1602.69	1602.68
P-10	1602.69	1602.32	1602.29	1602.27	1602.30
P-12	1602.77	1602.23	1602.21	1602.19	1602.24
P-13					
P-14	1602.61	1602.16	1602.14	1602.11	1602.15
P-15	1601.79	1601.42	1601.38	1601.36	1601.37
P-16					
P-18					
P-19		1602.01			
P-20A		1602.02	1602.02	1602.01	1602.06
P-20B		1602.20	1602.19	1602.16	1602.21
P-21		1602.08			1602.11
P-22		1601.71	1601.70	1601.68	1601.74
P-23	1602.08	1601.73		1601.69	
P-24			1601.74		1601.77
P-25		1602.70	1602.66	1602.62	1602.63
P-27					1602.10
P-28	1602.49				
P-29					
P-30					
P-31					
P-33					
P-34	1602.18	1601.96		1601.98	1602.03
P-35					
P-36					
P-37	1601.52	1601.29	1601.25	1601.21	1601.21
P-38		1601.62	1601.59	1601.57	1601.61
P-39	1602.79	1602.21	1602.20	1602.18	1602.21
P-41		1601.83			1601.84
P-42					
P-44	1602.05				
P-45		1601.78	1601.77	1601.75	1601.81
P-59					
P-60					
MW-1					
MW-2					
MW-3		1601.92	1601.89		1601.91

Appendix F, continued.

Well #	***Water level (m above m.s.l.)***				
	7/12/95	**8/15/95**	**8/24/95**	**8/31/95**	**10/20/95**
D-2	1602.16	1601.96			1601.92
D-3	1602.14	1601.89	1601.86		
D-4	1602.11	1601.82			1601.80
D-5	1602.00	1601.56	1601.54		1601.57
D-6	1602.45	1602.13	1602.08		1602.07
D-13	1602.47	1602.07			1602.08
D-14	1602.40	1602.11	1602.10		
D-15					
D-16			1602.13	1602.11	1602.17
D-18	1602.98	1602.66	1602.66		1602.69
D-19					1602.70
D-21	1603.00	1602.67	1602.65	1602.63	1602.68
D-26	1603.23	1602.75	1602.67		1602.61
D-27	1603.24	1603.05	1602.99	1602.95	1602.80
D-28	1602.74				
D-30	1603.71	1603.40	1603.39	1603.38	1603.44
D-31			1603.39	1603.38	1603.45
D-32	1602.76	1602.52			
D-33					
D-35	1602.60	1602.54			
D-38	1602.16	1602.44	1602.39	1602.35	1602.35
D-43	1602.46	1602.38	1602.34	1602.31	1602.33
D-44	1602.38	1602.36	1602.34	1602.32	1602.33
D-46		1603.01	1602.92	1602.89	1602.88
D-47		1603.02	1602.97	1602.94	1602.96
D-48		1603.26	1603.25	1603.24	1603.28
D-50				1602.96	1602.99
D-51		1603.15	1603.11		1603.13
D-52			1603.42	1603.40	1603.49
D-53		1603.48	1603.32	1603.30	1603.41
D-54		1603.51	1603.39	1603.39	1603.48
D-55			1603.50	1603.51	1603.60
D-56		1603.26	1603.16	1603.21	1603.26
D-57				1602.55	1602.59
D-58				1602.38	1602.48
SG-1		1601.66	1601.66	1601.64	1601.71
SG-2		1601.79	1601.77	1601.77	1601.82
SG-3		1601.89	1601.88	1601.87	1601.90
SG-4		1602.00	1602.00	1602.00	1602.05
SG-5		1602.10	1602.10	1602.09	1602.13
SG-6		1602.65	1602.65	1602.63	1602.69
SG-7		1602.49	1602.47	1602.46	1602.53
SG-8		1602.67	1602.66	1602.65	1602.70
SG-9		1603.27	1603.25	1603.24	1603.27
SG-10		1603.40	1603.37	1603.37	1603.42
TOB	1602.59	1602.30	1602.30	1602.29	1602.34

Appendix F, continued.

Well #	*Water level (m above m.s.l.)*				
	11/3/95	**12/11/95**	**2/9/96**	**3/15/96**	**4/26/96**
P-1	1602.05			1602.27	1602.27
P-1B					
P-3	1602.29		1602.52	1602.61	1602.78
P-4	1602.17		1602.70	1602.70	1602.61
P-5	1603.23		1603.76	1603.55	1603.46
P-6	1603.06	1603.26	1603.39	1603.56	1603.54
P-8					
P-9		1602.80	1602.78	1603.00	1603.23
P-10	1602.28		1602.59	1602.56	1602.67
P-12	1602.22	1602.27	1602.65	1602.60	1602.57
P-13					
P-14	1602.14		1602.47	1602.46	1602.50
P-15	1601.37		1601.69	1601.64	1601.78
P-16		1601.66			1601.86
P-18					
P-19		1602.05			
P-20A					1602.23
P-20B	1602.19				1602.35
P-21	1602.07				
P-22	1601.73				1601.99
P-23		1601.78	1602.50	1602.05	1602.03
P-24	1601.75				
P-25	1602.61		1602.76	1602.88	1603.05
P-27					
P-28					1602.41
P-29		1602.22			
P-30					
P-31					
P-33		1602.07			
P-34	1602.03		1602.14	1602.18	1602.26
P-35					
P-36					
P-37	1601.21		1601.54	1601.47	1601.60
P-38	1601.59	1601.62			
P-39	1602.20		1602.53	1602.54	1602.54
P-41		1601.88			1602.09
P-42		1601.94			
P-44		1601.73	1602.92		1601.91
P-45	1601.79				
P-59					
P-60					
MW-1					
MW-2					
MW-3	1601.91	1601.96	1602.35	1602.20	1602.21

Appendix F, continued.

Well #	*Water level (m above m.s.l.)*				
	11/3/95	**12/11/95**	**2/9/96**	**3/15/96**	**4/26/96**
D-2			1602.16	1602.25	1602.29
D-3			1602.24	1602.22	1602.22
D-4	1601.78	1601.88	1602.26	1602.15	1602.12
D-5		1601.62	1602.19	1601.90	1601.88
D-6	1602.06		1602.25	1602.46	1602.57
D-13		1602.15			1602.55
D-14		1602.14	1602.63	1602.31	1602.32
D-15					
D-16	1602.15	1602.21		1602.42	
D-18	1602.68	1602.71			
D-19	1602.68	1602.69			
D-21	1602.66	1602.70	1603.19	1602.96	1603.00
D-26	1602.59	1602.92	1602.90	1603.20	1603.21
D-27	1602.75			1603.25	1603.24
D-28			1602.57	1602.68	1602.84
D-30	1603.42	1603.45			
D-31	1603.43	1603.45			
D-32				1602.69	1602.88
D-33					
D-35					
D-38			1602.72		1602.82
D-43	1602.32	1602.37	1602.47	1602.57	1602.75
D-44	1602.32	1602.38	1602.55	1602.56	1602.73
D-46		1603.15	1603.16	1603.42	1603.40
D-47	1602.93	1603.13	1603.30	1603.40	1603.37
D-48	1603.28	1603.31			1603.51
D-50		1603.24		1603.57	1603.53
D-51		1603.23		1603.49	1603.50
D-52	1603.49		1603.85		1603.83
D-53	1603.39	1603.49			1603.88
D-54	1603.48	1603.51	1604.03	1603.79	1603.83
D-55	1603.60	1603.64	1604.27		1603.88
D-56	1603.27	1603.28			
D-57	1602.56	1602.59	1602.96		1602.87
D-58	1602.47		1602.98		1602.67
SG-1	1601.70	1601.75			
SG-2					
SG-3	1601.89	1601.94			
SG-4	1602.03				
SG-5	1602.12	1602.15		1602.26	
SG-6	1602.68	1602.72	1603.43		1602.92
SG-7					
SG-8	1602.69	1602.72			
SG-9	1603.27	1603.32			
SG-10	1603.41	1603.46			
TOB	1602.34	1602.37	1602.88	1602.53	1602.58

Appendix F, continued.

Well #	***Water level (m above m.s.l.)***			
	5/24/96	**6/27/96**	**7/30/96**	**8/22/96**
P-1		1602.15	1602.14	1602.03
P-1B				
P-3	1602.66	1602.48	1602.32	1602.26
P-4	1602.51	1602.34	1602.22	1602.12
P-5	1603.52	1603.28	1603.27	1603.15
P-6	1603.47	1603.26	1603.04	1602.96
P-8				
P-9	1603.11	1602.89	1602.64	1602.57
P-10	1602.61	1602.43	1602.32	1602.24
P-12	1602.57	1602.37	1602.28	1602.19
P-13				
P-14	1602.48	1602.30	1602.20	1602.12
P-15	1601.76	1601.56	1601.42	1601.35
P-16				
P-18				
P-19				
P-20A		1602.12	1602.12	1602.00
P-20B	1602.49	1602.27	1602.26	
P-21	1602.33	1602.13		
P-22		1601.89		
P-23	1602.11	1601.87	1601.95	1601.82
P-24		1601.87	1601.93	1601.81
P-25	1602.99	1602.84	1602.64	1602.57
P-27				
P-28		1602.24		1602.14
P-29				
P-30				
P-31				
P-33				
P-34	1602.29	1602.13	1602.09	1602.06
P-35				
P-36				
P-37	1601.61	1601.43	1601.31	1601.24
P-38	1601.96		1601.72	
P-39	1602.53	1602.37	1602.25	1602.18
P-41	1602.13			
P-42				
P-44	1602.00	1601.74		
P-45		1601.91		
P-59				
P-60				
MW-1				
MW-2				
MW-3	1602.26	1602.03	1601.97	1601.90

Appendix F, continued.

Well #	*Water level (m above m.s.l.)*			
	5/24/96	**6/27/96**	**7/30/96**	**8/22/96**
D-2	1602.23	1602.09	1601.94	1601.91
D-3	1602.19	1602.02	1601.91	1601.88
D-4	1602.12	1601.95	1601.88	1601.82
D-5	1601.92	1601.74	1601.74	1601.62
D-6	1602.42	1602.25	1602.08	1602.00
D-13		1602.23	1602.03	1601.98
D-14	1602.36	1602.17	1602.14	1602.03
D-15				
D-16		1602.30		
D-18				
D-19				
D-21	1603.04	1602.81	1602.75	1602.63
D-26	1603.11	1602.87	1602.65	1602.53
D-27	1603.16	1602.91	1602.74	1602.57
D-28	1603.47	1602.65		
D-30				
D-31				
D-32	1602.78	1602.60		
D-33				
D-35				
D-38	1602.67	1602.53	1602.36	1602.30
D-43	1602.65	1602.47	1602.30	1602.25
D-44	1602.65	1602.47	1602.32	1602.26
D-46	1603.35	1603.09	1602.91	1602.77
D-47	1603.37	1603.13	1603.00	1602.89
D-48	1603.59	1603.36	1603.35	1603.25
D-50				
D-51		1603.27	1603.12	
D-52	1603.81	1603.57	1603.52	1603.28
D-53	1603.75	1603.50	1603.29	1603.23
D-54	1603.90	1603.63	1603.52	1603.44
D-55	1603.92	1603.65	1603.63	1603.48
D-56				
D-57	1602.87	1602.68	1602.60	1602.49
D-58	1602.71	1602.55	1602.55	1602.38
SG-1				
SG-2				
SG-3				
SG-4		1602.07		
SG-5				
SG-6				
SG-7				
SG-8				
SG-9				
SG-10				
TOB	1602.63	1602.43		1602.32

Appendix G: Soil Moisture Data

Appendix G: Soil moisture data.

Tensiometer	Depth (m)	centibars of soil suction					
		20-Jun	27-Jun	17-Jul	30-Jul	7-Aug	22-Aug
T-4	0.152	21	19	32	26	32	31
T-3	0.305	18	18.5	22	21	23	22
T-2	0.61	18	18	21	21	23	24
T-1	1.22	17	16	19	20	19	19
AT-15	0.152	20	11	36	47	41	54
AT-30	0.297	26	20	47	59	57	62
AT-46	0.406	10	11	12	11	12	12
AT-87	0.889	18	18	19	16	18	18
AT-120	1.19	14	15	15	12	14	14
AT-141	1.42	15	15	17	14	16	17

Appendix H: Vadose Zone Water Chemistry Data

Appendix H: Vadose zone water chemistry.

all values reported in ppm

		pH	cond. (mS/cm)	Flouride	Chloride	Nitrite	Nitrate	Sulfate	Al	As	Ca
detection limit				0.1	0.1	0.1	0.1	0.1	0.03	0.06	0.055
Lysimeter											
LS-1	20-Jun	6.4	3.3	2.76	??	0	0	575	1.16	bdl	288
	17-Jul	6.1	3.6	7.24	80.6	0	0	2240	2.05	bdl	375
	7-Aug	5.1	3.9	7.69	91.9	0	35.4	2180	5.74	bdl	449
LS-2	20-Jun	??	??	2.79	21.4	0	0	??	bdl	bdl	204
LS-3	20-Jun	5.3	5.37	3.71	60.5	0	0	4410	bdl	0.115	768
	7-Aug	7	7.23	7.86	84.1	0	0	4820	bdl	0.177	792
AL-85	20-Jun	2.9	6.24	5.94	21.3	0	0.804	6550	370	0.109	327
	17-Jul	??	??	??	??	??	??	??			
	7-Aug	??	??	??	??	??	??	??	480	??	370

Appendix H, continued.

		Cd	Cu	Fe	Mg	Mn	Pb	S	Si	Zn
detection limit		0.009	0.006	0.015	0.1	0.006	0.075	0.05	0.05	0.006
Lysimeter										
LS-1	20-Jun	0.301	23.5	bdl	239	33.1	bdl	854	24.6	61.8
	17-Jul	0.202	10.7		175	31.7	bdl	719	39.1	62.3
	7-Aug	0.155	6.10	0.087	175	28.3	bdl	730	44.1	62.6
LS-2	20-Jun	0.022	1.30	0.033	83.6	1.40	bdl	358	8.46	3.68
LS-3	20-Jun	0.062	2.70	0.175	505	4.39	bdl	1550	23.8	8.57
	7-Aug	0.136	0.693	0.084	514	0.102	bdl	1520	29.5	0.729
AL-85	20-Jun	2.63	546	63.5	74.3	245	0.271	1910	56.4	670
	17-Jul									
	7-Aug	3.36	688	73.2	96.8	321	0.370	2410	66.8	818

Appendix I: Water Quality Data

Appendix I: Water quality data.

Sample Name	pH	cond (mS/cm)	D.O. (mg/l)	Flouride	Chloride	Nitrite	Nitrate
detection limits (all values reported in ppm)				0.1	0.1	0.1	0.1
D-2 3/31	4.6	1.77			21.2		
D-2 3/31	4.6	1.77			21.2		
D-4 3/31	4.1	2.52			19.7		
D-5 3/31	3.9	2.62			24.5		
P-6 3/31	6.3	1.20			21.8		
P-6 3/31	6.3	1.20			21.8		
P-25 3/31	3.7	0.82			19.9		
D-21 3/31	4.3	0.91			16.4		
D-26 3/31	3.8	??			18.4		
D-48 3/31	6.1	1.48			28.2		
D-52 3/31	5.8	0.58			16.4		
D-55 3/31	6.2	0.72			16.4		
DI BLANK 3/31					BDL		
D-2 6/6	4.3	1.78					
D-3 6/6	3.6	2.72					
D-4 6/6	3.7	2.34					
D-5 6/6	3.7	2.82					
D-13 6/6	5.7	2.20					
D-14 6/6	6.0	1.57					
D-21 6/6	4.1	1.54					
D-26 6/6	3.7	1.22					
D-52 6/6	6.0	0.57					
D-50 6/6	5.0	0.71					
DI BLANK 6/6							
D-55 6/6	6.1	0.9					
P-10 6/6	5.7	1.64					
P-25 6/6	4.0	1.10					
P-25 6/6	4.0	1.10					
D-26 6/20	3.7	1.12		1.65	18.7		2.42
D-26 6/20	3.7	1.12		1.63	18.9		2.41
S1-5C 6/20	4.3	1.48		2.76	20.1	0.324	4.61
S1-5C 6/20	4.3	1.48		2.76	20.1		4.61
S1-1C 6/20	4.0	1.19		1.81	18.8		3.79
S1-2C 6/20	4.5	1.35		2.19	18.5		5.44
S1-3C 6/20	4.1	1.17		1.98	18.2		5.18
S2-5C 6/20	6.0	1.29		0.745	16.7		
S2-1C 6/20	6.0	1.14		0.709	16.5		
S2-2C 6/20	4.6	1.24		2.72	15.6		
S2-3C 6/20	3.4	1.55		1.86	15.3		
DI BLANK 6/20					0.435		
D-4C 6/20	4.1	2.44		2.16	18.4		0.257
D-4C 6/20	4.1	2.44		2.22	18.0		0.240
S3-5C 6/20	4.2	2.39		2.75	18.7		
S3-1C 6/20	4.3	2.40		2.73	18.8		

Appendix I, continued.

Sample Name	pH	cond (mS/cm)	D.O. (mg/l)	Flouride	Chloride	Nitrite	Nitrate
detection limits				0.1	0.1	0.1	0.1
D-26C 7/17	3.9	1.14	1.0	1.32	18.4		2.09
S1-5C 7/17	4.5	1.24	1.2	1.97	18.7	1.05	2.37
S1-1C 7/17	4.2	1.16	1.2	1.51	18.4		3.14
S2-5C 7/17	6.1	0.65	1.4	0.853	15.5		0.512
S2-1C 7/17	6.1	0.51	0.9	1.51	16.4		1.51
S2-2C 7/17	4.8	0.56	1.1	0.961	15.8		1.34
S2-3C 7/17	3.3	0.96	0.9	0.931	15.7		0.783
D-4C 7/17	4.3	2.40	1.0	4.69	16.0		2.38
D-4C 7/17	4.3	2.40	1.0	4.62	15.8		2.48
D-4C 7/17	4.3	2.40	1.0	4.69	16.0		2.38
S3-5C 7/17	4.4	2.26	0.7	4.960	16.3		1.05
S3-1C 7/17	4.4	2.29	1.6 ?	4.82	16.7		0.696
D-26C 8/7	3.9	1.21	1.1	1.31	25.3		2.88
S1-5C 8/7	4.5	1.32	0.9	3.04	25.8		2.02
S1-1C 8/7	4.1	1.20	1.0	1.44	26.0		3.33
S2-5C 8/7	6.3	0.50	1.2	0.960	23.1		0.58
S2-1C 8/7	5.7	0.47	1.3	0.568	22.9		2.03
S2-2C 8/7	4.9	0.44	1.3	0.570	22.1		1.59
S2-3C 8/7	3.2	0.87	1.5	0.686	20.0		1.54
D-4C 8/7	4.1	2.44	1.2	3.21	18.8		
S3-5C 8/7	4.1	2.32	1.3	4.72	17.7		1.78
S3-5C 8/7	4.1	2.32	1.3	4.80	17.5		1.81
S3-5C 8/7	4.1	2.32	1.3	4.80	17.5		1.81

Appendix I, continued.

Sample Name	**Sulfate**	**Al**	**As**	**Ca**	**Cd**	**Cr**	**Cu**	**Fe**
detection limits	0.1	0.03	0.06	0.055	0.009	0.009	0.006	0.015
D-2 3/31	1090	1.38	BDL	244	0.071	BDL	1.31	BDL
D-2 3/31	1090	1.41	BDL	212	0.063	BDL	1.27	BDL
D-4 3/31	1780	26.5	BDL	272	0.474	BDL	72.9	28.7
D-5 3/31	1780	5.54	BDL	317	1.42	BDL	26.3	33.1
P-6 3/31	602	BDL	BDL	162	BDL	BDL	BDL	38.3
P-6 3/31	602	BDL	BDL	150	BDL	BDL	BDL	36.1
P-25 3/31	396	4.45	BDL	79.6	0.083	BDL	2.69	0.740
D-21 3/31	560	7.22	BDL	49.1	0.260	BDL	37.3	12.8
D-26 3/31	526	4.20	BDL	104	0.144	BDL	5.69	0.180
D-48 3/31	684	BDL	BDL	180	BDL	BDL	0.073	37.1
D-52 3/31	163	0.270	BDL	51.0	BDL	BDL	0.030	36.8
D-55 3/31	186	2.51	BDL	86.5	BDL	BDL	0.040	13.1
DI BLANK 3/31	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
D-2 6/6		1.52	BDL	211	0.061	BDL	1.25	0.090
D-3 6/6		38.1	BDL	291	0.389	BDL	59.2	19.9
D-4 6/6		26.6	BDL	227	0.372	BDL	64.2	27.8
D-5 6/6		8.39	BDL	310	1.39	BDL	40.4	35.7
D-13 6/6		0.358	BDL	252	BDL	BDL	BDL	19.2
D-14 6/6		BDL	BDL	179	BDL	BDL	BDL	27.5
D-21 6/6		21.4	0.062	90.0	0.480	BDL	67.5	24.4
D-26 6/6		7.93	BDL	136.8	0.192	BDL	7.24	0.550
D-52 6/6		BDL	BDL	54.7	BDL	BDL	BDL	42.8
D-50 6/6		2.70	BDL	75.5	0.047	BDL	3.112	12.8
DI BLANK 6/6		BDL	BDL	0.400	BDL	BDL	0.007	BDL
D-55 6/6		BDL	BDL	127	BDL	BDL	BDL	15.4
P-10 6/6		BDL	BDL	187	BDL	BDL	BDL	13.3
P-25 6/6		8.71	BDL	135	0.145	BDL	5.35	0.290
P-25 6/6		9.09	BDL	140	0.152	BDL	5.54	0.099
D-26 6/20	525.47	6.22	BDL	116	0.166	BDL	6.12	0.494
D-26 6/20	525.47	6.22	BDL	117	0.166	BDL	6.15	0.468
S1-5C 6/20	760.21	5.38	BDL	165	0.224	BDL	8.87	8.20
S1-5C 6/20	760.21	5.69	BDL	171	0.233	BDL	9.53	8.40
S1-1C 6/20	575.22	5.60	BDL	131	0.168	BDL	7.48	0.165
S1-2C 6/20	722.34	8.05	BDL	180	0.165	BDL	10.5	0.066
S1-3C 6/20	578.76	16.2	0.241	146	0.161	BDL	9.83	15.4
S2-5C 6/20	606.46	BDL	BDL	159	0.025	BDL	1.53	1.66
S2-1C 6/20	519.58	BDL	BDL	141	0.058	BDL	4.71	0.037
S2-2C 6/20	677.82	11.3	0.065	95.2	0.213	BDL	64.5	6.52
S2-3C 6/20	795.26	15.4	0.069	119	0.230	BDL	42.4	15.6
DI BLANK 6/20	1.05	BDL	BDL	0.100	BDL	BDL	0.010	BDL
D-4C 6/20	1550.66	24.8	0.062	225	0.362	BDL	60.8	27.2
D-4C 6/20	1539.74	24.4	BDL	220	0.351	BDL	59.1	26.9
S3-5C 6/20	1527.34	23.7	BDL	229	0.442	BDL	78.4	20.7
S3-1C 6/20	1534.27	26.8	BDL	235	0.455	BDL	80.7	17.7

Appendix I, continued.

Sample Name	**Sulfate**	**Al**	**As**	**Ca**	**Cd**	**Cr**	**Cu**	**Fe**
detection limits	0.1	0.03	0.06	0.055	0.009	0.009	0.006	0.015
D-26C 7/17	647.83	6.58	BDL	117	0.169	BDL	6.34	0.556
S1-5C 7/17	682.12	4.90	BDL	156	0.209	BDL	7.82	8.60
S1-1C 7/17	596.23	6.21	BDL	133	0.178	BDL	7.29	0.392
S2-5C 7/17	285.15	BDL	BDL	80.1	0.017	BDL	1.05	0.113
S2-1C 7/17	218.95	BDL	BDL	54.9	0.033	BDL	2.63	0.018
S2-2C 7/17	317.3	3.68	BDL	38.7	0.075	BDL	20.0	1.80
S2-3C 7/17	490	7.56	BDL	71.1	0.118	BDL	27.8	6.99
D-4C 7/17	1727.83	29.0	BDL	254	0.395	BDL	67.2	29.6
D-4C 7/17	1755.76	27.9	BDL	237	0.368	BDL	65.2	27.8
D-4C 7/17	1727.83	27.7	BDL	256	0.394	BDL	63.8	29.4
S3-5C 7/17	1349.06	23.9	BDL	233	0.434	BDL	77.2	20.3
S3-1C 7/17	1654.39	24.4	BDL	229	0.436	BDL	79.2	14.0
D-26C 8/7	638.52	7.18	BDL	126	0.187	BDL	7.10	0.765
S1-5C 8/7	691.21	4.83	BDL	159	0.215	BDL	7.82	8.22
S1-1C 8/7	655.18	6.40	BDL	133	0.185	BDL	7.33	0.830
S2-5C 8/7	197.6	BDL	BDL	56.2	0.015	BDL	1.08	0.039
S2-1C 8/7	207.51	BDL	BDL	44.2	0.050	BDL	4.84	0.021
S2-2C 8/7	248.66	1.58	BDL	30.5	0.053	BDL	13.1	0.579
S2-3C 8/7	443.49	7.49	BDL	58.2	0.103	BDL	21.8	4.86
D-4C 8/7	1696.81	29.6	BDL	242	0.374	BDL	69.2	26.8
S3-5C 8/7	1568.67	23.6	BDL	230	0.425	BDL	76.0	19.8
S3-5C 8/7	1509.51	23.9	BDL	230	0.421	BDL	76.8	19.8
S3-5C 8/7	1509.51	23.9	BDL	238	0.435	BDL	75.9	20.3

Appendix I, continued.

Sample Name	K	Mg	Mn	Mo	Na	P	Pb	S
detection limits	0.3	0.1	0.006	0.009	0.1	0.1	0.075	0.05
D-2 3/31	??	64.3	36.2	??	98.1		BDL	??
D-2 3/31	??	62.9	33.3	??	99.9		BDL	??
D-4 3/31	??	66.2	63.8	??	74.8		BDL	??
D-5 3/31	??	74.4	86.5	??	73.2		BDL	??
P-6 3/31	??	39.3	19.3	??	39.4		BDL	??
P-6 3/31	??	35.1	17.1	??	32.6		BDL	??
P-25 3/31	??	17.2	7.59	??	31.9		BDL	??
D-21 3/31	??	14.6	24.7	??	24.4		1.60	??
D-26 3/31	??	18.4	9.13	??	24.8		BDL	??
D-48 3/31	??	36.1	17.3	??	57.0		0.100	??
D-52 3/31	??	11.4	8.37	??	15.9		BDL	??
D-55 3/31	??	8.21	3.36	??	19.7		BDL	??
DI BLANK 3/31	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
D-2 6/6	8.79	63.5	32.4	BDL	104	BDL	BDL	369
D-3 6/6	7.41	85.9	64.0	BDL	108	BDL	0.333	636
D-4 6/6	7.44	59.8	56.3	BDL	85.2	BDL	BDL	507
D-5 6/6	11.8	82.5	104	BDL	96.9	BDL	BDL	609
D-13 6/6	8.04	76.6	47.6	BDL	143	0.170	BDL	411
D-14 6/6	7.31	46.1	35.3	BDL	84.1	0.179	BDL	282
D-21 6/6	4.46	30.4	45.9	BDL	32.4	BDL	2.33	305
D-26 6/6	6.89	25.7	12.8	BDL	36.3	BDL	BDL	198
D-52 6/6	4.88	12.5	8.67	BDL	20.1	BDL	BDL	62.5
D-50 6/6	5.80	18.7	12.5	BDL	22.9	BDL	BDL	124
DI BLANK 6/6	BDL	BDL	0.010	BDL	0.063	BDL	BDL	BDL
D-55 6/6	7.43	13.6	5.07	BDL	30.6	BDL	BDL	134
P-10 6/6	8.28	42.5	24.5	BDL	109	0.104	BDL	302
P-25 6/6	5.30	29.2	13.3	BDL	42.0	BDL	BDL	190
P-25 6/6	5.63	30.2	13.9	BDL	44.5	BDL	BDL	196
D-26 6/20	7.24	21.5	11.0	BDL	39.7	BDL	BDL	170
D-26 6/20	6.86	21.5	11.0	BDL	37.5	BDL	BDL	170
S1-5C 6/20	9.04	33.8	17.9	BDL	41.2	BDL	BDL	244
S1-5C 6/20	9.37	36.0	18.9	BDL	43.3	BDL	BDL	257
S1-1C 6/20	7.22	24.7	11.3	BDL	38.1	BDL	BDL	186
S1-2C 6/20	7.77	30.5	10.8	BDL	36.4	BDL	BDL	230
S1-3C 6/20	10.4	26.7	10.8	BDL	34.5	0.126	0.534	190
S2-5C 6/20	8.75	33.9	22.3	BDL	49.3	BDL	BDL	200
S2-1C 6/20	10.5	27.7	14.0	BDL	35.3	BDL	BDL	175
S2-2C 6/20	7.79	16.3	24.1	BDL	25.7	BDL	1.11	211
S2-3C 6/20	4.09	19.7	36.2	BDL	30.3	BDL	0.236	247
DI BLANK 6/20	0.445	BDL	0.009	BDL	0.038	BDL	BDL	0.094
D-4C 6/20	7.40	57.9	55.2	BDL	81.9	0.129	BDL	492
D-4C 6/20	7.19	56.5	53.8	BDL	79.3	0.103	BDL	480
S3-5C 6/20	7.13	57.6	56.2	BDL	86.1	BDL	BDL	508
S3-1C 6/20	8.94	60.6	56.9	BDL	91.1	BDL	BDL	512

Appendix I, continued.

Sample Name	K	Mg	Mn	Mo	Na	P	Pb	S
detection limits	0.3	0.1	0.006	0.009	0.1	0.1	0.075	0.05
D-26C 7/17	7.89	21.6	11.3	BDL	42.9	BDL	BDL	174
S1-5C 7/17	9.79	31.8	16.9	BDL	45.1	BDL	BDL	230
S1-1C 7/17	8.16	25.3	12.0	BDL	45.1	BDL	BDL	186
S2-5C 7/17	8.66	17.7	9.33	BDL	32.6	BDL	BDL	84.3
S2-1C 7/17	9.77	9.68	6.54	BDL	24.5	BDL	BDL	60.3
S2-2C 7/17	6.31	7.89	7.71	BDL	19.3	BDL	0.592	82.7
S2-3C 7/17	2.83	8.22	14.9	BDL	19.3	BDL	BDL	141
D-4C 7/17	8.75	65.2	61.5	BDL	91.7	BDL	0.081	537
D-4C 7/17	8.20	63.0	58.1	BDL	86.7	BDL	0.087	513
D-4C 7/17	7.86	62.6	60.3	BDL	84.7	BDL	0.077	525
S3-5C 7/17	7.59	57.6	57.3	BDL	87.3	BDL	BDL	504
S3-1C 7/17	8.22	58.0	55.3	BDL	89.1	BDL	BDL	508
D-26C 8/7	8.87	23.0	12.2	BDL	47.1	BDL	BDL	196
S1-5C 8/7	10.1	31.8	17.1	BDL	47.7	BDL	BDL	235
S1-1C 8/7	8.55	25.7	12.2	BDL	47.5	BDL	BDL	193
S2-5C 8/7	8.13	11.6	6.38	BDL	30.2	BDL	BDL	51.8
S2-1C 8/7	9.40	7.61	5.65	BDL	29.3	BDL	BDL	53.5
S2-2C 8/7	8.02	5.76	5.37	BDL	30.1	BDL	0.358	59.3
S2-3C 8/7	4.53	6.30	10.4	BDL	28.9	BDL	0.151	119
D-4C 8/7	9.03	66.1	59.5	BDL	96.3	BDL	BDL	546
S3-5C 8/7	8.23	58.1	56.4	BDL	92.5	BDL	BDL	511
S3-5C 8/7	8.12	58.3	56.9	BDL	89.6	BDL	BDL	507
S3-5C 8/7	8.05	57.9	57.8	BDL	92.5	BDL	BDL	511

Appendix I, continued.

Sample Name	Si	Sr	Ti	Zn
detection limits	0.05	0.01	0.006	0.006
D-2 3/31	32.0	1.28	??	33.0
D-2 3/31	31.2	1.23	??	29.6
D-4 3/31	44.9	1.14	??	152
D-5 3/31	43.1	1.20	??	140
P-6 3/31	22.8	0.900	??	11.3
P-6 3/31	21.4	0.78	??	9.79
P-25 3/31	28.5	0.37	??	14.6
D-21 3/31	28.8	0.33	??	70.8
D-26 3/31	33.3	0.49	??	26.8
D-48 3/31	17.5	1.34	??	13.6
D-52 3/31	16.2	0.31	??	5.93
D-55 3/31	18.3	0.29	??	13.7
DI BLANK 3/31	BDL	BDL	BDL	BDL
D-2 6/6	34.8	1.33	BDL	27.5
D-3 6/6	43.4	1.41	BDL	95.3
D-4 6/6	47.2	1.16	BDL	99.1
D-5 6/6	48.5	1.55	BDL	113
D-13 6/6	36.1	1.66	BDL	33.6
D-14 6/6	24.1	1.19	BDL	10.3
D-21 6/6	32.7	0.665	BDL	99.0
D-26 6/6	39.5	0.857	BDL	30.5
D-52 6/6	18.7	0.434	BDL	4.76
D-50 6/6	28.2	0.487	0.014	22.7
DI BLANK 6/6	0.134	BDL	BDL	0.026
D-55 6/6	10.8	0.575	BDL	19.3
P-10 6/6	27.7	1.06	BDL	3.79
P-25 6/6	30.2	0.713	BDL	23.2
P-25 6/6	30.0	0.741	BDL	24.1
D-26 6/20	39.3	0.733	BDL	26.0
D-26 6/20	39.3	0.739	BDL	26.2
S1-5C 6/20	34.9	1.04	BDL	41.9
S1-5C 6/20	36.2	1.08	BDL	43.7
S1-1C 6/20	39.0	0.750	BDL	28.1
S1-2C 6/20	43.0	1.06	BDL	29.5
S1-3C 6/20	73.0	0.933	0.521	28.7
S2-5C 6/20	15.8	0.978	BDL	11.8
S2-1C 6/20	14.9	0.781	BDL	19.8
S2-2C 6/20	28.9	0.482	BDL	59.3
S2-3C 6/20	38.6	0.471	0.075	59.1
DI BLANK 6/20	0.158	BDL	BDL	0.025
D-4C 6/20	44.9	1.14	BDL	96.0
D-4C 6/20	43.8	1.12	BDL	93.5
S3-5C 6/20	49.9	1.19	BDL	115
S3-1C 6/20	56.8	1.19	0.110	116

Appendix I, continued.

Sample Name	Si	Sr	Ti	Zn
detection limits	0.05	0.01	0.006	0.006
D-26C 7/17	40.1	0.756	BDL	26.9
S1-5C 7/17	39.5	1.00	BDL	38.3
S1-1C 7/17	43.0	0.796	BDL	29.0
S2-5C 7/17	15.9	0.483	BDL	7.41
S2-1C 7/17	18.1	0.337	BDL	16.7
S2-2C 7/17	20.4	0.226	BDL	23.8
S2-3C 7/17	28.4	0.284	BDL	32.9
D-4C 7/17	48.1	1.28	BDL	105
D-4C 7/17	45.9	1.19	BDL	100
D-4C 7/17	47.0	1.29	BDL	104
S3-5C 7/17	49.7	1.22	BDL	113
S3-1C 7/17	49.7	1.14	BDL	112
D-26C 8/7	45.1	0.828	BDL	29.5
S1-5C 8/7	40.1	1.03	BDL	38.7
S1-1C 8/7	44.6	0.817	BDL	30.0
S2-5C 8/7	17.6	0.348	BDL	6.21
S2-1C 8/7	19.8	0.277	BDL	17.6
S2-2C 8/7	20.9	0.187	BDL	16.3
S2-3C 8/7	33.6	0.261	0.011	29.3
D-4C 8/7	48.7	1.22	BDL	101
S3-5C 8/7	50.2	1.20	BDL	112
S3-5C 8/7	50.2	1.20	BDL	111
S3-5C 8/7	50.7	1.25	BDL	113