Feasibility Study
USG Interiors Puyallup Site
Puyallup, Washington

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December 4, 2013

CDM Smith®

A Report Prepared For:

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Chicago, Illinois 60661-3676

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USG INTERIORS PUYALLUP SITE
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Section 1

Introduction

This document presents the results of the feasibility study (FS) for the USG Interiors (USG) property located at 925 River Road in Puyallup, Washington. The site location is shown on **Figure 1**. This FS was performed to develop, evaluate, and provide recommendations for appropriate alternatives to remediate arsenic contamination in soil, groundwater, and sediment, and to satisfy the requirements of Agreed Order DE 5489 (current Order) between the Washington State Department of the Ecology (Ecology) and USG, under the Model Toxics Control Act (MTCA). The current Order came into effect on June 17, 2008.

1.1 FS Objectives

The objectives of this FS are summarized below:

- Develop remedial action objectives (RAOs) to achieve cleanup of the site.
- Screen potential remedial technologies to attain the RAOs.
- Combine remedial technologies to develop remedial action alternatives that address the RAOs.
- Develop conceptual level cost estimates for implementation, operation, and maintenance of the remedial action alternatives.
- Recommend the most appropriate remedial action alternative to implement at the site, based on the criteria in MTCA.

1.2 Location and Description

USG's Puyallup property consists of 1.58 acres located between River Road and the Puyallup River in Puyallup, Washington. The southern (paved) portion of the property was formerly occupied by several buildings, but is currently vacant. The northern portion of the property is unpaved. **Figure 2** shows the layout of the property and adjacent properties. The Inter-County River Improvement Right-of-Way (ICRI-ROW), administered by Pierce County Public Works and Utilities, runs between the property and the Puyallup River. A paved bike path is located on the ICRI-ROW and runs along the top of the south bank of the Puyallup River.

USG's property is bordered to the east and west by used car dealerships—Market Place Auto and Bonney Lake Used Cars, respectively. River Road borders USG's property to the south. The extent of the exploration stations shown on **Figure 2** are referred to as the "site" throughout this report, including portions of Bonney Lake Used Cars, the ICRI-ROW, and Market Place Auto in addition to all of USG's property.

1.3 Site History

The following description of property and site history is based on CDM Smith's interpretation of historical aerial photographs and information provided to Ecology by USG.

Exactly when commercial activity began at the property is not documented, but aerial photographs show business-related activities on the property by 1961. What appears to be a used car sales business occupied the southern portion of the property. The northern portion of the site at that time contained junk cars. Site use appears to be consistent throughout the remainder of the 1960s.

A February 1971 aerial photograph clearly shows fill being placed on the northern portion of the site. The source of this fill is unknown. Early to mid-1970s aerial photographs show that the northern portion of the property continued to be used as a junk car lot following the filling on the property that occurred circa 1971.

Aerial photographs taken in 1979 show a fence around most of the northern portion of the property; the area inside the fence was filled with junk cars. This fence arrangement is identical to that shown on an April 1982 topographic map of the property. An aerial photograph dated August 1982 shows the northern portion of the property still being used as a junk car lot, but there are noticeably fewer cars than seen in the 1979 aerial photograph.

Prior to 1971 through the early 1970s, industrial waste from USG's Tacoma, Washington plant was used as fill at the site. Because exact dates of these activities are not documented, their association with fill operations observed in the February 1971 aerial photograph cannot be determined.

It is known that from about 1959 to 1973, the USG Tacoma plant used ASARCO slag as a raw material for mineral fiber production. The ASARCO smelter was located on Commencement Bay in Ruston and Tacoma, Washington. It operated from 1890 to 1986 as a smelter of lead and copper ore. The copper ore contained high concentrations of arsenic, as did the slag. Baghouse dust and off-specification product with elevated arsenic concentrations was reportedly used as fill at the Puyallup site.

In the early 1980s, USG became aware of the association between ASARCO slag and arsenic contamination. Subsequently, USG purchased the Puyallup property in October 1982 to facilitate its cleanup. That same year, USG voluntarily approached Ecology to negotiate an administrative process to govern removal of industrial waste fill from the site. USG conducted an assessment in 1983 that characterized site geology and groundwater conditions (Dames & Moore, 1983).

Soil and groundwater cleanup standards had not been established in Washington State at this time. Accordingly, Agreed Order No. DE 84-506 established arsenic cleanup standards of 5 milligrams per liter (mg/L) by the EP Toxicity (leaching) method for soil and 0.5 mg/L for groundwater. Although detailed records have not been located, a March 1985 aerial photograph indicates a source removal action occurred in the spring of 1985. This photograph shows all of the junk cars had been removed and the unpaved (northern) portion of the site appears to have been graded. According to information submitted to Ecology by USG, 25,536 tons of industrial waste fill and underlying soil were removed from the site for off-site disposal. Of this total, approximately 3,500 tons of native soil was removed from the northwest corner of the property because verification samples collected immediately beneath the industrial waste fill did not achieve the soil cleanup standard. This area is termed the contaminant source area, and is located in the vicinity of the P3 (**Figure 2**) well cluster. An August 1985 aerial photograph shows that the site had undergone final grading after completion of the source removal action.

The 1984 Order also required USG to conduct post-cleanup groundwater monitoring. To this end, USG installed three clusters (P1, P2, and P3) of three monitoring wells each (P1-1, P1-2, P1-3, etc.) in May

1985 to assess the lateral and vertical extent of arsenic in groundwater. These monitoring wells are shown on **Figure 2**. Groundwater samples were collected from these wells on a monthly basis.

On April 22, 1987 Ecology issued Consent Order No. 86-S130, which required long-term groundwater sampling. The groundwater cleanup level listed in this Order was 500 micrograms per liter (µg/L). Groundwater sampling continued on a monthly basis for the P2 and P3 well clusters but was dropped for the P1 well cluster.

The Model Toxics Control Act (MTCA) was enacted and went into effect in March 1989. MTCA governs state-led environmental cleanups in Washington State. In 1991, Ecology established MTCA 'Method A' arsenic cleanup levels of 20 milligrams per kilogram (mg/kg) for soil and 5 µg/L for groundwater. These MTCA cleanup standards for arsenic did not come into force at the Puyallup site because it was under the cleanup levels established under Order No. 86-S130.

Long-term groundwater sampling performed by USG under Order 86-S130 continued until early 2006. In the last monitoring round conducted in April 2006, arsenic was detected at a concentration of 5,960 µg/L at groundwater monitoring well P3-1.

In 2006, Ecology determined that the MTCA Method A groundwater would not be attained in a reasonable time frame by natural attenuation and required that USG conduct a soil and groundwater assessment for arsenic. This assessment showed that arsenic in soil and groundwater exceeded MTCA Method A cleanup standards in the contaminant source area. On March 30, 2007, Ecology sent USG a letter naming USG as a potentially liable party for the release of arsenic at the site. This led to the issuance of the current Order in 2008.

Section 2

Remedial Investigation Summary

USG conducted an RI at the Puyallup site in 2009 through 2010. Results of the RI are presented in a CDM Smith report prepared for USG (CDM, 2011) and summarized below. All RI tables and figures are shown in **Appendices A** and **B**, respectively.

2.1 Environmental Setting

2.1.1 Geology

The site is located on the south bank of the lower Puyallup River within the Puyallup valley. Soils in the Puyallup valley consist of alluvium derived from the Puyallup River, underlain by glacial deposits. The Puyallup River alluvial deposits are consistent with alluvial deposits found worldwide and consist of three major types: overbank flood deposits, slack water deposits, and bar accretion deposits. It is important to note that these depositional processes are currently active.

The specific site geology is summarized in geologic cross-section A **-** A', which is shown on Figure 3 in **Appendix B**. Generalized stratigraphy consists of fill overlying alluvium associated with the Puyallup River.

The fill includes backfill material associated with the former remedial excavation and fill associated with early site development, likely prior to commercial use of the site. The fill extends to depths ranging from 2 to 16 feet below ground surface (bgs) and soil types include poorly graded sand with silt and gravel (SP-SM), poorly graded sand with gravel (SP), and poorly graded gravel (GP). Traces of man-made debris are present within the fill (paper, wood, plastic, metal, brick, and concrete fragments).

The fill is differentiated from alluvium by the presence of man-made debris and angular to subangular gravel. Minor quantities of recently deposited overbank flood deposits (poorly graded sand and silt) overlie fill in the northern portion of the site. This material was deposited during flood events that have occurred after the 1985 source removal action. As shown in the geologic cross-section on Figure 3 in **Appendix B**, alluvium underlies the site to the total depth explored. The alluvium is subdivided into four units based on depositional environment, including:

- **Unit A** – Overbank and point bar deposits
- **Unit B** – Channel and point bar deposits
- **Unit C** – Slack water deposits
- **Unit D** – Overbank deposits

Each of these units is described in more detail below.

Unit A – Overbank and Point Bar Deposits

This unit extends from the ground surface, or bottom of fill, to an approximate depth of 40 feet bgs. Unit A includes interlayered, fine-grained, poorly graded sand (SP) and well-graded sand (SW) with minor clay (CL) interbeds up to 6 inches thick. The soils were deposited by the Puyallup River and are exposed in the banks and bed of the river.

Unit B – Channel and Point Bar Deposits

This unit consists of gravel (GP, GW, and GW-GM), which represents higher energy deposition in an active river channel. The unit is less than 5 feet thick and underlies Unit A at a depth of approximately 40 feet bgs.

Unit C – Slack Water Deposits

Unit C consists of a sequence of silty sand (SM) containing wood fragments and organic matter. The presence of increased silt and organic matter indicates deposition in a lower energy slack water environment. The unit is approximately 15 feet thick and extends to total depths ranging from 54 to 61 feet bgs.

Unit D – Overbank Deposits

Unit D consists of dense, fine-grained silty sand (SM) and poorly graded sand with silt (SP-SM). The soil contains minor sub-horizontal laminations. The fine-grained sand and higher silt content indicate deposition in a lower energy environment such as overbank deposits distal to an active river channel. Unit D underlies Unit C and the total depth is not known.

2.1.2 Hydrogeology

Groundwater occurs under unconfined conditions at the site. The sands and gravels of Units A and B form the primary aquifer at the site and the lower permeability soils of Units C and D may act as a local aquitard, limiting downward vertical flow. During Remedial Investigation drilling, groundwater was first encountered at depths ranging from 10 to 18 feet bgs. Groundwater levels measured at the monitoring wells are listed in **Appendix A**.

The hydraulic conductivity of the shallow aquifer (Unit A) ranges from 80 to 120 feet/day, based on an estimate using the Hazen (1911) method and the grain size distribution results for a representative soil sample collected from this aquifer.

A groundwater elevation contour map for the shallow aquifer, based on November 10, 2009 depth to groundwater measurements, is shown on Figure 4 in **Appendix B**. The groundwater elevation contours indicate groundwater flows to the north. The horizontal hydraulic gradient ranges from 0.006 foot/foot in the south and central part of the site (between monitoring wells RRN and P3-1), flattening to approximately 0.004 foot/foot in the northern part of the site between well P3-1 and the bank of the Puyallup River.

The vertical hydraulic gradient was calculated at the P2-1 to P2-3, P3-1 to P3-3, MW4S to MW4D, and MW6S to MW6D well clusters. The vertical gradients were calculated by dividing the head differential between the shallow and deeper well by the vertical distance between screen midpoints. The results indicate an upward vertical hydraulic gradient of 0.005 foot/foot between wells MW4S and MW4D and 0.0006 foot/foot between MW6S and MW6D, indicating upward groundwater flow from the deeper portion of the aquifer (Unit B) toward the shallow portion of the aquifer near the discharge point at the Puyallup River. A slight downward vertical gradient in the uppermost portion of the aquifer (Unit A) was calculated at the P2-1 and P3-1 well clusters.

The average linear velocity of groundwater flow in the shallow aquifer is estimated to range from 1 to 2 feet/day based on the range of hydraulic conductivities and horizontal hydraulic gradients determined for the site. An effective porosity of 0.32 was assumed for the velocity measurement.

2.1.3 Surface Water

The Puyallup River extends 54 miles, flowing in a northwest direction from its glacial source on the southwestern slopes of Mt. Rainier and discharging into Commencement Bay adjacent to the City of Tacoma. The river and its tributaries drain an area of about 1,000 square miles in Pierce County and southern King County. The portion of the river adjacent to the site and near the city of Puyallup, approximately 8 miles upstream from Commencement Bay, is characterized by water flows that average 6,926 cubic feet per second (ft^3/s) and range from 597 to 40,700 ft^3/s; the median discharge is just under 3,000 ft^3/s (USGS, 2008). Three dams built in the early to mid-1900s are located upstream of the site, and discharge at the reach of the river adjacent to the site is largely controlled by the operation of these dams.

The site falls within the lower Puyallup River valley and the 500-year Lower Puyallup floodplain as determined by the Federal Emergency Management Agency in 2007. Recently, Pierce County commissioned a flood protection investigation of the lower Puyallup River extending from its mouth to the Meridian Street Bridge in Puyallup and upstream of the site. Levees run the entire length of both banks of the river in this study area (Tetra Tech, 2008). Despite the flood control levees located along the bank of the Puyallup River, occasional overbank flooding occurs during the winter months.

Sediment conditions of the lower Puyallup River were characterized as part of a study commissioned by Pierce County (Tetra Tech, 2008). The study determined that a wide range of particle sizes are found in the Puyallup River. Coarser substrates (gravel and cobble) dominate the Puyallup River sediment upstream of its confluence with the White River and finer material (sands, silts, and clays) dominantly occur downstream of this confluence.

In the upper 3 miles of the study area, sediments collected from the river thalweg (the central, deepest part of the channel) are characterized as consisting of both poorly graded fine sand and poorly graded gravel (Tetra Tech, 2008). Most of the estimates of suspended sediment load at the USGS City of Puyallup gauge range from 100 to 1,000 tons/day (Tetra Tech, 2008). The area of the Puyallup River adjacent to the site is expected to have no or minimal sediment deposition (Tetra Tech, 2008).

2.1.4 Groundwater/Surface Water Interaction

Under normal hydraulic conditions, the Puyallup River is a gaining stream, meaning groundwater from the site discharges to the river. This relationship is reversed during periods of overbank flooding (which occurs occasionally in the winter), but this condition is transitory.

2.2 Soil Investigation

2.2.1 Description

A total of 45 surface soil samples were collected from a roughly 50-foot offset grid to characterize arsenic concentrations in surface soil. **Figure 2** shows the location of the surface soil samples. Samples were analyzed for total arsenic by field portable x-ray fluorescence (XRF) and/or laboratory methods.

Twenty-six soil borings arrayed on a 100-foot offset grid were advanced using direct push technology (DPT) to depths ranging from 16 feet to 68 feet bgs to characterize the lateral and vertical extent of arsenic. The boring locations are shown on **Figure 2**. At each boring drilled in 2009, soil samples were collected at approximate 2-foot depth intervals from the ground surface to approximately 16 feet bgs for field XRF analysis of arsenic. In 2010, soil samples were collected at approximate 2-foot intervals from the ground surface to a depth at which XRF results were less than 20 parts per million (ppm) total arsenic.

In 2009, three of the borings—designated A4, C4, and E4—were extended to depths of up to 68 feet bgs for stratigraphic control at the site. Soil samples deeper than 16 feet bgs at these borings were collected only for geologic characterization. During the 2010 field investigation, seven borings that had been drilled in 2009—B5, C3, C4, C6, C8, D3, and E2—were extended up to 36 feet bgs to characterize deeper arsenic concentrations. The borings drilled in 2010 were appended with the letter D (i.e., B5D) to differentiate them from borings drilled in 2009 (**Figure 2**).

2.2.2 Distribution of Arsenic in Soil

The distribution of residual arsenic in soil was investigated during the 2006 subsurface assessment and the RI conducted in 2009 through 2010. Arsenic soil data from both the assessment and RI are tabulated in **Appendix A** and shown graphically in isocontour plots prepared for the RI Report and provided in **Appendix B**.

To help understand the distribution of arsenic in soil, it is helpful to refer to selected RI figures provided in **Appendix B**:

- Figure 3, Geologic Cross Section
- Figure 5, Arsenic in Soil at the Ground Surface
- Figure 6, Total Arsenic in Soil From EL 32 to 30
- Figure 7, Total Arsenic in Soil From EL 30 to 28
- Figure 8, Total Arsenic in Soil From EL 28 to 26
- Figure 9, Total Arsenic in Soil From EL 26 to 24
- Figure 10, Total Arsenic in Soil From EL 24 to 22
- Figure 11, Total Arsenic in Soil From EL 22 to 20
- Figure 12, Total Arsenic in Soil From EL 20 to 18
- Figure 13, Total Arsenic in Soil From EL 18 to 16
- Figure 14, Total Arsenic in Soil From EL 16 to 14
- Figure 15, Total Arsenic in Soil From EL 14 to 12
- Figure 16, Total Arsenic in Soil From EL 12 to 10
- Figure 17, Total Arsenic in Soil From EL 10 to 8
- Figure 18, Total Arsenic in Soil From EL 8 to 6

- Figure 19, Total Arsenic in Soil From EL 6 to 4
- Figure 20, Total Arsenic in Soil From EL 4 to 2
- Figure 21, Total Arsenic in Soil From EL 2 to 0
- Figure 22, Total Arsenic in Soil From EL 0 to -2
- Figure 23, Total Arsenic in Soil From EL -2 to -4

Arsenic data shown in the isocontour plots in the figures listed above show the effects of the historical remedial action. Arsenic concentrations are generally low—typically less than 20 mg/kg—across the site at ground surface and in vicinity of the P3 well cluster at the 32 to 30 and 30 to 28-foot elevation intervals as shown in Figures 5, 6, and 7 in **Appendix B**. This likely represents low arsenic concentrations in fill imported and placed over a broad area after the 1985 remedial action, and recent (post-1985) deposition from overbank flooding. Between elevations 28 to 26 feet (**Appendix B** - Figure 8), arsenic concentrations are lower in the vicinity of the P3 well cluster than they are to the southwest. A similar picture emerges between elevations 26 to 24 feet (**Appendix B -** Figure 9), where arsenic concentrations are higher to the west and southwest than they are at the P3 well cluster.

Arsenic isocontours change dramatically in the 24 to 22-foot and 22 to 20-foot elevation intervals as shown in Figures 10 and 11 in **Appendix B**, where the highest arsenic concentrations are near the P3 well cluster. These data indicate that soil excavation in 1985 was focused on the northwest corner of property and that it reached approximately 8 to 10 feet below the current grade at its deepest.

Also note that the arsenic concentrations shown in Figure 12 (elevations 20 to 18 feet) through Figure 23 (elevations -2 to -4 feet) in **Appendix B** are from saturated soil samples collected below the water table. The shift of arsenic soil concentrations to the north of the P3 well cluster shown in Figure 12 in **Appendix B** likely represents transport of dissolved arsenic by groundwater, and subsequent adsorption or precipitation of this arsenic. Also note that the soil sample with the highest arsenic concentration (D3 at 12 feet bgs) is below the water table.

2.3 Groundwater Investigation

2.3.1 Description

Six new groundwater monitoring wells were installed in 2009 and four new wells were installed in 2010 at locations shown on Figure 2. All new monitoring wells were screened near the water table except MW4D and MW6D, which were screened in a deeper gravel unit within the aquifer (Unit B). The purpose of the shallow monitoring wells was to evaluate the extent of arsenic dissolved in groundwater and determine groundwater flow direction and hydraulic gradient. The purpose of the deeper monitoring wells (MW4D and MW6D) was to evaluate the vertical extent of arsenic groundwater downgradient of the P3 well cluster. Groundwater samples were collected from each well for dissolved arsenic analysis. Selected groundwater samples were analyzed for other metals, arsenic speciation, and conventional parameters (e.g., alkalinity, carbonate, chloride, sulfate, total organic carbon, etc.).

2.3.2 Distribution of Arsenic in Groundwater

The distribution of dissolved total arsenic in groundwater at the site is shown on Figure 24 in **Appendix B**. The highest arsenic concentrations were detected in the area focused around the P3 well cluster. A maximum dissolved arsenic concentration of 6,100 µg/L was detected in monitoring well P3-1, the shallowest well in the P3 well cluster.

Arsenic concentrations attenuate by nearly an order of magnitude between P3-1 and MW-6S (a distance of 135 feet), adjacent to the Puyallup River. Arsenic concentrations also attenuate with depth. This is illustrated in the P3 well cluster where arsenic was detected at 6,100 µg/L in shallow well P3-1, at 420 µg/L in mid-level well P3-2, and at 2 µg/L in P3-3, the deepest well in the P3 cluster. The vertical distance between the P3-1 and P3-3 screened intervals is approximately 10 feet.

2.4 Sediment Investigation

A bathymetric survey of the Puyallup River and topographic survey of the adjacent bank were completed in 2009. Elevation contours are shown in **Figure 2**. These surveys were performed to define the geometry of the zone where site groundwater discharged to the Puyallup River and assist in selecting sediment sample locations.

Four sediment samples (SED1, SED2, SED3, and SED4) were collected in 2009 and another five sediment samples (SED5, SED6, SED7, SED8, and SED9) were collected in 2010. Sample locations are shown on **Figure 2**. Samples SED1 through SED4 were collected from the river bank or river bottom at a depth of 2.5 feet below the surface of the Puyallup River. This depth was selected to correspond to the upper portion of the groundwater discharge zone, where the highest concentrations of arsenic were detected in groundwater at the P3 and P2 well clusters. Samples SED5 through SED9 were collected from the river bank or river bottom at varying depths. These sample locations were selected to further characterize arsenic concentrations on the bank and into the Puyallup River. The 2009 samples were analyzed for total arsenic by laboratory methods and the 2010 samples were analyzed for total arsenic by field XRF methods.

Arsenic concentrations in two of the nine sediment samples (SED3 and SED5) exceeded the Sediment Management Standards (WAC Chapter 173-204) freshwater sediment cleanup screening level of 120 mg/kg. The sediment cleanup screening level is the level established for minor adverse effects to the benthic community. Arsenic concentrations in three of the nine sediment samples (SED3, SED4, and SED5) exceeded the Sediment Management Standards freshwater sediment cleanup objective of 14 mg/kg, which is the no adverse effects level for the benthic community. These three samples are located along the river bank.

2.5 Arsenic Fate and Transport

Arsenic fate and transport at this location was developed from our understanding of the environmental history of the site, data collected during the RI, arsenic geochemistry, bench-scale testing, and geochemical modeling performed using site-specific data. The results of geochemical modeling are presented in the RI (CDM, 2011), while the bench-scale study results are presented in the supplemental bench-scale treatability report (CDM Smith, 2013).

Industrial waste fill that served as the original source of arsenic at the site was removed in 1985, along with some of the impacted native soil in the contaminant source area. However, RI soil data indicate that not all of the arsenic-impacted soil in the vadose zone was removed in 1985, and this impacted soil serves as an ongoing source of groundwater contamination at the site, driven by precipitation infiltrating through this arsenic-impacted soil.

Elevated arsenic concentrations occur in soil from ground surface and extend to at least 0 feet MSL as shown on **Appendix B** (Figures 7 through 21). The base elevation vadose zone (i.e., top of the water table) varies seasonally. For purposes of this FS, the base of the vadose zone in the contaminant source area during the dry season is at 20 feet MSL. Elevated arsenic concentrations in soil in the saturated zone (i.e., below elevation 20 feet MSL) extend to the north of the contaminant source area. The arsenic contamination identified in soil within the saturated zone is interpreted to have leached out of the overlying material, transported downgradient by groundwater flow, and then adsorbed to soil or precipitated out of solution. This is evident in Figure 12 (elevation 20 to elevation 18) in **Appendix B**, where a "plume-like" distribution of elevated arsenic concentrations in soil is shown hydraulically downgradient of the contaminant source area.

Appendix B includes groundwater isocontour plots for key geochemical indicators such as arsenite and arsenate, dissolved iron, redox potential, and total organic carbon (TOC). Arsenic fate and transport at the site are summarized below:

- Arsenic in the contaminant source area (P3-1, P3-2, MW2) is found predominantly in the oxidized arsenate (As V) form.

- Elsewhere in the plume, arsenic exists predominantly in the reduced arsenite (As III) form. Over time, arsenite is predicted to oxidize to the less mobile arsenate form.

- Iron and arsenic concentrations in groundwater at the site are likely controlled geochemically by ferric oxyhydroxides, the mineral scorodite, and green rust phases. This interpretation is based on electron microprobe analyses and site-specific geochemical modeling performed for the RI and supplemental bench-scale treatability study.

- Redox conditions at the site are not in equilibrium with arsenic, dissolved oxygen, or TOC due to the presence of a redox gradient.

- Arsenic transport in groundwater is significantly slower than the groundwater velocity, resulting in long travel times for arsenic to migrate downgradient from the contaminant source area. This is a result of adsorption of arsenic to the surfaces of iron-bearing minerals and co-precipitation with iron oxyhydroxides, which retards the transport of arsenic relative to groundwater.

- Arsenic is elevated in Puyallup River sediment downgradient of the contaminant source. This indicates that dissolved arsenic is transported to the river by groundwater flow. Dissolved arsenic then precipitates onto sediment upon coming in contact with the oxygenated surface water.

2.6 Drinking Water Supplies

Elevated arsenic concentrations in site groundwater do not pose a threat to the drinking water supplies of the City of Puyallup. The City of Puyallup currently obtains drinking water from two springs, from five deep wells, and from an intertie with the City of Tacoma. Salmon Springs is located northeast of the City of Sumner, which is located east of Puyallup, and provides approximately 59% of Puyallup's water supply. Well No. 27 is located in the southwest quadrant of the city and provides approximately 18% of the city's water. Maplewood Springs, also located in the southwest, provides approximately 14% of the city's water. Four wells, known as Wells No. 13, 17, 33, and 43, supply approximately 8% of Puyallup's water. Less than 1% of the city's water is provided by the City of Tacoma.

The Puyallup site is located in the northwest quadrant of the city. The closest production well is Well No. 17, which is located approximately 2,160 feet north of the Puyallup site (approximately 0.4 mile). The Puyallup site is located outside the wellhead protection zone defined for this well (Gray & Osborne, Inc., 2011). In addition, this well is completed in the regional confined aquifer and hydraulically separated from the alluvium (well depth of 884 feet bgs). It is the deepest well in the City of Puyallup's production well network.

2.7 Terrestrial Ecological Evaluation

A simplified terrestrial ecological evaluation (TEE) was conducted during the RI to assess the potential risk of exposure to wildlife from arsenic in soil. The simplified TEE exposure analysis concluded that there is a risk of exposure to terrestrial wildlife. However, the site is relatively disturbed and there is significantly less than 10 acres of native vegetation within the property boundaries and within 500 feet of the site. While the site is adjacent to a narrow band of public land at the top of the river bank, the area includes a paved public walking path and contains limited habitat values.

2.8 MTCA Cleanup Levels

MTCA, administered by Ecology (Washington Administrative Code [WAC] 173-340), establishes cleanup levels at contaminated sites. This section discusses cleanup levels and points of compliance. A cleanup level is the concentration of a particular hazardous substance that is considered a threat to human health or the environment. Points of compliance designate the location at a site where the cleanup level must be met.

Under MTCA, cleanup levels that are protective of human health may be established under Method A, B, or C, as applicable. Method A provides tables of cleanup levels for 25 to 30 of the most common hazardous substances, including arsenic, found in soil and groundwater. Method A cleanup levels are available for both unrestricted and industrial land uses.

Cleanup levels under Method B are based on unrestrictive land uses and established using applicable state and federal laws and risk-based concentrations calculated using the equations specified in the regulations. Method C is similar to Method B, but cleanup levels are based on less stringent exposure assumptions and the lifetime cancer risk for carcinogens is set at 1 in 100,000 instead of 1 in 1,000,000.

Use of Method C is limited to industrial sites where Method A or B cleanup levels are lower than technically possible, or when attainment of those levels may result in a significantly greater overall threat to human health and the environment. Method C requires that all practical methods of treatment have been used and institutional controls are in place. Natural background concentrations and the practical quantitation limit (PQL) are also considered when establishing Method A, B, or C cleanup levels.

In addition to consideration of human health impacts, Methods A and B must account for potential terrestrial or aquatic ecological impacts unless it can be demonstrated that such impacts are not a concern at the site. The FS evaluates whether a site-specific TEE is warranted. If a site-specific TEE is not performed, the contaminant concentrations provided in Table 749-2 of WAC 173-340 may be used to provide cleanup levels for the Remedial Investigation and cleanup process. Pursuant to WAC 173-340-7492 and the values listed in Table 749-2, an arsenic (+3) cleanup level of 20 mg/kg to a depth of 6 feet with institutional controls or a depth of 15 feet without institutional controls would be protective of terrestrial wildlife.

Determination of environmental effects on aquatic life may be determined from a literature search or whole effluent toxicity (WET) test (bioassay testing). Bioassay testing was not conducted for this site. Freshwater sediment cleanup screening levels and sediment cleanup objectives for protection of the benthic community are established in the Sediment Management Standards (WAC 173-204). The freshwater sediment cleanup screening level for arsenic is 120 mg/kg, which is the concentration that minor adverse effects are expected to the benthic community. The freshwater sediment cleanup objective is 14 mg/kg, which is the concentration that no adverse effects are expected to the benthic community.

Because of the site's proximity to the Puyallup River, surface water quality standards must also be considered when establishing cleanup levels. Method A surface water quality standards generally refer back to the water quality standards in WAC 173-201A. Method B and C values based on human health protection can be calculated from standard calculations in MTCA.

The state-designated uses of the Puyallup River, as identified in WAC 173-201A Table 602 – Use Designations for Fresh Waters by Water Resources Inventory Area, are:

- Aquatic Life Uses – core summer salmonid habitat
- Recreation Uses – primary contact
- Water Supply Uses – domestic water, industrial water, agricultural water, and stock water
- Wildlife habitat and harvesting
- Commerce, navigation and boating
- Aesthetic values

Review of Applicable or Relevant and Appropriate Requirements (ARARs) provided by Ecology for surface water in its Cleanup Levels and Risk Calculations (CLARC) database indicates that criteria based on human health are the most stringent criteria and would be the driver for cleanup. Ecology guidance indicates that if surface water is classified as suitable for use as a domestic water supply under state law, the cleanup level must be at least as stringent as the potable groundwater cleanup level established under WAC 173-340-720 to protect drinking water beneficial uses.

The MTCA Method A groundwater cleanup level for arsenic is 5 µg/L. This value is based on natural background concentrations for Washington State in accordance with WAC 173-340-720 and would be applicable to surface water.

2.9 Points of Compliance

This subsection discusses points of compliance for soil, groundwater, and sediment. The principal threat to receptors is posed by residual arsenic in soil leaching to groundwater. Dissolved arsenic is then transported via the groundwater pathway to Puyallup River surface water and sediment. Water supply for the site and surrounding area is supplied by deep groundwater supply wells hydraulically separated from the alluvium and from springs located a significant distance from the site. Therefore, impacted groundwater from the site does not pose an imminent threat to human health via the drinking water pathway.

Table 1 summarizes cleanup levels for arsenic relevant to the site based on affected media and protection of the various receptors of concern. **Figure 3** is a conceptual site model showing potential contaminant source and exposure routes and potential human receptors.

2.9.1 Soil

MTCA (WAC 173-340-740(6)(d)) indicates that the point of compliance for maximum depth of soil cleanup levels based on human exposure via direct contact is 15 feet bgs. An institutional control is not necessary if soil contamination is deeper than this since it is considered that this depth represents a reasonable estimate of the maximum depth at which soil could be excavated and distributed to the surface. For sites with soil contamination at shallower depths, Ecology may grant a site-specific conditional point of compliance as long as institutional controls (e.g., environmental covenant) are implemented.

The point of compliance for protection of human health via direct contact for the site is 15 feet bgs.

2.9.2 Groundwater

The point of compliance is the point(s) where the groundwater cleanup levels have been established. The standard point of compliance is throughout the site, both vertically and horizontally throughout the aquifer.

A conditional point of compliance may be used where it can be demonstrated that it is not practical to meet the cleanup level throughout the site. A conditional point of compliance cannot be outside of the property boundary except under three specific situations. One of these situations includes properties, such as the subject property, that abut surface water. Ecology may approve of a conditional point of compliance that is located within the surface water as close as technically possible to the point(s) where the groundwater flows into the surface water subject to the following conditions:

1) Contaminated groundwater is entering the surface water and will continue to do so after implementation of the selected cleanup action.

2) It is not practicable to meet the cleanup standard at a point within the groundwater before entering the surface water within a reasonable restoration time frame.

3) Use of a mixing zone to demonstrate compliance with surface water cleanup levels is not allowed.

4) Groundwater discharges shall be provided with all known available and reasonable methods of treatment prior to discharge to the surface waters.

5) Groundwater discharges shall not result in exceedances of sediment quality standards.

6) Groundwater and surface water monitoring shall be conducted to assess the long-term performance of the selected cleanup action, including potential bioaccumulation problems resulting from surface water concentrations below method detection limits.

7) A notice of the proposal shall be mailed to the natural resources trustees, the Washington State Department of Natural Resources, and the United States Army Corps of Engineers.

2.9.3 Sediment

Groundwater from the site discharges into a cut-bank reach of the Puyallup River that has been stabilized with riprap. The river bank and bed in the area of groundwater discharge are subject to strong erosive forces. Sediment in the geologic sense (solid material settling out of suspension in water) doesn't really occur at the site. For purposes of this FS, sediment refers to soil in the river bank that is subject to groundwater discharge from the site. No arsenic was detected in sediment samples collected from the river bed.

Section 3

Identification and Screening of Remedial Technologies

This section documents the initial steps required to:

- Develop and screen remediation options for contaminated site soil, groundwater, and sediment.
- Identify general response actions.
- Screen viable technology types to remediate contaminated soil and groundwater.
- Comply with MTCA requirements.

Remedial technologies that are carried forward into the detailed description of selected technology alternatives (Section 4) are also summarized.

3.1 General Response Actions, Technologies, and Process Options

General response actions are broad classes of actions that may satisfy MTCA requirements for the site. General response action categories for the site are assembled based on the nature and extent of contamination, as described in Section 2. General response actions considered applicable to the arsenic contamination found at the site include treatment, containment, excavation, extraction, disposal, institutional controls, or a combination of these categories. The seven general response actions include the following:

- No Further Action
- Institutional Controls
- Monitored Natural Attenuation (MNA)
- Containment
- *In-situ* Treatment (soil and groundwater)
- Groundwater Pumping and Treatment
- Excavation and Off-site Disposal

Specific remedial technologies and process options potentially applicable to the site have been identified within the general response actions listed above. These technologies are summarized in **Table 2**. The following subsections further describe, discuss, and evaluate each technology and its applicability to metals contamination in soil and groundwater at the site.

3.2 Screening of Remedial Technologies

This subsection describes screening and evaluation of potential technology types for remediating contaminated soil and groundwater at the site. **Table 2** summarizes this screening and evaluation process.

Screening and evaluation of remedial technologies and related process options are based on the type, distribution, and volume of arsenic found in soil and groundwater at the site and on the MTCA requirements discussed in Section 2. Technology types were identified for each general response action. One or more process options were identified for each technology and then each was reviewed against site-specific conditions and evaluated based on three preliminary criteria: effectiveness, implementability, and relative cost. The basis for applying each of these three criteria to evaluate an individual technology process option is described below.

Effectiveness Evaluation: This evaluation focused on the potential effectiveness of each process option in remediating the contaminated soil and groundwater and in meeting the MTCA requirements. Specific information considered included types and levels of contamination, volume and areal extent of contaminated soil and groundwater, and time required to achieve remediation goals. Each process option was classified as being effective, limited, or not effective.

Implementability Evaluation: This evaluation rated the relative degree of technical execution and feasibility of implementing the process option. Aspects considered included any substantive requirements of potential permits for actions; availability of treatment, storage, and disposal services; space constraints of the property and location of the Puyallup River; and availability of necessary equipment and skilled workers to implement the technology. The implementability of each process option was classified as easy, moderately difficult, difficult, or not implementable.

Cost Evaluation: Cost evaluation was based on engineering judgment, and each process option was evaluated relative to other process options of the same technology type. Both capital and operating costs were considered. The cost of each process option was classified as none, low, moderate, high, or very high.

The following subsections further describe and summarize the screening results for each general response action.

3.2.1 No Further Action

No Further Action implies that no remedial action will be conducted on the site. The site is allowed to continue in its current state, and no future actions are conducted to remove or remediate the contamination. No access restrictions are put into place, and no deed restrictions are placed on the site. The No Further Action response provides a baseline for comparison to other remedial response actions.

Effectiveness: The No Further Action option is not effective to remediate contaminated soil and groundwater at this site or meet MTCA requirements.

Implementability: The No Further Action option is easy to implement technically because it does not require any actions to be taken. Administrative implementability is not evaluated in this FS.

Cost: There are no construction or operation and maintenance costs associated with the No Further Action option because no actions are taken and no site monitoring is conducted.

Screening Summary: The No Further Action option will not achieve MTCA requirements and is not acceptable under MTCA, so it is not retained for further evaluation.

3.2.2 Institutional Controls

Institutional controls are non-engineering measures, such as administrative or legal controls, that help minimize the potential for human exposure to contamination and/or protect the integrity of a remedy by limiting land or resource use. Washington defines institutional controls under WAC 173-340-440 as *measures undertaken to limit or prohibit activities that may interfere with the integrity of an interim action or cleanup action or that may result in exposure to hazardous substances at a site*. These institutional controls may include:

- Physical measures such as fences.
- Restrictions such as limitations on the use of property.
- Maintenance requirements for engineered controls such as inspection and repair of monitoring wells, treatment systems, or groundwater pumping systems.
- Educational programs such as signs, postings, public notices, health advisories, mailings, and similar measures that educate the public about site contamination and ways to limit exposure.
- Financial assurances.

Effectiveness: Institutional controls can be effective at managing human exposure to contaminated soil and groundwater; however, they do nothing to reduce existing contaminant concentrations. The effectiveness of institutional controls depends on the mechanisms used and the durability of the institutional control. The need for human actions to implement and maintain the controls makes them less reliable than engineering controls. Overall, institutional controls are considered to have limited effectiveness except minimizing human exposure.

Implementability: Institutional controls are typically easy to implement.

Cost: Institutional controls are usually low cost.

Screening Summary: Institutional controls alone may not achieve MTCA requirements; however, when used in conjunction with other remedies, it can improve overall protectiveness. Therefore, institutional controls are retained.

3.2.3 Monitored Natural Attenuation

MNA refers to the reliance on natural attenuation processes to achieve site-specific remedial objectives within a timeframe that is reasonable compared to other more active methods (EPA, 1999). The processes, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil or groundwater. *In-situ* processes for metals include dispersion, dilution, sorption, precipitation, co-precipitation, and the chemical or biological stabilization or transformation of contaminants. Ecology expects that natural attenuation of hazardous substances may be appropriate at sites where:

- Source control (including removal and/or treatment of hazardous substances) has been conducted to the maximum extent practicable.
- Leaving contaminants on-site during the restoration time frame does not pose an unacceptable threat to human health or the environment.
- There is evidence that naturally occurring adsorption, precipitation, biodegradation, or chemical degradation is occurring and will continue to occur at a reasonable rate at the site.
- Appropriate monitoring requirements are conducted to ensure that the natural attenuation process is taking place and that human health and the environment are protected.

Effectiveness: The effectiveness of MNA at the site depends on site conditions such as source strength and persistence, soil adsorption capacity, soil and groundwater chemistry, pH, temperature, and oxidation-reduction potential. MNA can be effective at decreasing arsenic concentrations in groundwater when combined with source control measures and under certain geochemical conditions.

Implementability: Implementation of MNA as a remediation technology entails a groundwater monitoring program to provide data to evaluate attenuation rates and monitor plume extent. A monitoring well network exists at the site to adequately monitor natural attenuation. Equipment and methods to sample and analyze groundwater are readily available. Therefore, MNA is easy to implement.

Cost: Costs to implement and maintain a groundwater monitoring program to monitor natural attenuation are low to moderate, depending on the number of wells sampled and frequency and duration of sampling.

Screening Summary: MNA may be able to achieve MTCA requirements, and can improve overall protectiveness when used in conjunction with other remedies. MNA is typically used in conjunction with contaminant source control measures, where it will share the role of compliance monitoring. MNA will be retained for consideration, but not as a stand-alone remedy.

3.2.4 Containment

Containment serves two functions: 1) to isolate contaminated soil or groundwater to reduce the possibility of exposure by direct contact, and 2) to control or reduce migration of the contaminated materials into the surrounding environment. Containment actions for contaminated groundwater typically include horizontal or vertical barriers or hydraulic gradient controls.

Capping

The impacted area of the site is not paved and is subject to seasonal overbank flooding from the Puyallup River. An impermeable liner may be more suitable for the site and easier to implement than an asphalt cap. Containment actions typically involve an engineered cap to block a contaminant migration pathway such as the precipitation-to-soil pathway. The Puyallup site is atypical in that infiltrating precipitation will promote oxidizing groundwater conditions and decrease arsenic mobility.

Effectiveness: A liner at the site could reduce the infiltration of precipitation to soil and groundwater, especially at the contaminant source area, which is currently unpaved. However, arsenic fate and transport modeling indicates that oxidizing groundwater conditions at the site currently limit the mobility and transport of arsenic. Installing a liner over the contaminant source area might lead to more reducing conditions within the aquifer and increased arsenic mobility. Accordingly, installing a cap at the site would need to be approached cautiously.

Implementability: Capping is considered a standard construction practice and installing a liner could be moderately difficult to accomplish while providing for drainage in this low area. Equipment and construction methods associated with capping are readily available, and design methods and requirements are well understood.

Cost: A permeable cap for the site source areas would have moderate construction and low maintenance costs.

Screening Summary: This option is retained. Partial capping with an impermeable liner might be a component of a long-term remedy lf implemented properly.

Vertical Barriers

Vertical barriers are physical containment methods used to contain contaminated groundwater or direct its flow. Vertical barriers include slurry walls or curtains. At the Puyallup site, these types of vertical barriers would be used to direct the flow of contaminated groundwater toward an *in-situ* treatment wall in a “funnel and gate” arrangement.

The vertical barrier technology evaluated for this site is a slurry wall. Most slurry walls are constructed of a mixture of soil, bentonite, and water. The bentonite slurry is used primarily for wall stabilization during trench excavation. A soil-bentonite backfill material is then placed into the trench (displacing the slurry) to create the cutoff wall.

Walls of this composition provide a barrier with low permeability (typically 10^{-7} centimeters per second) and chemical resistance at low cost. Other wall compositions such as cement/bentonite, pozzolan/bentonite, attapulgite, organically modified bentonite, or slurry/geomembrane composite may be used if greater structural strength is required or if chemical incompatibilities between bentonite and site contaminants exist. Other critical factors include acceptability of site soil for use in backfill, trench stability, chemical compatibility, available work area, water availability, longevity, and availability of off-site backfill materials (if required).

Slurry walls can be constructed at depths up to 100 feet and are generally 2 to 4 feet thick. The most effective application of a slurry wall for site remediation or pollution control is to base (or key) the slurry wall 2 to 3 feet into a low-permeability layer such as clay or bedrock. This keying in provides an effective foundation with minimum potential for leakage of contaminated groundwater under the slurry wall.

Effectiveness: To be effective at the site, a vertical groundwater barrier would need to adequately reduce the rate of contaminated groundwater flow. This may require keying the barrier into the top of Unit C, which underlies the shallow aquifer, and may serve as a local aquitard. In addition, the use of slurry walls without a gate or hydraulic controls (such as pump-and-treat) would likely result in higher groundwater elevations behind the wall and sharp hydraulic gradients across the walls. Higher groundwater levels could saturate arsenic-impacted soils currently within the vadose zone, while a high gradient would put pressure on the walls and possibly affect their integrity.

Implementability: Groundwater containment can be difficult to achieve; however, these actions have been successfully implemented at other similar sites. A slurry wall depth of between 50 to 60 feet (the approximate depth of the aquitard) is within the normal range for excavation equipment used for constructing slurry walls. Groundwater containment using a vertical barrier such as a slurry wall is ranked as moderately difficult to implement.

Cost: A vertical groundwater barrier using a slurry wall at the site would have a moderate to high cost to construct. Maintenance costs of vertical groundwater barriers are considered low.

Screening Summary: Vertical groundwater containment using a slurry wall could improve overall protectiveness when used in conjunction with other remedies. Therefore, although a vertical groundwater barrier is not considered as a primary remedial method, it is retained as part of a funnel and gate remedy.

Hydraulic Containment

Hydraulic containment can be used to prevent the groundwater plume from impacting Puyallup River surface water and sediment. Typically, hydraulic containment includes using pumping wells, French drains, or extraction trenches to create hydraulic sinks that collect contaminated groundwater and reduce further migration. Hydraulic containment would require water treatment prior to on- or off-site disposal or reintroduction (see Section 3.2.6 for additional discussion of pump-and-treat technologies).

Effectiveness: Hydraulic containment via conventional extraction methods is expected to be effective at reducing arsenic contaminant migration in groundwater, but does not remediate contaminated soil in source areas. Some reduction in source area contaminant mass would be achieved by this approach since hydraulic containment requires the removal of contaminated groundwater; however, containment by itself would not remediate source areas to achieve groundwater standards in a reasonable timeframe. Hydraulic containment would be difficult to attain with extraction wells close to the Puyallup River. The river would act as a recharge boundary and affect the ability of the extraction wells to capture water from the plume.

Implementability: Equipment and construction methods associated with conventional hydraulic containment are readily available, and design methods and requirements are well understood. Pump-and-treat systems can be difficult to maintain and are prone to fouling. Iron fouling of the extraction wells would be a concern because a likely component for treating the arsenic plume would include injection of ferrous sulfate. Hydraulic containment is lost when components fail or are shut down for maintenance. The location of the potential extraction well network is in an area prone to overbank flooding. Submersion of the electronic pump controls is expected to be problematic. Therefore, hydraulic containment is ranked as difficult to implement.

Cost: The cost of groundwater containment at the site is ranked moderate to high when considering long-term operations and maintenance costs.

Screening Summary: Hydraulic containment is not retained due the proximately of the Puyallup River as a recharge boundary, and potential maintenance problems caused by overbank flooding and treatment of the arsenic plume using ferrous iron.

3.2.5 *In-Situ* Treatment

In-situ treatment consists of actions that treat contaminants in place and covers a broad range of technologies that include treatment of both soil and groundwater. Methods of *in-situ* chemical treatment generally involve adding reagents to the subsurface (via injection and deep mixing or treatment walls) that facilitate chemical stabilization or immobilization. *In situ* treatment can be applied to vadose zone soil and groundwater.

Vadose Zone Soil

In situ treatment of contaminated soil includes vitrification, soil flushing, chemical stabilization, and solidification. Vitrification solidifies the soil matrix by high temperatures created using electric current. *In-situ* treatment methods to separate and remove contaminants include soil flushing or electrokinetic separation. Soil flushing involves introducing mixtures of water, acids, chemical surfactants, or cosolvents into the subsurface to strip or dissolve contaminants and then remove them through groundwater extraction. Electrokinetic separation uses electricity to separate and collect metals at electrodes.

In-situ treatment of arsenic soil contamination by stabilization or solidification involves physical mixing or pumping of cement, grout, or other reagent into the contaminated vadose zone soil to limit the leachability of the arsenic. Solidification and stabilization of arsenic at the site was evaluated by two bench-scale studies. These are discussed below.

The first bench-scale study (CDM Smith, 2012) evaluated the proprietary metals immobilization reagents of three vendors: Adventus, Ivey International, Inc. (Ivey), and Regenesis. Of the three materials tested, only the Ivey Atomisol® product showed promise for further testing. The two other agents, both of which targeted reducing conditions, were not only ineffective, but actually increased arsenic mobility.

The second supplemental bench-scale study (CDM Smith, 2013) was conducted to verify the effectiveness of the Atomisol® product; evaluate non-proprietary, off-the-shelf solidification/ stabilization reagents; evaluate removal mechanisms and stability of the treatments; and conduct additional geochemical modeling to evaluate groundwater conditions and the need for plume treatment.

Effectiveness: Vitrification is a somewhat exotic and extremely expensive treatment technology that is usually reserved for highly concentrated contaminant sources. It is inappropriate for the Puyallup site where a major source control action has already occurred. Vitrification is not retained as a remedial technology and will not be considered further.

Soil flushing is an expensive and largely unproven technology that is not appropriate for the Puyallup site, considering that arsenic in the vadose zone is already proven to be quite mobile and the proximity of the contaminant source area to the Puyallup River. Soil flushing is not retained as a remedial technology and will not be considered further.

Electrokinetic separation is most effective in clay soil, whereas the contaminant source area vadose zone soil is primarily alluvial sand and silt. Electrokinetic separation is not retained as a remedial technology and will not be considered further.

Chemical stabilization and solidification were examined in the two bench-scale treatability studies. This batch testing showed that solidification/stabilization obtained better results than chemical stabilization alone (i.e., Atomisol® and ferrous chloride). The best solidification mix design was a formulation consisting of 13% cement, 2% bentonite, and an iron addition 5 times the amount of arsenic in the soil (on a molar basis). This mix design resulted in an arsenic leachability of 0.0175 mg/L. This represents an approximate 60-fold reduction in arsenic when compared to an untreated sample.

Research and electron microprobe analyses conducted as part of the bench-scale testing indicated that as part of the treatment of soil by solidification, chemical stabilization occurs in two ways: 1) iron and arsenic are incorporated into the calcium-silicate-hydrates (C-S-H) formed with the addition of Portland cement where iron substitutes for calcium and arsenic substitutes for silica; and 2) finely divided iron-arsenic oxyhydroxides are formed. These oxyhydroxides are bound up into the calcium-silicate-hydrates. Chemical stabilization using Atomisol® and ferrous chloride was relatively ineffective when compared to treatment with the solidification/stabilization formulations. Accordingly, solidification/stabilization is retained as a remedial technology for the site while chemical stabilization alone is not.

Groundwater

In-situ groundwater treatment commonly used for arsenic includes co-precipitation with iron by applying additional iron and driving groundwater to either oxidizing or reducing conditions. Site-specific bench-scale testing results (CDM, 2013) indicate that the adsorption capacity of soil is likely exceeded in the center of the arsenic plume at the Puyallup site. Ferrous iron will need to be added to groundwater to drive co-precipitation of iron and arsenic to achieve arsenic cleanup standards. The iron-arsenic precipitates can be either oxyhydroxides or sulfides depending on whether oxidizing or reducing conditions are created. These approaches are described in detail below.

Oxidizing groundwater conditions can be achieved by either air sparging or by injecting/introducing an oxidant like permanganate or peroxide. Arsenite (As III) can be oxidized to the less mobile arsenate (As V) form using chemical oxidants, but the reaction is very slow for air sparging. Once oxidized, the arsenic is more efficiently removed from the groundwater, *in-situ,* as an iron-arsenic oxyhydroxide co-precipitate.

In-situ precipitation of arsenic can also be accomplished by creating reducing groundwater conditions. With this treatment method, a solution of iron is injected with an organic substrate. The reducing conditions created by bacterial action on the organic substrate keep the iron in the reduced ferrous state, allowing it to remain dissolved in the groundwater. Naturally occurring sulfate in the aquifer is reduced to sulfide, which then reacts with ferrous iron to precipitate out as iron sulfide. Iron sulfide can co-precipitate arsenic into its matrix and also provides a surface area that is highly sorptive.

Another form of *in-situ* groundwater treatment uses permeable treatment walls or gates, also known as permeable reactive barriers (PRBs). A PRB would most likely use ZVI or a proprietary metal remediation compound such as Adventus EHC-M® to treat arsenic. Groundwater with dissolved arsenic comes into contact with the ZVI, which corrodes (rusts), forming a high surface area material that has a high adsorption capacity for arsenic. PRBs are placed in the subsurface across the natural flow path of the contaminant plume. They can be combined with vertical barriers (e.g., slurry wall) in a funnel and gate arrangement in which groundwater flow is directed through the treatment wall or gate.

Effectiveness: Air sparging is not expected to be an effective treatment method in the contaminant source area because the majority of arsenic outside of the contaminant source area is in the As III valence state. As mentioned previously, As III oxidation by air is very slow. Air sparging may also lead to stripping of carbon dioxide from the groundwater, resulting in a pH increase and precipitation of carbonate minerals such as calcite. Precipitation of carbonates as well as iron oxyhydroxides could lead to plugging of the sparging wells. Injecting an oxidant (e.g., peroxide or permanganate) is a better method to create oxidizing conditions for *in-situ* treatment of arsenic at the site without stripping carbon dioxide from the groundwater. In addition, an air sparging system would be difficult to operate in a location prone to seasonal overbank flooding.

Creating reducing groundwater conditions to precipitate iron-arsenic sulfides is a potentially applicable approach to treating arsenic in groundwater. However, in order to be effective, the conditions within the aquifer must be sulfate-reducing. Should the reducing agent achieve only iron-reducing conditions, the arsenic mobility at the site could actually be increased due to the dissolution of arsenic-bearing iron oxyhydroxides. Bench-scale testing conducted for the Puyallup site demonstrated that reagents that targeted reducing conditions were ineffective and increased arsenic mobility.

Geochemical conditions are likely to be sufficiently stable for a permeable reactive barrier to be effective. Typical pH values within a ZVI-based PRB are about 10 standard units, which could lead to precipitation of iron carbonate (siderite) and/or calcite and plugging of the wall. Bench-scale and pilot-scale studies would be required to better predict treatment effectiveness of this remedial technology.

Implementability: Implementability of *in-situ* treatment technologies varies widely, ranging from moderately difficult to difficult at the Puyallup site. The contaminant source area is relatively open and accessible, meaning the deep mixing augers used for soil solidification could be deployed at the site. However, the potential scale of operations indicates that soil solidification would be moderately difficult to implement. Injecting an oxidant or other reagents to treat arsenic-contaminated groundwater would be moderately difficult to implement. A PRB constructed downgradient of the contaminant source area would be moderately difficult to implement because of the potential depth of the wall, which would likely be greater than 40 feet.

In-situ treatment methods for groundwater would require pilot testing to demonstrate effectiveness and provide design data.

Cost: The cost of *in-situ* treatment varies with the specific technology. The costs of reagent injections to treat groundwater and air sparging are moderate to high. The cost of solidification to treat vadose zone soil is considered moderate to high, especially because of mobilization costs. The cost of *in-situ* soil flushing and electrokinetic separation is considered to be high. The construction cost of a PRB is expected to be high, but the maintenance costs are typically low.

Screening Summary: *In-situ* treatment methods cover a broad range of technologies. Most *in-situ* treatment methods are associated with a high degree of uncertainty regarding implementability and attaining MTCA requirements. **Table 2** identifies *in-situ* technologies retained for further evaluation.

3.2.6 Groundwater Extraction and Treatment

Collection, treatment, and discharge (pump-and-treat) can be used to reduce groundwater arsenic levels more rapidly than plume containment or MNA. In addition, a pump-and-treat system can be used to lessen further plume migration.

An extraction system would be used to remove contaminated groundwater from the affected aquifer. This step is followed by treatment, if required, and discharge or reinjection of treated water back into the aquifer. Extraction can be achieved by using pumping wells, French drains, or extraction trenches. Pumping may be continuous or pulsed to remove contaminants after they have been given time to desorb from the aquifer material and equilibrate with groundwater.

Above-ground treatment may involve physical and chemical processes such as adsorption/absorption, ion exchange, membrane filtration, precipitation/coagulation, or evaporation, depending on the physical and chemical properties of the contaminants. Discharge options at the site include discharge to a publically owned treatment works (POTW), groundwater reinjection, or discharge to surface water.

Pump-and-treat expands on the hydraulic barrier option described previously by providing a means for treatment and discharge of the extracted groundwater.

Extraction Wells and Collection Trenches

Groundwater extraction wells are considered more applicable to the site source area than collection trenches. Extraction wells are drilled into the aquifer and completed with a well screen and pump placed below the water table. Design of the extraction wells, including spacing, would be based on aquifer characteristics such as hydraulic gradient and hydraulic conductivity.

Computer modeling may be used to predict required well spacing and pumping rate, but a pumping test may be recommended to further define aquifer characteristics. Extraction wells could be designed to remove water from specific depths within the aquifer or from across the entire saturated thickness.

Effectiveness: Collection trenches are considered to have limited effectiveness at the site. Extraction wells are considered effective for intercepting and extracting groundwater and plume control. Pump-and-treat could be effective at removing arsenic mass from the area around the P3 well cluster or preventing off-site migration of contaminated groundwater through hydraulic containment. Pump-and-treat is not expected to be effective at remediating the source materials to the point where groundwater would one day no longer require treatment. Although pump-and-treat can remove a significant mass of arsenic, desorption and dissolution reactions from the source material are diffusion-limited, resulting in diminishing returns over time.

Implementability: Collection trenches would be moderately difficult to implement at the site. Extraction wells are easy to construct and are a well-established and widely available technology.

Cost: Extraction well capital and maintenance costs are considered moderate to high and depend on the number of wells or trenches that must be installed and the length of operation.

Screening Summary: Pump-and-treat scenarios using extraction wells are effective methods for containing and treating groundwater, but it is unknown if MTCA Method A groundwater cleanup standards could be met within a reasonable timeframe. This technology using extraction wells is considered further as an alternative in conjunction with treatment and discharge options and also in conjunction with soil/source removal remedial methods.

Physical/Chemical Treatment of Extracted Groundwater

Adsorption: Adsorption treatment involves pumping groundwater through a series of vessels that contain arsenic-adsorbing media. Numerous types of adsorption media are available and include iron-based sorbents and activated alumina. Spent treatment media may be either removed and regenerated or disposed of and replaced with new media. Spent arsenic adsorbing media typically pass TCLP tests and are disposed of as non-hazardous waste rather than being re-generated.

Manganese has not been measured in site groundwater but, if present, can also be problematic because coatings of manganese oxides or carbonates can passivate the surfaces of the media. Precipitation of calcite is predicted to occur in response to carbon dioxide degassing (based on modeling presented in the RI). Calcite also has the potential to passivate the media or cause plugging issues. The use of adsorptive media would be effective only when used in conjunction with a pre-oxidation/precipitation/filtering step.

Ion Exchange: Ion exchange removes ions from the aqueous phase by exchanging cations or anions between the contaminants and the exchange medium. Ion exchange materials may consist of resins made from materials containing ionic functional groups that attach to exchangeable ions. Resins can be regenerated for re-use after the capacity of the resin has been exhausted.

Membrane Technologies: Membrane technologies can include microfiltration, reverse osmosis (RO), or electrodialysis. RO and microfiltration is the process of pushing a solution through a filter that traps solute on one side and allows the solvent to pass through to the other side. This process is best known for its use in desalination, but has been routinely applied for metals treatment. RO treatment results in the production of brine that typically represents 20 percent of the water volume treated, depending on the efficiency of the system. The RO brine would require disposal or additional treatment.

Electrodialysis is a physical method for removing ionic contaminants. Contaminated water is exposed to electric current as it passes through a semi-permeable membrane. This action separates the contaminant ions from groundwater and surface water. This technology is not retained because of the waste brine it would generate.

Evaporation Ponds: Extracted groundwater can also be discharged to lined ponds and allowed to evaporate. The ponds would periodically be dried and sludge removed and disposed of. This technology has limited effectiveness at the site because of the wet and cool climate and the limited site area available for evaporation ponds. This remedial technology is not retained.

Effectiveness: As can be seen by the descriptions above, there are numerous treatment technologies that could be effective for removing arsenic from groundwater extracted at the site. Technology selection would depend on the POTW, groundwater, or surface water discharge requirements as described below. Groundwater pump-and-treat would be potentially effective in a hydraulic control scenario when combined with re-introduction of treated groundwater and *in situ* application of ferrous iron. Pump-and-treat would also be potentially effective at removing arsenic from groundwater to address high concentrations of this contaminant in groundwater in the vicinity of the P3 well cluster. However, groundwater pump-and-treat as a sole remedy has a poor record of achieving groundwater cleanup standards in a reasonable timeframe.

Implementability: Precipitation/coagulation/flocculation and membrane filtration are readily available technologies and would be relatively easy to moderately difficult to construct and implement at the site. Depending on the size of the required facility, sufficient space may be available on-site for facilities and infrastructure.

Cost: Treatment using precipitation/coagulation/flocculation and membrane filtration is considered to have moderate to high capital and operation and maintenance costs.

Screening Summary: All identified treatment technologies except evaporation ponds and membrane technologies are retained as potential options. The most appropriate technology or combination of technologies will be selected after bench or pilot studies. Pump-and-treat scenarios using on-site precipitation/coagulation/flocculation are retained for further evaluation as a representative treatment technology. The technology is considered further as an alternative in conjunction with groundwater extraction and discharge options.

Treated Groundwater Discharge

Injection Wells or Trenches: Reinjection of treated water into the aquifer would require that the water be treated to concentrations that meet site-specific remediation levels. Reinjection can increase the hydraulic gradient in the aquifer and therefore the effectiveness of downgradient extraction wells. At the Puyallup site, treated groundwater could be re-injected using an upgradient infiltration gallery.

Discharge to Surface Water: Discharge to surface waters would require the water meet surface water quality standards. The volume of treated water discharged in this manner is not expected to have any limitations. Achieving surface water quality standards for arsenic using on-site pre-treatment may be difficult. Discharge to surface water is not retained in conjunction with extraction and treatment options.

Discharge to a POTW: Treated groundwater can be discharged to a POTW. Discharge to a POTW would require that site effluent meet permit requirements for the POTW and that there is adequate capacity to receive the treated flows. Discharge of groundwater to a POTW is retained.

Effectiveness: Discharge of treated groundwater to an infiltration gallery or POTW are potentially viable and effective technologies.

Implementability: Discharge of treated groundwater to an infiltration gallery would be moderately difficult to implement. Discharge to the POTW would be easy to implement.

Cost: The cost of discharging treated groundwater to an infiltration gallery or to the POTW is considered moderate or high, respectively.

Screening Summary: Pump-and-treat scenarios using on-site pre-treatment and discharge to an infiltration gallery or POTW are retained for further analysis.

3.2.7 Soil Excavation, Transport, and Disposal

This remedial technology was used during the 1985 source removal action. RI data indicate the source removal action was successful and that virtually all of the arsenic-impacted waste material was removed from the site and disposed of off-site. However, arsenic leached out of this waste material prior to the 1985 source removal action and was attenuated onto the underlying soils. These soils represent a secondary source that exceeds current MTCA cleanup standards.

This action involves excavation of contaminated soil and fill exceeding soil cleanup standards. Excavated soil and fill would then be transported off-site and disposed of in a landfill. Contaminated soil and fill would be excavated using conventional earth-moving equipment such as front-end loaders and hydraulic excavators.

Excavated soil exceeding the cleanup standard would be transported off-site in trucks to a transfer station in Tacoma. The contaminated soil and fill material would then be shipped by rail to Waste Management's Columbia Ridge Facility or Allied Waste's Roosevelt Landfill for disposal.

Soil with arsenic concentrations below the cleanup levels would need to be excavated to access all of the soil that exceeds the cleanup levels, especially with depth of the excavation. This 'clean' soil would be stockpiled on-site and used to backfill the excavation.

Likewise, contaminated sediment from the Puyallup River could be dredged or excavated and transported off-site for disposal. Following removal, the embankment would be restored to riparian habitat similar to the adjoining embankment.

Effectiveness: Excavation and off-site disposal of soil and fill exceeding cleanup standards for arsenic would be effective in achieving soil and sediment cleanup standards provided that all of the soils are accessible and can be removed

Implementability: Excavation and removal of contaminated soil above the water table should be relatively straightforward; however, note that the 1985 removal action encountered issues with caving sands at the site in the northwest corner of the property where elevated arsenic concentrations remain. Soil excavation below the water table and near the Puyallup River would be difficult because it would require temporary shoring and dewatering.

Cost: Excavation and removal of contaminated soil beneath the water table is expected to have a very high cost. At the Puyallup site, a considerable volume of 'clean' fill was used to backfill the contaminant source removal excavation. This fill would need to be excavated and stockpiled to reach deeper arsenic-impacted fill material and soil.

Screening Summary: Excavation and removal of contaminated soil and disposal at an off-site facility is expected to meet MCTA requirements for soil and sediment. This option is retained for further evaluation as an alternative.

3.3 Initial Alternatives Screening Summary

Technologies that are retained for further consideration in this FS include:

- Institutional Controls
  - Land use restrictions, groundwater use restrictions, and site administrative procedures
- Monitored Natural Attenuation and Compliance Monitoring
- Containment
  - Horizontal barrier (liner cap)
  - Vertical barrier (slurry wall)
- *In-Situ* Treatment

  - Oxidant injection (groundwater)
  - Permeable reactive barrier (groundwater)
  - Solidification (soil)
- Groundwater Pump-and-Treat
  - Extraction wells
  - On-site pre-treatment by precipitation/coagulation/flocculation
  - Discharge of groundwater to an infiltration gallery or the POTW
- Soil and Sediment Removal
  - Excavation and off-site disposal of soil and sediment exceeding cleanup levels.

Section 4

Remedial Action Alternatives

4.1 Remedial Goals and Objectives

The overall goals for the proposed remedies at this site are to:

- Protect human health and the environment.
- Comply with applicable regulations.
- Satisfy all provisions of the Order and receive written notification from Ecology that USG has completed the remedial activity required by the Order.

The following remedial action objectives (RAOs) have been developed to meet these overall goals.

Remedial Action Objective #1 – Remediate Soil Exceeding Cleanup Levels. Arsenic exceeds MTCA cleanup levels over a wide area. The objective of this remedial action is to prevent exposure or remediate soil to be protective of human health and environmental receptors.

Remedial Action Objective #2 – Achieve MTCA Method A Cleanup Standards for Arsenic in Groundwater at the Standard Point of Compliance. Remediate groundwater to achieve MTCA Method A cleanup standards for arsenic in groundwater across the entire site. This RAO will be used in conjunction with RAO 3.

Remedial Action Objective #3 – Mitigate Arsenic in Groundwater to be Protective of Surface Water or Sediment at a Conditional Point of Compliance. Set a conditional point of compliance for groundwater in pore water adjacent to the Puyallup River or at groundwater monitoring wells adjacent to the river. This point of compliance would be protective of Puyallup River surface water and sediment. A conditional point of compliance would be established if achieving RAO 2 is technically impracticable or disproportionately costly.

Remedial Action Objective #4 – Remediate Sediment Exceeding Cleanup Levels. Sediment at the bank of the Puyallup River exceeds cleanup levels for arsenic. The objective of this remedial action is to remove impacted sediment to protect ecological receptors.

4.2 Remedial Technologies Evaluation

Section 3 and **Table 2** screened out remedial technologies that are not applicable to the site. This subsection evaluates the remaining remedial technologies potentially capable of meeting the RAOs listed in Section 4.1 by evaluating them against the criteria listed in WAC 173-340-360, Model Toxics Control Act, "Selection of Cleanup Actions."

4.2.1 Minimum Requirements

CDM-Smith used minimum requirements drawn from WAC 173-340-360 (2) to develop the remedial action alternatives. These minimum requirements are divided into "threshold requirements" and "other requirements." The threshold requirements are:

1. Protect Human Health and the Environment: This includes an evaluation of the degree to which existing risks to human health and the environment are reduced,
2. Compliance with Cleanup Standards: This includes an evaluation of the cleanup alternative and its ability to meet or exceed cleanup levels established in accordance with MTCA requirements.
3. Compliance with Applicable State and Federal Laws: Cleanup actions must comply with existing state or federal laws.
4. Compliance Monitoring: The cleanup action must provide for monitoring to verify that the cleanup action achieves cleanup or other performance standards and that it remains effective over time.

Remedial action alternatives that meet the threshold requirements must also: 1) provide permanent solutions to the maximum extent practicable, 2) have a reasonable restoration time frame, and 3) consider public concerns. MTCA refers to these as "other requirements," which are a subset of the minimum requirements.

Remedial action alternatives that do not meet the minimum requirements are not considered further. An example of this would be a remedial action alternative that used only institutional controls and MNA. A remedial alternative consisting of these two remedial technologies would not meet MTCA's minimum requirements for a cleanup action. Institutional controls and MNA are included in the remedial action alternatives, but only in combination with active remedial technologies.

4.2.2 Remedial Technologies Evaluation

CDM Smith evaluated the most promising remedial technologies and compared them to the RAOs for applicability. The result of our evaluation is shown on **Table 3**. The criteria are "yes," "uncertain," and "not applicable."

4.3 Description of Remedial Action Alternatives

Three remedial alternatives have been developed based on the retained technology options. These three remedial alternatives are summarized in **Table 4**. Although additional combinations of technology options are possible, the alternatives presented here are considered to represent a reasonable range of approaches and costs.

4.3.1 Technical Basis for Determining the Extent of Treatment Area for Soil Solidification

Remedial action alternatives 1 and 2 use solidification/stabilization to treat arsenic impacted soil in the vadose zone. This subsection provides the technical basis for how the treatment area for soil solidification was developed.

As shown in **Appendix B**, arsenic in soil has a heterogeneous spatial distribution with depth as shown in the 2-foot elevation intervals. Soil solidification is typically performed with auger mixing of soil, where mixing is conducted while injection of a cement-based reagent and stabilization agent is also occurring. The auger is typically raised and lowered two to three times during the injection to provide adequate mixing. Two features of soil solidification by auger mixing become evident:

- Arsenic tends to be transported and homogenized over the vertical extent of the treatment zone due to the mixing action of the auger as it is raised and lowered.

- Soil solidification by auger mixing is a mass-production operation. Thus, it is not practical to target individual depth intervals for treatment.

The geospatial analysis performed during the RI consisted of variogram analysis followed by block kriging. This produced a series of soil arsenic concentration maps at 2-foot elevation intervals. In addition to the contour maps (shown in **Appendix B**), this analysis calculated an average arsenic concentration for each 20-foot by 20-foot by 2-foot block of soil**.** Note that the 20-foot length and 20-foot width are nominal dimensions used for purposes of discussion. The actual dimensions determined by the kriging algorithm are 19.72 feet by 19.81feet. These actual dimensions are used for volume calculations.

For the purposes of this analysis, the thickness of the vadose zone is approximately 12 feet (in the unpaved northern portion of the site), corresponding to 32-foot to 20-foot elevation intervals. While these intervals will vary seasonally with the depth of the water table, this assumption is appropriate for a Feasibility Study level estimate. Thus, the mean arsenic concentration in the vadose zone for each 20-foot by 20-foot block was calculated by finding the average concentration of the 6 corresponding 2-foot intervals.

The resulting calculations are presented in **Appendix C**, which shows the percentage of the mass of arsenic (=/> 20 mg/kg arsenic) treated with “cut” lines ranging from 20 mg/kg to 320 mg/kg, and the number of "blocks" and a map showing the average concentrations. Three scenarios are analyzed: 1) treating all soil with average arsenic concentrations greater than 90 mg/kg, 2) treating all soil with arsenic with average arsenic concentrations of 50 mg/kg, and 3) treating all soil with average arsenic concentrations greater than 20 mg/kg. Scenarios 1 and 2 treat 70 percent and 82 percent of the arsenic mass in vadose zone soil, respectively.

4.3.2 Remedial Action Alternative 1

Under this remedial action alternative, soil with arsenic concentrations exceeding 20 mg/kg (scenario 3 as defined in Section 4.3.1) would be treated by solidification/stabilization and vertical auger mixing. This treatment area is shown on **Figure 4**. Bench-scale testing performed previously (CDM Smith, 2013) showed that the most effective solidification/stabilization mix design was a formulation consisting of 13% cement, 2% bentonite, and an iron addition 5 times the amount of arsenic in the soil (on a molar basis).

The treatment zone at Puyallup is relatively shallow. This will allow use of a large-diameter auger (diameters ranging from 3 feet to 12 feet) to uniformly mix the soil while injecting the solidification reagent. Vertical auger mixing is typically applied in an overlapping "brick" pattern that provides full horizontal and vertical coverage of the proposed treatment area. Soil solidification is planned for the fall, when groundwater levels are lowest, to allow solidification of contaminated soil that is in seasonal contact with the water table. Monitoring wells within the treatment area would be abandoned prior to mobilizing the solidification equipment. As shown in **Appendix C**, remedial action alternative 1 calls for the treating 193 20-foot by 20-foot by 12-foot "blocks," corresponding to approximately 33,500 cubic yards of soil.

Groundwater would be treated using a funnel (slurry wall) and gate (PRB) approach. The conceptual layout of the funnel and gate system is shown on **Figure 4**. The effectiveness of this treatment would be determined by performance groundwater monitoring. For cost estimating purposes, it was assumed that the slurry wall would extend down to the aquitard, an estimated depth of 45 feet. The total length of the two sides of the funnel is 640 feet.

The PRB will be constructed of ZVI and is assumed to have a top depth of 10 feet bgs and a base of 45 feet bgs. It is assumed the PRB will be replaced every 10 years or twice during the duration of the remediation.

The effectiveness of the PRB in treating the arsenic plume will be assessed by performance groundwater monitoring. The cost estimate assumes the groundwater performance monitoring will be semi-annual for the first 5 years and annual afterward for a total of 30 years.

The final remedial action objective is remediating Puyallup River sediment. The extent of the remediation area is shown on **Figure 4**. Sediment cleanup would be implemented when soil and groundwater cleanup actions have demonstrated that there is no risk of recontamination of sediment from groundwater.

The Puyallup River sediment cleanup would take place during an in-water work period. The area of sediment cleanup used for cost estimating purposes is shown on **Figure 4** and includes all arsenic sediment concentrations exceeding the current no-effects sediment arsenic level of 14 mg/kg. A sediment sampling round would need to be performed prior to cleanup to provide current data. A site-specific arsenic cleanup level may be developed using a human health and environmental risk assessment as described in WAC 173-304.

Sediment cleanup is expected to be relatively simple from a construction standpoint, with an excavator digging sediment from the river bank and loading it into trucks. Turbidity resulting from the excavation would be managed using silt curtains.

4.3.3 Remedial Action Alternative 2

Remedial action alternative 2 evaluates solidification to treat the 3 different arsenic cut-lines defined in Section 4.3.1 as sub-alternatives. Remedial action alternative 2a treats soil with arsenic concentrations exceeding approximately 90 mg/kg; remedial action alternative 2b treats soil with arsenic concentrations exceeding approximately 50 mg/kg; and remedial action alternative 2c treats soil with arsenic concentrations exceeding 20 mg/kg (the same as remedial action alternative 1). Soil would be treated by solidification/stabilization and vertical auger mixing. The treatment areas are shown on **Figures 5a**, **5b**, and **5c**. As described earlier, bench-scale testing performed previously (CDM Smith, 2013) showed that the most effective solidification mix design was a formulation consisting of 13% cement, 2% bentonite, and an iron addition 5 times the amount of arsenic in the soil (on a molar basis).

Soil Solidification - Overview

As described in Section 4.3.2, the treatment zone at Puyallup is relatively shallow, allowing use of a large-diameter auger (diameters ranging from 3 feet to 12 feet) to uniformly mix the soil while injecting the solidification/stabilization reagent. Vertical auger mixing is typically applied in an overlapping "brick" pattern that provides full horizontal and vertical coverage of the proposed treatment area. Soil solidification is planned for the late fall, when groundwater levels are lowest, to allow solidification of contaminated soil that is in seasonal contact with the water table. Monitoring wells within the treatment area would be abandoned prior to mobilizing the solidification equipment.

The following sections describe the remedial action sub-alternatives. These sub-alternatives differ primarily in the amount (volume and areal extent) of soil solidified. As shown on **Figures 5a**, **5b**, and **5c**, some other features of the remedial action sub-alternatives (for example – the location of the ferrous iron injection trench) are adjusted to be outside the solidified soil area, but these adjustments are not expected to significantly affect the cost estimates.

Proposed Soil Solidification Area - Remedial Action Alternative 2a

As shown on **Figure 5a** and in **Appendix C**, remedial action alternative 2a specifies treating 66 20-foot by 20-foot by 12-foot soil "blocks", corresponding to approximately 11,460 cubic yards of soil. Treating this area will solidify approximately 70% of the arsenic in vadose zone soil that is above the cleanup level. This metric was selected because it treats the soil in the contaminant source area and the surrounding soil. Soil above the cleanup level and outside of the treatment area shown on **Figure 5a** can be addressed in several ways:

- Shallow arsenic soil hot spots (such as encountered in boring A-6) can be excavated and transported to the treatment area for solidification.
- Institutional controls can be implemented to limit potential human contact with the soil exceeding the cleanup level.
- Potential impacts to groundwater from arsenic leaching out of vadose zone soil from peripheral areas can be addressed by *in-situ* treatment using ferrous iron and oxidants as described below.
- Areas outside the solidification area shown on **Figure 5a** can be solidified later (greater than 20 mg/kg and less than 90 mg/kg arsenic) if an analysis of performance monitoring data indicates that this will result in attainment of the groundwater cleanup standard.

Proposed Soil Solidification Area - Remedial Action Alternative 2b

As shown on **Figure 5b** and in **Appendix C**, remedial action alternative 2b specifies treating 95 20-foot by 20-foot by 12-foot soil “blocks”, corresponding to approximately 16,500 cubic yards of soil. Treating this area will solidify approximately 82% of the arsenic in vadose zone soil that is above the cleanup level. This metric was selected to provide an intermediate solidification scenario between 90 mg/kg and 20 mg/kg arsenic. Methods to address soil above the cleanup level in the area surrounding the treatment area shown on **Figure 5b** are the same as described in the section above for remedial action alternative 2a.

Proposed Soil Solidification Area – Remedial Action Alternative 2c

As shown on **Figure 5c** and in **Appendix C**, remedial action alternative 2c specifies treating 193 20-foot by 20-foot by 12-foot soil “blocks”, corresponding to approximately 33,500 cubic yards of soil. Treating this area will solidify all of the arsenic in vadose zone soil that is above the cleanup level.

Qualitative Analysis of Remedial Action Alternative 2 Sub-Alternatives

The sub-alternatives presented under remedial alternative 2 present a somewhat unique balancing of risks in remediating arsenic in soil and groundwater. Clearly, the residual arsenic hot-spot in soil centered at the P3 well cluster needs to be remediated to address the co-located arsenic hot-spot in groundwater. All of the remedial alternative 2 sub-alternatives treat the arsenic soil hot-spot and the surrounding soil by solidification. In addition, remedial alternative 2 (all sub-alternatives) treats arsenic in groundwater (both in the hot-spot and in the surrounding area) by injecting ferrous iron and an oxidant.

On the other side of the ledger, the oxidizing groundwater conditions at the site (caused by infiltrating precipitation) are currently attenuating dissolved arsenic in groundwater by precipitation of iron-arsenic oxyhydroxides. A risk faced in selecting a more robust soil solidification sub-alternative is if too much soil is solidified (over too great an area), this will cause less precipitation to infiltrate near the heart of the plume, making groundwater conditions more reducing. More reducing groundwater conditions will tend to increase the mobility of arsenic in groundwater.

When comparing the solidification areal extent of the sub-alternatives, sub-alternative 2c encompasses approximately 3 times the surface area as sub-alternative 2a (compare **Figures 5a** and **5c**). Clearly, if the area shown on **Figure 5c** is solidified, the existing, favorable patterns of precipitation infiltration will be drastically altered, potentially making groundwater conditions more reducing. In addition, the solidification area shown on **Figure 5c** will be difficult to construct from a practicality standpoint.

When comparing sub-alternatives 2a and 2b, sub-alternative 2b encompasses an approximately 50% greater surface area when compared to sub-alternative 2a. However, the increased mass of arsenic solidified (82% for sub-alternative 2b versus 70% for sub-alternative 2a) is relatively minor. This reflects the arsenic distribution in soil at the site, where most of the arsenic in soil (on a total mass basis) is concentrated in the source area. Arsenic in soil outside of the source area is widely disseminated. The proposed groundwater treatment approach, described below, is designed to address groundwater impacts resulting from widely disseminated arsenic in the vadose zone.

Groundwater Treatment

Groundwater for all three sub-alternatives would be treated using *in-situ* application of ferrous iron and an oxidant. As shown on **Figures 5a**, **5b**, and **5c**, our conceptual approach includes a trench where ferrous iron can be continuously introduced into the groundwater upgradient of the plume. Also shown are injection points where ferrous iron can be injected directly into the arsenic plume. A greater density of ferrous iron points is shown in and around the arsenic hot spot in groundwater centered at the P3 monitoring well cluster. Ferrous iron would be injected using a DPT drill rig.

Geochemical modeling indicates that, in addition to ferrous iron, an oxidant will need to be introduced into groundwater to oxidize the arsenic and to drive the iron-arsenic oxyhydroxide co-precipitation reactions. **Figures 5a**, **5b**, and **5c** show a conceptual layout of in-situ chemical oxidation (ISCO) injection points or wells. Selection of the oxidant and optimal dose would be made by bench-scale and/or pilot-scale testing.

For this remedy to be effective over the long-term it will be necessary to maintain the redox gradient where groundwater comes in contact with oxygenated infiltration water. This causes the precipitation of iron-arsenic oxyhydroxides, which remove dissolved arsenic from groundwater. The conceptual design includes a stormwater infiltration gallery (shown on **Figures 5a**, **5b**, and **5c**) to maintain these existing groundwater geochemical conditions after solidification.

The cost estimate assumes an initial application of ferrous iron and oxidant as shown on **Figures 5a**, **5b**, and **5c**. The effectiveness of this remedy would be assessed by performance monitoring. An adaptive management approach, based on performance monitoring data, would be used to determine the scope of future ferrous iron and oxidant applications. For the purpose of our cost estimate, we assumed that there will be annual applications for 4 years after the initial application, and bi-annual applications totaling two rounds after that. The cost estimate assumes the performance monitoring will be performed on a quarterly basis for 4 years, semi-annual for 6 years, and annually for an additional 20 years, for 30 years total.

Sediment Cleanup

The cleanup of Puyallup River sediment will be the same as described in remedial action alternative 1.

4.3.4 Remedial Action Alternative 3

Under this alternative soil exceeding the 20 mg/kg arsenic soil cleanup level would be excavated and disposed of off-site. Due to the proximity of the Puyallup River, the excavation would be performed in two phases as shown on **Figure 6**. The excavation is planned to extend an average of 3 feet below the water table.

The cost estimate assumes that 82,000 cubic yards of soil would need to be excavated for remedial action alternative 3. Upon excavation, soil would be tested for waste profiling purposes. The cost estimate assumes that approximately 28,150 cubic yards of soil would be disposed of in a solid (nonhazardous) waste landfill. This soil would be trucked to a transfer station in Tacoma for haulage by rail to the Rabanco Landfill in Roosevelt, Washington or the Columbia Ridge Landfill in Arlington, Oregon.

As shown on **Figure 6**, the two excavation phases would require approximately 1,310 linear feet of sheet pile shoring to allow excavation at depth. Puyallup River sediment exceeding the cleanup levels would be remediated as part of the second phase of excavation.

Excavation near or below the water table would require dewatering. Groundwater generated during these dewatering operations would be pre-treated in a wastewater treatment plant installed on-site. Pre-treated wastewater would be discharged to the POTW.

Soil meeting the cleanup standards would be considered as suitable for use as backfill. Quarry spalls would be used to backfill areas where the excavation extends below the water table. Stockpiled and imported soil would be used to backfill the excavation above the water table.

Following restoration, the monitoring well network would be re-installed. The cost estimate assumes an MNA program will be implemented on a semi-annual for the first 5 years and an annual basis afterward for a total of 30 years.

4.4 Cost Estimates

This section discusses CDM Smith's cost estimates for the remedial action alternatives. **Table 5** presents the cost estimate summary for the alternatives.

General assumptions for the conceptual level cost estimates shown on **Table 5** are as follows:

- Future capital costs and ongoing costs are presented in present worth terms with a 5 percent discount rate.
- All present worth costs are rounded to the nearest 1,000 dollars.

- All construction costs include a construction contingency of 25 percent along with a contractor fee (contractor overhead, profit, and business and occupation tax) of 15 percent.
- All construction items include 8.6 percent sales tax.
- Initial and future capital costs assume the engineering cost at 10 percent of the total and project management costs at 12 percent of the total. Ongoing monitoring and maintenance costs assume no engineering costs and project management costs at 12 percent of the total.
- The duration of each alternative, including construction and/or long-term monitoring, totals 30 years.

Tables D-1 through D-3 in **Appendix D** provide alternative-specific assumptions used in preparing the cost estimates. Tables D-4 through D-6 in **Appendix D** provide detailed cost breakdowns of the remedial action alternatives. These cost estimates are based on the conceptual remediation approaches described in this section and were prepared for the purposes of this FS. An engineer's cost estimate for the selected remedial action alternative will be based on the remedial design.

Remedial action sub-alternatives 2b and 2c will not be carried forward for the remainder of the FS analysis. Remedial action sub-alternative 2a will hereafter be referred to as remedial action alternative 2. This selection is based primarily on the qualitative analysis of the sub-alternatives presented above, and also on the cost estimates presented on **Table 5** and in **Appendix D**. Remedial action alternatives 2b and 2c solidify vadose zone arsenic in soil from the disseminated periphery around the contaminant source area. When considering the whole approach (combining soil and groundwater) to remediation planned in remedial action alternative 2, potential groundwater impacts from arsenic in soil in this peripheral zone will best be addressed by *in situ* methods and trying to maintain the oxidizing groundwater conditions currently present at the site.

Section 5

Detailed Evaluation of Remedial Action Alternatives

This section evaluates the remedial action alternatives according to the process described in WAC 173-340-360.

5.1 Method of Evaluation

The evaluation criteria are listed in WAC 173-340-360 (3)(f) and described in detail below.

Protectiveness: Overall protectiveness of human health and the environment, including the degree to which existing risks are reduced, time required to reduce risk at the site and attain cleanup standards, risks resulting from implementing the alternative, and improvement of the overall environmental quality.

Permanence: The degree to which the technology permanently reduces the toxicity, mobility, or volume of hazardous substances, including its adequacy to destroy the hazardous substances, reduce or eliminate hazardous substance releases and sources of releases, degree of irreversibility of waste treatment process, and characteristics and quantity of treatment residuals generated.

Cost: The cost to implement the technology, including the cost of construction and the net present value of any long-term costs. Long-term costs include operation and maintenance, monitoring, equipment replacement, and maintaining institutional controls.

Effectiveness over the long term: Long-term effectiveness includes the degree of certainty that the technology will be successful, reliability of the alternative during the period of time hazardous substances are expected to remain on-site at concentrations that exceed cleanup levels, magnitude of residual risk with the alternative in place, and effectiveness of controls required to manage treatment residues or remaining wastes. The following types of cleanup action components may be used as a guide, in descending order, when assessing the relative degree of long-term effectiveness: Reuse or recycling; destruction or detoxification; immobilization or solidification; on-site or off-site disposal in an engineered, lined, and monitored facility; on-site isolation or containment with attendant engineering controls; and institutional controls and monitoring.

Management of short-term risks: The risk to human health and the environment associated with the technology during construction and implementation, and the effectiveness of measures that will be taken to manage such risks.

Technical and administrative implementability: Ability to be implemented, including consideration of whether the technology is technically possible, availability of necessary off-site facilities, services and materials, administrative and regulatory requirements, permitting, scheduling, size, complexity, monitoring requirements, access for construction operations and monitoring, and integration with current commercial operations and other current or potential remedial actions.

Consideration of public concerns: Whether the community has concerns regarding the technology and, if so, the extent to which the technology addresses those concerns. This criterion includes concerns from individuals, community groups, local governments, tribes, federal and state agencies, or any other organization that may have an interest in or knowledge of the site.

5.2 Comparative Evaluation of Remedial Action Alternatives

This subsection comparatively evaluates the remedial action alternatives with regard to the criteria listed above. The evaluation is summarized in **Table 6**.

Protectiveness: All three remedial action alternatives would improve the overall protectiveness. Arsenic-contaminated soil exceeding the Method A cleanup standard would be treated by a combination of solidification/stabilization, excavation and off-site disposal, and institutional controls. All remedial alternatives address impacts from groundwater to Puyallup River sediment and surface water, providing protectiveness to human and environmental receptors.

Remedial action alternatives 1 and 2 would treat arsenic-contaminated soil in the vadose zone by solidification/stabilization. The difference between these alternatives is the extent of soil treated. Remedial action alternative 1 would treat all soil above the MTCA Method A cleanup level, for an estimated total of approximately 33,500 cubic yards.

Solidification/stabilization for remedial action alternative 2 is focused on the contaminant source area and would treat all soil above 90 mg/kg, for an estimated total of approximately 11,460 cubic yards. The peripheral area (with soil concentrations greater than 20 mg/kg and less than 90 mg/kg) for remedial action alternative 2 would be addressed with institutional controls and performance groundwater monitoring. The smaller solidification footprint in remedial action alternative 2 is compatible with its *in-situ* groundwater remediation approach, which relies on maintaining the current oxidation-reduction gradient in groundwater that is causing arsenic to co-precipitate with iron in the form of oxyhydroxides.

Implementation of a barrier wall and PRB as a ‘funnel and gate’ configuration in remedial action alternative 1 presents technical uncertainty and risk. Barrier walls and PRBs function best when they are keyed into an aquitard. At the Puyallup site, the aquitard is approximately 45 feet deep, and while within practical construction limits, would pose some challenge because of its depth.

Experience shows that groundwater tends to flow under a barrier's walls, and groundwater leaks (lateral flow) occur in the barrier wall and in the area where the barrier wall and PRB join. The funnel also increases groundwater velocity through the PRB, which can decrease residence time required for treatment. Additionally, groundwater with high arsenic concentrations can consume a very small portion of the PRB and create a hole for treating the arsenic in groundwater. Leaks and holes are typically difficult to detect and isolate by groundwater monitoring. Accordingly, we rank remedial action alternative 1 as uncertain for protectiveness.

Remedial action alternative 3 would remove all arsenic-contaminated soil from the site, but would require significant effort, including: 1) excavating and stockpiling clean soil to access contaminated soil, and 2) excavating and disposing of arsenic-contaminated soil beneath the water table that poses little risk to Puyallup River sediment and surface water (if current geochemical conditions can be maintained). An evaluation of site geochemistry shows that arsenic exceeding the MTCA Method A cleanup level in soil beneath the water table has for the most part precipitated out of solution. Excavating and disposing of this soil off-site will do little to improve the overall protectiveness.

Permanence: Remedial action alternatives 1 and 2 use solidification to address arsenic-contaminated soil in the vadose zone. Research and bench-scale testing (CDM, 2013) indicate that the solidification mix-design proposed for this project will immobilize arsenic by both chemical stabilization and solidification. While cement-based solidification of nonorganic wastes is generally viewed as a permanent remedy, performance monitoring would be necessary to verify that solidification is acting as a permanent remedy to greatly reduce leaching of arsenic.

Geochemical modeling indicates that oxidizing groundwater conditions at the site are permanently removing dissolved arsenic from groundwater by precipitation into iron-arsenic oxyhydroxides. Adding ferrous iron and oxidants to groundwater will speed and enhance this naturally occurring process. Oxidizing groundwater conditions will ensure that iron-arsenic oxyhydroxides remain insoluble. Engineering measures will need to be taken during final site grading to ensure that oxidizing groundwater conditions that allow precipitation to infiltrate are maintained. This issue is also addressed in the discussion of effectiveness over the long-term.

Remedial action alternative 3 gets a very favorable rating for permanence because it includes excavation and off-site disposal of all soil and sediment exceeding MTCA cleanup standards.

Cost: Cost estimates for each remedial action alternative are shown in **Table 5**. The estimates were then ranked against the FS evaluation criteria as summarized below.

Evaluation Criteria	FS Cost Estimate Range	Remedial Action Alternative
Very Favorable	$100,000 to $2,000,000	None
Favorable	$2,00,000 to $4,000,000	2
Somewhat Favorable	$4,000,000 to $8,000,000	None
Unfavorable	$8,000,000 to $16,000,000	1
Very Unfavorable	Greater than $16,000,000	3

These rankings are shown on **Table 6**. Note that the FS cost estimate includes capital and the net present value of long-term operations, maintenance, and monitoring costs.

Effectiveness over the long term: An evaluation of remedial action alternative 1 found uncertainty over its long-term effectiveness. As discussed under the protectiveness criteria, groundwater contaminated with arsenic could bypass the PRB by flowing through leaks in the barrier wall or flow under the barrier wall or PRB. In addition, holes can develop in sections of the PRB that are in contact with portions of the plume with high arsenic concentrations. In any case, the FS assumes that the PRB will be replaced after 10 years.

Remedial action alternative 2 relies on introducing ferrous iron and ISCO to cause precipitation of iron-arsenic oxyhydroxides, thus immobilizing dissolved arsenic in groundwater. Long-term effectiveness and permanence are closely related for this alternative. The long-term effectiveness of alternative 2 depends on maintaining the current oxidizing groundwater conditions in the core remediation area. The conceptual design for remedial action alternative 2 incorporates a stormwater infiltration gallery to maintain the current oxidizing groundwater conditions. The FS gives a score of 3 to remedial action alternative 2 because maintaining this current geochemical process will rely on long-term performance monitoring to verify its effectiveness after the site is modified by solidification.

Remedial action alternative 3 is very favorable for effectiveness over the long-term for the same rationale discussed for the permanence criteria.

Management of short-term risks: Remedial action alternative 1 is rated as uncertain for management of short-term risks. The footprint of the solidification is quite large and extends onto adjoining businesses. Constructing a slurry wall and PRB would require careful management to avoid impacting the Puyallup River with excavation spoils or slurry. The PRB could also result in ferrous iron bleed into the Puyallup River and cause downstream staining.

Remedial action alternative 2 is favorable for managing short-term risks. *In-situ* treatment of soil and groundwater minimizes the chance of human exposure to arsenic during remediation.

Remedial action alternative 3 is unfavorable for short-term risk management. This alternative calls for extensive excavation beneath the water table, which is inherently risky, especially with respect to caving. The conceptual design prepared for the FS specifies temporary shoring along River Road and the Puyallup River. However, if either of these shoring walls were to fail during construction, the results would be catastrophic.

Technical and administrative implementability: Remedial action alternatives 1 and 2 received a somewhat favorable or uncertain ranking for this criterion. The *in-situ* groundwater treatment methods (slurry wall and PRB for remedial alternative 1 and ferrous iron and oxidant injections for remedial alternative 2) are implementable from a technical standpoint. However, determining the effectiveness of these measures will require careful analysis of performance monitoring data. Access agreements with the adjoining property owners will need to be obtained prior to conducting work.

Remedial action alternative 3 received an unfavorable ranking for technical and administrative implementability. Excavation and off-site disposal envisioned in the FS conceptual design would be large, complex, and adversely impact the existing commercial operations. Finding space to stockpile the large quantity of clean soil for backfill would be difficult. Conducting the second phase of excavation out to the Puyallup River would be technically difficult to implement because of the shoring required.

Consideration of public concerns: Remedial action alternatives 1 and 2 received a somewhat favorable or uncertain ranking for consideration of public concerns. Construction activities would have some impact to the bike path adjoining the Puyallup River. Concerns from the general public about the Puyallup site are unknown at this time.

Remedial action alternative 3 received an unfavorable ranking, primarily for the deep excavations next to River Road and the Puyallup River. The bike path adjacent to the Puyallup River would need to be closed for a significant period of time to accommodate construction.

5.3 Cost Disproportionate Analysis

MTCA Section 173-340-360(3) outlines the method for conducting a cost disproportionate analysis. The objective is to determine whether costs are disproportionate to benefits of the incremental cost of the alternative over that of the lower cost alternative.

Table 6 lists the evaluation criteria described above and provides a numeric ranking from 1 to 5 for each criterion for each alternative. Scores range from 1 as very unfavorable to 5 as very favorable. A weighting factor was applied to each criterion and the weighting factor was multiplied by the numeric ranking assigned to the criterion for each alternative. The value derived for each criterion was then summed to derive an overall ranking value for each alternative. **Table 7** summarizes the rationale for the numeric ranking assigned to each criterion for each alternative. The cost disproportionate analysis scored remedial action alternative 2 as the highest with a score of 3.7 as shown on **Table 6**; thus, remedial action alternative 2 is the preferred alternative.

Section 6

Implementation of the Preferred Alternative

This section describes USG's plan for implementing remedial action alternative 2.

6.1 Remediate Arsenic in Groundwater

CDM Smith's conceptual approach to remediate arsenic in groundwater is by *in-situ* application of ferrous iron and chemical oxidant via DPT borings, wells, and an introduction trench. The first step in implementing this remedy is expected to be a pilot test conducted to verify that ferrous iron and oxidant injections will be effective under field condition. Full-scale application such as shown on **Figure 5a** would then be implemented using a DPT drill rig. Included in this initial phase would be construction and operation of the ferrous iron introduction trench. The next phase of remediation would be soil solidification as described below.

The stormwater infiltration gallery would be constructed after soil solidification is completed. The monitoring well network would be re-installed and performance monitoring would commence. Additional injections of ferrous iron and the oxidant would be made based on performance monitoring data.

Ferrous iron would be applied in two ways: 1) continuously introduced into the upgradient trench, and 2) through DPT borings. The oxidant would be applied down-gradient of the iron injection locations. CDM Smith's conceptual approach envisions constructing ISCO injection wells where a slow-release oxidant in a solid form can be placed in the injection well and easily replaced when consumed (such as solid oxidant within a "sock" than can be lowered into a well).

The stormwater infiltration gallery would maintain the redox gradient downgradient of the contaminant source area and promote precipitation and long-term stability of iron-arsenic oxyhydroxides

Remedy effectiveness would need to be verified by performance monitoring. An analysis of performance monitoring data would determine the course of *in-situ* groundwater treatment. Conceptually, the estimated remediation timeframe for *in-situ* groundwater remediation is about 10 years.

This proposed remedy will be inherently flexible because it will follow an adaptive management approach with the scope of subsequent *in-situ* groundwater treatment based on performance monitoring. Part of the adaptive management approach will include development of a performance monitoring plan that will contain provisions to perform an assessment should results indicate the remedy is not functioning as intended. The assessment will determine the cause of the inadequate performance, followed by an evaluation of potential correction actions. For example, the duration of ferrous iron and/or oxidant injections could be extended to treat groundwater.

6.2 Soil Solidification

Soil solidification would be accomplished by vertical auger. The cement-bentonite-iron solidification reagent would be injected during auger mixing. Monitoring wells in the solidification area would be abandoned prior to construction.

Schedule is a key consideration for implementing soil solidification. Soil solidification would be scheduled for late fall, when the water table is its lowest. This would enable the solidified soil 'monolith' to extend into the water table when the water table is higher.

The proposed *in-situ* groundwater remediation approach combined with performance monitoring is compatible with soil solidification because its effectiveness can be evaluated by performance monitoring.

6.3 Remediate Sediment in the Puyallup River

Puyallup River sediment would be cleaned up after treatment of arsenic in soil and groundwater has commenced. The remedial approach is conceptually straightforward and includes: 1) constructing curtains to contain the turbidity that would be generated during sediment removal, 2) excavating sediment above arsenic cleanup levels and disposing of it off- site, and 3) restoring the river bank.

Section 7

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Tables

Table 1
Development of Draft Cleanup Levels
USG Interiors Puyallup Site
Puyallup, Washington

Cleanup Level Method and Basis [a]		**Arsenic**
Soil		**mg/kg**
Method A	Unrestricted Land Use	20
	Industrial	20
Method B	Unrestricted Land Use (Ingestion)	0.67
Method B	Groundwater Protection	N/A
Method C	Industrial	88
Background	Puget Sound (including Pierce County) [b]	7.3
Groundwater		**µg/L**
Method A	Unrestricted Use	5 [c]
Method B	Unrestricted Use	0.058
Method C	Industrial	0.58
MCL	Drinking Water Standards	10
Surface Water		**µg/L**
Method B	Human Ingestion of aquatic org.	0.098
Method C	Human Ingestion of aquatic org.	2.5
National Toxics Rule - 40 CFR 131	Human Health	0.018
Clean Water Act 304	Human Health	0.018
National Toxics Rule - 40 CFR 131	Fresh Water Aquatic Life - acute	360
	- chronic	190
Clean Water Act 304	Fresh Water Aquatic Life - acute	340
	- chronic	150
WAC 173-201A	Fresh Water Aquatic Life - acute	360
	- chronic	190
Sediment		**mg/kg**
WAC 173-204	Fresh Water Sediment Cleanup Screening Level	120
WAC 173-204	Fresh Water Sediment Cleanup Objective	14

Notes:

a) Downloaded from Department of Ecology's Cleanup Levels and Risk Calculations (CLARC) online database except as noted. (Downloaded 03/15/2013)

b) San Juan, Charles. 1994 Natural Background Soil Metals Concentrations in Washington State. Washington State Dept. of Ecology. Publication 94-115, October.

c) This cleanup level is based on natural background concentrations for Washington State.

µg/L - micrograms per liter (parts per billion)
mg/kg - milligrams per kilogram (parts per million)
MCL - maximum contaminant level
WAC - Washington Administrative Code
N/A - not available

CDM Smith

Table 2
Identification and Screening of Potential Remedial Technologies
Feasibility Study - USG Puyallup Site
Puyallup, Washington

General Response Action	Technology	Process Option	Description	Effectiveness	Implementability	Cost	Screening Result
No Further Action	None	None	Conduct no further action	Not Effective.	Easy	None	Not Retained
Institutional Controls	Administrative	Access controls, maintenance, education	Fences or site maintenance to limit exposure. Postings, public notices, health advisories, and mailings to educate.	Limited effectiveness. Effective at minimizing human exposure.	Easy	Low	Retained
	Legal	Deed restrictions, groundwater use controls, financial assurances	Limitations on the use of property or resources; or requirements that cleanup action occur if existing pavement is disturbed or removed.	Effective at minimizing human exposure.	Easy	Low	Retained
Monitored Natural Attenuation (MNA)	MNA	MNA	Natural biological, chemical, and physical processes. Primary future action is groundwater monitoring.	Effective at reducing arsenic concentrations in groundwater when combined with source control measures and under certain geochemical conditions.	Easy	Low to Moderate	Retained
Containment	Horizontal Barrier - Impermeable	Surface cap (e.g., asphalt or impermeable liner)	Form an impermeable barrier to direct contact, surface water, and infiltrating precipitation.	Effective at reducing infiltrating precipitation from coming in contact with fill in vadose zone. However, may make groundwater conditions more reducing and increase arsenic mobility.	Moderately difficult	Moderate construction cost. Low maintenance cost.	Retained
	Vertical Barrier	Slurry wall	Form an impermeable hydrologic barrier to groundwater flow. Placement options include downgradient edge of site or to encircle the source area.	Effective if paired with other technologies in "funnel and gate" application.	Moderately difficult	Moderate to high to construction cost. Low maintenance cost.	Retained
	Hydraulic Containment	Extraction wells	Capture groundwater plume to preven migration to the Puyallup Rever. Requires corresponding discharge/treatment option.	Potentially effective for controlling plume migration to Puyallup River surface water and sediment. Maintaining continuous operation would be difficult because of potential site-specific issues such as overbank flooding and iron fouling.	Difficult	Moderate to high when considering long-term operations and maintenance costs	Retained
In-Situ Treatment	Stabilization/ Precipitation	*In-situ* stabilization of arsenic in soil	Inject reagent to chemically stabilize arsenic and reduce leaching.	Limited effectiveness. Stabilization reagents were tested during bench-scale testing and shown to be less effective than solidification.	Difficult	Moderate	Not Retained
		Inject reagent to create reducing groundwater conditions.	Inject ferrous iron and carbon substrate causing bacterial reduction of sulfate to sulfide and reaction with iron to precipitate iron sulfide. Arsenic co-precipitates with iron sulfide.	Limited effectiveness. Ambient geochemical conditions are not favorable to create permanent sulfate-reducing conditions and ensure arsenic remains as a sulfide. Could potentially increase arsenic mobility by dissolving existing arsenic-bearing iron oxyhydroxides. Would require bench-scale and/or pilot test to demonstrate effectiveness.	Difficult	Moderate to high	Not Retained
		Inject ferrous iron and oxidant to create groundwater conditions favorable for arsenic precipitation.	Inject ferrous iron and oxidant (such as permanganate or hydrogen peroxide). This will create oxidizing conditions resulting in precipitation of iron oxides and hydroxides with co-precipitation of arsenic.	Effective. Ambient geochemical conditions in the shallow groundwater are more favorable for the permanence of this kind of arsenic remedy than trying to create reducing conditions. Oxidation appears to be the predominant natural arsenic attenuation process at the site, and can be maintained by remedial design that promotes the infiltration of stormwater.	Difficult	Moderate	Retained
		Air sparging	Injection of air to oxidize ferrous iron (added by injection). Co-precipitate arsenic from solution and create a solid phase with a highly sorptive surface area.	Not effective. Much of arsenic downgradient of the contaminant source area is in the Arsenic III valence state. Air sparging is not very effective in oxidizing and precipitating Arsenic III. Air sparging is predicted to result in calcite precipitation, which could result in plugging issues.	Moderately difficult	High when considering long-term operations and maintenance costs	Not Retained
	Permeable Reactive Barrier (PRB)	ZVI	Treats groundwater as it flows through PRB. Can be used in a "funnel and gate" application with a slurry wall as well.	Effective for controlling future off-property migration. Would require bench-scale and/or pilot testing to demonstrate effectiveness and develop design data. Assume PRB will need to be replaced after 15 years.	Moderately difficult	High	Retained
		EHC-M or similar compound	Treats groundwater as it flows through PRB. Can be used in a "funnel and gate" application with a slurry wall as well.	Limited effectiveness. Bench-scale or pilot testing required to demonstrate effectiveness. However, is a less proven technology than ZVI and offers no real advantages over ZVI at this site.	Moderately difficult	Moderate to high	Not retained

Table 2
Identification and Screening of Potential Remedial Technologies
Feasibility Study - USG Puyallup Site
Puyallup, Washington

General Response Action	Technology	Process Option	Description	Effectiveness	Implementability	Cost	Screening Result
In-Situ Treatment (continued)	Solidification/Stabilization	*In-situ* injection and mixing of a Portland cement based reagent.	Solidification and chemical stabilization of arsenic in soil by pumping and mixing cement grout ammended with bentonite and ferrous iron.	Effective. Proven in bench-scale testing.	Moderately difficult	Moderate to high	Retained
		Vitrification	Uses electric current to create high temperatures to melt soil and create a vitrified mass.	Not effective. Technology is inappropriate for site where major contaminant source control action has already been conducted.	Difficult	Very high	Not Retained
	Soil Flushing	Acid/cosolvent/ surfactant injection	Injection of acid/cosolvent/surfactant mixture upgradient of the contaminated area. The solvent with dissolved arsenic is then extracted downgradient and treated above ground.	Limited effectiveness.Technology is largely unproven.	Difficult	High	Not Retained
	Electrokinetic Separation	Electrokinetic separation	Application of a low-intensity direct current through the soil to mobilize arsenic. Removal of arsenic at the electrode may be accomplished through several means among which are: electroplating, precipitation or co-precipitation, pumping of water, or complexing with ion exchange resins.	Limited effectiveness. Most effective in clays - the Puyallup site is primarily sand and silt. Must be combined with another *in-situ* or removal technology. Largely unproven.	Difficult	High	Not Retained
Pump-and-Treat	Extraction	Trenches	Horizontal extraction trench constructed of gravel, horizontal perforated pipe and vertical well(s). Can be effective where groundwater depth is shallow.	Limited effectiveness. Groundwater is approximately 12 to 15 feet deep on north edge of property, requiring a deep trench. Vertical wells are a better application for the Puyallup site.	Moderately difficult	Moderate to high when considering long-term operations and maintenance costs of groundwater treatment	Not Retained
		Wells	Vertical wells screened in specific zones or across entire water producing zone.	Proven and well-established technology. Will require pumping test to determine aquifer properties. Well spacing to ensure plume capture determined by groundwater modeling.	Easy to moderately difficult	Moderate to high when considering long-term operations and maintenance costs of groundwater treatment	Retained
	Ex situ treatment	Adsorption	Removal of arsenic by adsorption to media such as iron based sorbents and activated alumina.	Effective.	Easy to moderately difficult	Moderate	Retained
		Ion exchange	Removal of arsenic ions by exchange of cations or anions between groundwater and the exchange medium.	Effective.	Easy to moderately difficult	High	Retained
		Membrane filtration	Separation of arsenic from water by passing through semi-permeable membrane.	Effective, but results in large volumes of arsenic-bearing brine requiring disposal.	Easy to moderately difficult	High	Not Retained
		Evaporation ponds	Water pumped to lined ponds to evaporate. Evaporation may be enhanced through spraying or other agitation methods.	Limited effectiveness due to low net evaporation at the site.	Difficult to implement due to limited area	Moderate	Not Retained
	Discharge	Groundwater	Discharge treated water to groundwater by infiltration gallery.Needs to be combined with groundwater extraction and treatment system.	Effective.	Moderately difficult.	Moderate	Retained
		Surface water	Discharge treated water to surface water. Discharge limits usually established by surface water standards.	Effective.	Difficult.	Moderate	Not retained
		Publically owned treatment works (POTW)	Pre-treat groundwater on-site and discharge to POTW. Discharge pre-treatment levels determined by POTW.	Effective.	Easy.	High	Retained
Soil and Sediment Removal	Excavation	Excavation and off-site disposal of residual waste, fill, and arsenic contaminated soil and sediment	Physical removal of arsenic-contaminated soil. Disposal in solid waste landfill. Backfill with clean soil.	Effective.	Difficult to implement due to depth of arsenic-contaminated soil. Would require de-watering and shoring.	Very high	Retained

Table 3
Remedial Technologies Evaluation

Feasibility Study - USG Puyallup Site
Puyallup, Washington

ID #	Remedial Technology	Remedial Action Objective	RAO 1: Remediate Soil Exceeding Cleanup Levels	RAO 2: Achieve MTCA Method A Cleanup Standards for Arsenic in Groundwater at the Standard Point of Compliance	RAO 3: Mitigate Arsenic in Groundwater Exceeding Surface Water and Sediment Standards at a Conditional Point of Compliance.	RAO 4: Remediate Sediment Exceeding Cleanup Screening Levels.
1	**Institutional Controls**		Y	Y	Y	-
2	**Excavation and Off-Site Disposal**		Y	-	-	Y
4	**Soil Solidification/Stabilization**		Y	-	-	-
5	***In Situ* Groundwater Treatment with Ferrous Iron and Oxidant**		-	Y	Y	-
6	**Temporary Groundwater Extraction, Treatment**		-	Y	Y	-
7	**Permeable Reactive Barrier - Zero Valent Iron**		-	U	Y	-
8	**Monitored Natural Attenuation and Performance Monitoring - Post Remediation**		-	Y	Y	-

Applicablity

Y	Yes
U	Uncertain
-	Not Applicable

Table 4

Remedial Alternatives Summary

Feasibility Study - USG Puyallup Site
Puyallup, Washington

RAO	Description	Alternative 1	Alternative 2	Alternative 3
1	Remediate Soil Exceeding Cleanup Levels	Solidification/stabilization	Solidification/stabilization and institutional controls	Excavation and off-site disposal
2	Achieve MTCA Method A Groundwater Cleanup Levels - Standard Point of Compliance	Slurry walls and PRB in 'funnel and gate' configuration; performance monitoring	*In-Situ* remediation consisting of ferrous iron injection by DPT borings and injection trench; ISCO injection via wells and DPT borings;stormwater infiltration; performance monitoring	Monitored natural attenuation
3	Achieve MTCA Method A Groundwater Cleanup Levels - Conditional Point of Compliance	Slurry walls and PRB in 'funnel and gate' configuration; performance monitoring; pore-water sampling; institutional controls	*In-Situ* remediation consisting of ferrous iron injection by DPT borings and injection trench; ISCO injection via wells and DPT borings; stormwater infiltration; performance monitoring; pore-water sampling; institutional controls	Monitored natural attenuation, pore-water sampling; institutional controls
4	Remediate Sediment Exceeding Cleanup Levels	Excavation and off-site disposal	Excavation and off-site disposal	Excavation and off-site disposal

DPT: Direct push technology
ISCO: *In-situ* chemical oxidation

Table 5
Cost Estimate Summary
Feasibility Study - USG Puyallup Site
Puyallup, Washington

Alternative 1									
	Pre-Design Activities		**1st Phase**	**2nd Phase**		**3rd Phase**	**Performance Monitoring Phase**		
	Prepare Cleanup Action Plan, Field Pilot Testing, and JARPA		Solidification / Stabilization of Soil Hotspot (≥ 20 mg/kg)	Slurry Walls	Permeable Reactive Barrier	Sediment Removal	Performance Monitoring	Institutional Controls	Total
Capital Cost	$ 90,000		$ 3,974,187	$ 2,703,517	$ 882,321	$ 225,577	$ 56,439	$ 37,749	$ 7,969,790
OM&M Cost					$ 882,321		$ 45,684	$ 10,000	$ 938,006
OM&M Duration (years)					Year 10		5	30	
OM&M Cost					$ 882,321		$ 22,842		$ 905,163
OM&M Duration (years)					Year 20		25		
Total - Present Worth	**$ 90,000**		**$ 3,970,000**	**$ 2,700,000**	**$ 1,800,000**	**$ 226,000**	**$ 483,000**	**$ 189,000**	**$ 9,460,000**

Alternative 2a									
	Pre-Design Activities	**1st Phase**	**2nd Phase**	**3rd Phase**	**4th Phase**	**5th Phase**	**Performance Monitoring Phase**		
	Prepare Cleanup Action Plan, Perform Soil Delineation, Bench-Scale, Field Pilot Testing, and JARPA	Ferrous Iron and ISCO Injection (DPT Borings and Wells)	Ferrous Iron Introduction System (Trench)	Solidification / Stabilization of Soil Hotspot (≥ 90 mg/kg)	Stormwater Infiltration Gallery	Sediment Removal	Performance Monitoring	Institutional Controls	Total
Capital Cost	$ 150,000	$ 137,558	$ 83,669	$ 1,203,338	$ 66,662	$ 225,577	$ 56,439	$ 37,749	$ 1,960,992
OM&M Cost		$ 68,779	$ 112,000				$ 91,369	$ 10,000	$ 282,148
OM&M Duration (years)		Year 2-5,7,9	10				4	30	
OM&M Cost							$ 45,684		$ 45,684
OM&M Duration (years)							6		
OM&M Cost							$ 22,842		$ 22,842
OM&M Duration (years)							20		
Total - Present Worth	**$ 150,000**	**$ 381,000**	**$ 371,000**	**$ 1,200,000**	**$ 67,000**	**$ 226,000**	**$ 689,000**	**$ 189,000**	**$ 3,270,000**

Alternative 2b									
	Pre-Design Activities	**1st Phase**	**2nd Phase**	**3rd Phase**	**4th Phase**	**5th Phase**	**Performance Monitoring Phase**		
	Prepare Cleanup Action Plan, Perform Soil Delineation, Bench-Scale, Field Pilot Testing, and JARPA	Ferrous Iron and ISCO Injection (DPT Borings and Wells)	Ferrous Iron Introduction System (Trench)	Solidification / Stabilization of Soil Hotspot (≥ 50 mg/kg)	Stormwater Infiltration Gallery	Sediment Removal	Performance Monitoring	Institutional Controls	Total
Capital Cost	$ 150,000	$ 137,558	$ 83,669	$ 1,672,908	$ 66,662	$ 225,577	$ 56,439	$ 37,749	$ 2,430,562
OM&M Cost		$ 68,779	$ 112,000				$ 91,369	$ 10,000	$ 282,148
OM&M Duration (years)		Year 2-5,7,9	10				4	30	
OM&M Cost							$ 45,684		$ 45,684
OM&M Duration (years)							6		
OM&M Cost							$ 22,842		$ 22,842
OM&M Duration (years)							20		
Total - Present Worth	**$ 150,000**	**$ 381,000**	**$ 371,000**	**$ 1,670,000**	**$ 67,000**	**$ 226,000**	**$ 689,000**	**$ 189,000**	**$ 3,740,000**

Alternative 2c									
	Pre-Design Activities	**1st Phase**	**2nd Phase**	**3rd Phase**	**4th Phase**	**5th Phase**	**Performance Monitoring Phase**		
	Prepare Cleanup Action Plan, Perform Soil Delineation, Bench-Scale, Field Pilot Testing, and JARPA	Ferrous Iron and ISCO Injection (DPT Borings and Wells)	Ferrous Iron Introduction System (Trench)	Solidification / Stabilization of Soil Hotspot (≥ 20 mg/kg)	Stormwater Infiltration Gallery	Sediment Removal	Performance Monitoring	Institutional Controls	Total
Capital Cost	$ 150,000	$ 137,558	$ 83,669	$ 3,260,267	$ 66,662	$ 225,577	$ 56,439	$ 37,749	$ 4,017,920
OM&M Cost		$ 68,779	$ 112,000				$ 91,369	$ 10,000	$ 282,148
OM&M Duration (years)		Year 2-5,7,9	10				4	30	
OM&M Cost							$ 45,684		$ 45,684
OM&M Duration (years)							6		
OM&M Cost							$ 22,842		$ 22,842
OM&M Duration (years)							20		
Total - Present Worth	**$ 150,000**	**$ 381,000**	**$ 371,000**	**$ 3,260,000**	**$ 67,000**	**$ 226,000**	**$ 689,000**	**$ 189,000**	**$ 5,330,000**

Alternative 3									
	Pre-Design Activities			**1st Phase**		**2nd Phase**	**MNA Phase**		
	Prepare Cleanup Action Plan, Perform Soil Delineation, and JARPA			Soil Removal	Short Term Pump and Treat	Sediment Removal	Monitored Natural Attenuation	Institutional Controls	Total
Capital Cost	$ 140,000			$ 25,319,465	$ 87,741	$ 225,577	$ 56,439	$ 37,749	$ 25,726,970
OM&M Cost					$ 750,820		$ 45,684	$ 10,000	$ 806,504
OM&M Duration (years)					5		5	30	
OM&M Cost							$ 22,842		$ 22,842
OM&M Duration (years)							25		
Total - Present Worth	**$ 140,000**			**$ 25,300,000**	**$ 2,750,000**	**$ 226,000**	**$ 483,000**	**$ 189,000**	**$ 28,900,000**

Notes:
1. Present worth value calculated using a 5% discount rate with 2014 initial construction year.

Table 6

Evaluation of Remedial Action Alternatives and Disproportionate Cost Analysis

Feasibility Study - USG Puyallup Site
Puyallup, Washington

Alternative	Description	Disproportionate Cost Analysis Criteria	Protectiveness		Cost		Permanence		Long-term Effectiveness		Management of Short-Term Risks		Technical and Administrative Implementability		Consideration of Public Concerns		Sum	Overall Recommendation
	Weighting Factor		0.2		0.2		0.15		0.15		0.1		0.1		0.1		1	
			Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value	Rank	Value		
1	Solidification/Stabilization of Vadose Zone Soil Greater than 20 mg/kg Arsenic, Groundwater Treatment with PRB is 'Funnel and Gate' Configuration, Sediment Removal, Performance Monitoring		3	0.6	2	0.4	4	0.6	3	0.45	3	0.3	3	0.3	3	0.3	3.0	No
2	Solidification/Stabilization of Vadose Zone Soil Greater than 90 mg/kg Arsenic, Institutional Controls, Injection of Ferrous Iron to Groundwater with an Up-Gradient Trench and DPT Borings, ISCO by DPT Borings by DPT Borings and Wells, Performance Monitoring		4	0.8	4	0.8	4	0.6	3	0.45	4	0.4	3	0.3	3	0.3	3.7	**Yes**
3	Excavation of Soil Exceeding 20 mg/kg Arsenic and Off-Site Disposal, Extraction of Groundwater During Excavation, Pre-Treatment of Groundwater and Disposal to the POTW, Sediment Removal, MNA		5	1	1	0.2	5	0.75	5	0.75	2	0.2	2	0.2	2	0.2	3.3	No

Disproportionate Cost Analysis Ranking Criteria

5	Very Favorable, Ideal
4	Favorable, Good
3	Somewhat Favorable or Uncertain
2	Unfavorable
1	Very Unfavorable

Table 7
Disproportionate Cost Analysis
Feasibility Study - USG Puyallup Site
Puyallup, Washington

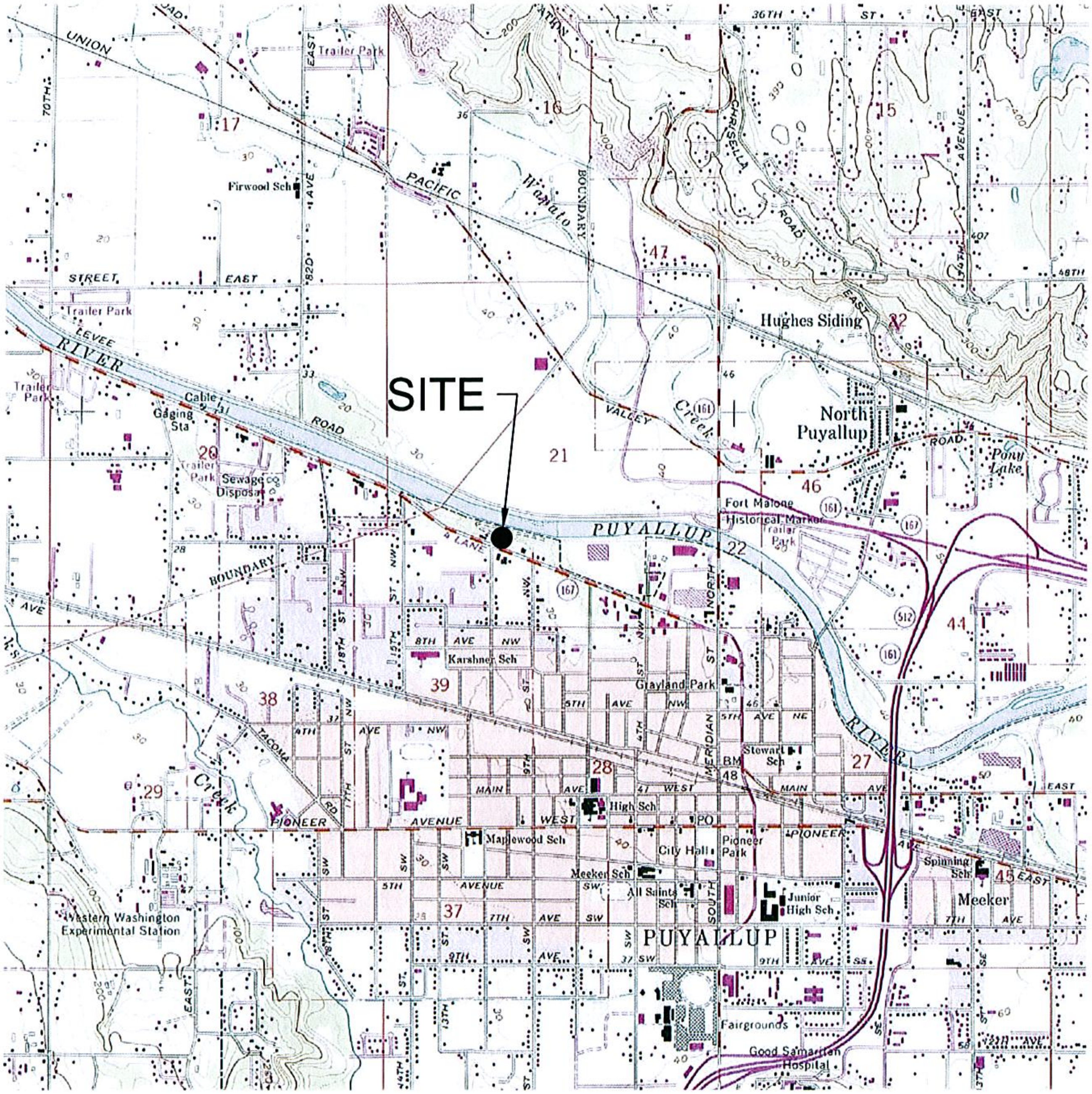
	Alternative Number					
	Alternative 1		Alternative 2		Alternative 3	
Alternative Information	**Description**	**Score**	**Description**	**Score**	**Description**	**Score**
Description	Solidification/Stabilization of Vadose Zone Soil Greater than 20 mg/kg Arsenic, Groundwater Treatment with PRB in a 'Funnel and Gate' Configuration, Sediment Removal, Performance Monitoring		Solidification/Stabilization of Vadose Zone Soil Greater than 90 mg/kg Arsenic, Institutional Controls, Injection of Ferrous Iron to Groundwater with an Upgradient Trench and DPT Borings, ISCO by DPT Borings by DPT Borings and Wells, Performance Monitoring		Excavation of Soil Exceeding 20 mg/kg Arsenic and Off-Site Disposal, Extraction of Groundwater During Excavation, Pre-Treatment of Groundwater and Disposal to the POTW, Sediment Removal, MNA	
Amount of Soil Treated	33,500 cubic yards		11,460 cubic yards		--	
Amount of Soil Removed	--		--		28,150 cubic yards	
Overall Alternative Ranking	3.0		3.7		3.3	
Evaluation Criteria						
Protectiveness - Weight 20%	This alternative will achieve overall protection. Arsenic-contaminated soil in the vadose zone would be treated by solidification/stabilization. However, use of barrier wall and PRB in a "funnel and gate" configuration presents technical uncertainty as it will be impractical to key into an aquitard based on aquitard depth and leaks/holes will be difficult to detect and isolate.	3	This alternative will achieve overall protection. Risk that "hot spot" removal may not be sufficient to reduce overall site mean contaminant concentration below the MTCA Method A cleanup level. The smaller solidification footprint is compatible with the *in situ* groundwater remediation approach, which relies on maintaining the current oxidation-reduction gradient in groundwater that is causing arsenic to co-precipitate with iron.	4	This alternative will achieve overall protection as all soil exceeding 20 mg/kg arsenic would be excavated and disposed of off-site.	5
Cost - Weight 20%	$9,460,000	2	$3,270,000	4	$28,900,000	1
Permanence - Weight 15%	Arsenic will be immobilized by solidifying and chemically stabilizing contaminated soil in the vadose zone.	4	Soil containing arsenic at concentrations exceeding 90 mg/kg will be immobilized by solidification and chemical stabilization. The smaller footprint of soil to be treated is compatible with the *in situ* groundwater remediation approach, which relies on maintaining the current oxidation-reduction gradient in groundwater that is causing arsenic to attenuate by co-precipitation with iron.	4	Alternative reduces the volume of impacted material located at the site by completely removing contaminated soil to the greatest degree technically feasible. This alternative does not reduce the toxicity or volume of the hazardous substance as the contaminated material is simply transferred to a landfill.	5
Long-Term Effectiveness - Weight 15%	The long-term effectiveness is uncertain based on the use of a barrier wall and PRB in a "funnel and gate" configuration, which presents technical uncertainty as it will be impractical to key into an aquitard based on aquitard depth and leaks/holes will be difficult to detect and isolate.	3	Relies on introducing ferrous iron and ISCO to cause precipitation of iron-arsenic oxyhydroxides, thus immobilizing dissolved arsenic in groundwater. Long-term effectiveness depends on maintaining the current oxidizing groundwater conditions in the core remediation area. The conceptual design incorporates a stormwater infiltration gallery to maintain the current oxidizing groundwater conditions.	3	Alternative removes and disposes of contaminated soil off-site.	5
Short-Term Risk Management - Weight 10%	The footprint of the solidification is quite large and extends onto adjoining businesses. Constructing a slurry wall and PRB would require careful management to avoid impacting the Puyallup River with excavation spoils or slurry. The PRB could also result in ferrous iron bleed into the Puyallup River and cause downstream staining.	3	Favorable for managing short-term risk. In-situ treatment of soil and groundwater minimizes the chance of human exposure to arsenic during remediation, and the treatment footprint is smaller than Alternative 1.	4	Creates the most disturbance of impacted soil and the highest short-term risks. This alternative calls for extensive excavation beneath the water table, which is inherently risky, especially with respect to caving. Temporary shoring is specified along River Road and the Puyallup River. However, the impact would be significant if either of these shoring walls were to fail during construction.	2
Implementability - Weight 10%	Implementable; solidification and the slurry wall and PRB are implementable from a technical standpoint. However, determining the effectiveness of these measures will require careful analysis of performance monitoring data. Access agreements with the adjoining property owners will need to be obtained prior to conducting work.	3	Implementable; solidification and the ferrous iron and oxidant injections are implementable from a technical standpoint. However, determining the effectiveness of these measures will require careful analysis of performance monitoring data. Access agreements with the adjoining property owners will need to be obtained prior to conducting work.	3	Difficult to implement; the excavation would be large, complex, and adversely impact the existing commercial operations. Finding space to stockpile the large quantity of clean soil for backfill would be difficult. Conducting the second phase of excavation out to the Puyallup River would be technically difficult to implement because of the shoring required.	2
Consideration of Public Concerns - Weight 10%	Construction activities would have some impact to the bike path adjoining the Puyallup River. Concerns from the general public about the Puyallup site are unknown at this time.	3	Construction activities would have some impact to the bike path adjoining the Puyallup River. Concerns from the general public about the Puyallup site are unknown at this time.	3	Deep excavations would occur next to River Road and the Puyallup River. Traffic impacts expected caused by trucks hauling contaminated soil offsite for disposal and bringing backfill to site. The bike path adjacent to the Puyallup River would need to be closed for a significant period of time to accommodate construction.	2

Notes:
DPT - direct push technology
ISCO - in situ chemical oxidation
mg/kg - milligram per kilogram
MNA - monitored natural attenuation
POTW - publicly owned treatment works
PRB - Permeable Reactive Barrier

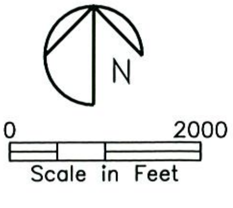
Criteria Ranking

5	Very Favorable, Ideal
4	Favorable, Good
3	Somewhat Favorable or Uncertain
2	Unfavorable
1	Very Unfavorable

Figures



Source: USGS Puyallup, Wash. 7.5' Quadrangle, 1981



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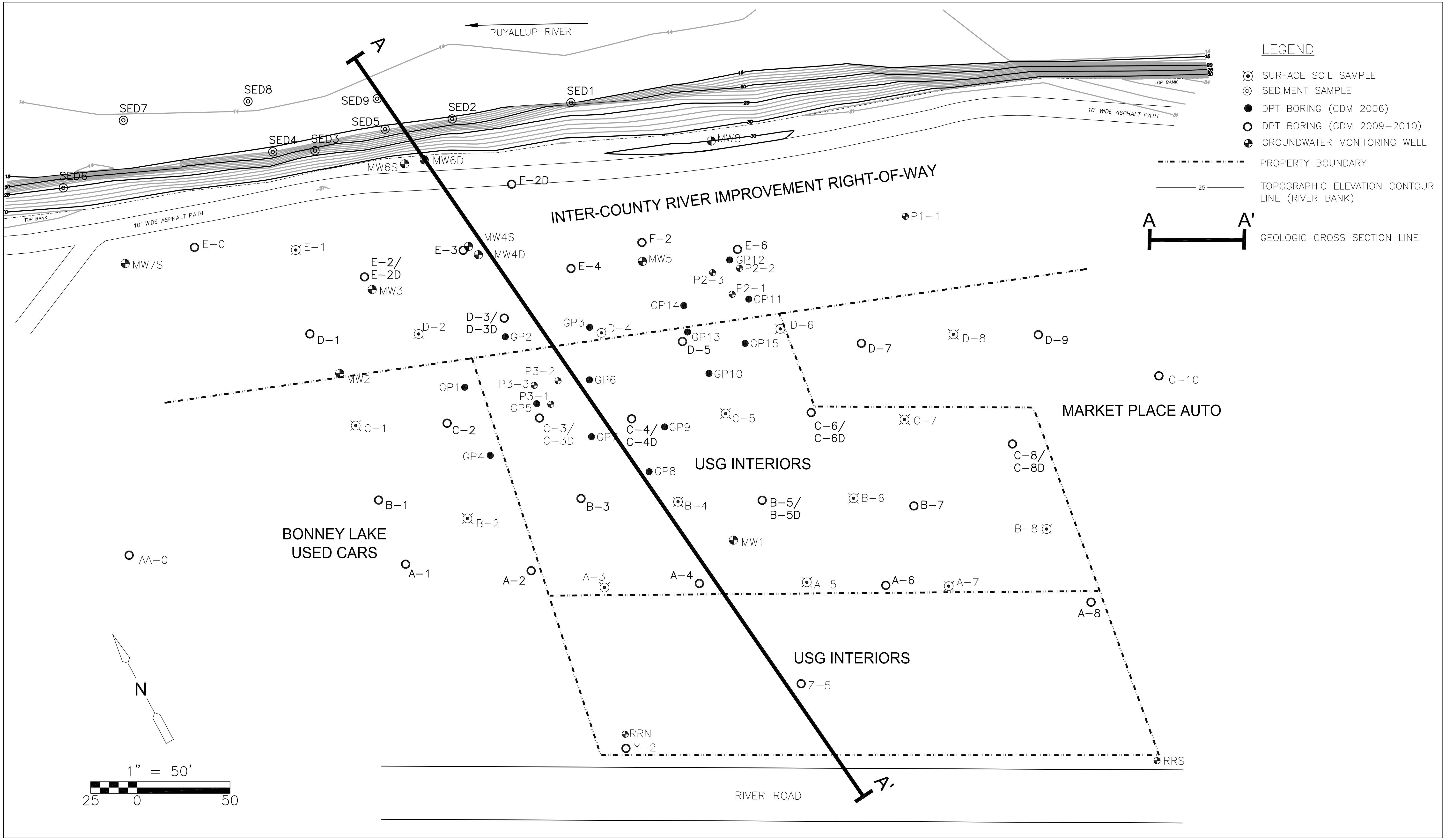
USG INTERIORS/REMEDIAL INVESTIGATION
PUYALLUP, WASHINGTON

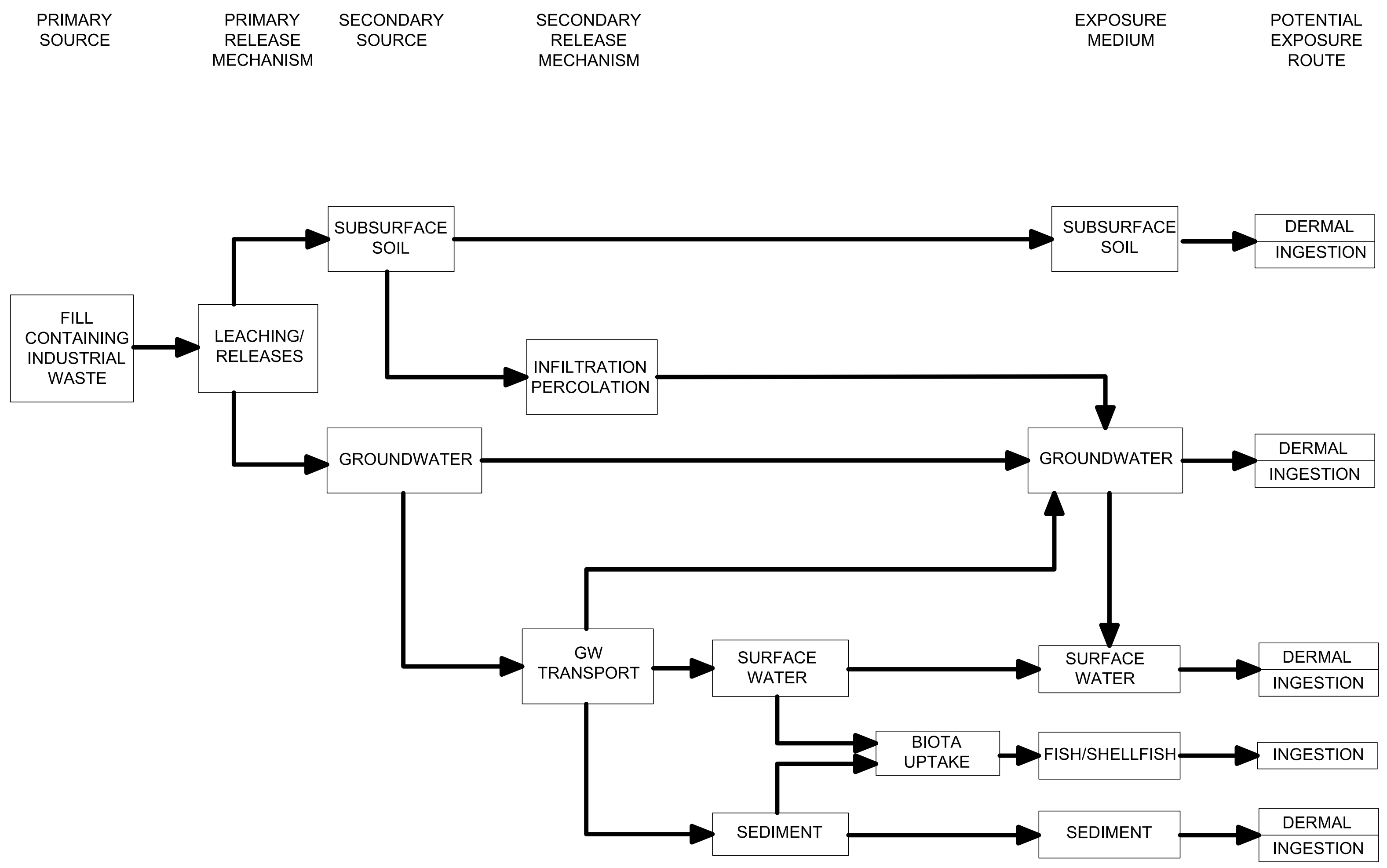
Figure No. 1
Vicinity Map

CDM



USG INTERIORS/FEASIBILITY STUDY
PUYALLUP, WASHINGTON

Figure No. 2
Site Map and Sample Locations



POTENTIAL HUMAN RECEPTOR

EXPOSURE MEDIUM	POTENTIAL EXPOSURE ROUTE	CURRENT LAND USE				FUTURE LAND USE				
		INDOOR WORKER	OUTDOOR WORKER	TRESPASSER	RECREATIONAL USER	INDOOR WORKER	OUTDOOR WORKER	CONSTRUCTION WORKER	TRESPASSER	RECREATIONAL USER
SUBSURFACE SOIL	DERMAL	X	●	X	X	X	X	●	X	X
	INGESTION	X	X	X	X	X	X	●	X	X
GROUNDWATER	DERMAL	X	X	X	X	X	X	●	X	X
	INGESTION	X	X	X	X	●	●	●	X	X
SURFACE WATER	DERMAL	X	X	●	●	X	X	X	●	●
	INGESTION	X	X	●	●	X	X	X	●	●
FISH/SHELLFISH	INGESTION	X	X	●	●	X	X	X	●	●
SEDIMENT	DERMAL	X	●	●	●	X	X	X	●	●
	INGESTION	X	X	●	●	X	X	X	●	●

LEGEND:

● COMPLETE EXPOSURE PATHWAY

X INCOMPLETE EXPOSURE PATHWAY

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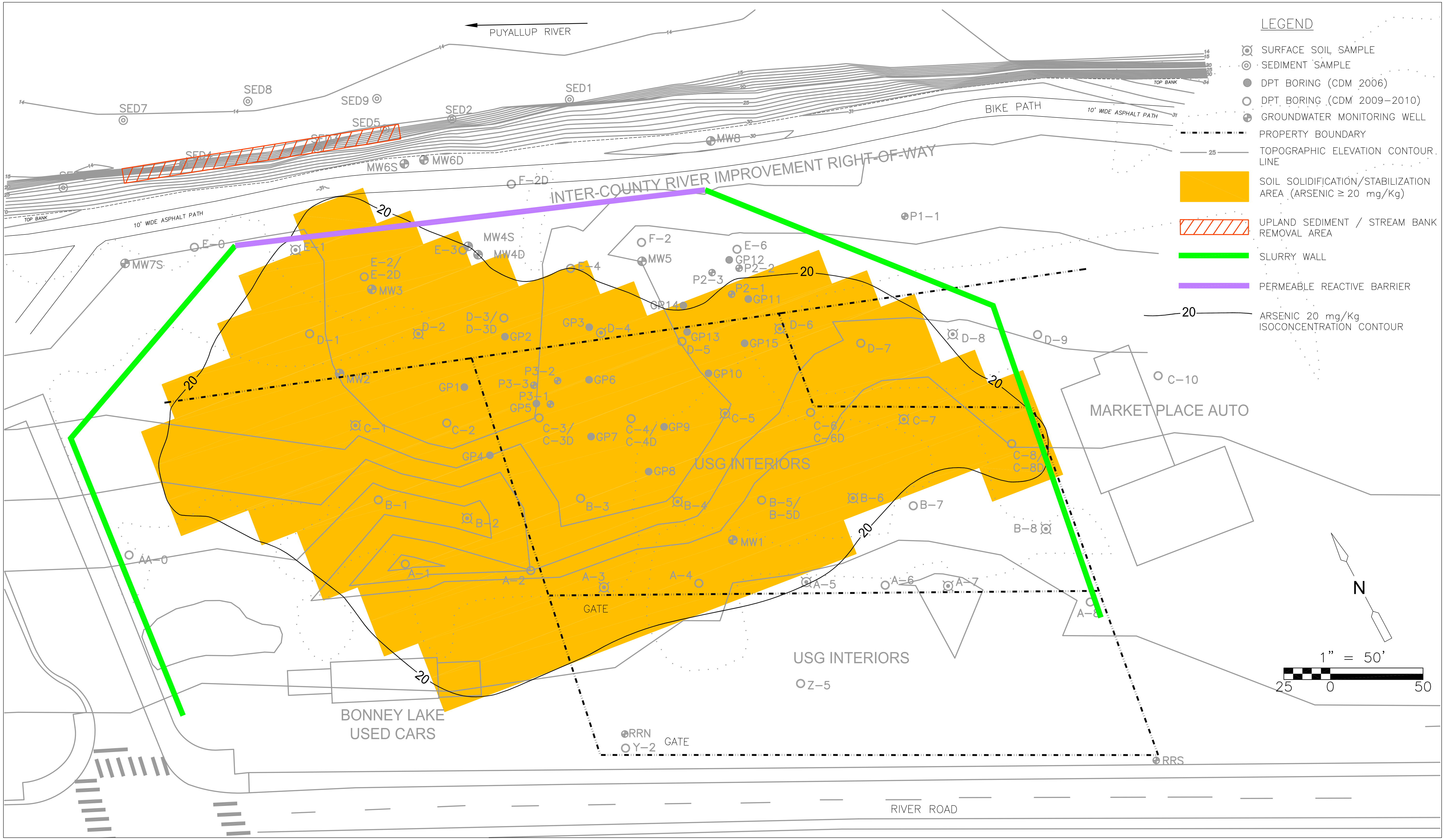
USG INTERIORS/FEASIBILITY STUDY
PUYALLUP, WASHINGTON

Figure No. 3
Conceptual Site Model



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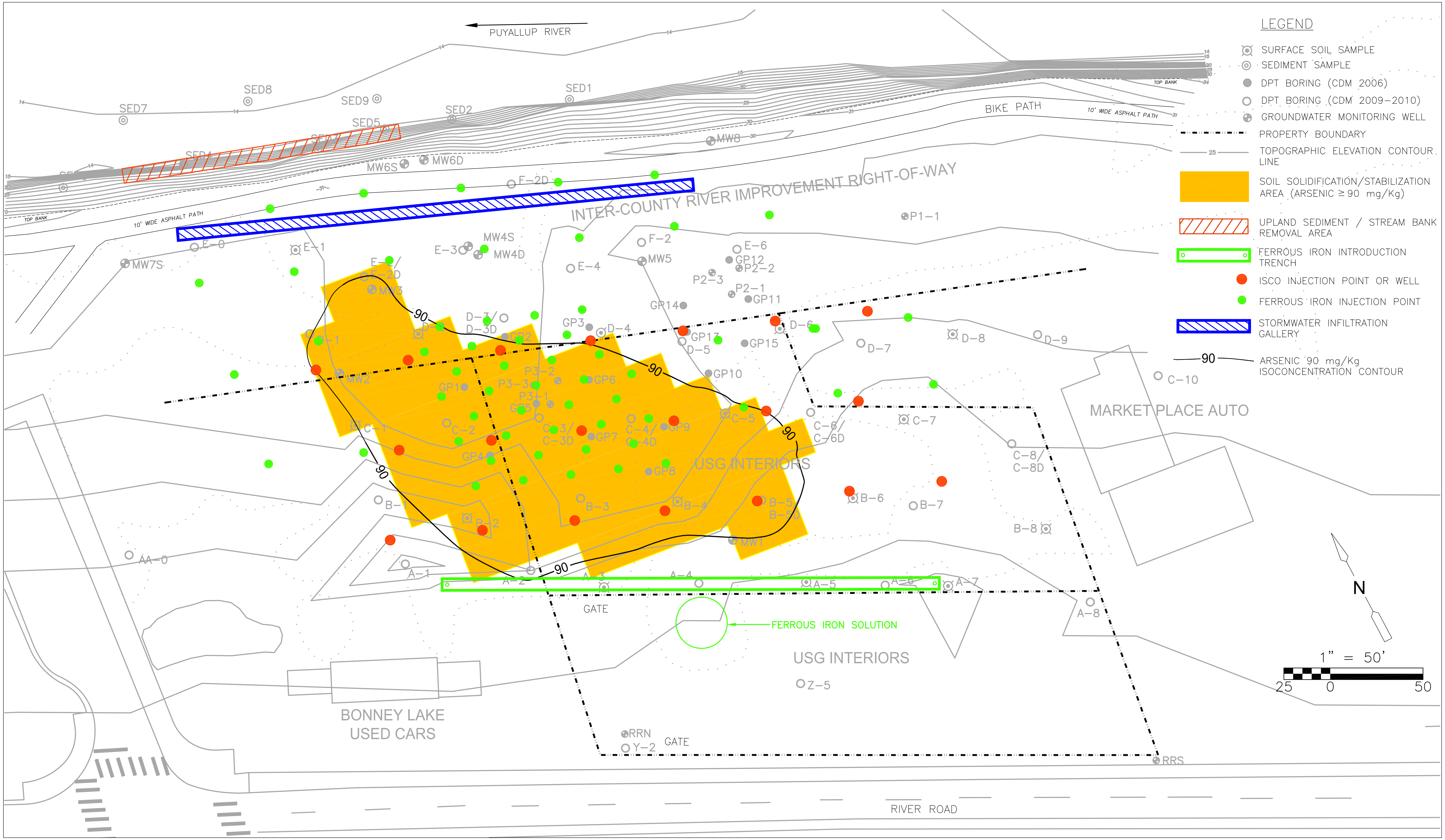
USG INTERIORS/FEASIBILITY STUDY
PUYALLUP, WASHINGTON

Figure No. 4
Remedial Action Alternative No. 1



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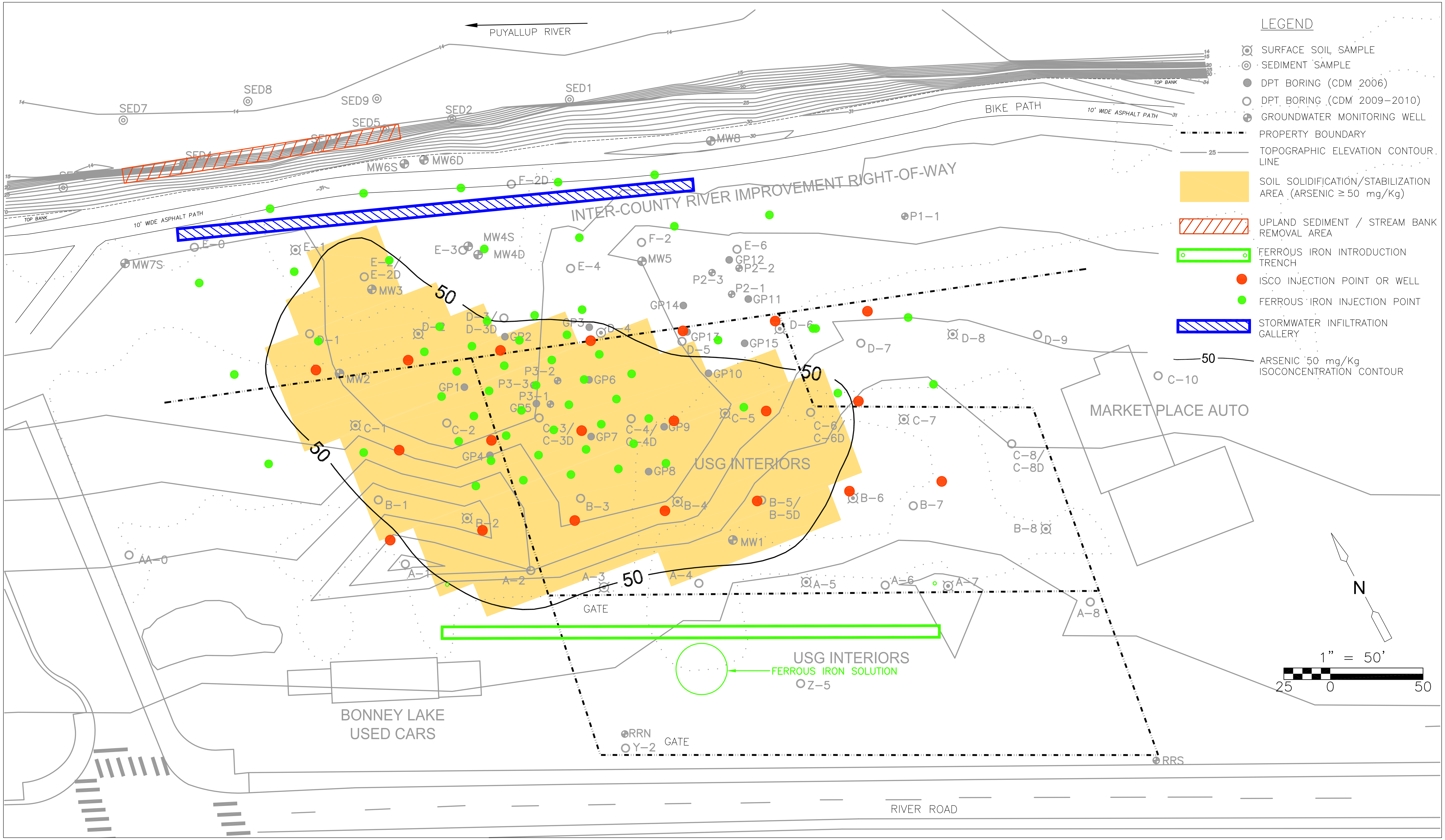
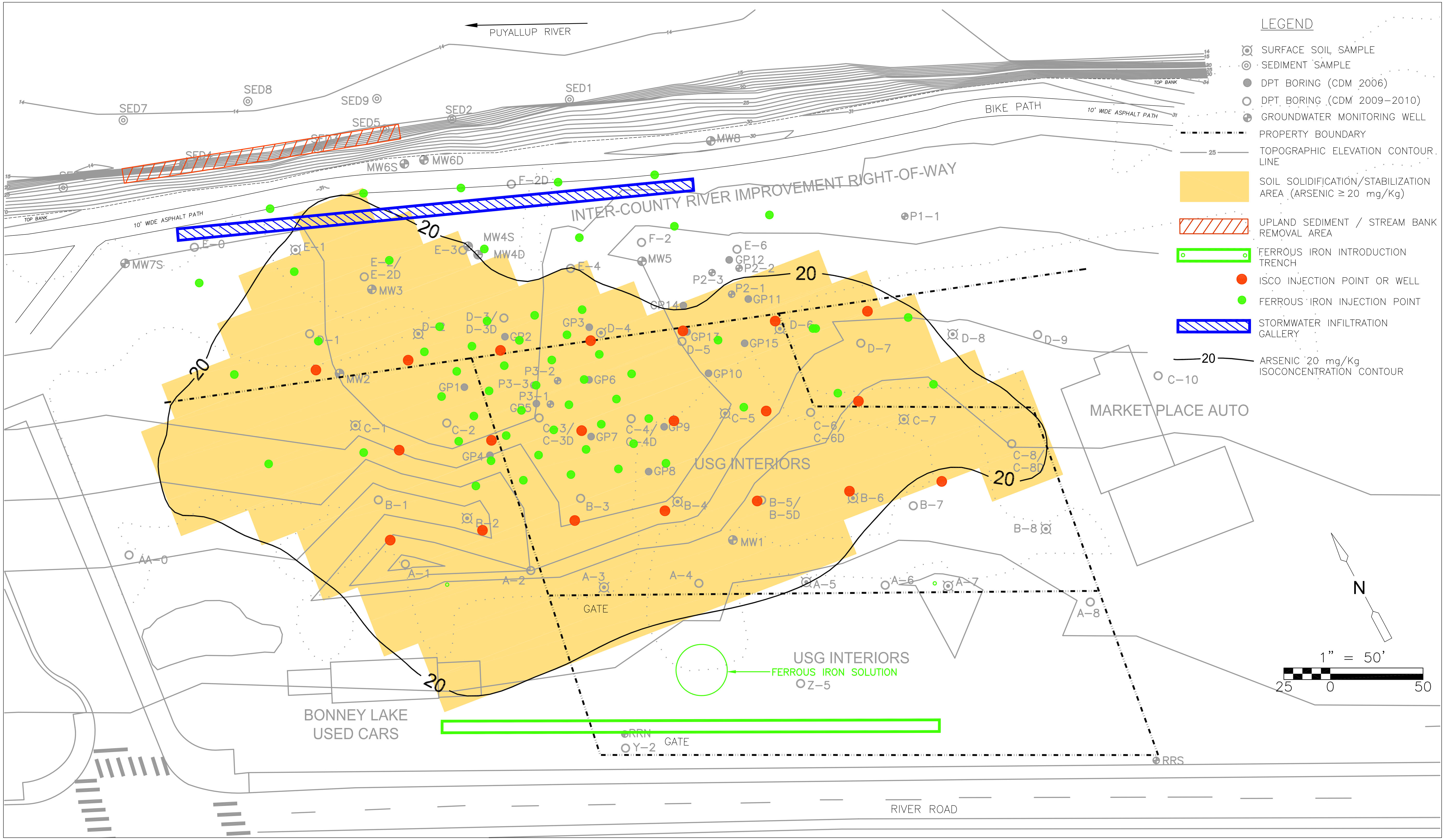
USG INTERIORS/FEASIBILITY STUDY
PUYALLUP, WASHINGTON

Figure No. 5A
Remedial Action Alternative No. 2A



USG INTERIORS/FEASIBILITY STUDY
PUYALLUP, WASHINGTON

Figure No. 5B
Remedial Action Alternative No. 2B



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USG INTERIORS/FEASIBILITY STUDY
PUYALLUP, WASHINGTON

Figure No. 5C
Remedial Action Alternative No. 2C

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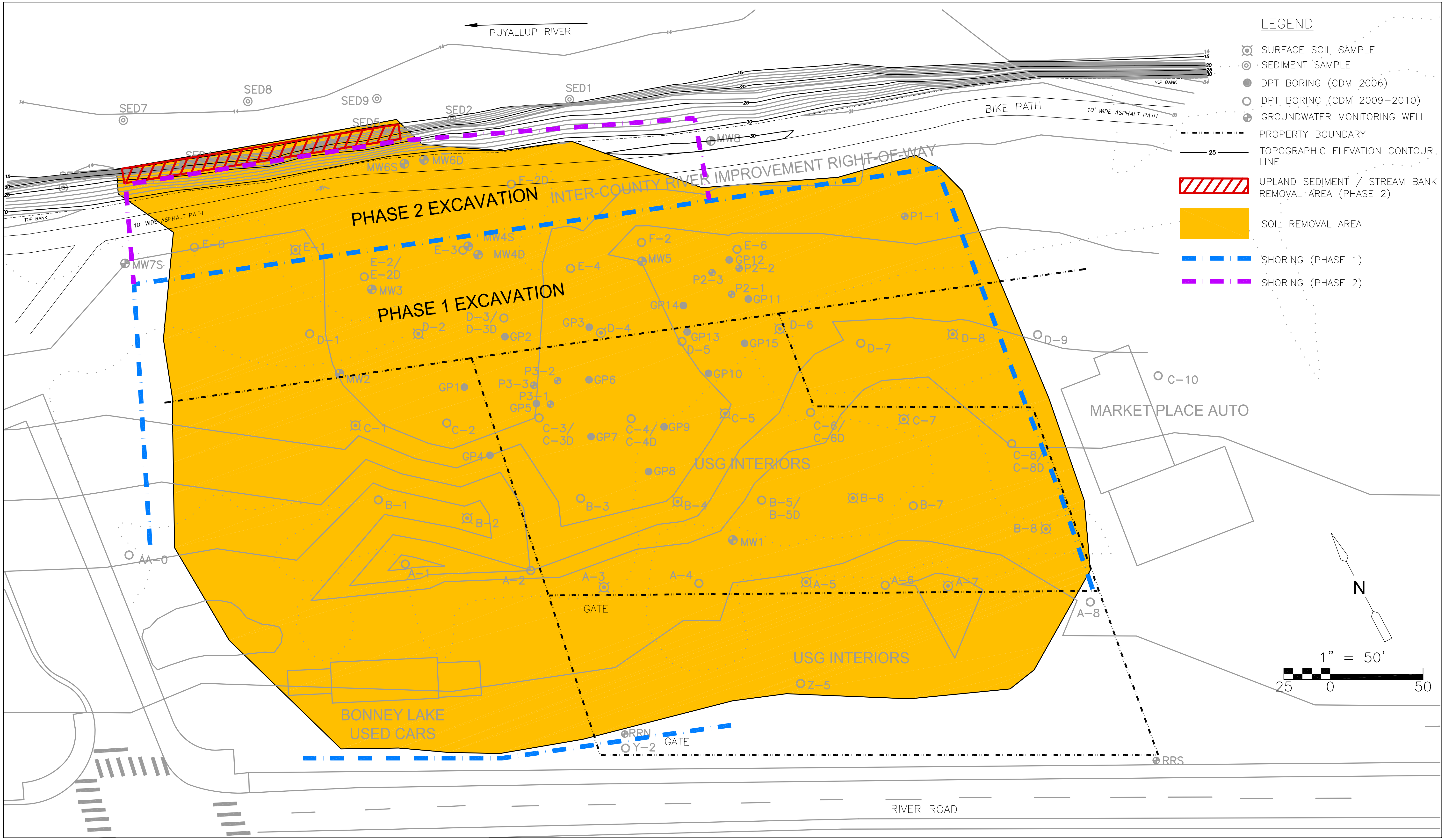

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USG INTERIORS/FEASIBILITY STUDY
PUYALLUP, WASHINGTON

Figure No. 6
Remedial Action Alternative No. 3

Appendix A
RI Tables

Table 1
Well Construction Details

USG Interiors/Remedial Investigation
Puyallup, Washington

Well I.D.	Easting [a]	Northing [a]	TOC Elevation (ft AMSL) [b]	Boring Total Depth (ft)	Screen Depth Interval (ft)	Depth to Top of Filter Pack (ft)	Casing Diameter (in)	Slot Size (in)	Drilled Date
P1-1	1191456.74	686927.89	34.14	17.00	~15-20	~13.5	4	0.01	05/07/85
P1-2	--	--	34.27	22.50	~20-25	~19	4	0.01	05/08/85
P1-3	--	--	35.35	27.50	~25-30	~23.5	4	0.01	05/08/85
P2-1	1191354.58	686922.13	33.14	17.50	~15-20	~14.5	4	0.01	05/06/85
P2-2	1191363.34	686933.80	34.76	22.50	~25-30	~20.5	4	0.01	05/06/85
P2-3	1191348.89	686936.78	34.04	28.50	~30-35	~23.5	4	0.01	05/07/85
P3-1	1191242.19	686901.85	33.66	15.00	~15-20	~13	4	0.01	05/03/85
P3-2	1191250.35	686912.26	32.93	20.00	~20-25	~17.5	4	0.01	05/03/85
P3-3	119215.95	686721.62	32.92	25.00	~25-30	~17	4	0.01	05/03/85
MW-1	1191307.78	686798.34	42.25	25.50	17-22	18.00	2	0.01	10/28/09
MW-2	1191142.04	686958.00	35.11	20.00	15-20	13.40	2	0.01	10/28/09
MW-3	1191174.56	686994.06	33.70	20.00	15-20	14.00	2	0.01	10/29/09
MW-4S	1191231.30	686997.11	32.22	20.50	15.5-20.5	13.00	2	0.01	10/29/09
MW-4D	1191234.67	686990.98	32.77	45.50	40-45	38.00	2	0.01	10/30/09
MW-5	1191315.85	686956.00	37.36	25.00	20-25	17.50	2	0.01	10/29/09
MW-6S	1191215.11	687050.90	30.50	25.00	20-25	17.50	2	0.01	10/12/10
MW-6D	1191225.72	687049.07	30.72	45.00	38-43	36.00	2	0.01	10/12/10
MW7S	1191055.40	687054.77	30.90	25.00	15-25	13.00	1	0.01	08/20/10
MW8	1191373.66	687003.24	29.93	25.00	16-21	15.00	2	0.01	10/12/10
RRN	1191478.16	686605.75	45.07	28.00	~20-25	--	2	--	09/14/82
RRS	1191215.95	686721.62	44.72	28.00	~25-30	--	2	--	09/14/82

Notes:

a) Washington State Plane North American Datum of 1983 (NAD 83), Zone 12, feet.

b) ft AMSL - feet above mean sea level. Elevations based on North American Vertical Datum of 1988 (NAVD 88).

TOC - top of casing.

~ approximately.

-- unknown.

Table 2
Summary of Groundwater Elevation Measurements

USG Interiors/Remedial Investigation
Puyallup, Washington

Date	Well I.D.	Measured Depth to Groundwater (ft) TOC	Well TOC Elevation (ft AMSL) [a]	Groundwater Elevation (ft AMSL) [a]
11/10/2009	P1-1	14.20	34.14	19.94
	P1-2 [b,c]	14.74	34.27	19.53
	P1-3 [b,c]	14.20	35.35	21.15
	P2-1	13.22	33.14	19.92
	P2-2	14.83	34.76	19.93
	P2-3	14.15	34.04	19.89
	P3-1	13.71	33.66	19.95
	P3-2	12.97	32.93	19.96
	P3-3	13.00	32.92	19.92
	MW-1	21.53	42.25	20.72
	MW-2	15.37	35.11	19.74
	MW-3	14.00	33.70	19.70
	MW-4S	12.60	32.22	19.62
	MW-4D	13.02	32.77	19.75
	MW-5	17.52	37.36	19.84
	RRN	23.32	45.07	21.75
	RRS	23.83	44.72	20.89
10/20/2010	MW-6S	12.35	30.50	18.15
	MW-6D	12.56	30.72	18.16
	MW-7S	12.78	30.90	18.12
	MW-8	11.51	29.93	18.42

Notes:

TOC - Top of Casing

a) ft AMSL - feet above mean sea level. Elevations based on North American Vertical Datum of 1988 (NAVD 88).

b) Estimated casing addition to P1-2 and P1-3 = P1-1 addition of 2.44 ft from historical data.

c) TOC elevation above MSL calculated from P1-1 difference from historical to recent survey data.

Table 3
Geochemical Indicator Parameters in Groundwater
USG Interiors/Remedial Investigation
Puyallup, Washington

Well I.D.	Date Sampled	pH	ORP (mV)	DO (mg/L)	Temperature (ºC)	Conductivity (µS/cm)
P1-1	11/12/2009	6.3	-60.8	0.47	13.22	365
P2-1	11/12/2009	6.33	-93.2	1.55	12.9	440
P2-2	11/12/2009	6.64	-108.6	1.32	12.3	349
P2-3	11/12/2009	6.41	-120.9	0.52	12.26	354
P3-1	11/11/2009	5.98	31	0.35	13.38	456
P3-2	11/11/2009	5.87	47.1	0.5	13.09	258
P3-3	11/11/2009	5.85	-25.4	0.47	12.84	225
MW-1	11/12/2009	5.62	65.1	1.22	12.8	225
MW-2	11/11/2009	6.08	36.4	0.56	12.61	355
MW-3	11/11/2009	5.21	15	0.51	13.23	211
MW-4S	11/10/2009	5.09	-10.4	0.47	12.5	147
MW-4D	11/10/2009	6.59	-168.5	0.35	12.33	270
MW-5	11/11/2009	6.01	-131.4	0.36	12.59	303
MW-6S	10/20/2010	7.17	-102.3	0.76	13.2	245
MW-6D	10/20/2010	7.56	-156.7	0.69	12.53	337
MW-7S	10/20/2010	7.26	-110.8	0.76	13.35	289
MW-8	10/20/2010	7.24	-172	0.99	12.64	386
RRN	11/10/2009	5.73	123	2.55	13.72	254
RRS	11/10/2009	6.06	91.6	0.93	12.96	275

Notes:
ORP - oxidation/reduction potential.
DO - dissolved oxygen.
mg/L - milligrams per liter.
mV - millivolts.

Table 4
Vertical Gradient Between Shallow and Deeper Groundwater Monitoring Points

USG Interiors/Remedial Investigation
Puyallup, Washington

Well I.D.	Well TOC Elevation MSL[a] (ft)	Screen Midpoint Elevation MSL[a] (ft)	Groundwater Elevation MSL[a] (ft)	Vertical Gradient Between Shallow and Deeper Groundwater Monitoring Points	
				Upward	Downward
P2-1	33.14	14.99	19.92		0.003
P2-2	34.76	8.36	19.93		
P2-3	34.04	3.89	19.89		
P3-1	33.66	15.91	19.95		0.003
P3-2	32.93	10.93	19.96		
P3-3	32.92	4.67	19.92		
MW-4S	32.22	14.22	19.62	0.005	
MW-4D	32.77	-13.57	19.75		
MW-6S	30.50	8.00	18.15	0.001	
MW-6D	30.72	-9.78	18.16		

Notes:

Based on groundwater level measurements collected on November 10, 2009 and October 20, 2010.

a) MSL - Mean Sea Level. Elevations based on North American Vertical Datum of 1988 (NAVD 88).

TOC - top of casing.

Table 5
Arsenic Concentrations in Soil
USG-Puyallup Site
Puyallup, Washington

Boring I.D.	Sample Depth (ft bgs)	Date Sampled	Total Arsenic-XRF [a] mg/kg	Total Arsenic-Lab mg/kg	TCLP Arsenic-Lab mg/kg
A1-0	0	10/12/09	24	--	--
A1-0.5	0.5	10/12/09	155	--	--
A1-2	2	10/12/09	5	--	--
A1-8	8	10/12/09	54	<60	--
A1-10	10	10/12/09	5	--	--
A1-12	12	10/12/09	11	--	--
A1-16	16	10/12/09	5	--	--
A1-18	18	10/12/09	9	--	--
A1-20	20	10/12/09	4	--	--
A2-0	0	10/12/09	5	--	--
A2-2	2	10/12/09	61	--	--
A2-4	4	10/12/09	9	--	--
A2-6	6	10/12/09	123	39	--
A2-8	8	10/14/09	401	--	--
A2-10	10	10/12/09	232	--	--
A2-12	12	10/12/09	177	--	--
A2-16	16	10/12/09	82	--	--
A3-0	3	10/14/09	16	--	--
A4-0	3	10/14/09	13	42	--
A4-2	2	10/14/09	10 [b]	17	--
A4-8	8	10/14/09	90	--	--
A4-10	10	10/14/09	5	--	--
A4-12	12	10/14/09	146	--	--
A4-14	14	10/14/09	5	--	--
A4-16	16	10/14/09	5	--	--
A4-18	18	10/14/09	5	--	--
A4-20	20	10/14/09	49	--	--
A4-22	22	10/14/09	5	--	--
A5-0	0	10/14/09	143	--	--
A6-0	0	10/14/09	554	--	--
A6-2	2	10/14/09	125	--	--
A6-6	6	10/14/09	70	48	--
A6-8	8	10/14/09	5	--	--
A6-10	10	10/14/09	5	--	--
A6-12	12	10/14/09	5	--	--
A6-14	14	10/14/09	5	--	--
A6-16	16	10/14/09	5	--	--
A7-0	0	10/15/09	28	--	--
A8-0	0	10/15/09	8	--	--
A8-2	2	10/15/09	12	<5	--
A8-4	4	10/15/09	22	--	--
A8-6	6	10/15/09	10	--	--
A8-8	8	10/15/09	5	--	--
A8-10	10	10/15/09	10	--	--

Table 5
Arsenic Concentrations in Soil
USG-Puyallup Site
Puyallup, Washington

Boring I.D.	Sample Depth (ft bgs)	Date Sampled	Total Arsenic-XRF [a] mg/kg	Total Arsenic-Lab mg/kg	TCLP Arsenic-Lab mg/kg
A8-12	12	10/15/09	5	--	--
A8-14	14	10/15/09	10	--	--
A8-16	16	10/15/09	5	<6	--
A8-18	18	10/15/09	5	--	--
A8-20	20	10/15/09	5	--	--
B2-0	0	10/15/09	13	--	--
B3-0	0	10/15/09	11	--	--
B3-2	2	10/15/09	98	--	--
B3-4	4	10/15/09	703	--	--
B3-6	6	10/15/09	468	--	--
B3-8	8	10/15/09	337	--	--
B3-10	10	10/15/09	235	--	--
B3-12	12	10/15/09	626	632	--
B3-14	14	10/15/09	56	--	--
B3-16	16	10/15/09	5	--	--
B4-0	0	10/15/09	4	--	--
B5-0	0	10/15/09	11	--	--
B5-2	2	10/16/09	15	--	--
B5-4	4	10/16/09	5	--	--
B5-6	6	10/16/09	5	--	--
B5-8	8	10/16/09	5	--	--
B5-10	10	10/15/09	514	--	--
B5-12	12	10/15/09	315	588	--
B5-14	14	10/15/09	513	--	--
B5-16	16	10/15/09	930	--	--
B5D-18	18	08/18/10	222	--	--
B5D-20	20	08/18/10	12	--	--
B5D-22	22	08/18/10	22	--	--
B5D-23	23	08/18/10	40	--	--
B5D-26	26	08/18/10	22	--	--
B5D-27.5	27.5	08/18/10	5	--	--
B6-0	0	10/16/09	5	--	--
B7-4	4	10/16/09	4	--	--
B7-6	6	10/16/09	11	6	--
B7-8	8	10/16/09	5	--	--
B7-10	10	10/16/09	4	--	--
B7-14	14	10/16/09	5	--	--
B7-16	16	10/16/09	5	--	--
B8-0	0	10/16/09	38	--	--
C1-0	0	10/14/09	4	--	--
C2-0	0	10/15/09	4	--	--
C2-2	2	10/12/09	1090	1110	--
C2-4	4	10/14/09	748	--	--
C2-6	6	10/14/09	1,060	--	--

Table 5
Arsenic Concentrations in Soil
USG-Puyallup Site
Puyallup, Washington

Boring I.D.	Sample Depth (ft bgs)	Date Sampled	Total Arsenic-XRF [a] mg/kg	Total Arsenic-Lab mg/kg	TCLP Arsenic-Lab mg/kg
C2-8	8	10/15/09	1,045	1,220	--
C2-10	10	10/15/09	237	314	--
C2-12	12	10/16/09	714	594	--
C2-14	14	10/12/09	39	--	--
C2-16	16	10/12/09	26	--	--
C3-0	0	10/15/09	5	--	--
C3D-18	18	08/17/10	72	--	--
C3D-19.5	19.5	08/17/10	149	--	--
C3D-24	24	08/17/10	12	--	--
C3D-26	26	08/17/10	9	--	--
C4-0	0	10/15/09	10	--	--
C4-2	2	10/14/09	5	--	--
C4-4	4	10/14/09	10	--	--
C4-6	6	10/14/09	767	--	--
C4-8	8	10/14/09	443	--	--
C4-10	10	10/16/09	496	633	--
C4-12	12	10/16/09	808	804	--
C4-14	14	10/16/09	184	--	--
C4-16	16	10/12/09	123	--	--
C4D-18	18	08/18/10	146	--	--
C4D-20	20	08/18/10	63	--	--
C4D-22.5	22.5	08/18/10	83	--	--
C4D-24	24	08/18/10	80	--	--
C4D-26.5	26.5	08/18/10	62	--	--
C4D-28	28	08/18/10	5 [b]	--	--
C4D-30	30	08/18/10	5	--	--
C4D-32	32	08/18/10	5	--	--
C5-0	0	10/15/09	12	--	--
C6-0	0	10/15/09	15	--	--
C6-2	2	10/14/09	4	--	--
C6-4	4	10/14/09	8	--	--
C6-8	8	10/15/09	5	--	--
C6-12	12	10/16/09	9	--	--
C6-14	14	10/12/09	4	--	--
C6-16	16	10/12/09	499	--	--
C6D-18	18	10/26/10	210	--	--
C6D-20	20	10/26/10	168	--	--
C6D-22	22	10/26/10	382	--	--
C6D-24	24	10/26/10	72	--	--
C6D-26	26	10/26/10	122	--	--
C6D-28	28	10/26/10	22	--	--
C6D-30	30	10/26/10	19	--	--
C7-0	0	10/15/09	28	--	--
C8-0	0	10/16/09	16	--	--

Table 5
Arsenic Concentrations in Soil
USG-Puyallup Site
Puyallup, Washington

Boring I.D.	Sample Depth (ft bgs)	Date Sampled	Total Arsenic-XRF [a] mg/kg	Total Arsenic-Lab mg/kg	TCLP Arsenic-Lab mg/kg
C8-2	2	10/12/09	5	--	--
C8-8	8	10/14/09	13	--	--
C8-10	10	10/16/09	33	87	--
C8-12	12	10/12/09	85	--	--
C8-14	14	10/12/09	20	--	--
C8D-16	16	10/26/10	4	--	--
C8D-18	18	10/26/10	3	--	--
C8D-24	24	10/26/10	13	--	--
C8D-26	26	10/26/10	4	--	--
C8D-28	28	10/26/10	4	--	--
C8D-29.5	29.5	10/26/10	4	--	--
C10-0	0	08/19/10	3	--	--
C10-2	2	08/19/10	5	--	--
C10-4	4	08/19/10	15	--	--
C10-6	6	08/19/10	4	--	--
C10-8	8	08/19/10	4	--	--
C10-10	10	08/19/10	4	--	--
C10-12	12	08/19/10	4	--	--
C10-14	14	08/19/10	3	--	--
C10-16	16	08/19/10	3	--	--
D1-0	0	10/16/09	5	--	--
D1-2	2	10/14/09	5	--	--
D1-4	4	10/14/09	28	--	--
D1-6	6	10/14/09	123	--	--
D1-8	8	10/15/09	92	74	--
D1-10	10	10/14/09	698	1,010	--
D1-12	12	10/15/09	122	--	--
D1-14	14	10/15/09	442	--	--
D1-16	16	10/12/09	112	--	--
D2-0	0	10/15/09	5	--	--
D3-0	0	10/15/09	4	--	--
D3-2	2	10/16/09	5	--	--
D3-4	4	10/12/09	19	--	--
D3-6	6	10/14/09	16	13	--
D3-10	10	10/16/09	5	--	--
D3-12	12	10/14/09	2540	2,900	--
D3-16	16	10/15/09	379	389	--
D3-20	20	10/16/09	326	--	--
D3D-18	18	08/17/10	81	--	--
D3D-22	22	08/17/10	923	--	--
D3D-24	24	8/17/10	888	--	--
D3D-26	26	08/17/10	709	--	--
D3D-28	28	08/17/10	525	--	--
D3D-30	30	08/17/10	5	--	--

Table 5
Arsenic Concentrations in Soil
USG-Puyallup Site
Puyallup, Washington

Boring I.D.	Sample Depth (ft bgs)	Date Sampled	Total Arsenic-XRF[a] mg/kg	Total Arsenic-Lab mg/kg	TCLP Arsenic-Lab mg/kg
D4-0	0	10/14/09	5	--	--
D5-0	0	10/15/09	9	--	--
D5-2	2	10/16/09	5	--	--
D5-4	4	10/16/09	10	--	--
D5-6	6	10/15/09	5	--	--
D5-8	8	10/16/09	10	--	--
D5-10	10	10/16/09	16	--	--
D5-12	12	10/15/09	29	--	--
D5-14	14	10/16/09	82	--	--
D5-16	16	10/15/09	37	36	--
D6-0	0	10/16/09	4	--	--
D7-0	0	10/16/09	19	--	--
D7-2	2	10/14/09	4	--	--
D7-2	2	10/14/09	12	--	--
D7-4	4	10/15/09	9	--	--
D7-8	8	10/14/09	24[b]	9	--
D7-10	10	10/14/09	39	--	--
D7-14	14	10/15/09	9	--	--
D7-16	16	10/15/09	132[b]	--	--
D8-0	0	10/14/09	23	--	--
D9-0	0	08/19/10	6	--	--
D9-2	2	08/19/10	4	--	--
D9-4	4	08/19/10	30	--	--
D9-6	6	08/19/10	9	--	--
D9-8	8	08/19/10	4	--	--
D9-12	12	08/19/10	13	--	--
D9-14	14	08/19/10	4	--	--
E0-0	0	08/20/10	30	--	--
E0-2	2	08/20/10	4	--	--
E0-4	4	08/20/10	12	--	--
E0-6	6	08/20/10	4	--	--
E0-8	8	08/20/10	4	--	--
E0-10	10	08/20/10	4	--	--
E0-12	12	08/20/10	4	--	--
E0-14	14	08/20/10	4	--	--
E0-16	16	08/20/10	10	--	--
E1-0	0	10/15/09	5	--	--
E2-0	0	10/14/09	5	--	--
E2-2	2	10/15/09	5	--	--
E2-6	6	10/16/09	75	69	--
E2-8	8	10/14/09	12	78	--
E2-10	10	10/14/09	745	--	--
E2-12	12	10/14/09	26	--	--
E2-14	14	10/14/09	284	--	--

Table 5
Arsenic Concentrations in Soil
USG-Puyallup Site
Puyallup, Washington

Boring I.D.	Sample Depth (ft bgs)	Date Sampled	Total Arsenic-XRF [a] mg/kg	Total Arsenic-Lab mg/kg	TCLP Arsenic-Lab mg/kg
E2D-16	16	08/17/10	373	--	--
E2D-18	18	08/17/10	1358	--	--
E2D-20	20	08/17/10	1990	--	--
E2D-23	23	08/17/10	37	--	--
E2D-24	24	08/17/10	167	--	--
E2D-26	26	08/17/10	95	--	--
E2D-28	28	08/17/10	146	--	--
E2D-30	30	08/17/10	408 [b]	--	--
E2D-32	32	08/17/10	57	--	--
E2D-34	34	08/17/10	11	--	--
E3-0	0	10/14/09	6	--	--
E4-0	0	10/12/09	5	--	--
E4-2	2	10/15/09	16	--	--
E4-4	4	10/14/09	5	--	--
E4-6	6	10/15/09	17	--	--
E4-8	8	10/15/09	12	--	--
E4-10	10	10/15/09	13	--	--
E4-12	12	10/16/09	104	--	--
E4-14	14	10/15/09	204	--	--
E4-16	16	10/15/09	147	58	--
E4-18	18	10/12/09	74	--	--
E4-20	20	10/15/09	40 [b]	26	--
E4-22	22	10/15/09	70	--	--
E4-24	24	10/15/09	37	--	--
E4-28	28	10/16/09	16	--	--
E6-0	0	10/14/09	5	--	--
E6-2	2	10/14/09	15	--	--
E6-4	4	10/15/09	5	--	--
E6-6	6	10/15/09	5	--	--
E6-8	8	10/16/09	5	--	--
E6-10	10	10/15/09	12	--	--
E6-12	12	10/14/09	5	--	--
E6-14	14	10/14/09	10	--	--
E6-16	16	10/14/09	22	19	--
F1-0	0	10/16/09	10	--	--
F1-2	2	10/15/09	5	--	--
F1-4	4	10/15/09	17	--	--
F1-6	6	10/15/09	127	--	--
F1-8	8	10/12/09	61	--	--
F1-10	10	10/12/09	605	--	--
F1-12	12	10/15/09	139	--	--
F1-14	14	10/15/09	304	--	--
F1-16	16	10/14/09	376	--	--
F2-0	0	10/15/09	11	--	--

Table 5
Arsenic Concentrations in Soil
USG-Puyallup Site
Puyallup, Washington

Boring I.D.	Sample Depth (ft bgs)	Date Sampled	Total Arsenic-XRF [a] mg/kg	Total Arsenic-Lab mg/kg	TCLP Arsenic-Lab mg/kg
F2-2	2	10/15/09	5	--	--
F2-4	4	10/15/09	5	<7	--
F2-6	6	10/15/09	11	--	--
F2-8	8	10/16/09	5	--	--
F2-10	10	10/15/09	17	--	--
F2-12	12	10/15/09	5	--	--
F2-14	14	10/15/09	5	--	--
F2-16	16	10/15/09	18	--	--
F2D-0	0	8/20/10	4	--	--
F2D-2	2	8/20/10	4	--	--
F2D-4	4	8/20/10	4	--	--
F2D-6	6	8/20/10	10	--	--
F2D-8	8	8/20/10	4	--	--
F2D-12	12	8/20/10	3	--	--
F2D-14	14	8/20/10	50 [b]	--	--
F2D-17	17	08/20/10	13	--	--
F2D-16	16	10/26/10	29	--	--
F2D-18	18	10/26/10	15	--	--
F2D-20	20	10/26/10	22	--	--
F2D-22	22	10/26/10	4	--	--
F2D-24	24	10/26/10	3	--	--
F2D-26	26	10/26/10	31	--	--
F2D-28	28	10/26/10	3	--	--
F2D-30	30	10/26/10	4	--	--
F2D-32	32	10/26/10	4	--	--
F2D-34	34	10/26/10	4 [b]	--	--
SED1	0	11/12/09	--	<7	--
SED2	0	11/12/09	--	<7	--
SED3	0	11/12/09	--	136	--
SED4	0	11/12/09	--	75	--
SED5	0	08/20/10	219	--	--
SED6	0	08/20/10	3	--	--
SED7	0	08/19/10	3	--	--
SED8	0	08/19/10	3	--	--
SED9	0	08/19/10	3	--	--
GP1@8.5	8.5	09/06/06	--	480	--
GP1@13	13	09/06/06	--	68	--
GP1@19 1/2	19.5	09/06/06	--	14	--
GP2@9	9	09/06/06	--	1,200	7.2
GP2@12	12	09/06/06	--	640	--
GP2@17 1/2	17.5	09/06/06	--	1,100	2.9
GP3@9 1/2	19.5	09/06/06	--	650	0.64
GP3@16	16	09/06/06	--	20	--
GP4@10	10	09/06/06	--	76	--

Table 5
Arsenic Concentrations in Soil
USG-Puyallup Site
Puyallup, Washington

Boring I.D.	Sample Depth (ft bgs)	Date Sampled	Total Arsenic-XRF [a] mg/kg	Total Arsenic-Lab mg/kg	TCLP Arsenic-Lab mg/kg
GP4@12	12	09/06/06	--	75	--
GP4@17	17	09/06/06	--	<12	--
GP5@10 1/2	10.5	09/06/06	--	1,700	6.5
GP5@12 1/2	12.5	09/06/06	--	870	--
GP5@17	17	09/06/06	--	120	--
GP6@9 1/2	9.5	09/06/06	--	830	--
GP6@12	12	09/06/06	--	390	--
GP6@17	17	09/06/06	--	83	--
GP7@5	5	09/06/06	--	670	--
GP7@9 1/2	9.5	09/06/06	--	2100	5.5
GP7@12 1/2	12.5	09/06/06	--	57	--
GP7@17 1/2	17.5	09/06/06	--	30	--
GP8@10 1/2	10.5	09/06/06	--	410	--
GP8@15	15	09/06/06	--	100	--
GP8@18	18	09/06/06	--	<13	--
GP9@8	8	09/06/06	--	560	--
GP9@10 1/2	10.5	09/06/06	--	750	3.5
GP9@17 1/2	17.5	09/06/06	--	300	--
GP10@10 1/2	10.5	09/06/06	--	470	<0.40
GP10@15	15	09/06/06	--	91	--
GP10@18 1/2	18.5	09/06/06	--	12	--
GP11@10	10	09/06/06	--	100	--
GP11@15	15	09/06/06	--	<13	--
GP11@17 1/2	17.5	09/06/06	--	<13	--
GP12@11 1/2	11.5	09/06/06	--	770	0.53
GP12@16 1/2	16.5	09/06/06	--	15	--
GP13@10	10	09/06/06	--	36	--
GP13@15	15	09/06/06	--	36	--
GP13@18 1/2	18.5	09/06/06	--	<12	--
GP14@10	10	09/06/06	--	18	--
GP14@15	15	09/06/06	--	59	--
GP14@18	18	09/06/06	--	<12	--
GP15@5 1/2	5.5	09/06/06	--	<12	--
GP15@10	10	09/06/06	--	76	--
GP15@15	15	09/06/06	--	81	--
GP15@17 1/2	17.5	09/06/06	--	38	--
MW6D-02	2	10/27/10	4	--	--
MW6D-04	4	10/27/10	4	--	--
MW6D-06	6	10/27/10	5	--	--
MW6D-09	9	10/27/10	5	--	--
MW6D-12	12	10/27/10	4	--	--
MW6D-14	14	10/27/10	121 [b]	--	--
MW6D-16	16	10/27/10	11	--	--
MW6D-18	18	10/27/10	12	--	--

Table 5
Arsenic Concentrations in Soil
USG-Puyallup Site
Puyallup, Washington

Boring I.D.	Sample Depth (ft bgs)	Date Sampled	Total Arsenic-XRF [a] mg/kg	Total Arsenic-Lab mg/kg	TCLP Arsenic-Lab mg/kg
MW6D-20	20	11/02/10	50 [b]	--	--
MW6D-22	22	11/02/10	140	--	--
MW6D-24	24	11/02/10	6	--	--
MW6D-26	26	11/02/10	3	--	--
MW6D-28	28	11/02/10	1	--	--
MW6D-30	30	11/02/10	4	--	--
MW6D-32	32	11/02/10	0	--	--
MW6D-34	34	11/02/10	2	--	--
MW6D-36	36	11/02/10	3	--	--
MW6D-38	38	11/02/10	3	--	--
MW6D-40	40	11/02/10	3	--	--
MW6D-42	42	11/02/10	6	--	--
MW6D-44	44	11/02/10	5	--	--
MW7S-0	0	08/20/10	4	--	--
MW7S-2	2	08/20/10	4	--	--
MW7S-4	4	08/20/10	4	--	--
MW7S-6	6	08/20/10	55	--	--
MW7S-8	8	08/20/10	21	--	--
MW7S-10	10	08/20/10	4	--	--
MW7S-12	12	08/20/10	3	--	--
MW7S-14	14	08/20/10	4	--	--
MW7S-16	16	08/20/10	3	--	--
MW7S-18	18	08/20/10	3	--	--
MW7S-20	20	08/20/10	11	--	--
MW7S-22	22	08/20/10	10	--	--
MW7S-24	24	08/20/10	3	--	--
Y2-0	0	08/18/10	7	--	--
Y2-2	2	08/18/10	12	--	--
Y2-4	4	08/18/10	16	--	--
Y2-6	6	08/18/10	15	--	--
Y2-8	8	08/18/10	10	--	--
Y2-10	10	08/18/10	5	--	--
Y2-12	12	08/18/10	5	--	--
Y2-14	14	08/18/10	9	--	--
Y2-15.5	15.5	08/18/10	5	--	--
Z5-0	0	08/18/10	5	--	--
Z5-2	2	08/18/10	5	--	--
Z5-4	4	08/18/10	5	--	--
Z5-6	6	08/18/10	10	--	--
Z5-8	8	08/18/10	13	--	--
Z5-10	10	08/18/10	10	--	--
Z5-12	12	08/18/10	9	--	--
Z5-14	14	08/18/10	12	--	--
Z5-16	16	08/18/10	5	--	--

Table 5
Arsenic Concentrations in Soil
USG-Puyallup Site
Puyallup, Washington

Boring I.D.	Sample Depth (ft bgs)	Date Sampled	Total Arsenic-XRF [a] mg/kg	Total Arsenic-Lab mg/kg	TCLP Arsenic-Lab mg/kg
AA0-0	0	10/26/10	13	--	--
AA0-2	2	10/26/10	12	--	--
AA0-4	4	10/26/10	51	--	--
AA0-6	6	10/26/10	9	--	--
AA0-8	8	10/26/10	6	--	--
AA0-10	10	10/26/10	39	--	--
AA0-12	12	10/26/10	12	--	--
AA0-14	14	10/26/10	20	--	--
AA0-16	16	10/26/10	37	--	--
AA0-18	18	10/26/10	12	--	--
AA0-20	20	10/26/10	4	--	--
AA0-24	24	10/26/10	6	--	--
AA0-26	26	10/26/10	3	--	--
AA0-28	28	10/26/10	4	--	--
AA0-30	30	10/26/10	3	--	--
AA0-33	33	10/26/10	3	--	--
AA0-34	34	10/26/10	4	--	--
Method A Cleanup Level [c]			20	20	NA
Dangerous Waste TCLP Threshold			NA	NA	5

Notes:

Shaded concentrations exceed Method A or TCLP cleanup levels.

a) Results from XRF corrected by statistical correlation with laboratory results. XRF samples containing arsenic below the detection limit have been set to half the detection limit.

b) Sample analyzed in replicate with the XRF. Result presented is average of replicate results.

c) Washington Administrative Code Chapter 173-340, Model Toxics Control Act Cleanup Regulation, Method A suggested soil cleanup level for unrestricted land uses/industrial properties; promulgated August 15, 2001.

mg/kg - milligrams per kilogram.

mg/L - milligrams per liter.

ft bgs - feet below ground surface.

NA - not applicable.

-- not analyzed.

< - analyte not detected at or greater than the listed concentration.

Table 6
Analytical Results - Groundwater
USG Interiors/Remedial Investigation
Puyallup, Washington

	Sample I.D. and Sample Date					
	USGPuy-RRS-11/09	USGPuy-RRN-11/09	USGPuy-MW1-11/09	USGPuy-MW2-11/09	USGPuy-MW3-11/09	USGPuy-MW0-11/09*
Analyte	**11/10/2009**	**11/10/2009**	**11/12/2009**	**11/11/2009**	**11/11/2009**	**11/11/2009**
Dissolved Metals (mg/L)						
EPA Methods 7060A/6010B)						
Arsenic	0.001	<0.001	0.044	1.5	0.71	0.67
Iron	<0.05	<0.05	0.76	0.21	0.43	0.40
Total Metals (mg/L)						
EPA Method 6010B						
Arsenic (EPA Method 7060A)	--	--	--	2.0	--	--
Calcium	31.2	19.8	15.1	34.1	16.2	14.3
Iron	<0.05	<0.05	0.91	0.66	0.65	0.57
Magnesium	6.02	9.91	6.67	13.7	8.48	7.47
Potassium	2.8	2.7	2.2	3.7	2.6	2.3
Sodium	12.2	13.9	13.0	14.8	10.3	9.2
Arsenic Speciation (µg/L)						
Arsenic (III)	--	--	40.0	93.5	357	477
Arsenic (V)	--	--	3.71	1,310	296	306
Conventionals						
Alkalinity (SM 2320; mg/L CaCO$_3$)	105	73.1	85.8	120	85.1	84.4
Carbonate (SM 2320; mg/L CaCO$_3$)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Bicarbonate (SM 2320; mg/L CaCO$_3$)	105	73.1	85.8	120	85.1	84.4
Hydroxide (SM 2320; mg/L CaCO$_3$)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Total Suspended Solids (EPA 160.2; mg/L)	<1.1	<1.1	3.0	<1.0	<1.0	<1.0
Chloride (EPA 300.0; mg/L)	6.1	6.2	3.4	18.9	5.4	5.4
N-Nitrate (EPA 300.0; mg-N/L)	0.6	4.8	0.1	2.8	0.5	0.5
N-Nitrite (EPA 300.0; mg-N/L)	<0.1	<0.1	<0.1	0.1	<0.1	<0.1
Sulfate (EPA 300.0; mg/L)	25.5	20.2	20.7	20.0	15.0	15.0
Chemical Oxygen Demand (EPA 410.4; mg/L)	7.08	<5.00	8.31	9.55	6.46	8.62
Total Organic Carbon (EPA 415.1; mg/L)	2.15	2.21	2.26	3.66	2.48	2.46

Table 6
Analytical Results - Groundwater
USG Interiors/Remedial Investigation
Puyallup, Washington

Analyte	Sample I.D. and Sample Date					
	USGPuy-MW4S-11/09	**USGPuy-MW4D-11/09**	**USGPuy-MW5-11/09**	**USGPuy-P1-1-11/09**	**USGPuy-P2-1-11/09**	**USGPuy-P2-2-11/09**
	11/10/2009	**11/10/2009**	**11/11/2009**	**11/12/2009**	**11/12/2009**	**11/12/2009**
Dissolved Metals (mg/L)						
EPA Methods 7060A/6010B)						
Arsenic	0.65	0.033	0.43	0.002	0.90	<0.002
Iron	0.35	0.92	20.3	17.0	26.2	9.54
Total Metals (mg/L)						
EPA Method 6010B						
Arsenic (EPA Method 7060A)	--	--	--	--	--	0.004
Calcium	18.5	36.0	19.8	27.2	30.7	22.1
Iron	0.48	9.19	26.1	16.5	35.8	18.4
Magnesium	9.24	9.19	7.60	9.65	7.83	10.6
Potassium	2.9	4.9	3.2	3.3	4.3	3.6
Sodium	11.7	32.8	13.2	11.3	10.5	14.5
Arsenic Speciation (µg/L)						
Arsenic (III)	291	149	464	--	1,040	1.80
Arsenic (V)	267	7.87	47.5	--	122	0.63
Conventionals						
Alkalinity (SM 2320; mg/L $CaCO_3$)	87.3	170	136	182	198	167
Carbonate (SM 2320; mg/L $CaCO_3$)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Bicarbonate (SM 2320; mg/L $CaCO_3$)	87.3	170	136	182	198	167
Hydroxide (SM 2320; mg/L $CaCO_3$)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Total Suspended Solids (EPA 160.2; mg/L)	<1.1	31.3	35.3	2.7	7.4	29.0
Chloride (EPA 300.0; mg/L)	4.9	6.7	5.6	8.0	4.8	4.9
N-Nitrate (EPA 300.0; mg-N/L)	0.7	<0.1	<0.1	<0.1	<0.1	<0.1
N-Nitrite (EPA 300.0; mg-N/L)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Sulfate (EPA 300.0; mg/L)	17.6	42.2	0.7	3.2	0.5	<0.1
Chemical Oxygen Demand (EPA 410.4; mg/L)	7.08	9.86	14.5	14.5	24.4	17.3
Total Organic Carbon (EPA 415.1; mg/L)	2.53	5.15	5.19	4.35	8.07	5.48

Table 6
Analytical Results - Groundwater
USG Interiors/Remedial Investigation
Puyallup, Washington

Analyte	Sample I.D. and Sample Date					
	USGPuy-P2-3-11/09	USGPuy-P3-1-11/09	USGPuy-P3-2-11/09	USGPuy-P3-3-11/09	USGPuy-MW6D-10/10	USGPuy-MW6S-10/10
	11/12/2009	11/11/2009	11/11/2009	11/11/2009	10/20/2010	10/20/2010
Dissolved Metals (mg/L)						
EPA Methods 7060A/6010B)						
Arsenic	<0.002	6.1	0.42	0.002	0.016	0.70
Iron	5.86	<0.05	<0.05	3.50	14.3	9.79
Total Metals (mg/L)						
EPA Method 6010B						
Arsenic (EPA Method 7060A)	--	--	0.44	--	--	--
Calcium	25.7	55.1	22.6	14.4	20.4	13.6
Iron	15.6	<0.05	<0.05	6.02	13.0	8.77
Magnesium	9.60	14.2	10.5	11.0	7.60	9.31
Potassium	4.1	6.0	3.0	3.6	3.3	2.6
Sodium	15.5	11.3	12.8	10.1	17.2	8.7
Arsenic Speciation (µg/L)						
Arsenic (III)	--	<2.4	<0.24	0.798	9.78	388
Arsenic (V)	--	4,640	296	0.431	1.77	219
Conventionals						
Alkalinity (SM 2320; mg/L $CaCO_3$)	170	189	92.3	110	145	103
Carbonate (SM 2320; mg/L $CaCO_3$)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Bicarbonate (SM 2320; mg/L $CaCO_3$)	170	189	92.3	110	145	103
Hydroxide (SM 2320; mg/L $CaCO_3$)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Total Suspended Solids (EPA 160.2; mg/L)	42.2	<1.0	<1.1	6.5	50.0	6.3
Chloride (EPA 300.0; mg/L)	5.3	7.1	5.8	3.4	5.9	3.8
N-Nitrate (EPA 300.0; mg-N/L)	<0.1	1.4	1.9	<0.1	<0.1	<0.1
N-Nitrite (EPA 300.0; mg-N/L)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Sulfate (EPA 300.0; mg/L)	0.1	43.0	19.9	4.2	2.3	4.9
Chemical Oxygen Demand (EPA 410.4; mg/L)	10.8	12.3	7.69	9.24	9.51	7.56
Total Organic Carbon (EPA 415.1; mg/L)	5.46	7.17	2.41	3.00	4.30	2.99

Table 6
Analytical Results - Groundwater

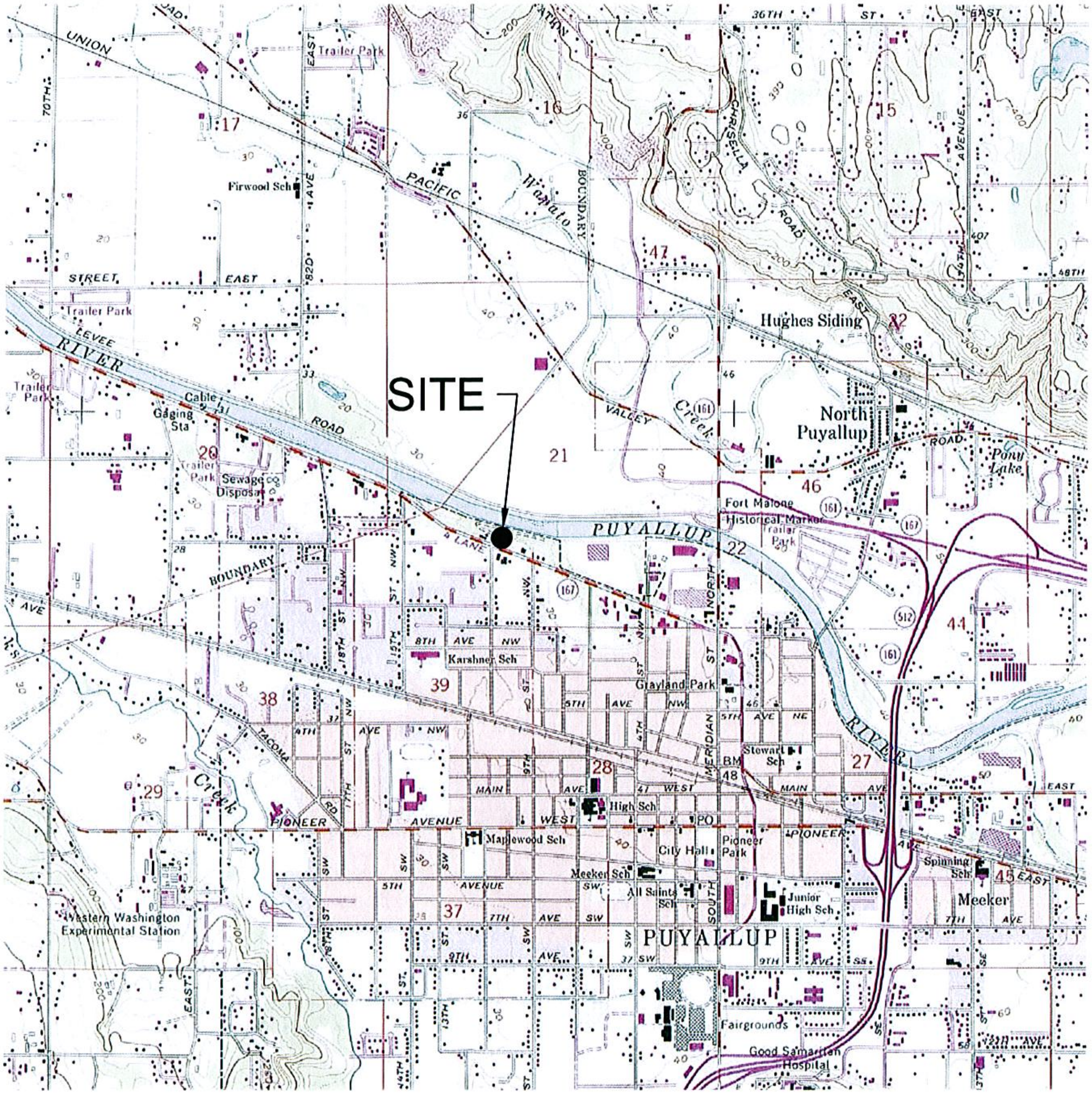
USG Interiors/Remedial Investigation
Puyallup, Washington

Analyte		Sample I.D. and Sample Date	
	USGPuy- MW0-10/10*	USGPuy-MW7-10/10	USGPuy-MW8-10/10
	10/20/2010	10/20/2010	10/20/2010
Dissolved Metals (mg/L)			
EPA Methods 7060A/6010B)			
Arsenic	0.72	0.001	0.076
Iron	--	4.43	21.6
Total Metals (mg/L)			
EPA Method 6010B			
Arsenic (EPA Method 7060A)	--	--	--
Calcium	--	31.4	24.1
Iron	--	4.05	19.4
Magnesium	--	4.16	9.82
Potassium	--	4.2	3.5
Sodium	--	10.8	12.8
Arsenic Speciation (µg/L)			
Arsenic (III)	--	<0.96	51.0
Arsenic (V)	--	<0.95	6.00
Conventionals			
Alkalinity (SM 2320; mg/L $CaCO_3$)	--	125	161
Carbonate (SM 2320; mg/L $CaCO_3$)	--	<1.0	<1.0
Bicarbonate (SM 2320; mg/L $CaCO_3$)	--	125	161
Hydroxide (SM 2320; mg/L $CaCO_3$)	--	<1.0	<1.0
Total Suspended Solids (EPA 160.2; mg/L)	--	<1.1	37.2
Chloride (EPA 300.0; mg/L)	--	4.9	6.9
N-Nitrate (EPA 300.0; mg-N/L)	--	<0.1	<0.1
N-Nitrite (EPA 300.0; mg-N/L)	--	<0.1	<0.1
Sulfate (EPA 300.0; mg/L)	--	10.3	<0.1
Chemical Oxygen Demand (EPA 410.4; mg/L)	--	8.21	9.83
Total Organic Carbon (EPA 415.1; mg/L)	--	3.12	4.34

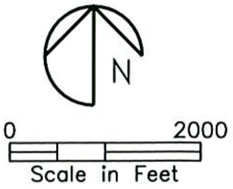
Notes:

*USGPuy-MW0-11/09 is a duplicate of USGPuy-MW3-11/09.
USGPuy-MW0-10/10 is a duplicate of MW6S-10/10.
mg/L - milligrams per liter.
µg/L - micrograms per liter.
-- not analyzed.
< - analyte not detected at or greater than the listed concentration.

Appendix B
RI Figures



Source: USGS Puyallup, Wash. 7.5' Quadrangle, 1981



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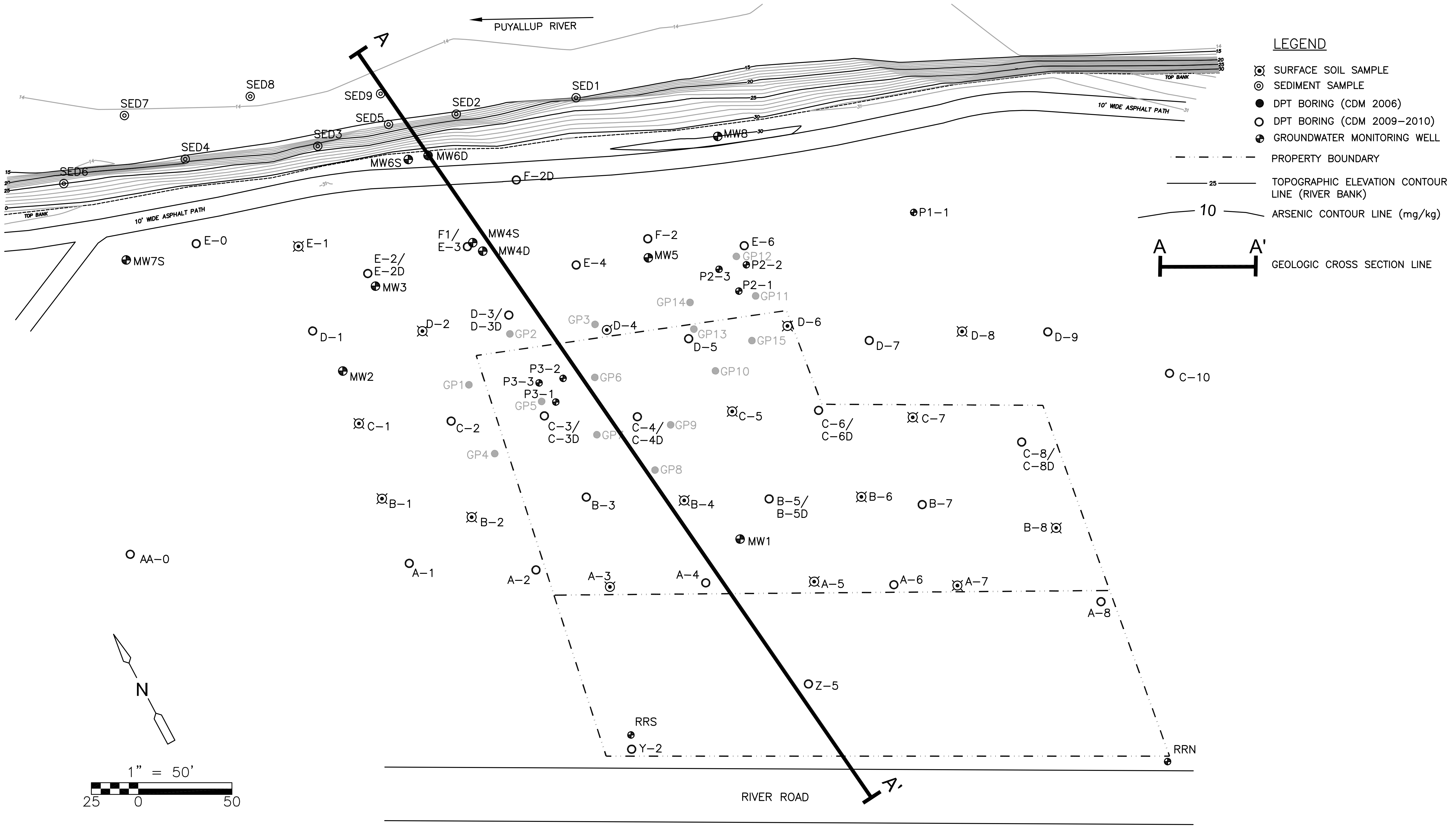
USG INTERIORS/REMEDIAL INVESTIGATION
PUYALLUP, WASHINGTON

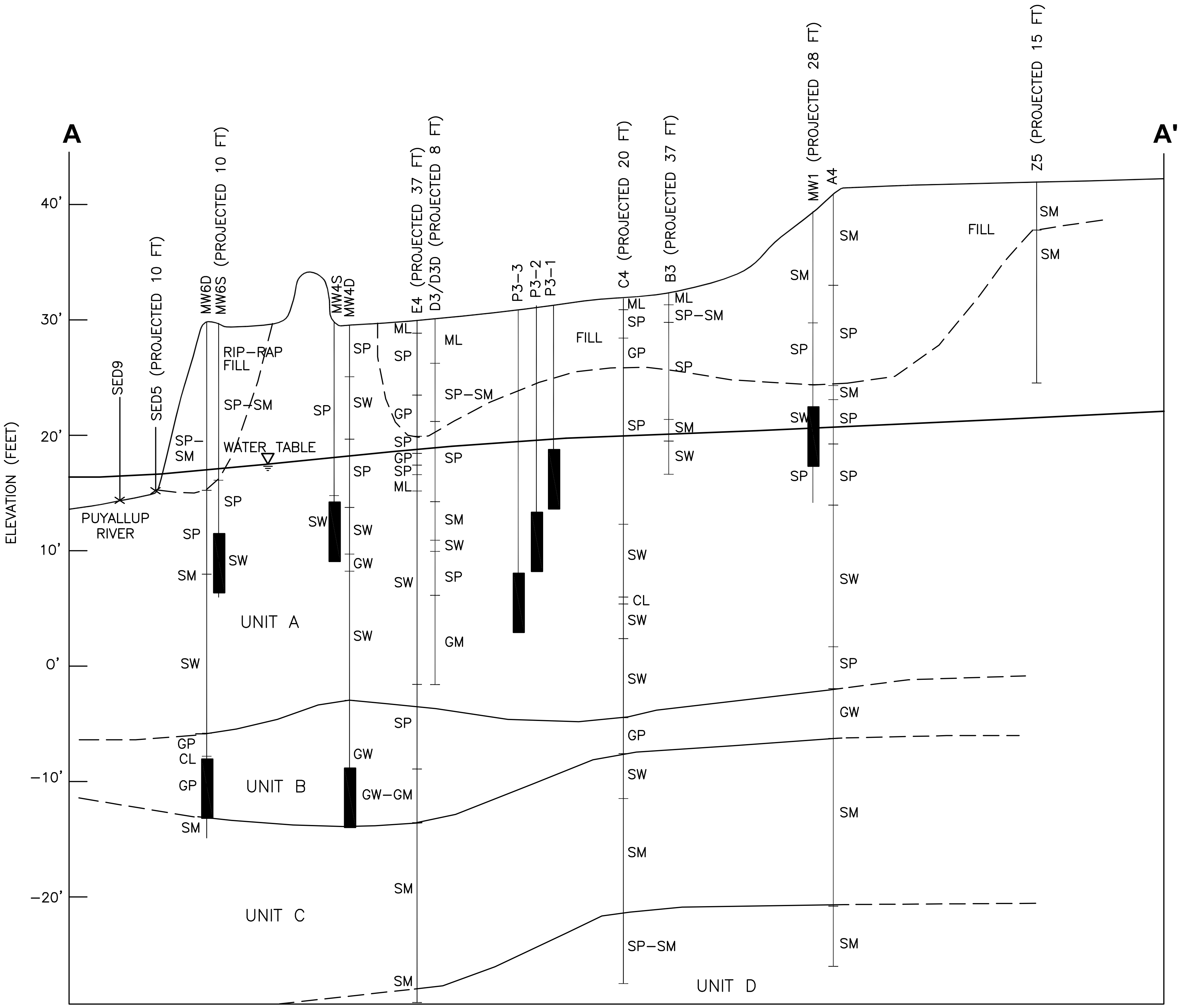
Figure No. 1
Vicinity Map

CDM



N:\ACAD2008\19921-74559\ Fig-2 06/10/11 10:04 talbotwk XREFS: _CDM-SITE, 11X17BDR, 36130-SURV-TP02

Figure No. 2
Site Map and Sample Locations



GENERALIZED HYDROGEOLOGIC UNITS

UNIT A – OVERBANK AND POINT BAR DEPOSITS HAVING MODERATE TO HIGH HYDRAULIC CONDUCTIVITY. INCLUDES POORLY GRADED SAND, FINE TO MEDIUM GRAINED AND WELL GRADED SAND, FINE TO COARSE GRAINED WITH TRACE TO SOME FINE TO MEDIUM GRAVEL.

UNIT B – CHANNEL AND POINT BAR DEPOSITS HAVING HIGH HYDRAULIC CONDUCTIVITY. INCLUDES WELL GRADED AND POORLY GRADED GRAVEL, WELL GRADED GRAVEL WITH SILT, AND POORLY GRADED SAND WITH GRAVEL.

UNIT C – SLACKWATER DEPOSITS HAVING LOW TO MODERATE HYDRAULIC CONDUCTIVITY. INCLUDES SILTY SAND, FINE TO MEDIUM GRAINED WITH TRACE GRAVEL AND WOOD FRAGMENTS.

UNIT D – OVERBANK DEPOSITS HAVING LOW HYDRAULIC CONDUCTIVITY. INCLUDES SILTY SAND AND POORLY GRADED SAND WITH SILT, DENSE, FINE GRAINED SAND, LAMINATED.

LEGEND

GEOLOGIC CONTACT, DASHED WHERE INFERRED

▽ WATER TABLE BASED ON DEPTH TO GROUNDWATER DURING DRILLING IN AUGUST AND OCTOBER 2010

MONITORING WELL

SW UNIFIED SOIL CLASSIFICATION SYSTEM (USCS) SOIL TYPE

1” = 50’

25 0 50

HORIZONTAL

VERTICAL EXHAGGERATION 2X

P:\19921\74559\ Fig-3-SECT A-A 05/02/11 15:41 riehlepj XREFS: 11X17BDR

Figure No. 3
Geologic Cross Section A–A’

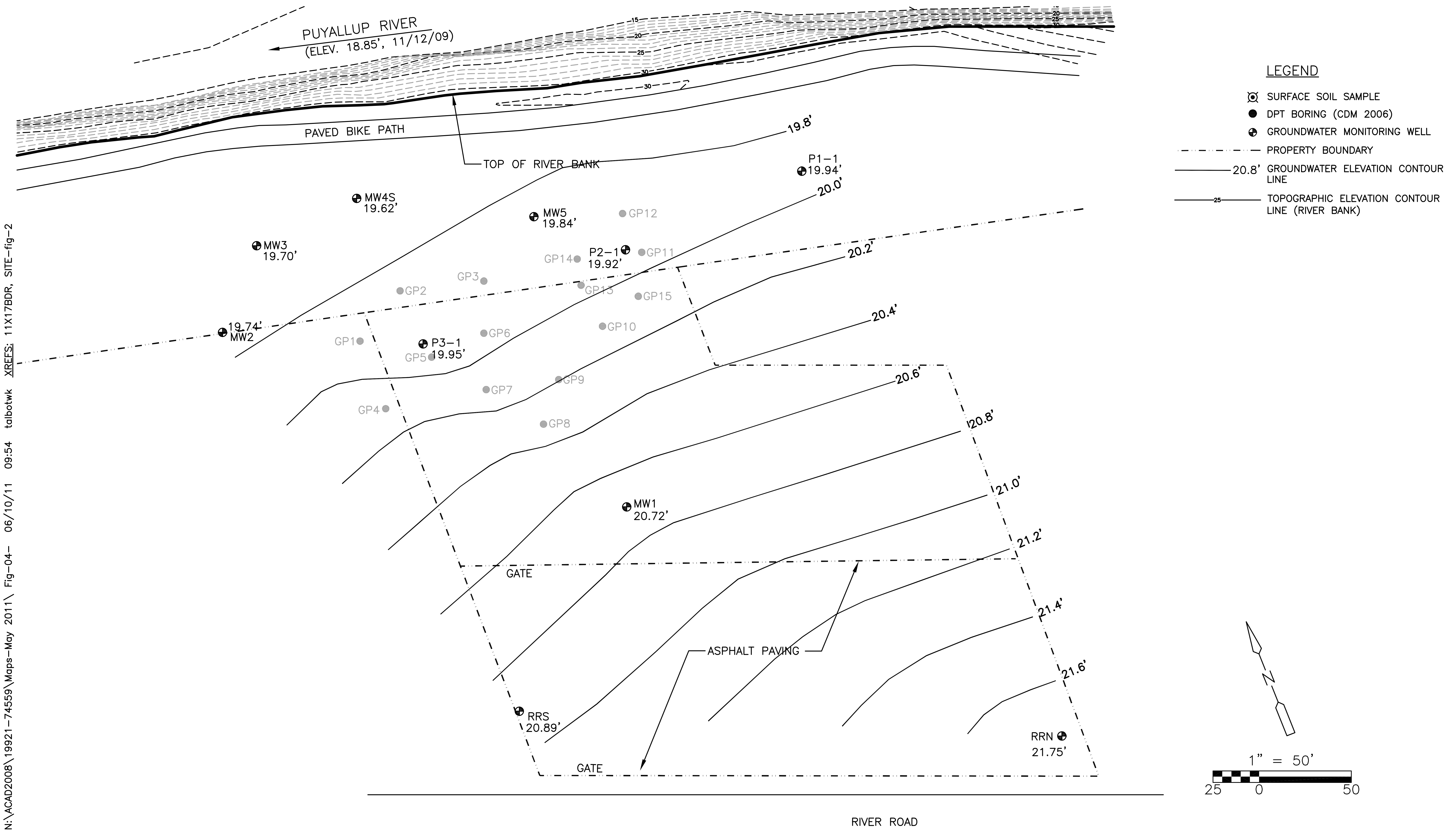


Figure No. 4
Groundwater Elevation Contours
Shallow Aquifer
November 10, 2009

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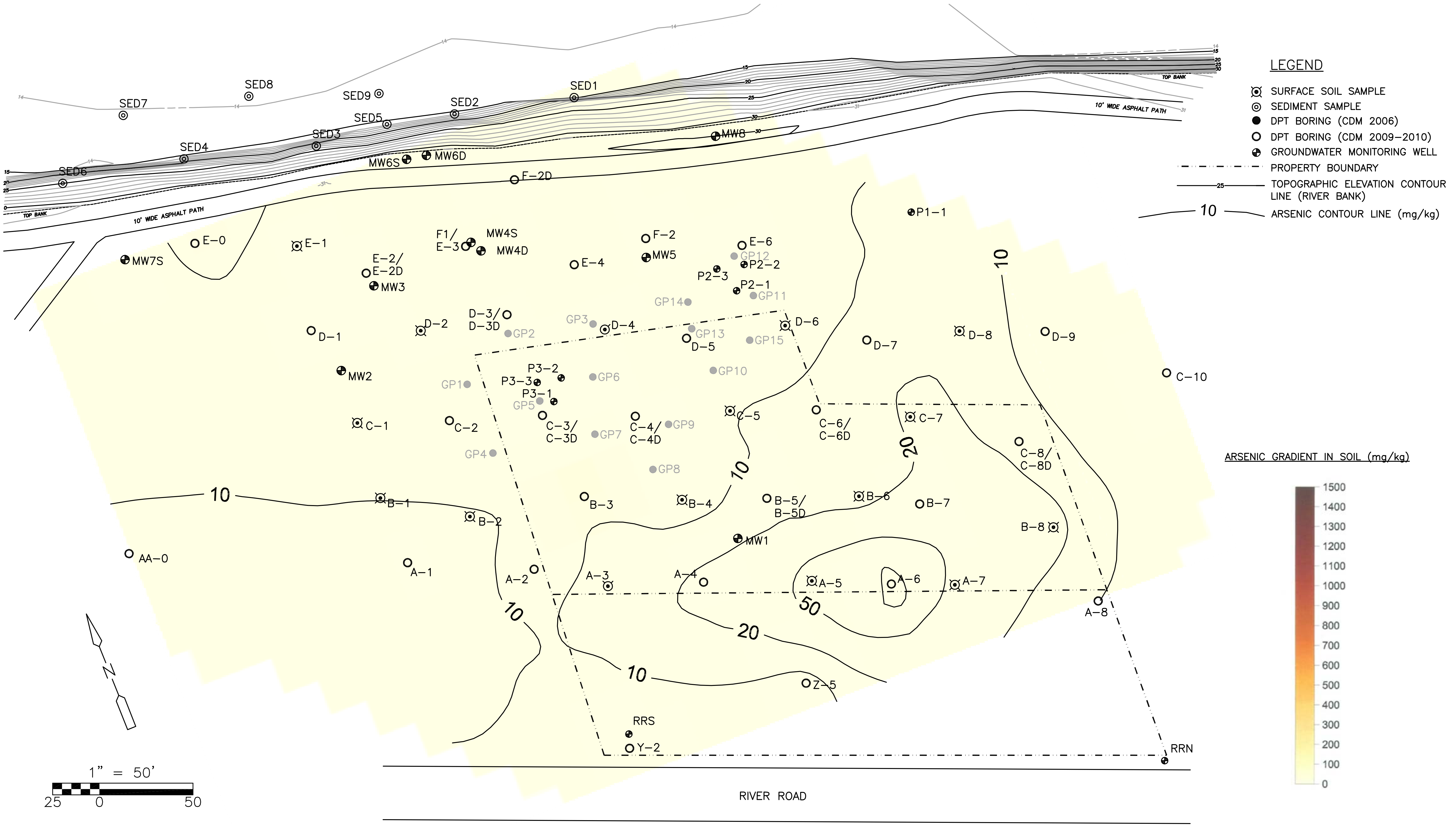

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CDM

Figure No. 5
Site Map
Arsenic in Soil at the Ground Surface

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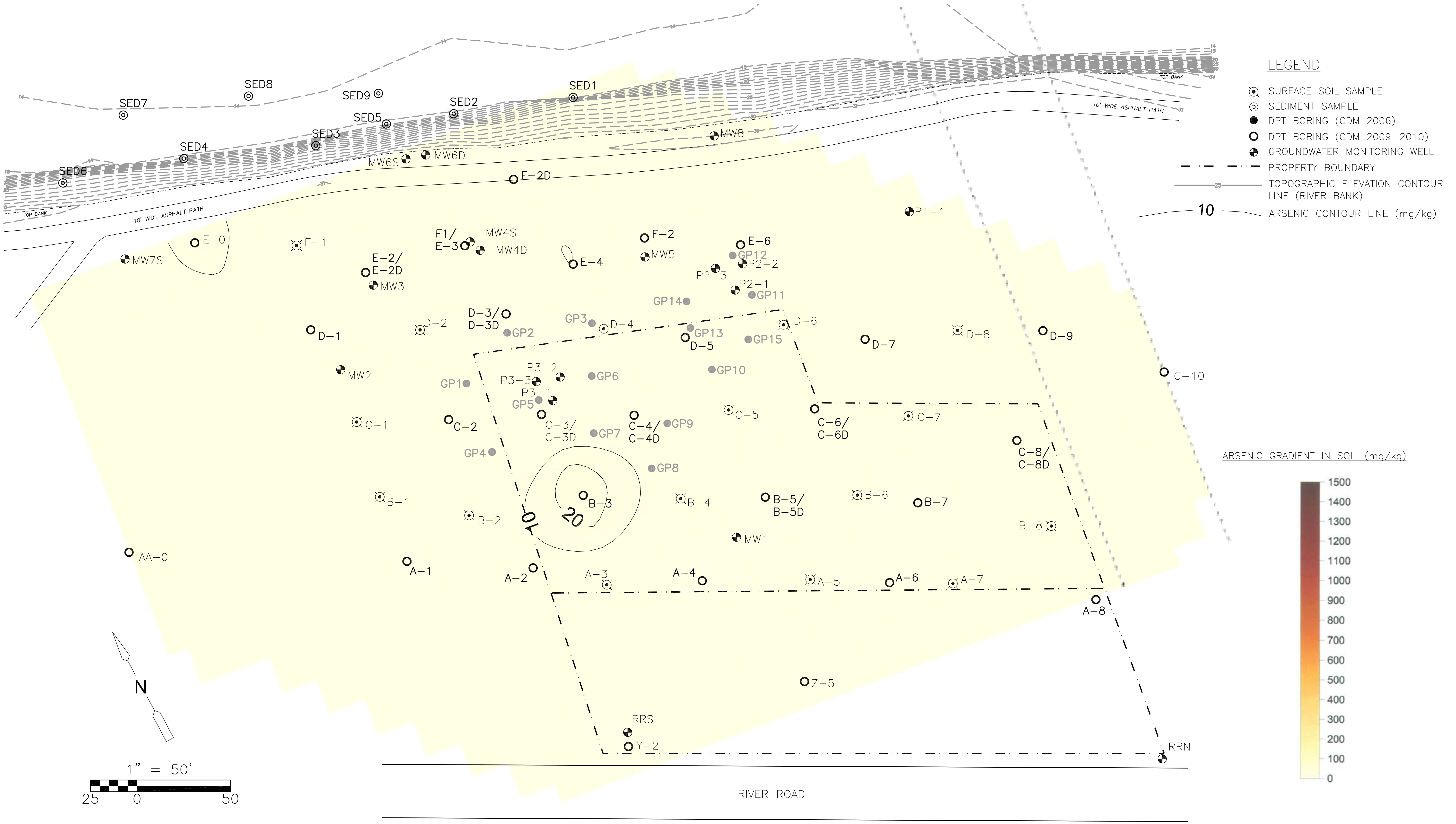
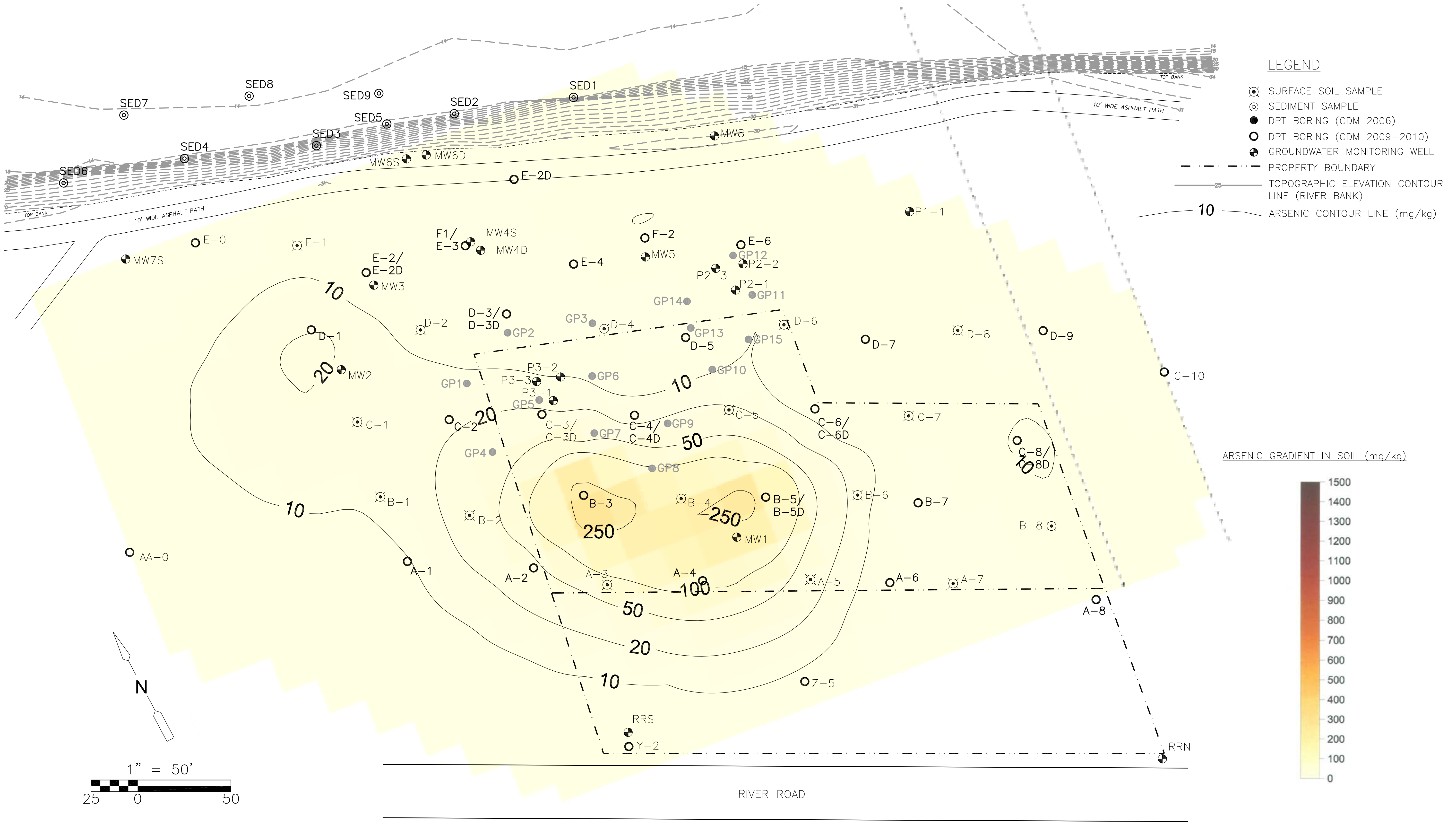


NOTE: SOIL IN VADOSE ZONE

Figure No. 6
Site Map
Total Arsenic in Soil from EL. 32 to EL. 30

CDM



NOTE: SOIL IN VADOSE ZONE

Figure No. 7
Site Map
Total Arsenic in Soil from EL. 30 to EL. 28

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CDM

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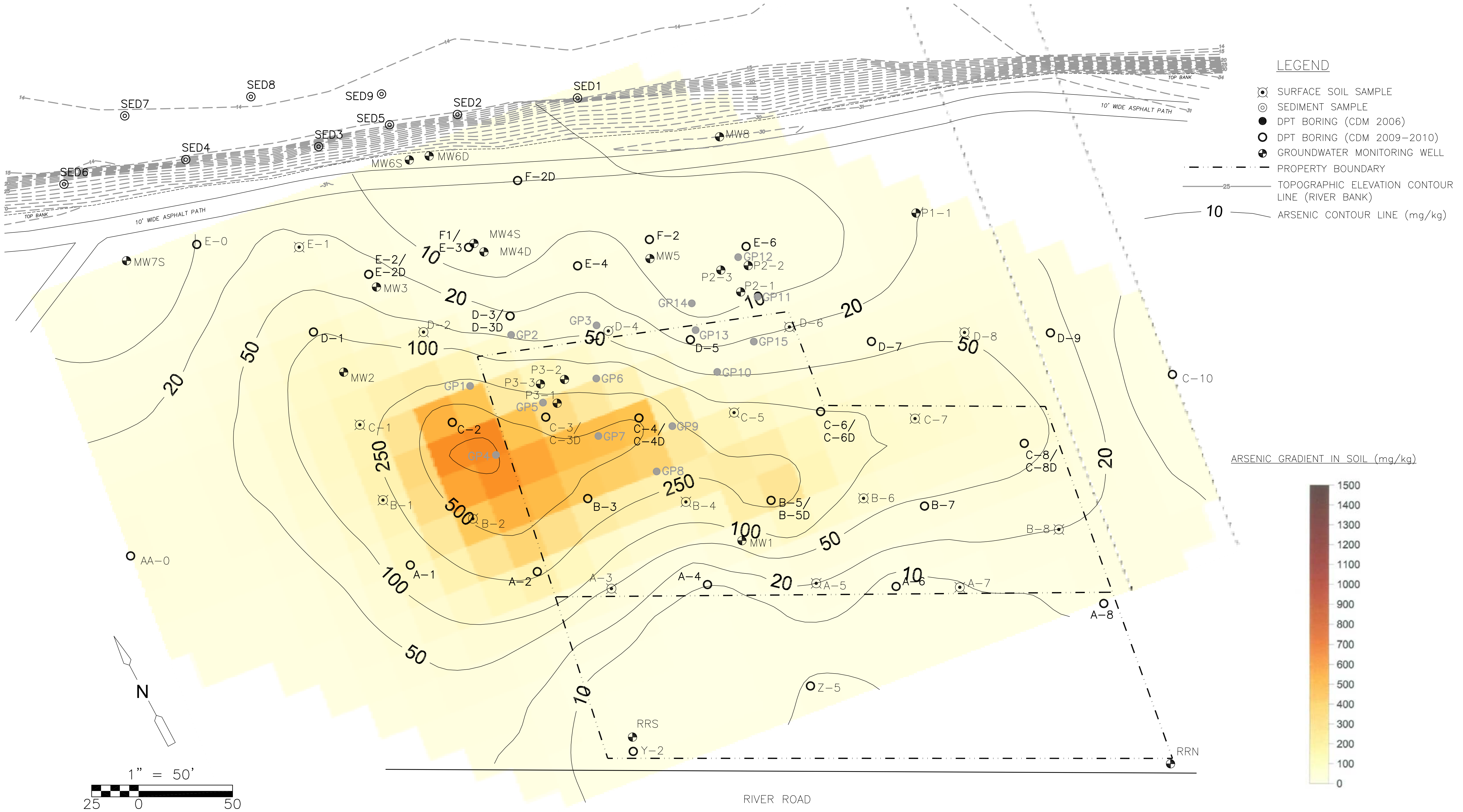
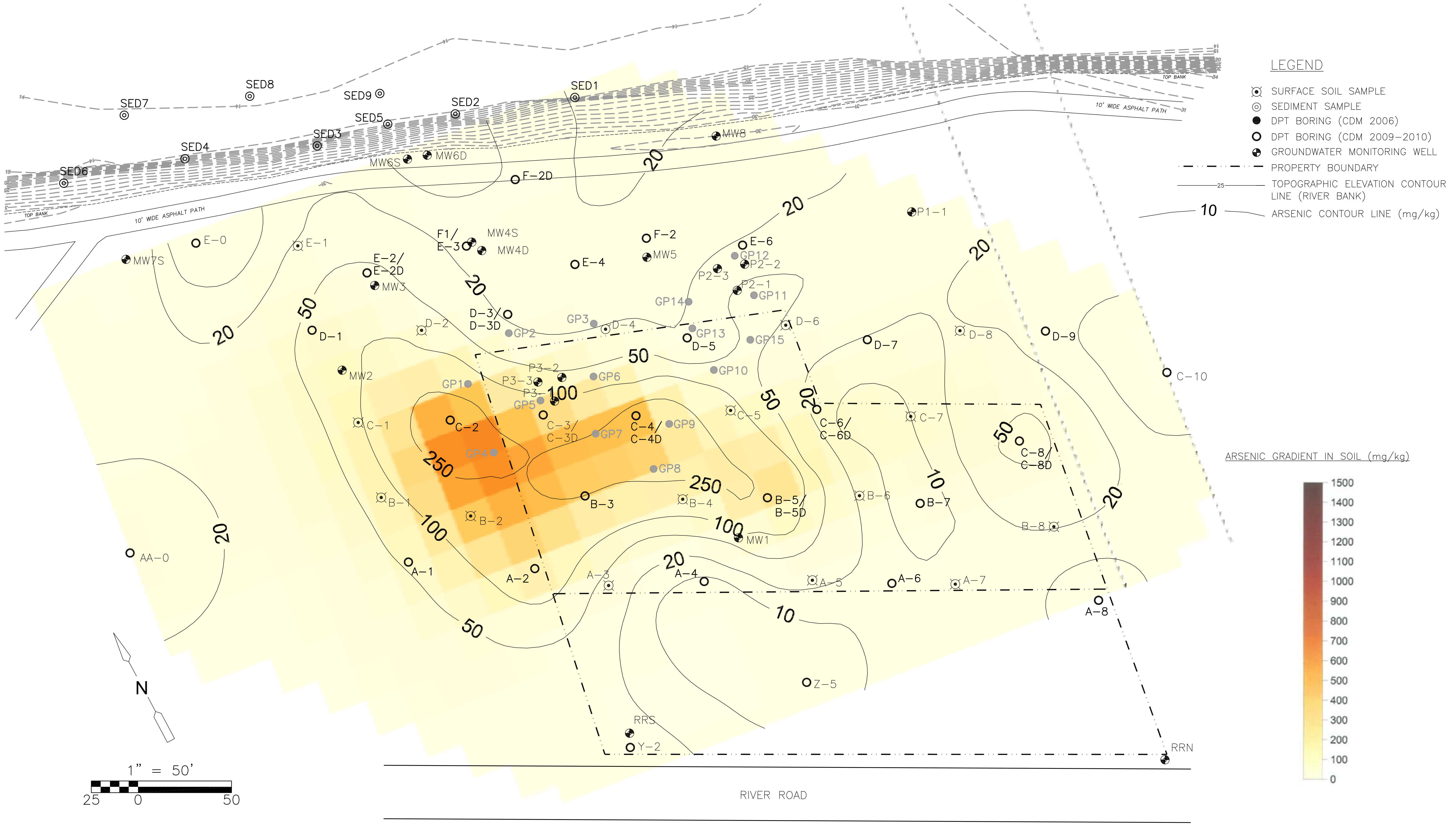


NOTE: SOIL IN VADOSE ZONE

Figure No. 8
Site Map
Total Arsenic in Soil from EL. 28 to EL. 26



NOTE: SOIL IN VADOSE ZONE

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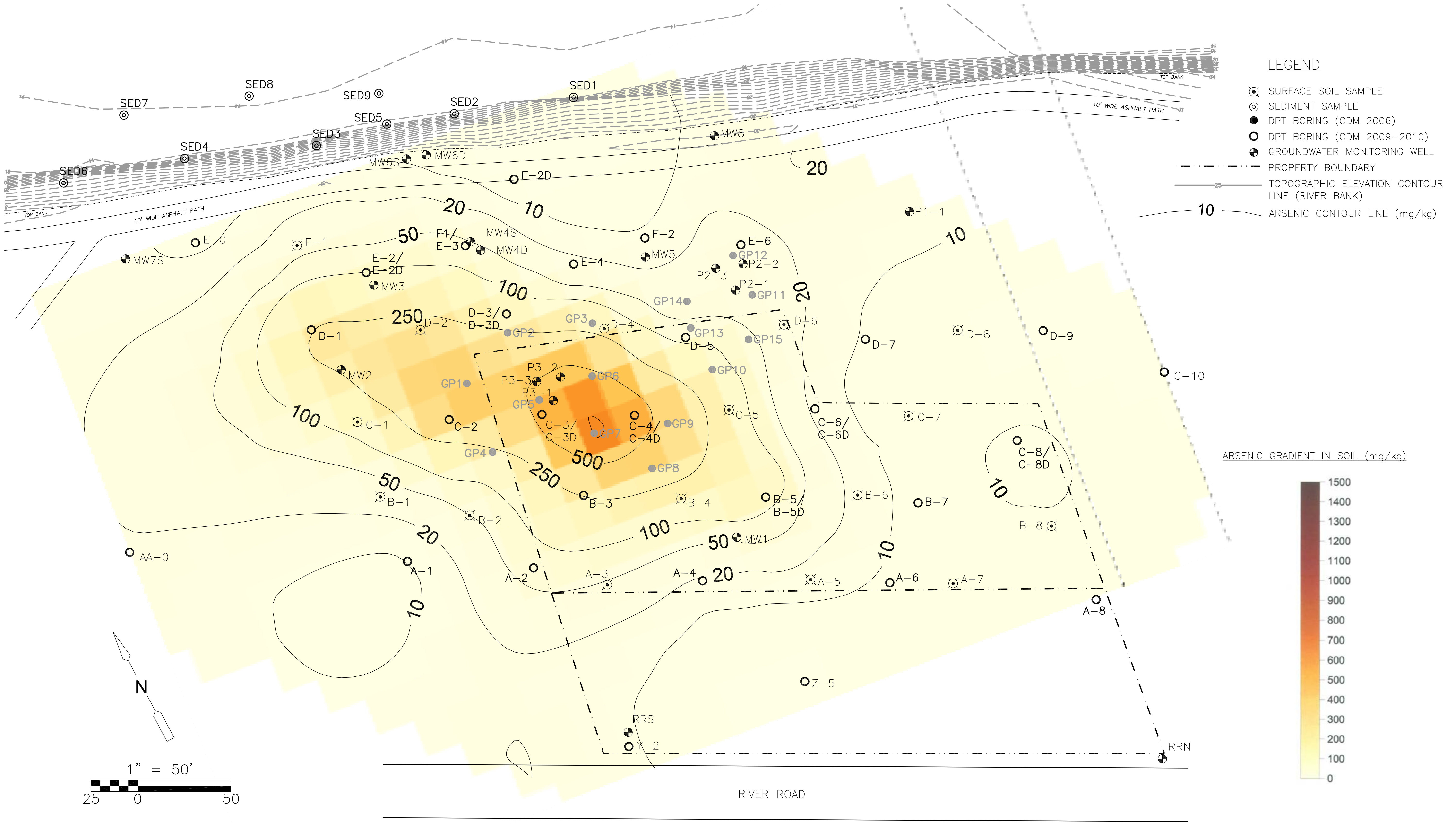
Figure No. 9
Site Map
Total Arsenic in Soil from EL. 26 to EL. 24

P:\19921\99784\TASK-5\ Fig-10 as_4_24_22 10/22/13 13:25 riehlepj XREFS: _CDM-SITE, 36130-SURV-TP02, Map_4_As_24_22_p, 11X17BDR NO TITLE

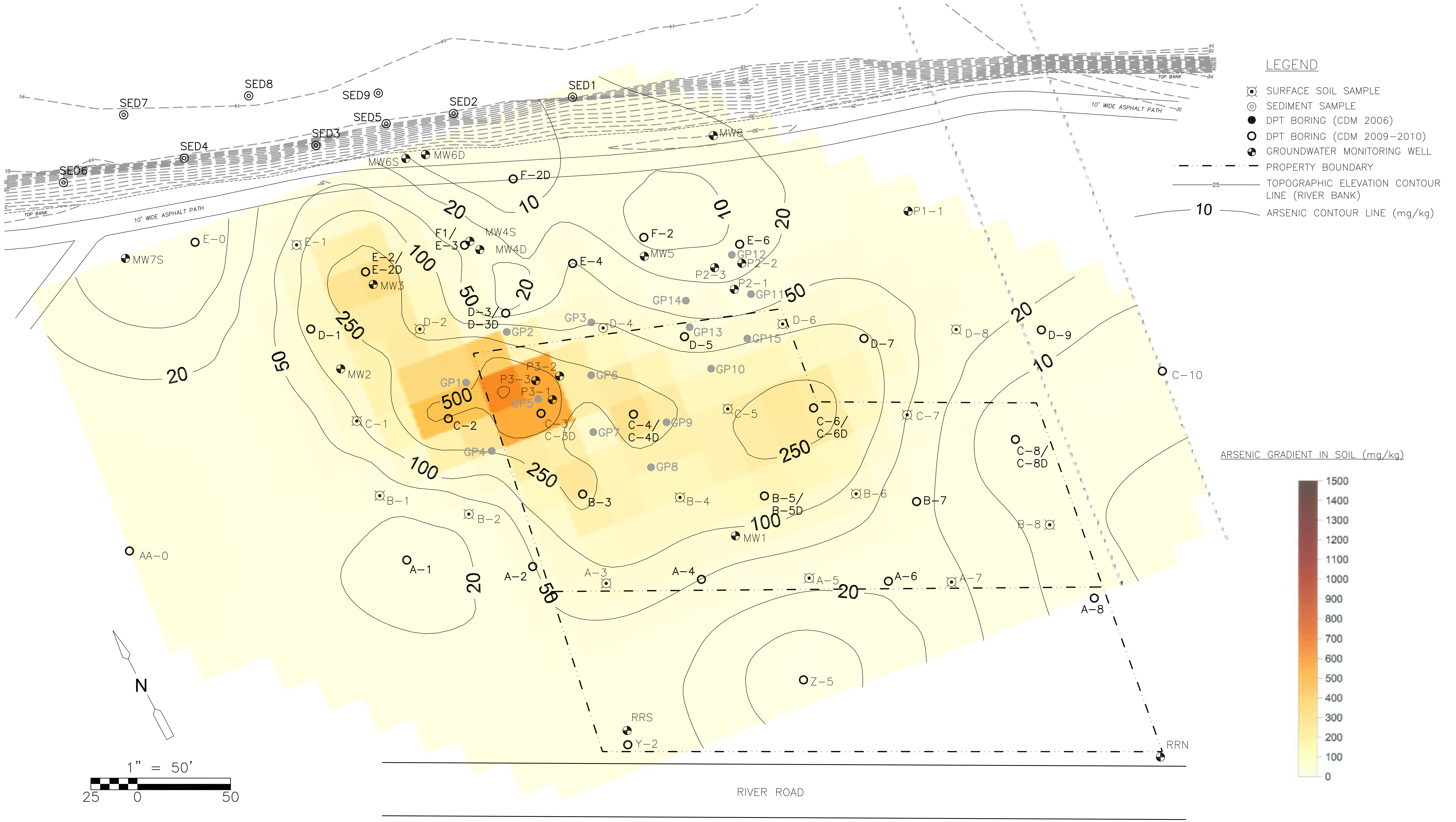


NOTE: SOIL IN INTERMITTENTLY SATURATED ZONE

CDM

Figure No. 10
Site Map
Total Arsenic in Soil from EL. 24 to EL. 22

P:\19921\99784\TASK-5\ Fig-11 as_4_22_20 10/22/13 13:32 riehlepj XREFS: _CDM-SITE, 36130-SURV-TP02, Map_4_As_22_20_p, 11X17BDR NO TITLE

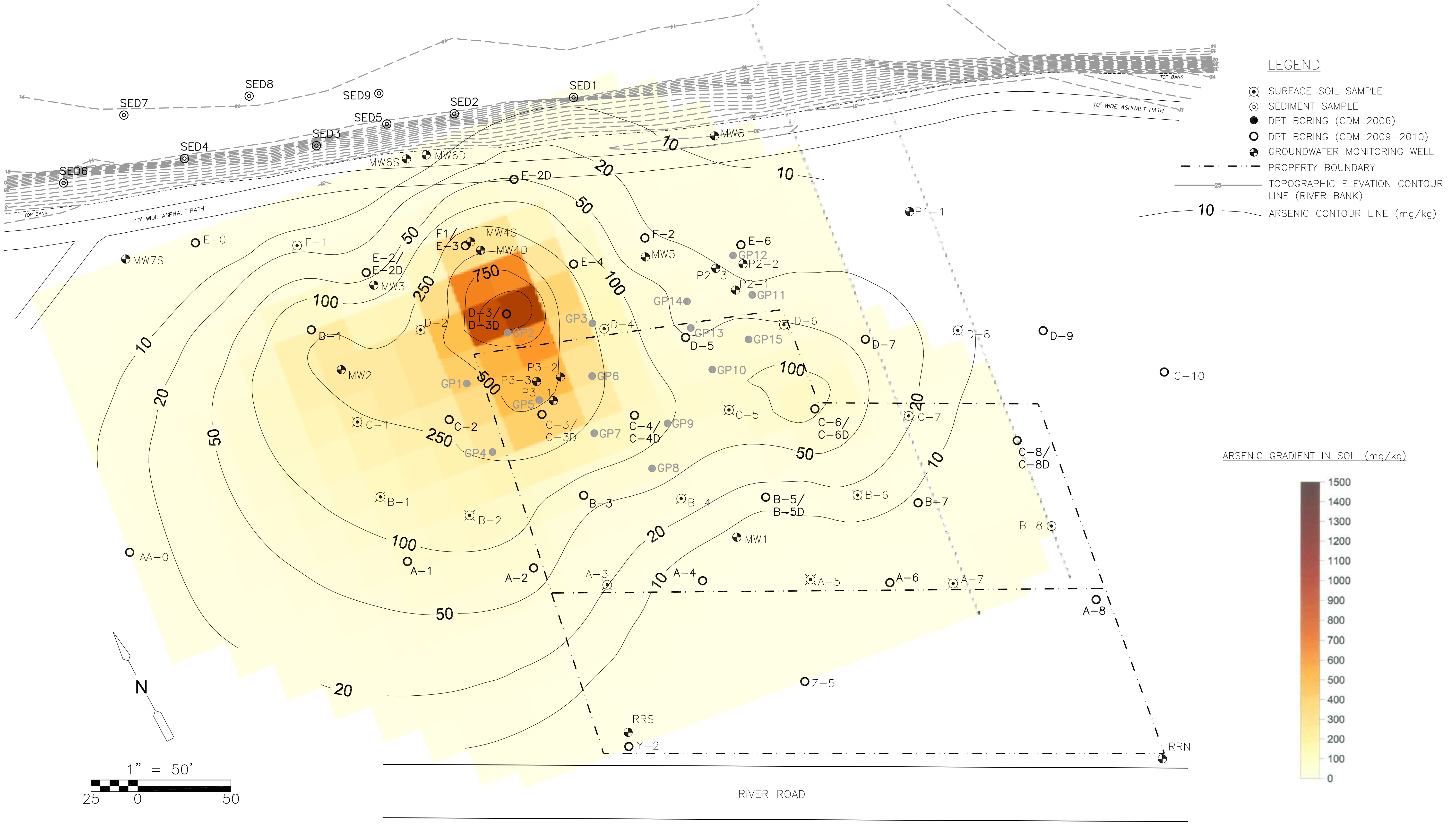


NOTE: SOIL IN INTERMITTENTLY SATURATED ZONE

CDM

Figure No. 11
Site Map
Total Arsenic in Soil from EL. 22 to EL. 20

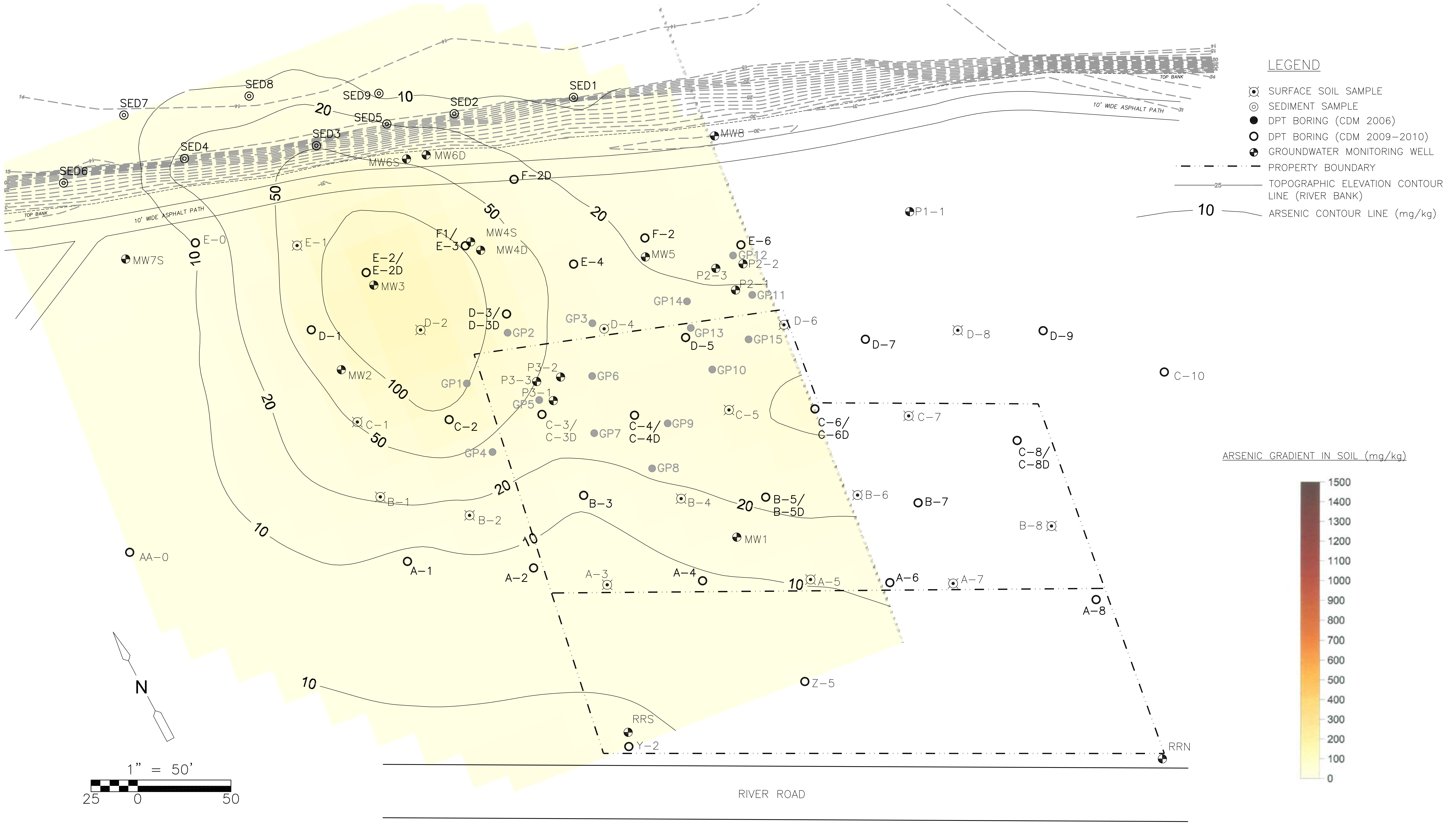
P:\19921\99784\TASK-5\ Fig-12 as_4_20_18 10/22/13 13:43 riehlepj XREFS: _CDM-SITE, 36130-SURV-TP02, Map_4_As_20_18_p, 11X17BDR NO TITLE



NOTE: SOIL IN INTERMITTENTLY SATURATED ZONE

Figure No. 12
Site Map
Total Arsenic in Soil from EL. 20 to EL. 18

P:\19921\99784\TASK-5\ Fig-13 as_4_18_16 10/22/13 13:57 riehlepj XREFS: _CDM-SITE, 36130-SURV-TP02, 11X17BDR NO TITLE

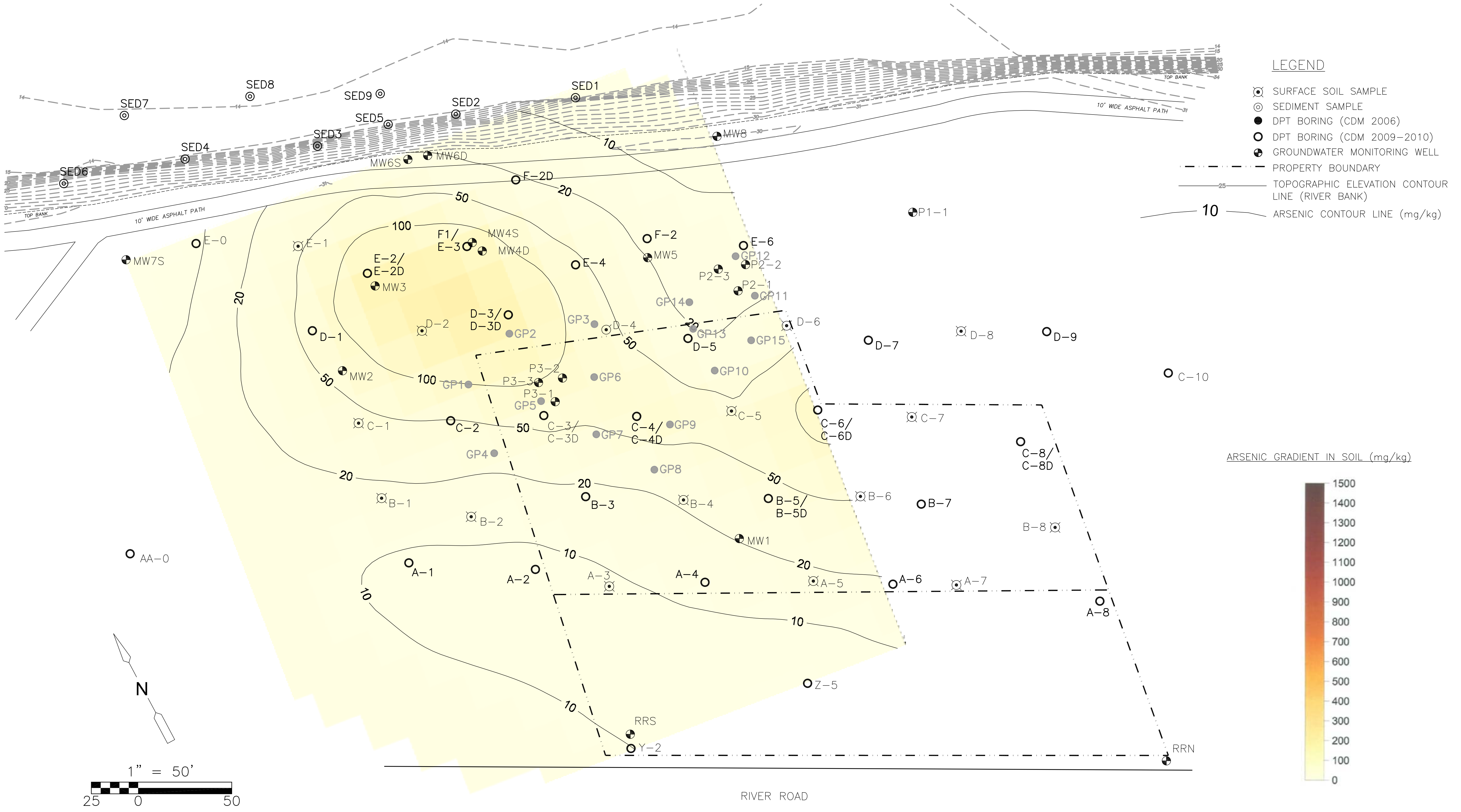


NOTE: SOIL IN SATURATED ZONE

Figure No. 13
Site Map
Total Arsenic in Soil from EL. 18 to EL. 16

CDM

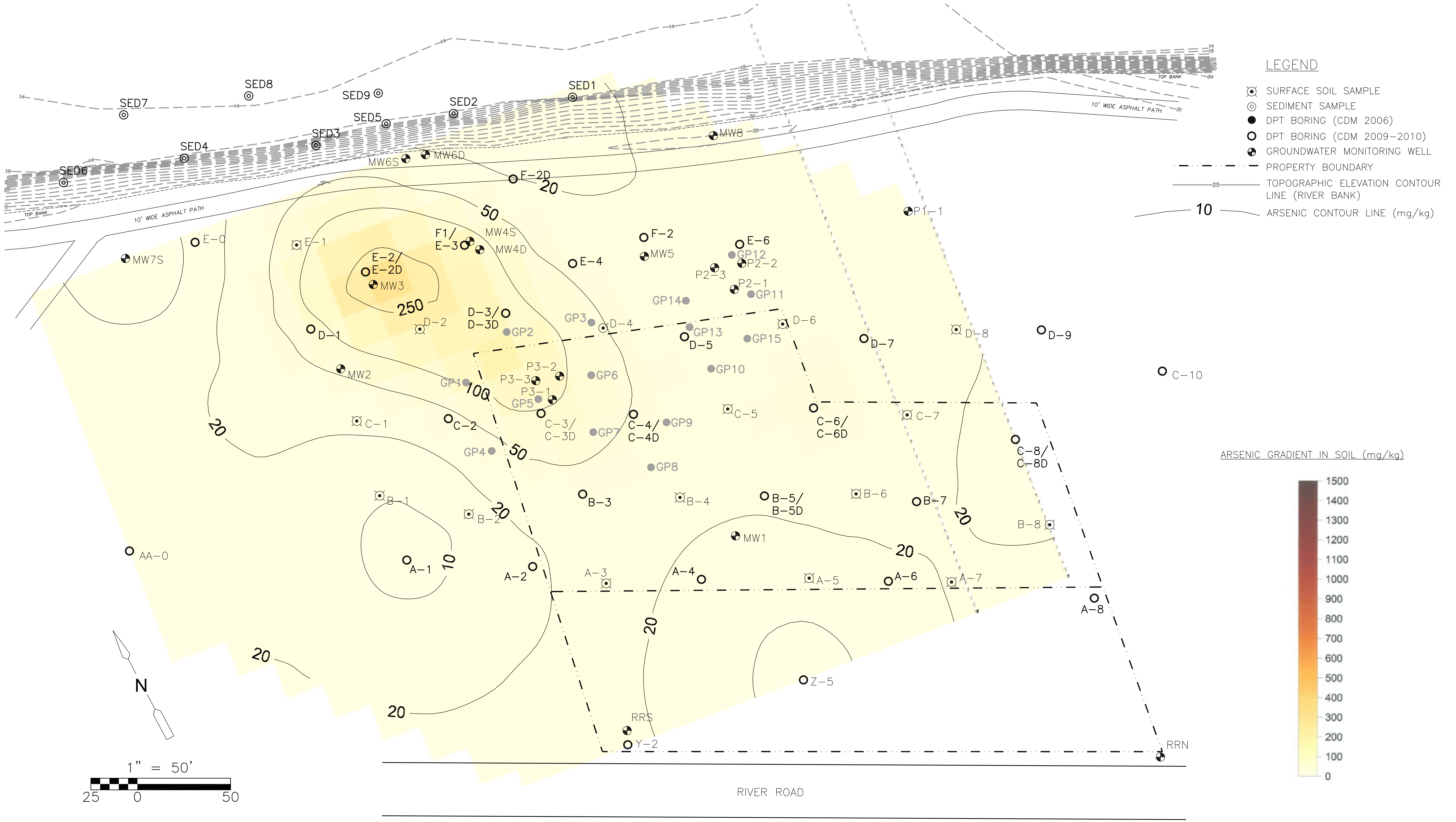
P:\19921\99784\TASK-5\ Fig-14 as_4_16_14 10/22/13 14:02 riehlepj XREFS: _CDM-SITE, 36130-SURV-TP02, 11X17BDR NO TITLE



NOTE: SOIL IN SATURATED ZONE

CDM

Figure No. 14
Site Map
Total Arsenic in Soil from EL. 16 to EL. 14



NOTE: SOIL IN SATURATED ZONE

Figure No. 15
Site Map
Total Arsenic in Soil from EL. 14 to EL. 12

P:\19921\99784\TASK-5\ Fig-15 as_4_14_12 10/22/13 14:34 riehlepj XREFS: _CDM-SITE, 36130-SURV-TP02, 11X17BDR NO TITLE

CDM

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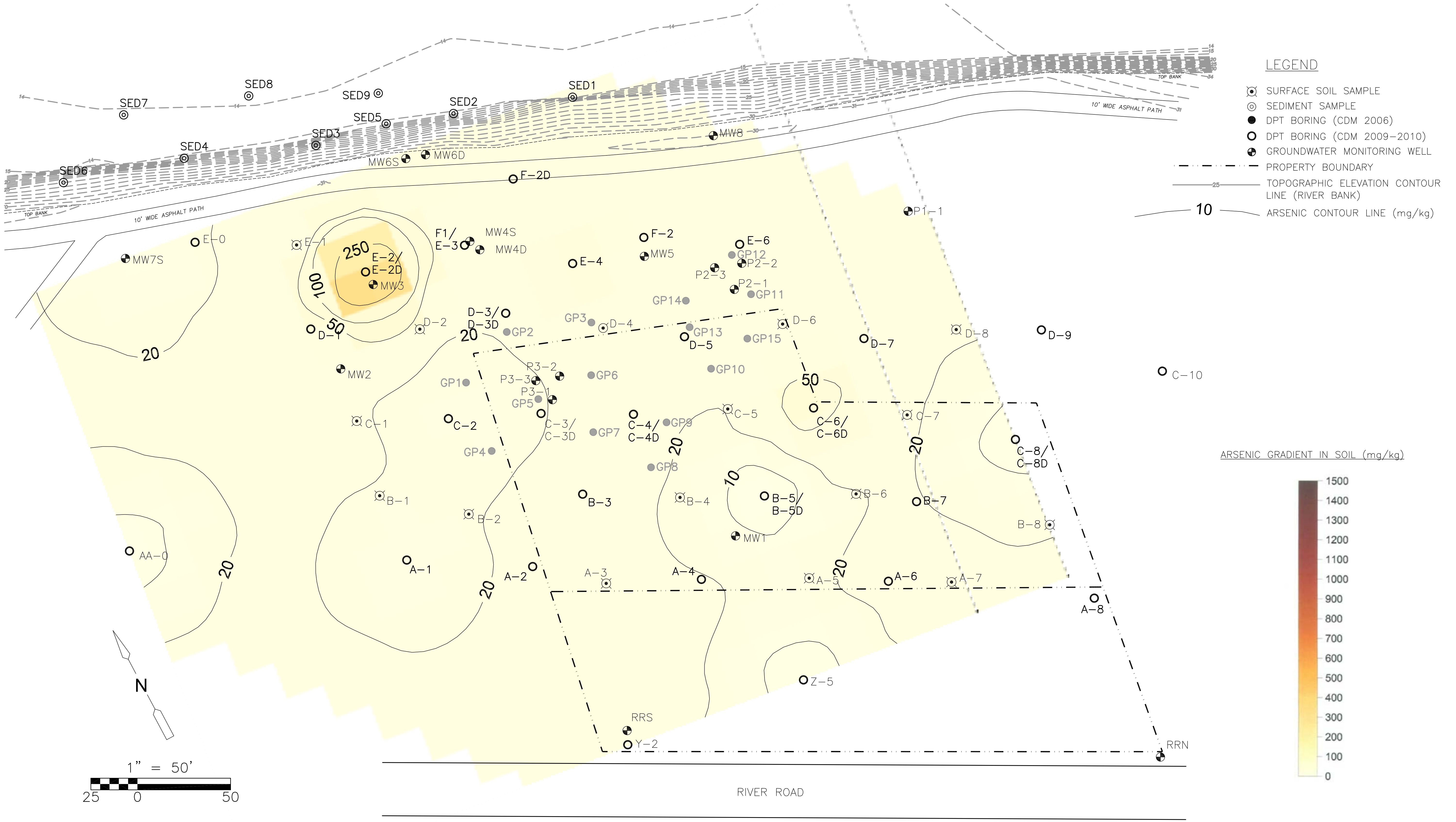

NOTE: SOIL IN SATURATED ZONE

Figure No. 16
Site Map
Total Arsenic in Soil from EL. 12 to EL. 10

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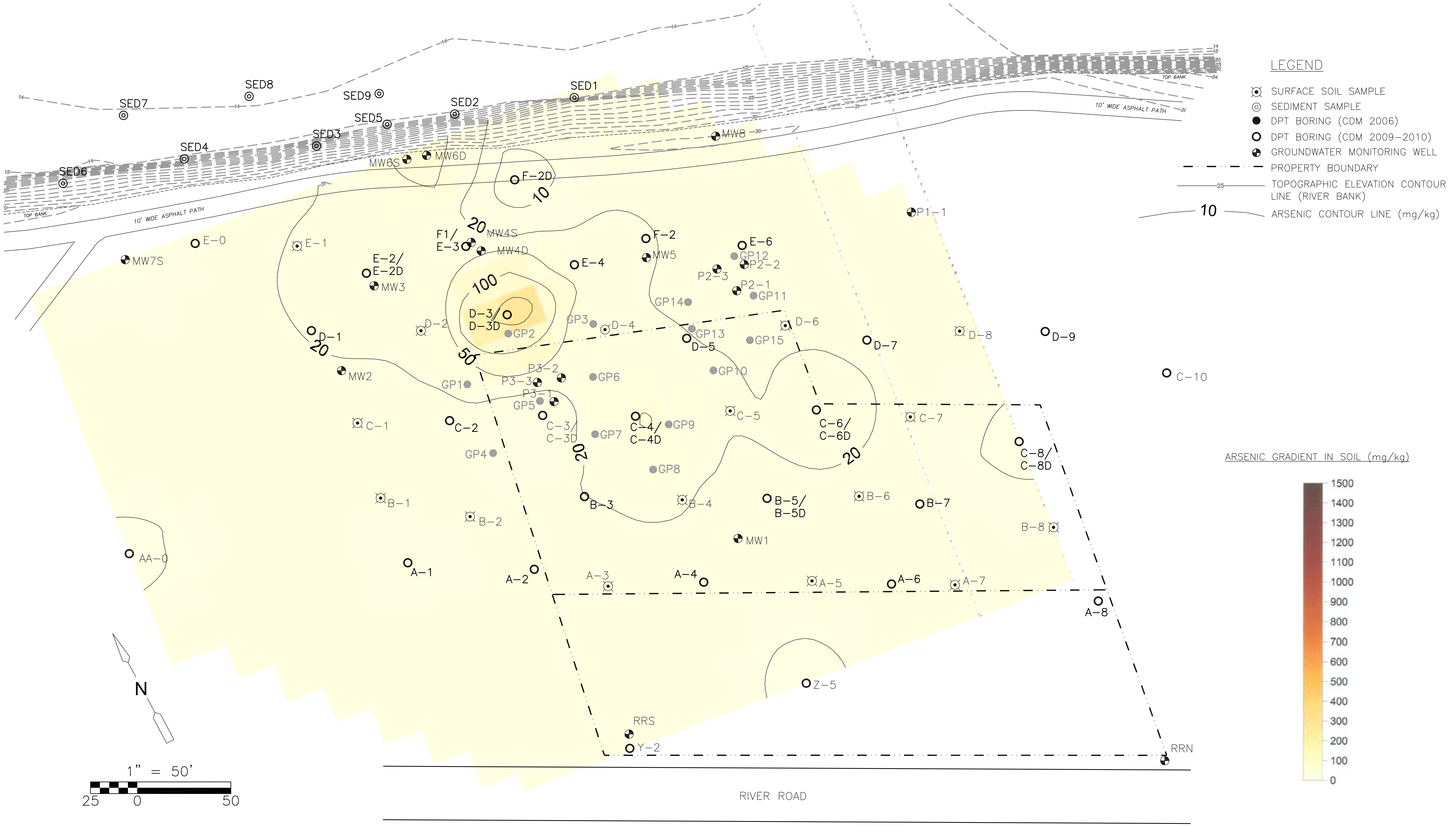
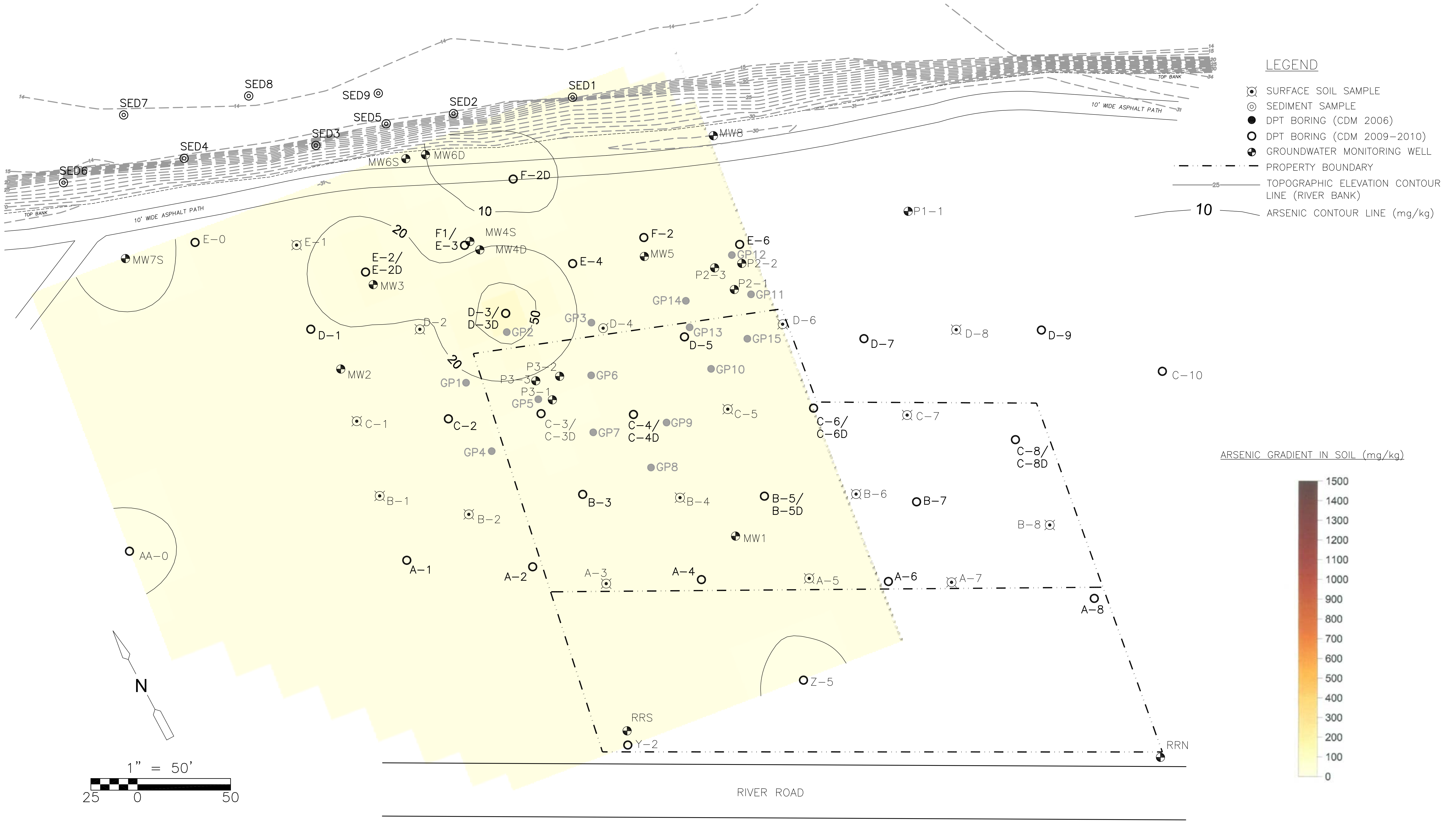


NOTE: SOIL IN SATURATED ZONE

Figure No. 17
Site Map
Total Arsenic in Soil from EL. 10 to EL. 8

CDM



NOTE: SOIL IN SATURATED ZONE

Figure No. 18
Site Map
Total Arsenic in Soil from EL. 8 to EL. 6

CDM

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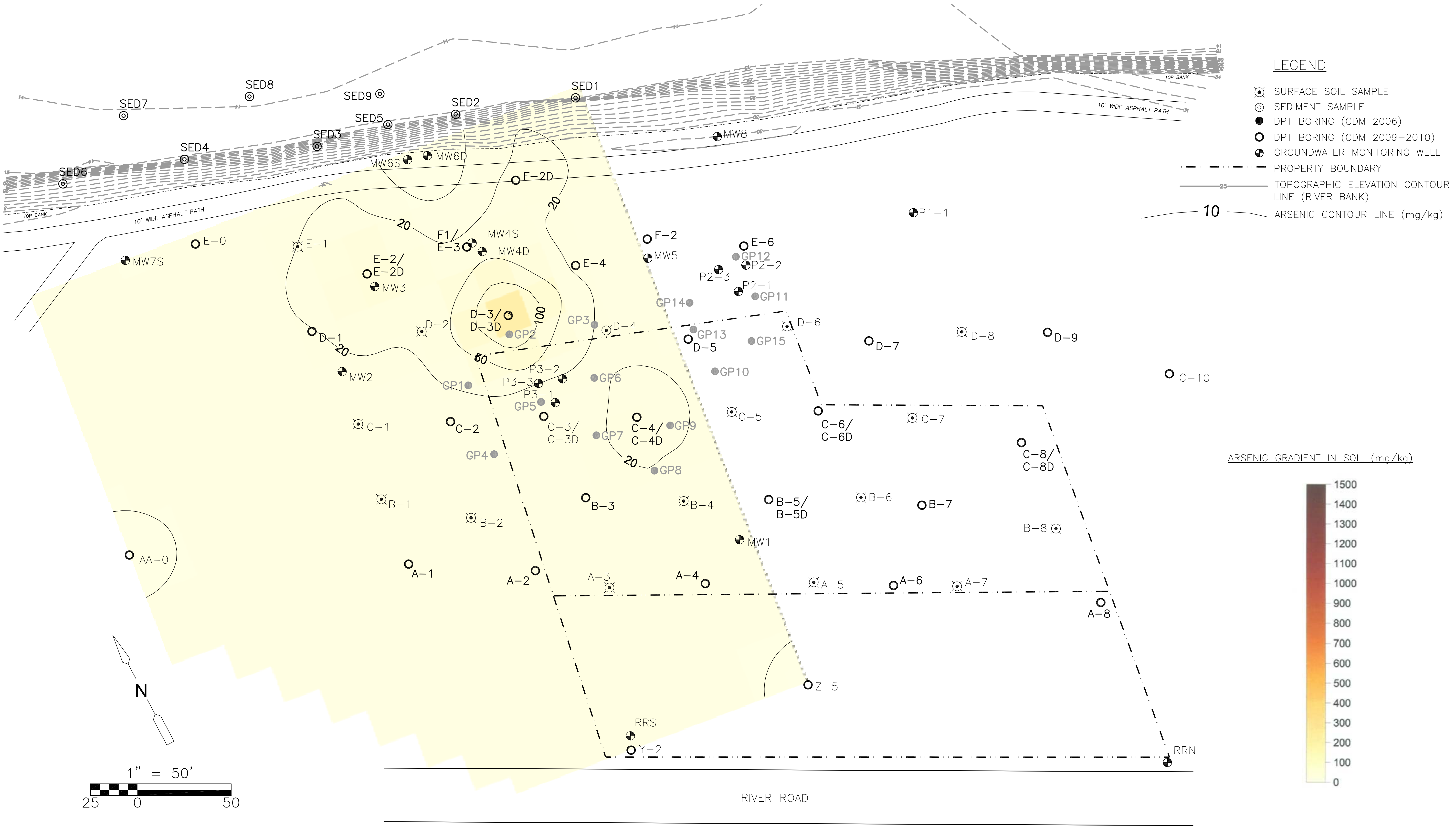
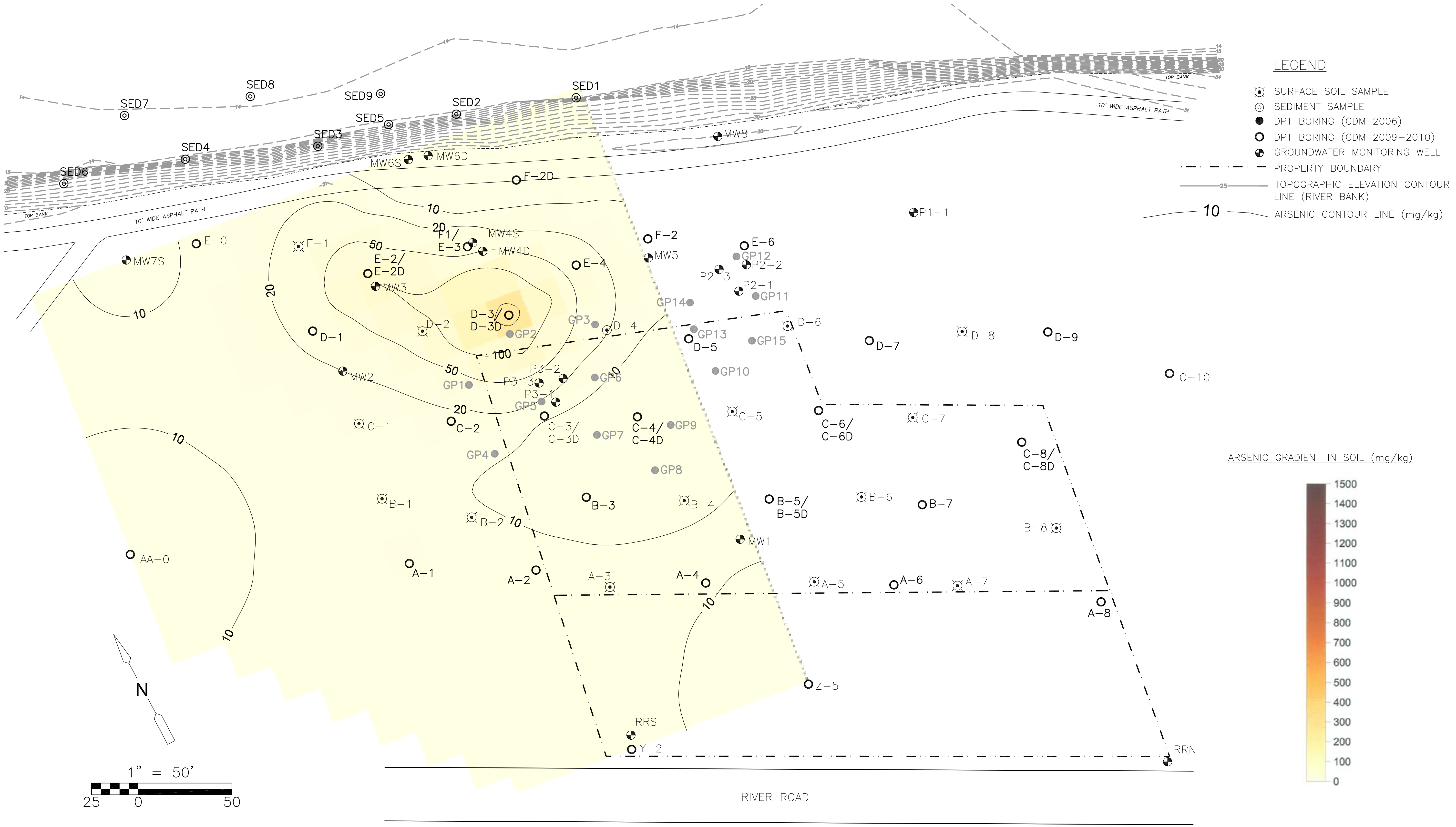


NOTE: SOIL IN SATURATED ZONE

CDM

Figure No. 19
Site Map
Total Arsenic in Soil from EL. 6 to EL. 4

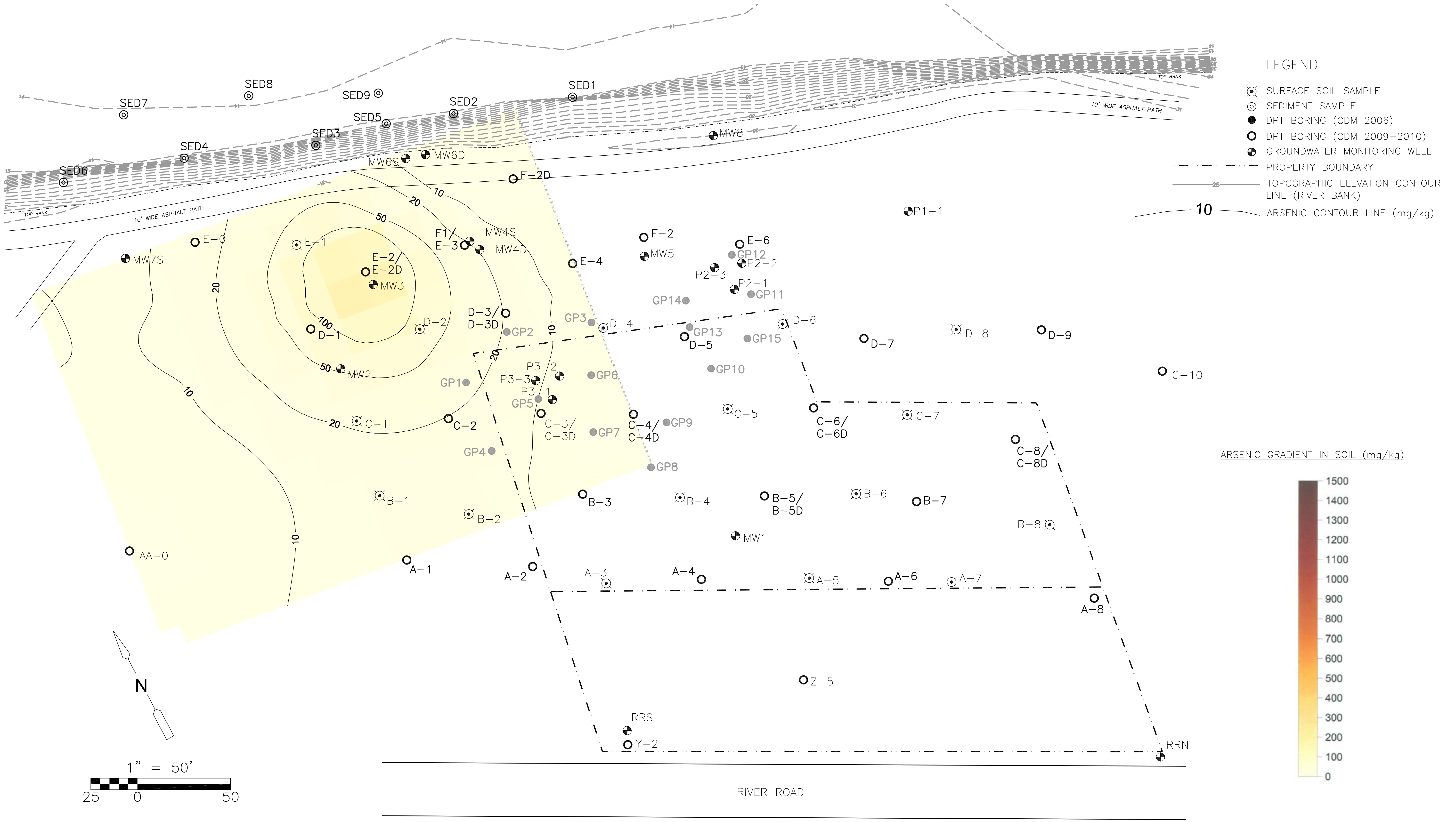
P:\19921\99784\TASK-5\ Fig-20 as_4_4_2 10/23/13 10:06 riehlepj XREFS: _CDM-SITE, 36130-SURV-TP02, 11X17BDR NO TITLE



NOTE: SOIL IN SATURATED ZONE

Figure No. 20
Site Map
Total Arsenic in Soil from EL. 4 to EL. 2

CDM

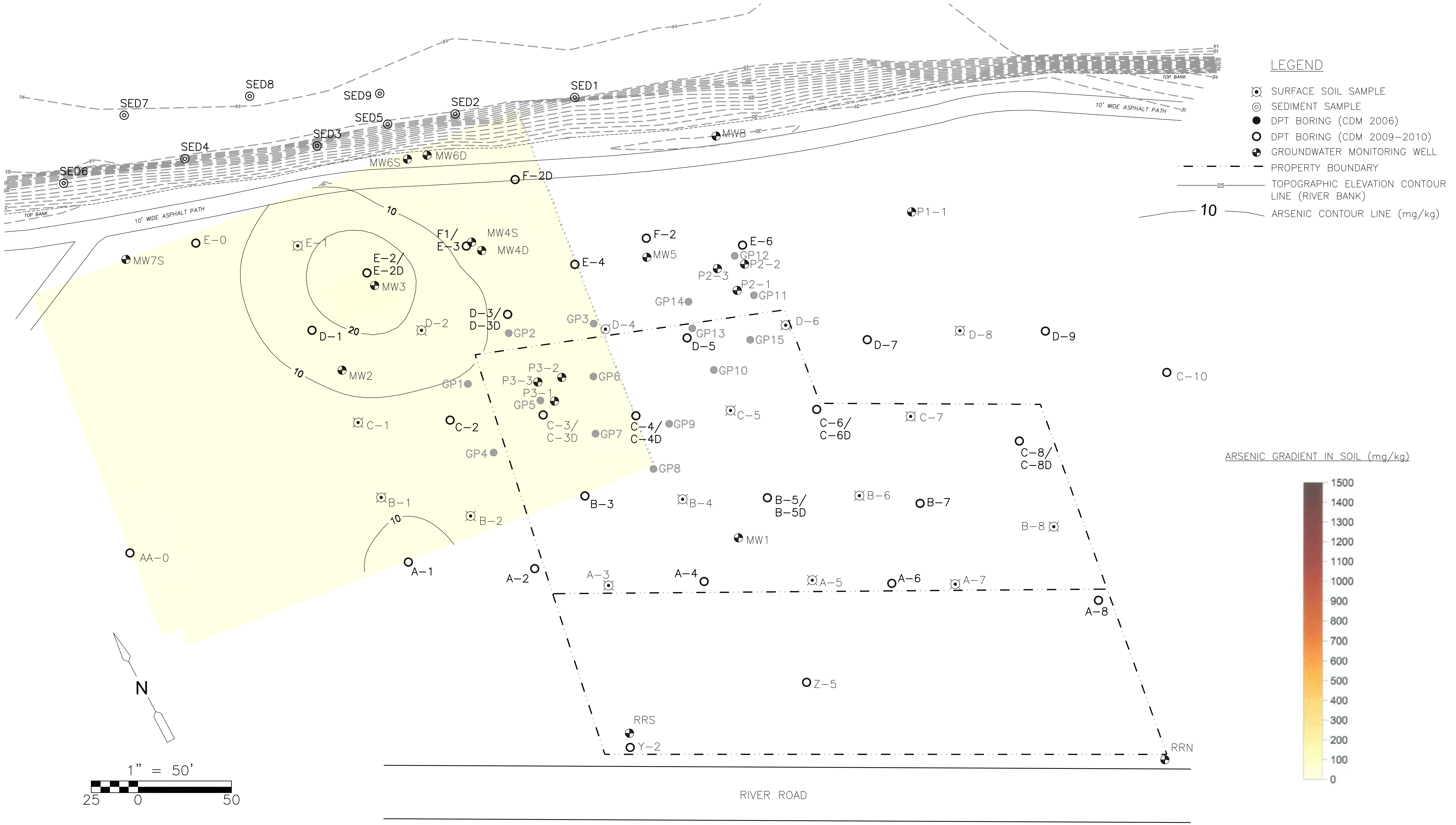


NOTE: SOIL IN SATURATED ZONE

P:\19921\99784\TASK-5\ Fig-21 as_4_2_0 10/23/13 10:35 riehlepj XREFS: _CDM-SITE, 36130-SURV-TP02, 11X17BDR NO TITLE

CDM

Figure No. 21
Site Map
Total Arsenic in Soil from EL. 2 to EL. 0



NOTE: SOIL IN SATURATED ZONE

P:\19921\99784\TASK–5\ Fig–22 as_4_0_–2 10/23/13 10:48 riehlepj XREFS: _CDM–SITE, 36130–SURV–TP02, 11X17BDR NO TITLE

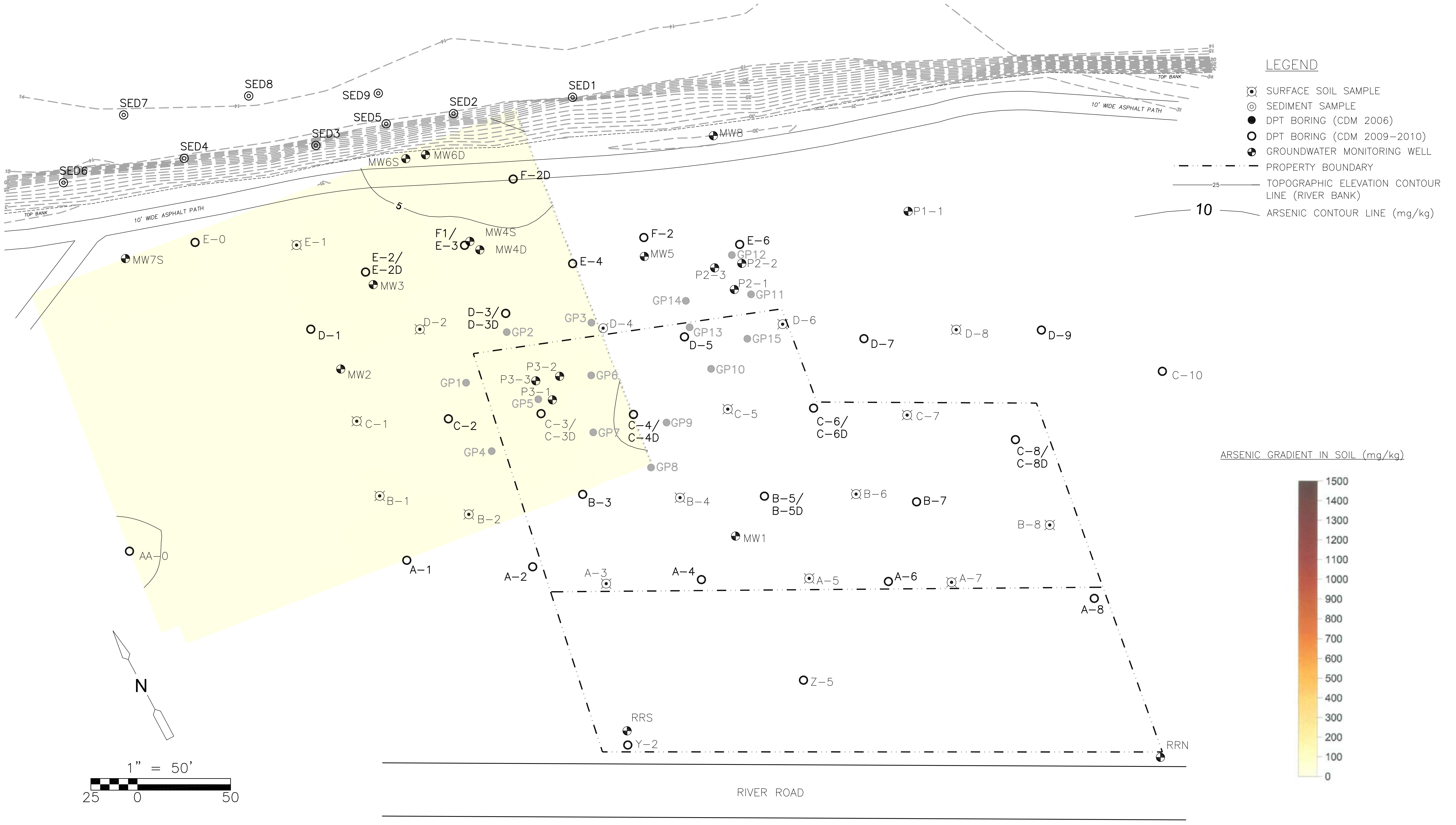
CDM

Figure No. 22

Site Map

Total Arsenic in Soil from EL. 0 to EL. –2

P:\19921\99784\TASK-5\ Fig-23 as_4_-2_-4 10/23/13 11:10 riehlepj XREFS: _CDM-SITE, 36130-SURV-TP02, 11X17BDR NO TITLE



NOTE: SOIL IN SATURATED ZONE

Figure No. 23
Site Map
Total Arsenic in Soil from EL. -2 to EL. -4

CDM

N:\ACAD2008\19921-74559\Maps-May 2011\ Fig-24 GW_AS 06/10/11 13:10 talbotwk XREFS: 11X17BDR, _CDM-SITE, 36130-SURV-TP02

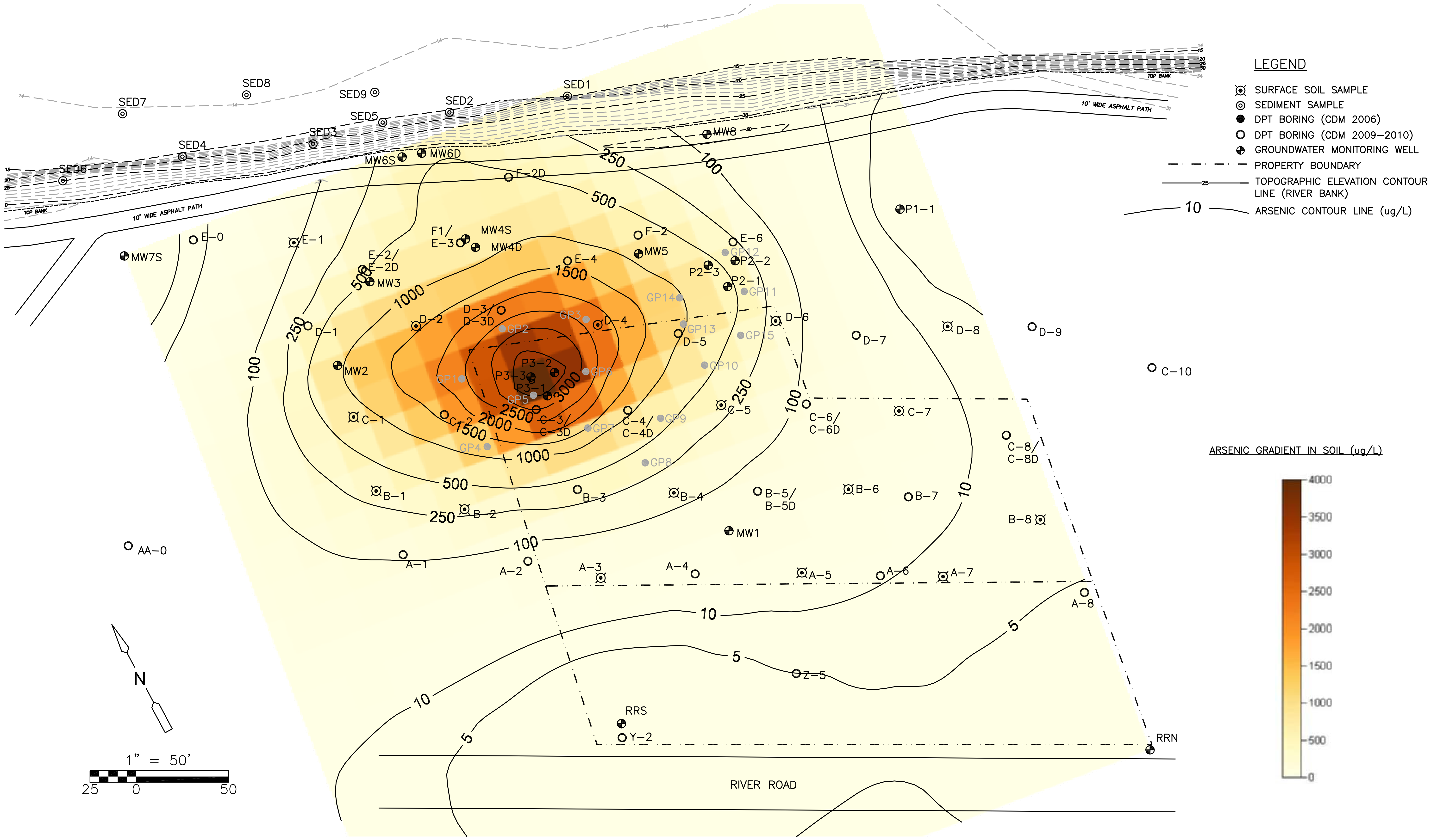
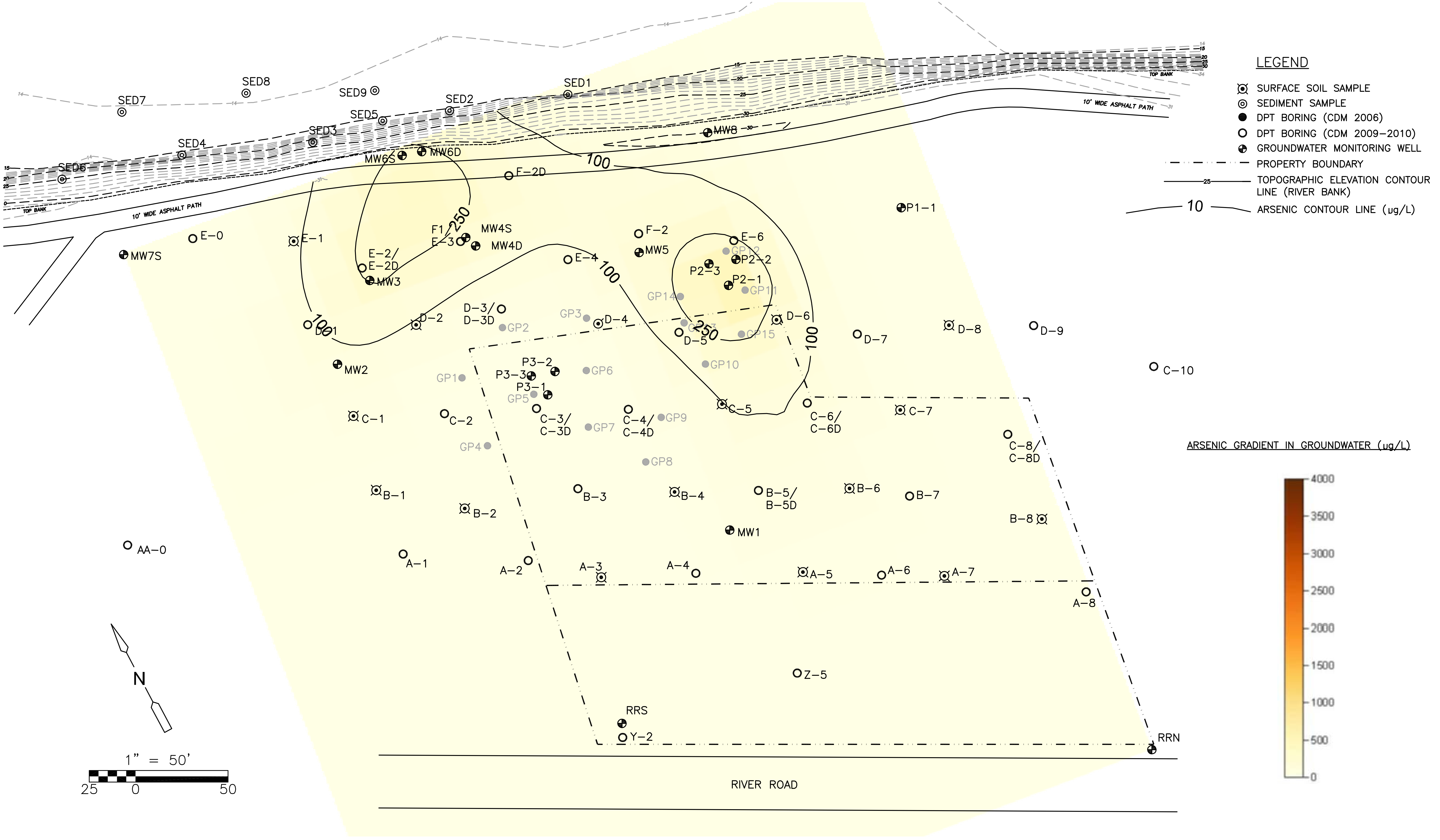


Figure No. 24
Site Map
Dissolved Arsenic in Groundwater

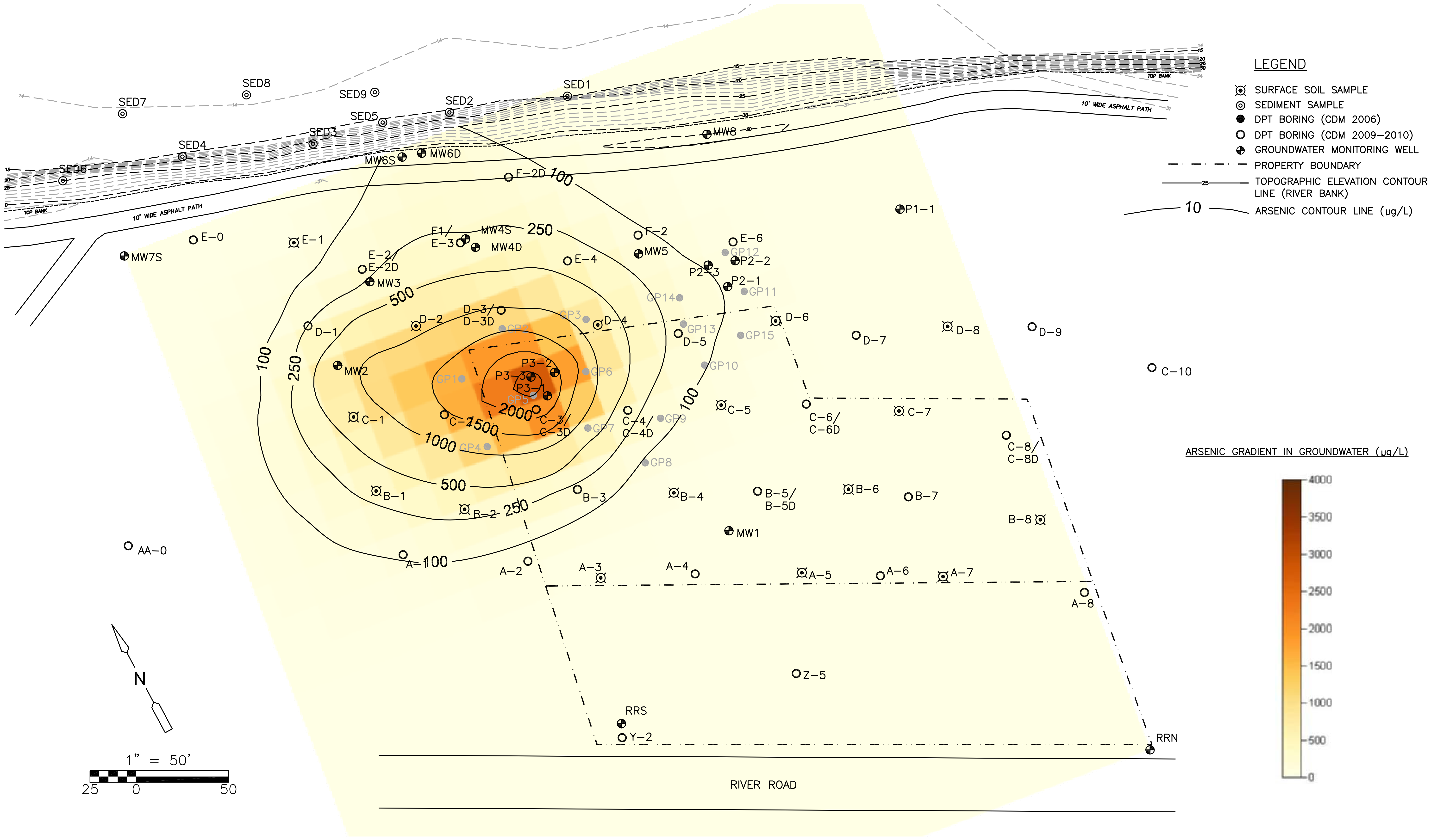
N:\ACAD2008\19921-74559\Maps-May 2011\ Fig-25 GW_AS3 06/10/11 13:10 talbotwk XREFS: 11X17BDR, _CDM-SITE, 36130-SURV-TP02



CDM

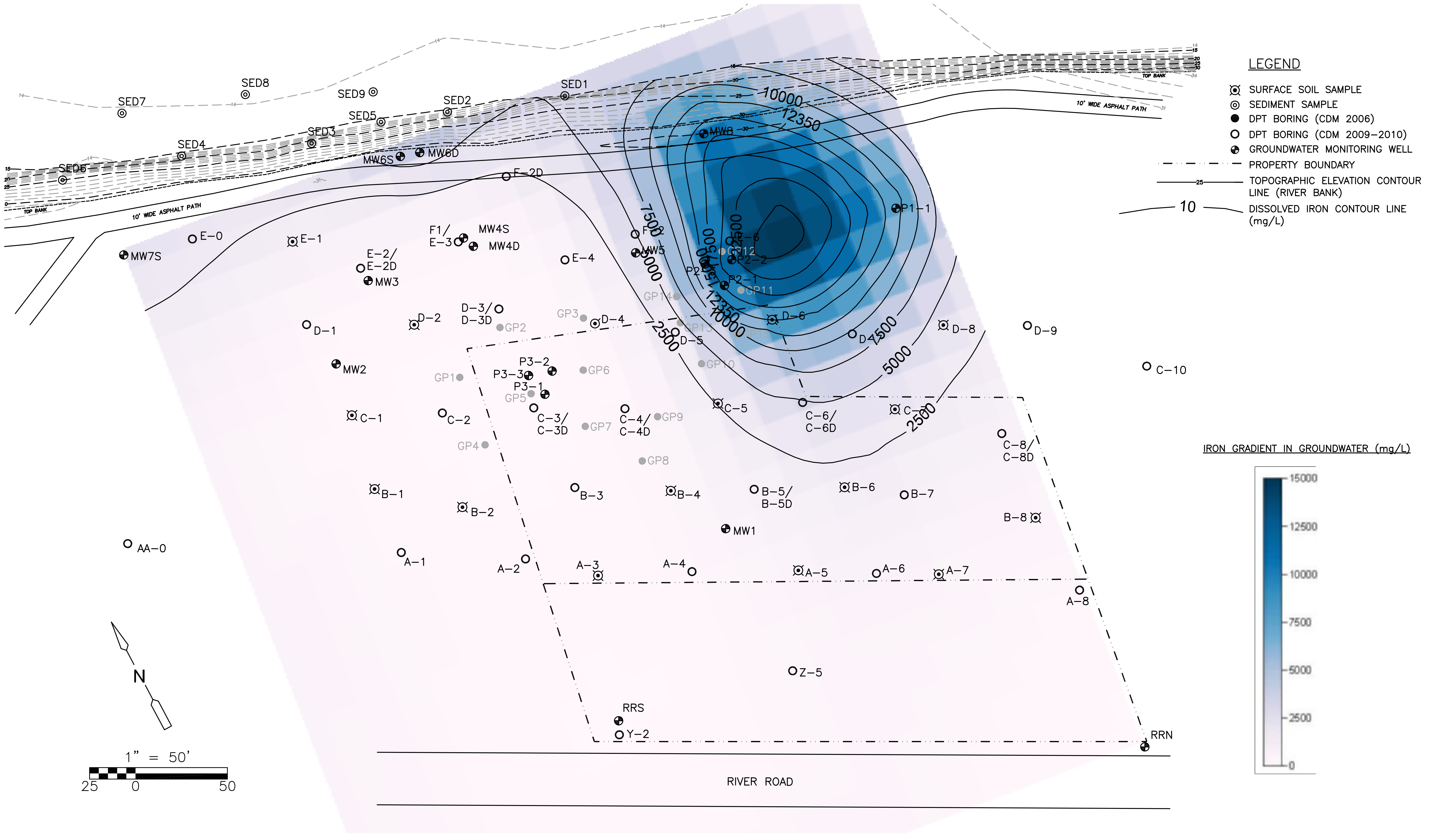
Figure No. 25
Site Map
Arsenic +3 in Groundwater

N:\ACAD2008\19921-74559\Maps-May 2011\ Fig-26 GW_AS5 06/10/11 13:11 talbotwk XREFS: 11X17BDR, _CDM-SITE, 36130-SURV-TP02



CDM

Figure No. 26
Site Map
Arsenic +5 in Groundwater



N:\ACAD2008\19921-74559\Maps-May 2011\ Fig-27_GW_Fe 06/10/11 13:12 talbotwk XREFS: 11X17BDR, _CDM-SITE, 36130-SURV-TP02

Figure No. 27
Site Map
Dissolved Iron in Groundwater

CDM

N:\ACAD2008\19921-74559\Maps-May 2011\ Fig-28_GW_ORP 06/10/11 13:13 talbotwk XREFS: 11X17BDR, _CDM-SITE, 36130-SURV-TP02

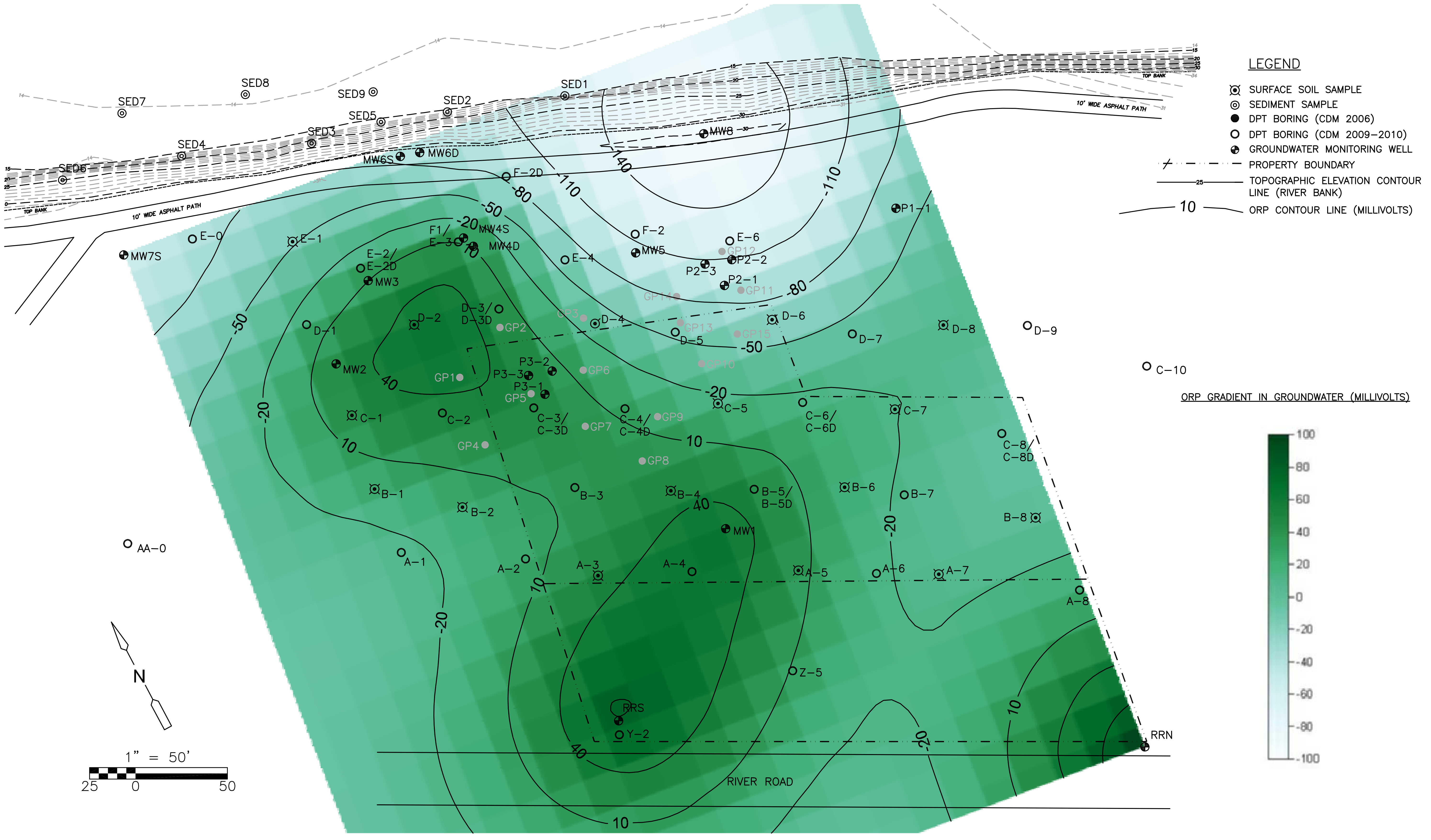


Figure No. 28
Site Map
Oxidation Reduction Potential in Groundwater

N:\ACAD2008\19921-74559\Maps-May 2011\ Fig-29_GW_TOC 06/10/11 13:14 talbotwk XREFS: 11X17BDR, _CDM-SITE, 36130-SURV-TP02

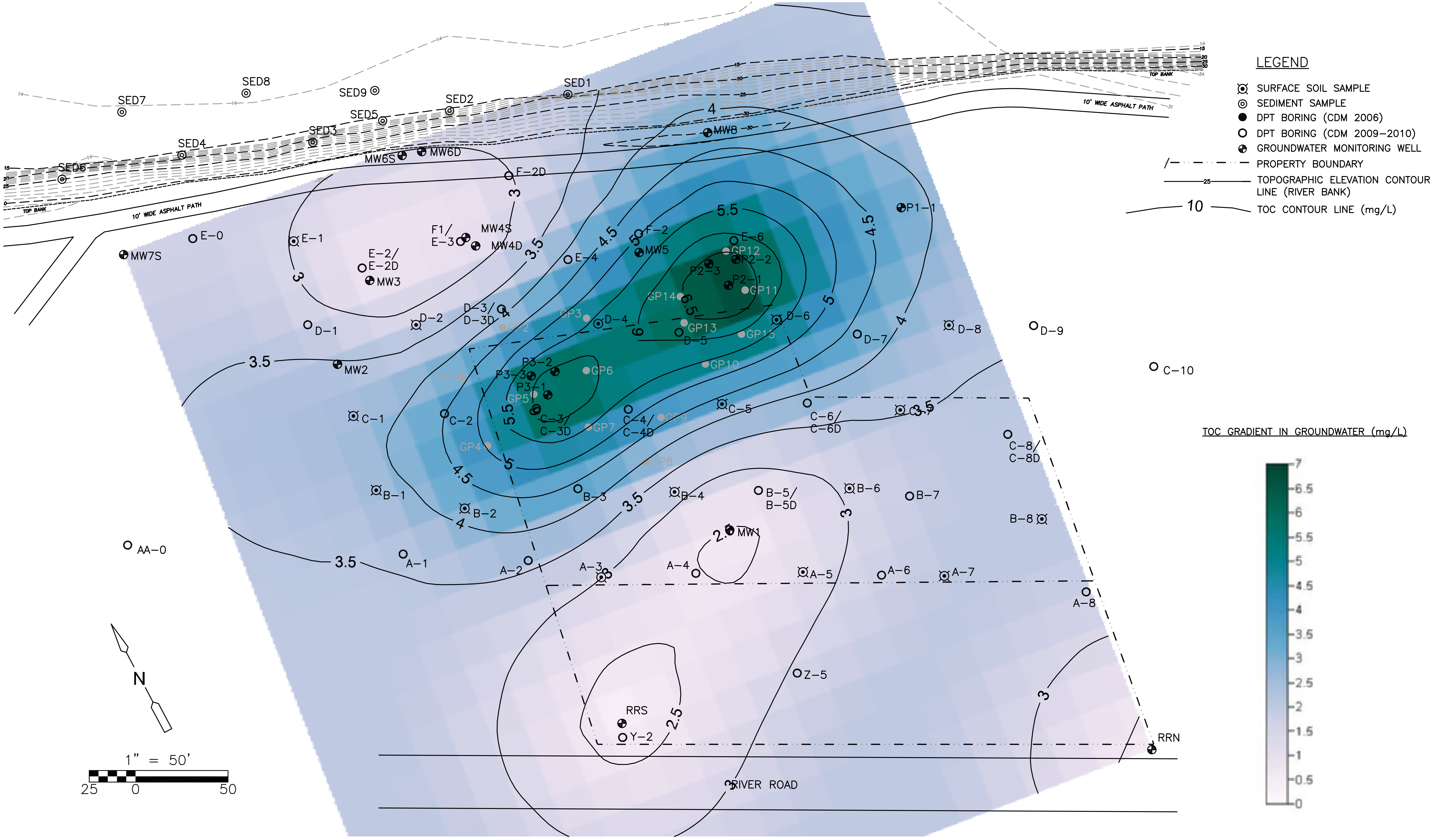


Figure No. 29
Site Map
Total Organic Carbon in Groundwater

CDM

N:\ACAD2008\19921-74559\Maps-May 2011\ Fig-30-Asenic in Sediment 06/10/11 13:16 talbotwk XREFS: _CDM-SITE, 11X17BDR, 36130-SURV-TP02

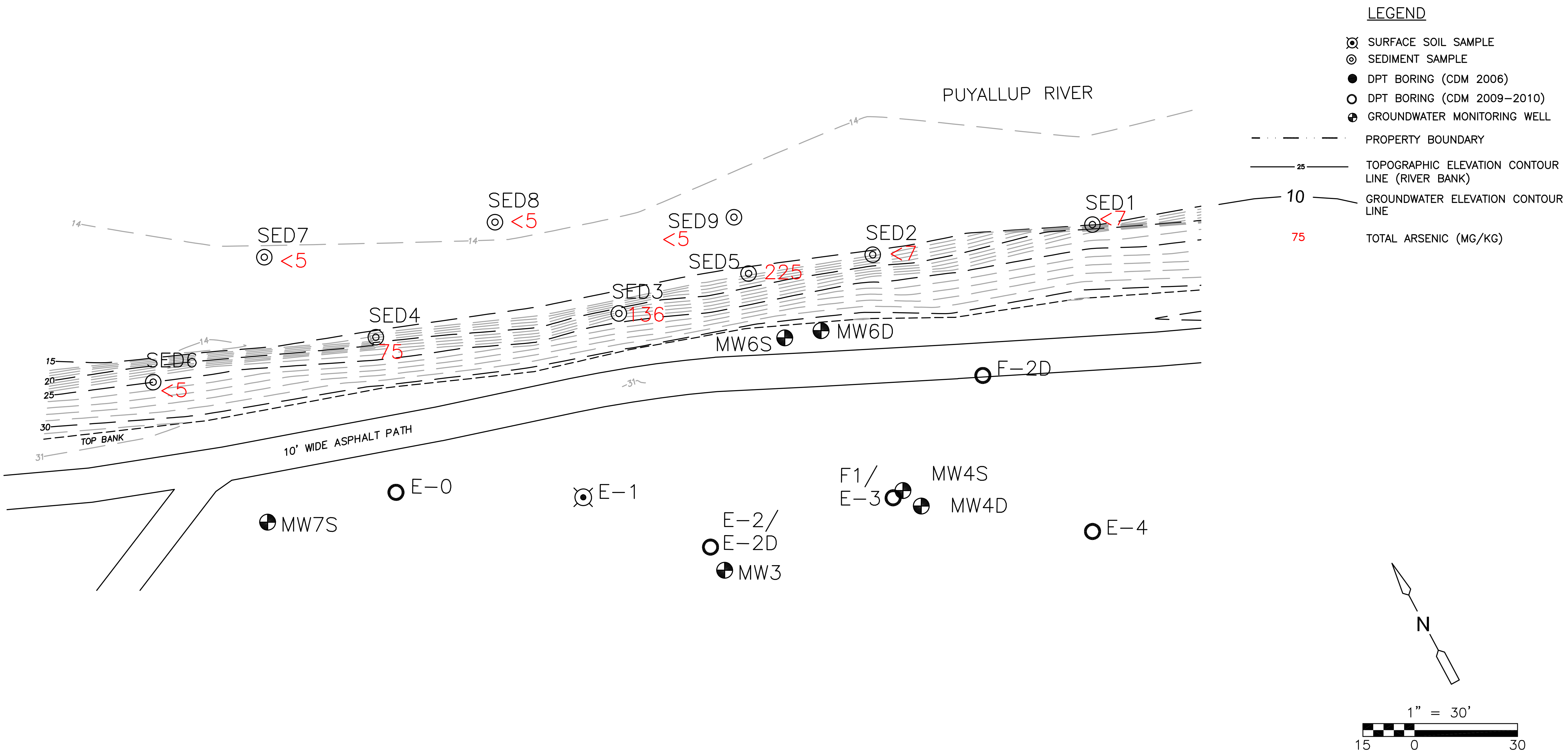
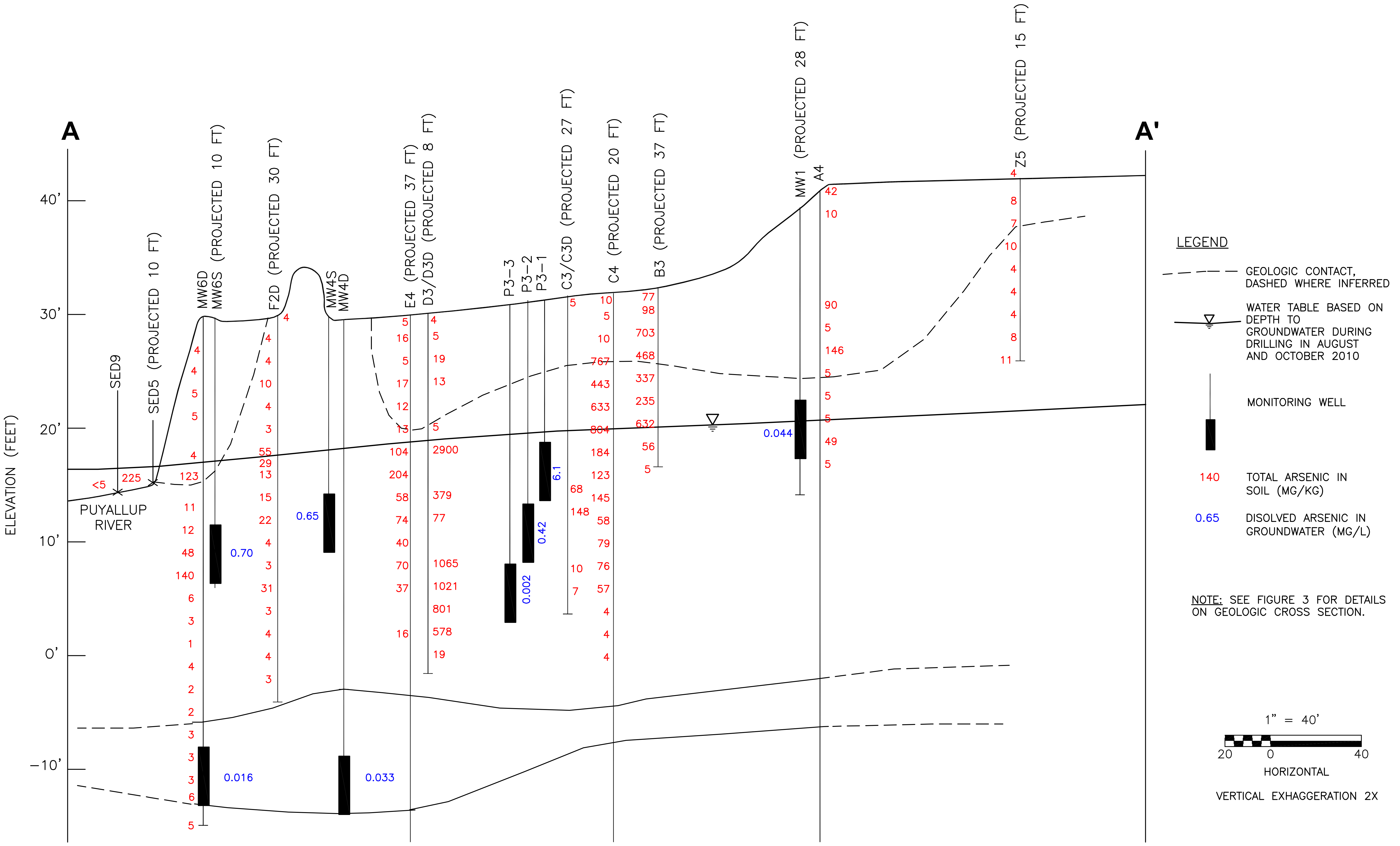


Figure No. 30
Asenic in Sediment



N:\ACAD2008\19921-74559\Maps-May 2011\ Fig-31 Asenic in Soil 7 Groundwater A-A 06/10/11 09:05 talbotwk

Figure No. 31
Arsenic in Soil & Groundwater A–A'

Appendix C
Solidification Calculations

TECHNICAL MEMORANDUM

FROM: Rick W. Chappell, Ph.D.

DATE: October 22, 2013

SUBJECT: USG Puyallup Site – Soil Arsenic Treatment Calculations

---

Introduction

Geospatial analysis produced a series of soil arsenic concentration maps at the site. Maps for the 2-ft intervals from the 32-ft to the 20-ft elevation are provided on the ‘maps’ sheet in the accompanying workbook file: **USG_FS_calcs.xlsx**, which also contains all of the calculations summarized in this technical memorandum. The workbook calculations correspond to the remedial alternative of *in situ* solidification/stabilization (S/S).

Parameters

The geospatial analysis consisted of variogram analysis followed by block kriging. This produced a series of six approximately 20 x 20 ft area and 2 ft depth block estimates of arsenic concentration. The actual areal dimensions of the blocks are 19.72 x 19.81 ft. The blocks were combined by averaging the arsenic values for each of the six corresponding blocks, producing a new set of 20 x 20 x 12 ft blocks (from the 32 to the 20 ft elevation, i.e., surface to the water table). The volume of each block is about 174 yd^3. Assuming a soil density of 2.7 g/cm^3, each block was calculated to have a total soil mass of 358,475 kg (≈358 metric tons).

Block Map

The resulting block map is provided in **Attachment A** (first map). Again, each block is approximately 20 x 20 x 12 ft and the values shown are the average arsenic concentrations. A color scale is also provided. The block map may be overlain on the site map for more definitive delineation of remediation limits, and for use in determining other remediation parameters, such as the amount of stabilization fluid required.

Calculations

Table 1 provides results for various remediation limits or “cutlines” (i.e., treatment levels for various block arsenic concentrations). The table shows the percent mass of arsenic treated, the number of blocks treated, and the total volume of soil treated. This information is also displayed graphically in **Attachment B**.

Table 1
Treatment Calculations

Cutline (mg/kg)	Mass of Arsenic Treated (%)[1]	Number of Blocks Treated	Total Volume of Soil Treated (yd^3)
≥ 20	100	193	33,515
≥ 25	94.83	155	26,916
≥ 30	90.65	130	22,575
≥ 35	88.86	121	21,012
≥ 40	86.84	112	19,449
≥ 45	84.26	102	17,713
≥ 50	82.21	95	16,497
≥ 60	78.82	85	14,761
≥ 70	75.62	77	13,371
≥ 80	72.94	71	12,329
≥ 90	70.39	66	11,461
≥ 100	65.81	58	10,072
≥ 120	58.07	46	7,988
≥ 140	52.51	39	6,773
≥ 160	46.93	33	5,731
≥ 180	39.52	26	4,515
≥ 200	34.84	22	3,820
≥ 220	28.41	17	2,952
≥ 240	24.20	14	2,431
≥ 260	19.54	11	1,910
≥ 280	14.60	8	1,389
≥ 300	5.72	3	521
≥ 320	1.96	1	174

[1] Based on all blocks with average arsenic ≥ 20 mg/kg.

<u>90 mg/kg Cutline</u>

A block map showing only those blocks with average arsenic ≥ 90 mg/kg for the 20 x 20 x 12 ft blocks is also provided in Attachment A (second map). As indicated in Table 1, *in situ* S/S treatment of these 66 blocks (≈11,500 yd^3 of soil) would provide treatment of approximately 70% of the total mass of arsenic above 20 mg/kg at the site. The remaining 30% of arsenic mass, between the 20 mg/kg and 90 mg/kg contour lines shown on the map, is anticipated to be treated via only injection of the stabilization fluid.

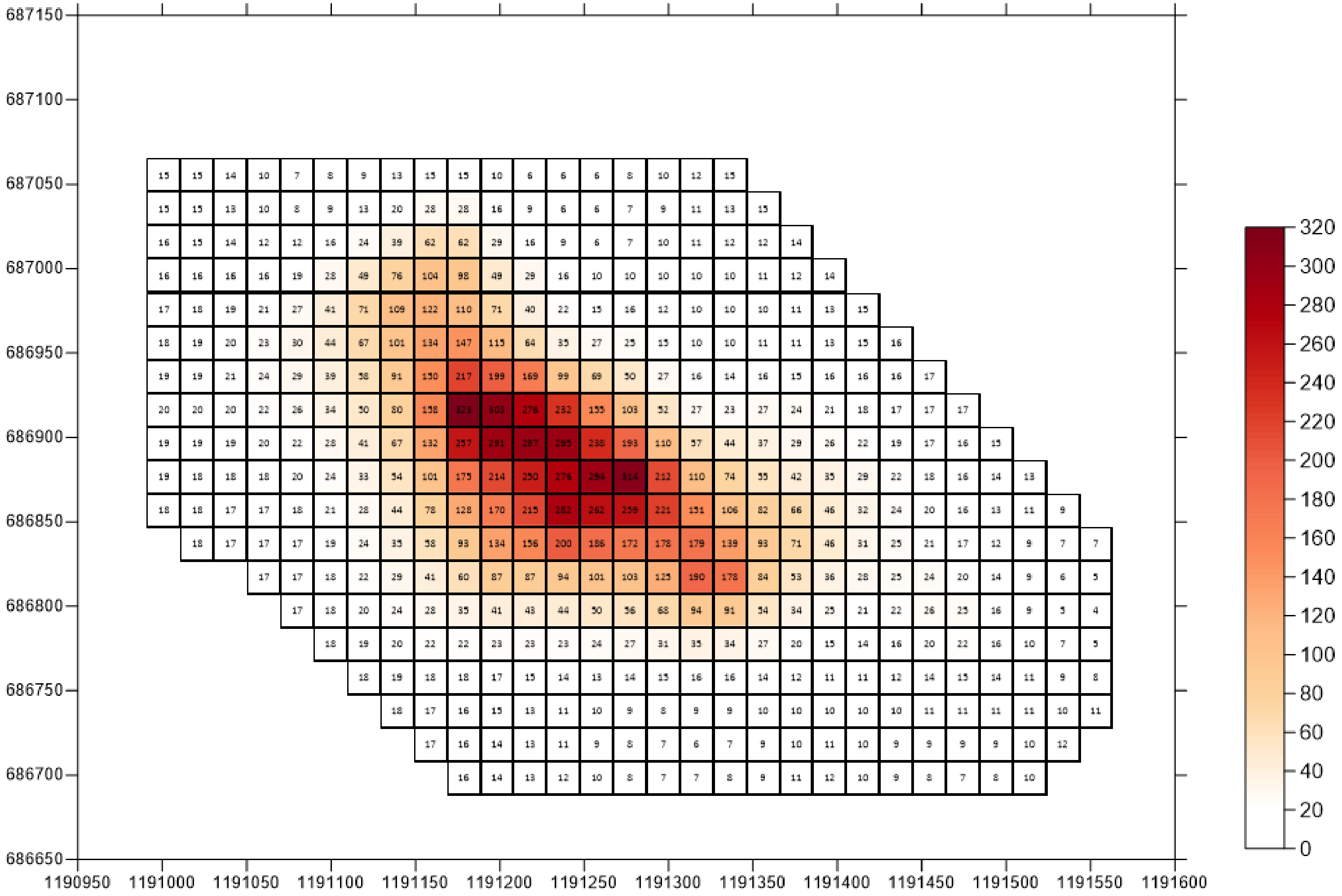
<u>50 mg/kg Cutline</u>

A block map showing only those blocks with average arsenic ≥ 50 mg/kg for the 20 x 20 x 12 ft blocks is also provided in Attachment A (third map). As indicated in Table 1, *in situ* S/S treatment of these 95 blocks (≈16,500 yd^3 of soil) would provide treatment of approximately 82% of the total mass of arsenic above 20 mg/kg at the site.

20 mg/kg Cutline

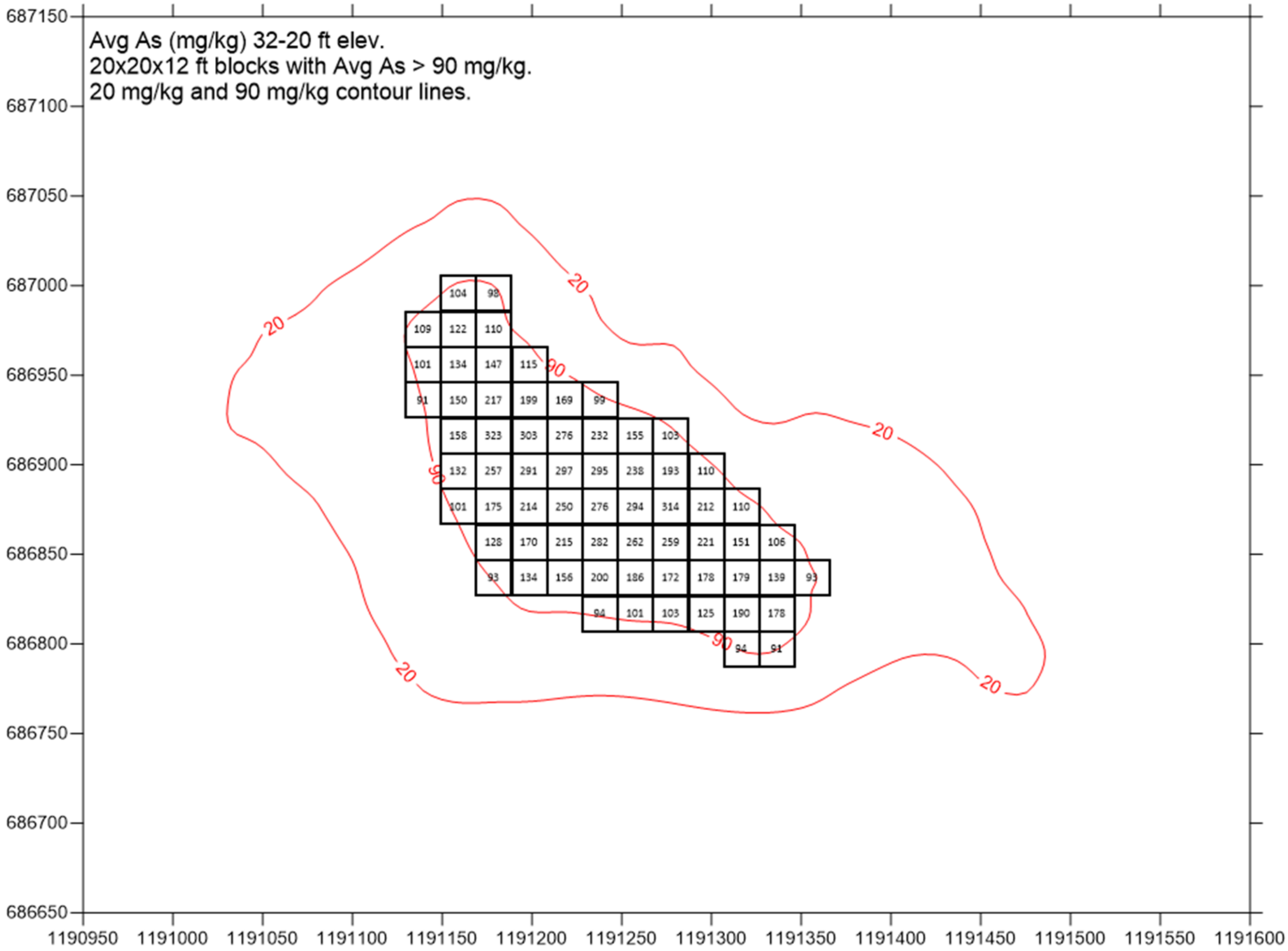
A block map showing all blocks with average arsenic ≥ 20 mg/kg for the 20 x 20 x 12 ft blocks is also provided in Attachment A (fourth map). As indicated in Table 1, *in situ* S/S treatment of these 193 blocks (≈33,500 yd^3 of soil) would provide treatment of 100% of the total mass of arsenic above 20 mg/kg at the site.

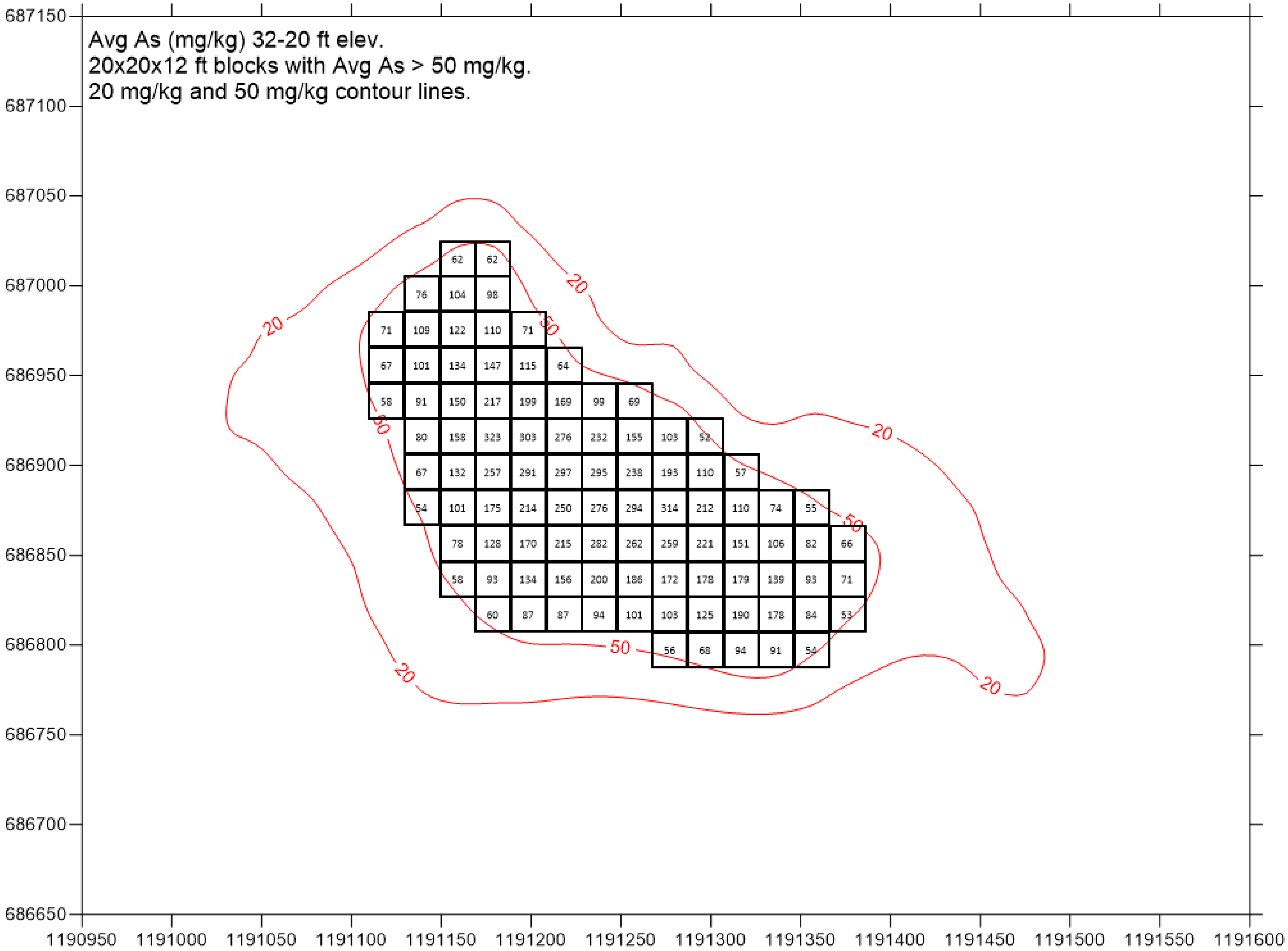
Attachment A - Block Maps

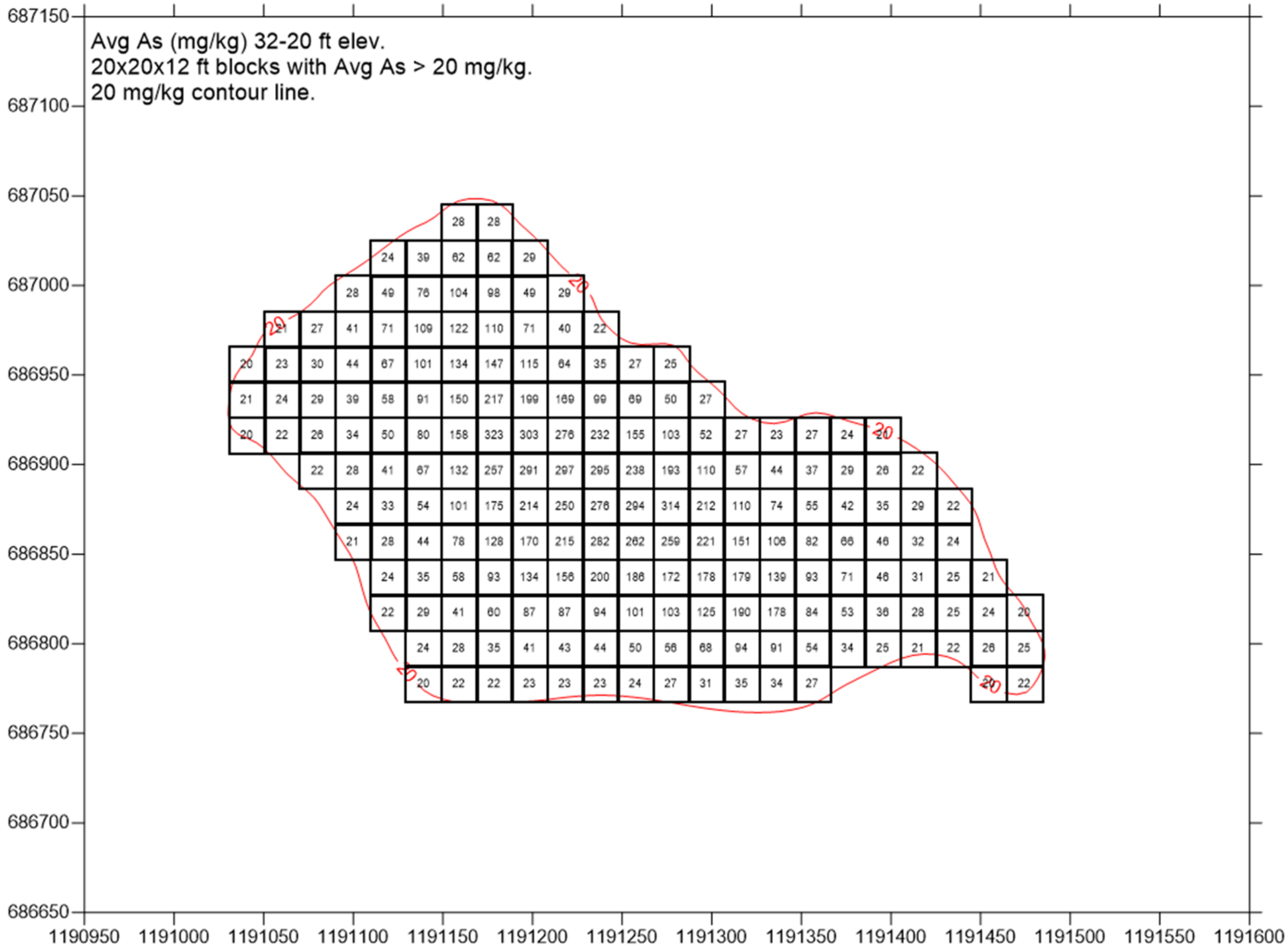


15	15	14	10	7	8	9	13	15	15	10	6	6	6	8	10	12	15											
15	15	13	10	8	9	13	20	28	28	16	9	6	6	7	9	11	13	15										
16	15	14	12	12	16	24	39	62	62	29	16	9	6	7	10	11	12	12	14									
16	16	16	16	19	28	49	76	104	98	49	29	16	10	10	10	10	10	11	12	14								
17	18	19	21	27	41	71	109	122	110	71	40	22	15	16	12	10	10	10	11	13	15							
18	19	20	23	30	44	67	101	134	147	115	64	35	27	25	15	10	10	11	11	13	15	16						
19	19	21	24	29	39	58	91	150	217	199	169	99	69	50	27	16	14	16	15	16	16	16	17					
20	20	20	22	26	34	50	80	158	323	303	276	232	155	103	52	27	23	27	24	21	18	17	17	17				
19	19	19	20	22	28	41	67	132	257	291	297	295	238	193	110	57	44	37	29	26	22	19	17	16	15			
19	18	18	18	20	24	33	54	101	175	214	250	276	294	314	212	110	74	55	42	35	29	22	18	16	14	13		
18	18	17	17	18	21	28	44	78	128	170	215	282	262	259	221	151	106	82	66	46	32	24	20	16	13	11	9	
	18	17	17	17	19	24	35	58	93	134	156	200	186	172	178	179	139	93	71	46	31	25	21	17	12	9	7	7
			17	17	18	22	29	41	60	87	87	94	101	103	125	190	178	84	53	36	28	25	24	20	14	9	6	5
				17	18	20	24	28	35	41	43	44	50	56	68	94	91	54	34	25	21	22	26	25	16	9	5	4
					18	19	20	22	22	23	23	23	24	27	31	35	34	27	20	15	14	16	20	22	16	10	7	5
						18	19	18	18	17	15	14	13	14	15	16	16	14	12	11	11	12	14	15	14	11	9	8
							18	17	16	15	13	11	10	9	8	9	9	10	10	10	10	10	11	11	11	11	10	11
								17	16	14	13	11	9	8	7	6	7	9	10	11	10	9	9	9	9	10	12	
									16	14	13	12	10	8	7	7	8	9	11	12	10	9	8	7	8	10		

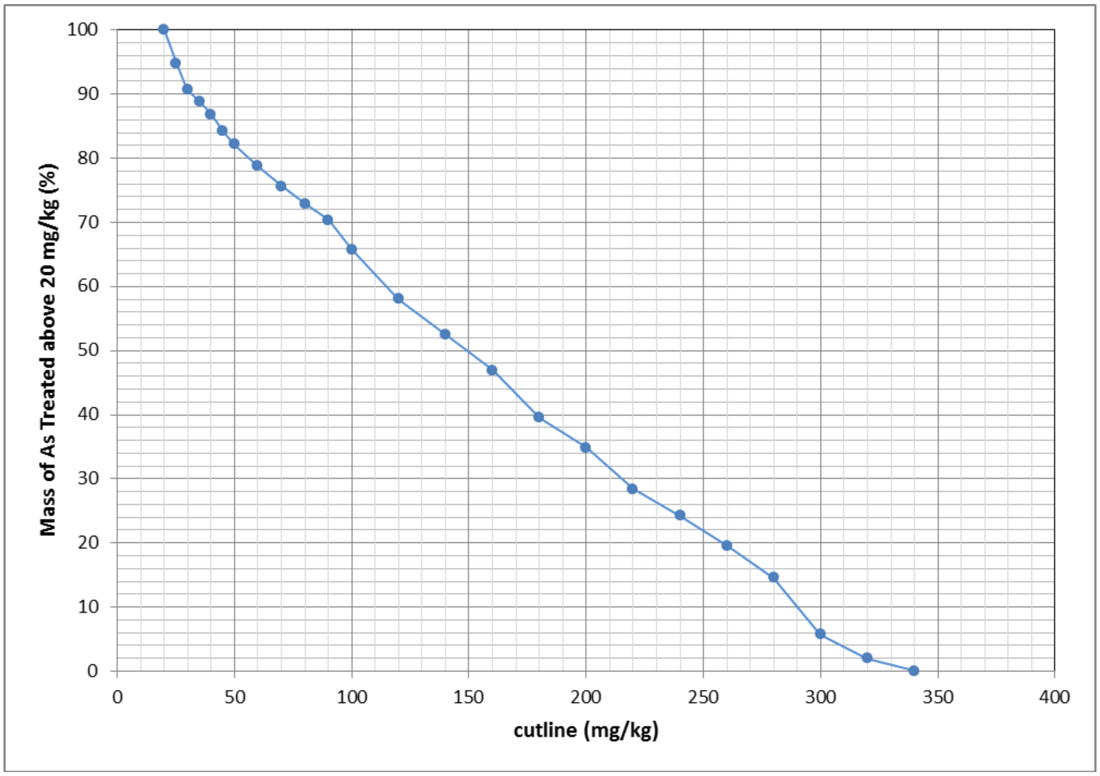
Avg As (mg/kg) 32-20 ft elev.

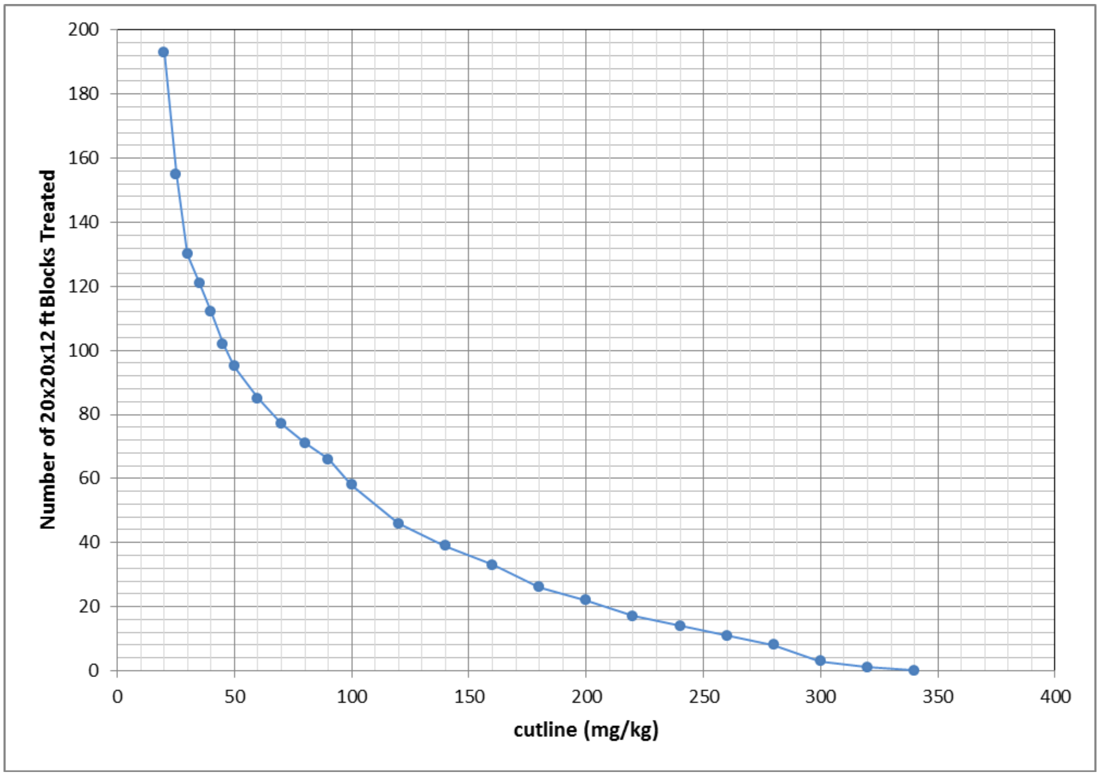

Avg As (mg/kg) 32-20 ft elev.
20x20x12 ft blocks with Avg As > 90 mg/kg.
20 mg/kg and 90 mg/kg contour lines.
687150
687100
687050
687000
686950
686900
686850
686800
686750
686700
686650
1190950
1191000
1191050
1191100
1191150
1191200
1191250
1191300
1191350
1191400
1191450
1191500
1191550
1191600
20
20
20
20
20
90
90
90
104 98
109 122 110
101 134 147 115
91 150 217 199 169 99
158 323 303 276 232 155 103
132 257 291 297 295 238 193 110
101 175 214 250 276 294 314 212 110
128 170 215 282 262 259 221 151 106
93 134 156 200 186 172 178 179 139 93
94 101 103 125 190 178
94 91

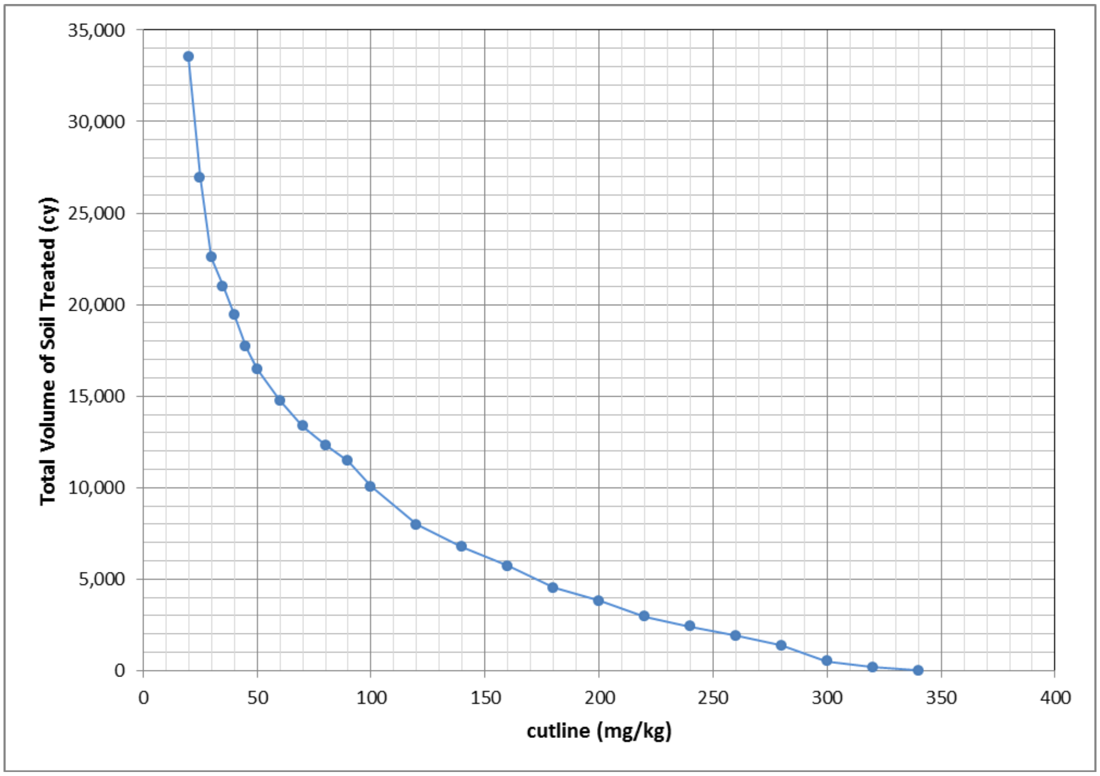
Avg As (mg/kg) 32-20 ft elev.
20x20x12 ft blocks with Avg As > 50 mg/kg.
20 mg/kg and 50 mg/kg contour lines.
687150
687100
687050
687000
686950
686900
686850
686800
686750
686700
686650
1190950
1191000
1191050
1191100
1191150
1191200
1191250
1191300
1191350
1191400
1191450
1191500
1191550
1191600
20
20
20
20
20
50
50
50
50
62 62
76 104 98
71 109 122 110 71
67 101 134 147 115 64
58 91 150 217 199 169 99 69
80 158 323 303 276 232 155 103 52
67 132 257 291 297 295 238 193 110 57
54 101 175 214 250 276 294 314 212 110 74 55
78 128 170 215 282 262 259 221 151 106 82 66
58 93 134 156 200 186 172 178 179 139 93 71
60 87 87 94 101 103 125 190 178 84 53
56 68 94 91 54


Avg As (mg/kg) 32-20 ft elev.
20x20x12 ft blocks with Avg As > 20 mg/kg.
20 mg/kg contour line.
687150
687100
687050
687000
686950
686900
686850
686800
686750
686700
686650
1190950
1191000
1191050
1191100
1191150
1191200
1191250
1191300
1191350
1191400
1191450
1191500
1191550
1191600
28 28
24 39 62 62 29
28 49 76 104 98 49 29
21 27 41 71 109 122 110 71 40 22
20 23 30 44 67 101 134 147 115 64 35 27 25
21 24 29 39 58 91 150 217 199 169 99 69 50 27
20 22 26 34 50 80 158 323 303 276 232 155 103 52 27 23 27 24 21
22 28 41 67 132 257 291 297 295 238 193 110 57 44 37 29 26 22
24 33 54 101 175 214 250 276 294 314 212 110 74 55 42 35 29 22
21 28 44 78 128 170 215 282 262 259 221 151 106 82 66 46 32 24
24 35 58 93 134 156 200 186 172 178 179 139 93 71 46 31 25 21
22 29 41 60 87 87 94 101 103 125 190 178 84 53 36 28 25 24 20
24 28 35 41 43 44 50 56 68 94 91 54 34 25 21 22 26 25
20 22 22 23 23 23 24 27 31 35 34 27 20 22
20
20
20
20
20

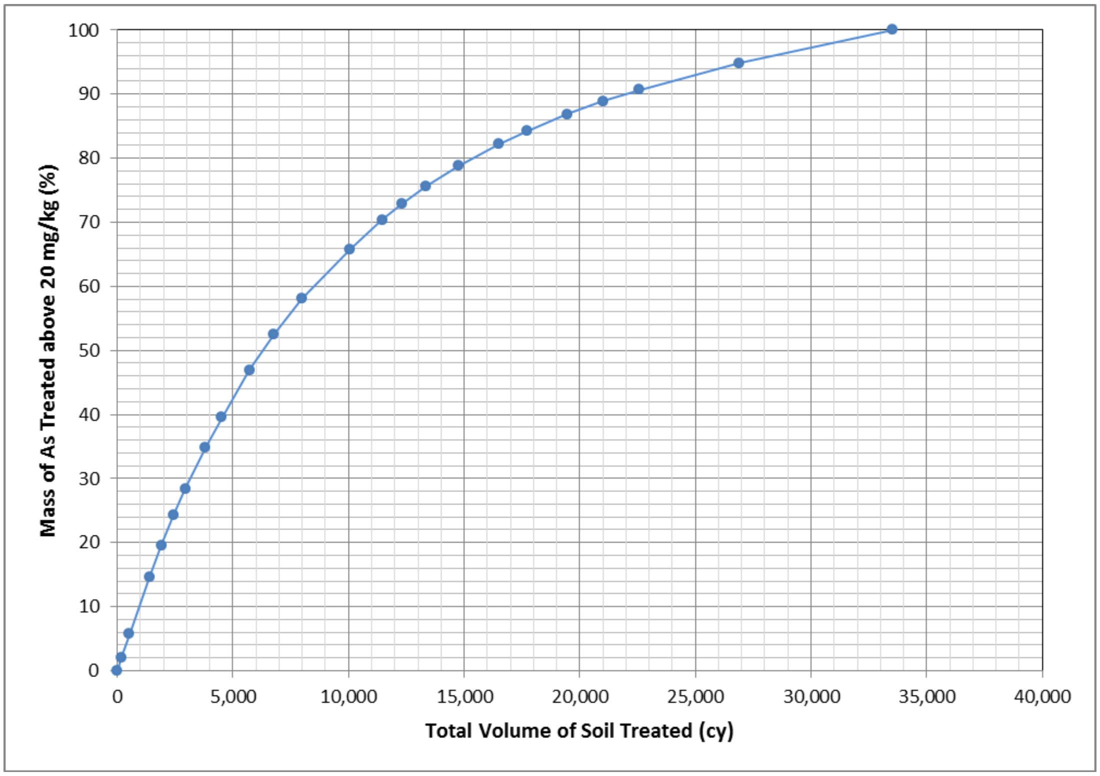
Attachment B – Calculation Graphs







35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Total Volume of Soil Treated (cy)
0
50
100
150
200
250
300
350
400
cutline (mg/kg)



100
90
80
70
60
50
40
30
20
10
0
Mass of As Treated above 20 mg/kg (%)
0
5,000
10,000
15,000
20,000
25,000
30,000
35,000
40,000
Total Volume of Soil Treated (cy)

Appendix D
Alternative Design Assumptions and Cost Estimates

Table D-1

Assumptions for Conceptual Design of Alternative 1

In-Situ Soil Solidification/Stabilization, Slurry Wall, PRB, Upland Sediment Removal and Streambank Restoration, Performance Monitoring and Institutional Controls

Feasibility Study - USG Puyallup
Puyallup, Washington

Component	Specifications
Soil Solidification/Stabilization	
Bin Length (feet):	19.71
Bin Width (feet):	19.82
Bin Height (feet):	12
Bin volume (cubic yards):	174
Target contamination limit for 100% removal (mg/kg)	20
Number of bins above target contamination limit	193
Volume of soil above target contamination limit (cubic yards)	33,509
Mixing Disposal Allowance (0% of soil mix volume in cubic yards)	0
Safety Factor	25%
Design Soil Volume (cubic yards)	41,887
Swell Factor	1.3
Soil density (tons/cubic yards)	1.45
Cement Mix (%)	10%
Number of wells to be abandoned:	9
Average depth of wells to be abandoned:	36
Mix Design Study Cost (already performed)	$0
Slurry Wall	
Slurry Wall Length (linear feet):	640
Slurry Wall Maximum Depth (feet):	45
Slurry Wall Minimum Depth (feet):	10
Slurry Wall Area (square feet):	22,400
Permeable Reactive Barrier	
Length of PRB (feet):	250
Bottom Depth of PRB (feet) from surface:	45
Top Depth of PRB (feet) from surface:	10
Thickness of PRB (feet):	3
Volume of PRB media (cubic yards)	972
Volume excavated and disposed (cubic yards)	1250
Soil density (tons/cubic yards)	1.45
Soil transported and disposed (tons)	1813
Volume of fill to be emplaced above PRB media (cubic yards)	278
Installation:	Trench
Media:	Zero-Valent Iron
Sediment Removal / Remediation	
Length of removal area (feet)	150
Width of removal area (feet)	9
Depth of removal area (feet)	6
Volume of sediment removal (bcy)	300
Density of sediment removed (tons/bcy)	1.75
Density of replacement fill (tons/bcy)	1.75
Swell	1.3
Backfill Source	Off-Site
Performance Monitoring	
Total Number of New Wells Installed:	10
Total Number of Existing Wells (after construction):	6
Average depth of new monitoring wells (feet):	25
Analytes:	Dissolved metals
Aquifer Sampling Frequency:	Semi-annual for first 5 years; annual thereafter
Monitoring Duration:	30 years
Institutional Controls	Restrictive covenants
JARPA and Cleanup Action Plan	
Cost for Impacted Soil Delineation Investigation:	$0
Cost for Bench-Scale Study:	$0
Cost for Field Pilot Test:	$0
JARPA	$60,000
Cost for Cleanup Action Plan	$30,000
Total:	$90,000

Notes:
1. Extent of plume above cleanup levels is not fully defined. Assumptions have been made to delineate the extent of the contaminating exceeding site

Table D-2A

Assumptions for Conceptual Design of Alternative 2A

Iron Compound Injection, Soil Solidification/Stabilization, Water Treatment, Upland Sediment Removal and Streambank Restoration, Performance Monitoring and Institutional Controls

Feasibility Study - USG Puyallup
Puyallup, Washington

Component	**Specifications**
Iron Compound Injection	
Miscellaneous Equipment	dpt, mobilization, demobilization, setup, decontamination
Injection Material	Iron Compound
Injection - Wells	Assumes 4-inch borehole with 2-inch well installation to 30 ft bgs
Total Injection Borings (Ferrous Iron and ISCO)	72
Sub-contractor injection rate (borings/day)	4
Total Days for Injection	18
Sub-contractor Labor and Equipment Cost ($/day)	$2,500
Sub-contractor Materials Cost ($/day)	$500
Operations and Maintenance	Assumes 1/2 scale injection 4 years after the first year full injection, along with 1/2 scale injections after the 7th and 9th years
Soil Solidification	
Bin Length (feet):	19.71
Bin Width (feet):	19.82
Bin Height (feet):	12
Bin volume (cubic yards):	174
Target contamination limit for 70% removal (mg/kg)	90
Number of bins above target contamination limit	66
Volume of soil above target contamination limit (cubic yards):	11,459
Mixing Disposal Allowance (0% of soil mix volume in cubic yards)	0
Swell Factor	1.3
Density (tons/cubic yard)	1.45
Cement Mix (%)	10%
Number of wells to be abandoned:	6
Average depth of wells to be abandoned:	36
Soil Mixing can be Performed by Excavator with Attachment - no separate injection/mill required	
No waste stream generated	
Mix Design Study Cost	$40,000
Iron Introduction System	
Re-introduction trench length (feet)	280
Re-introduction trench depth (feet)	12
Re-introduction trench width (feet)	2
Stormwater Infiltration Gallery	
Re-introduction trench length (feet)	270
Re-introduction trench depth (feet)	12
Re-introduction trench width (feet)	2
Sediment Removal, Institutional Controls	Same as Alt. 1
Performance Monitoring	
Total Number of New Wells Installed:	10
Total Number of Existing Wells (after construction):	6
Average depth of new monitoring wells (feet):	25
Analytes:	Dissolved metals
Aquifer Sampling Frequency:	Quarterly for first 4 years, Semi-annual for next 6 years; annual thereafter
Monitoring Duration:	30 years
Pilot Test, JARPA, and Cleanup Action Plan	
Cost for Field Pilot Test (iron injection and introduction):	$60,000
JARPA	$60,000
Cost for Cleanup Action Plan	$30,000
Total:	$150,000

Notes:

Table D-2B

Assumptions for Conceptual Design of Alternative 2B

Iron Compound Injection, Soil Solidification/Stabilization, Water Treatment, Upland Sediment Removal and Streambank Restoration, Performance Monitoring and Institutional Controls

Feasibility Study - USG Puyallup
Puyallup, Washington

Component	Specifications
Iron Compound Injection	
Miscellaneous Equipment	dpt, mobilization, demobilization, setup, decontamination
Injection Material	Iron Compound
Injection - Wells	Assumes 4-inch borehole with 2-inch well installation to 30 ft bgs
Total Injection Borings (Ferrous Iron and ISCO)	72
Sub-contractor injection rate (borings/day)	4
Total Days for Injection	18
Sub-contractor Labor and Equipment Cost ($/day)	$2,500
Sub-contractor Materials Cost ($/day)	$500
Operations and Maintenance	Assumes 1/2 scale injection 4 years after the first year full injection, along with 1/2 scale injections after the 7th and 9th years
Soil Solidification	
Bin Length (feet):	19.71
Bin Width (feet):	19.82
Bin Height (feet):	12
Bin volume (cubic yards):	174
Target contamination limit for 82% removal (mg/kg)	50
Number of bins above target contamination limit	95
Volume of soil above target contamination limit (cubic yards):	16,494
Mixing Disposal Allowance (0% of soil mix volume in cubic yards)	0
Swell Factor	1.3
Density (tons/cubic yard)	1.45
Cement Mix (%)	10%
Number of wells to be abandoned:	6
Average depth of wells to be abandoned:	36
Soil Mixing can be Performed by Excavator with Attachment - no separate injection/mill required	
No waste stream generated	
Mix Design Study Cost	$40,000
Iron Introduction System	
Re-introduction trench length (feet)	280
Re-introduction trench depth (feet)	12
Re-introduction trench width (feet)	2
Stormwater Infiltration Gallery	
Re-introduction trench length (feet)	270
Re-introduction trench depth (feet)	12
Re-introduction trench width (feet)	2
Sediment Removal, Institutional Controls	Same as Alt. 1
Performance Monitoring	
Total Number of New Wells Installed:	10
Total Number of Existing Wells (after construction):	6
Average depth of new monitoring wells (feet):	25
Analytes:	Dissolved metals
Aquifer Sampling Frequency:	Quarterly for first 4 years, Semi-annual for next 6 years; annual thereafter
Monitoring Duration:	30 years
Pilot Test, JARPA, and Cleanup Action Plan	
Cost for Field Pilot Test (iron injection and introduction):	$60,000
JARPA	$60,000
Cost for Cleanup Action Plan	$30,000
Total:	$150,000

Notes:

Table D-2C
Assumptions for Conceptual Design of Alternative 2C
Iron Compound Injection, Soil Solidification/Stabilization, Water Treatment, Upland Sediment Removal and Streambank Restoration, Performance Monitoring and Institutional Controls

Feasibility Study - USG Puyallup
Puyallup, Washington

Component	Specifications
Iron Compound Injection	
Miscellaneous Equipment	dpt, mobilization, demobilization, setup, decontamination
Injection Material	Iron Compound
Injection - Wells	Assumes 4-inch borehole with 2-inch well installation to 30 ft bgs
Total Injection Borings (Ferrous Iron and ISCO)	72
Sub-contractor injection rate (borings/day)	4
Total Days for Injection	18
Sub-contractor Labor and Equipment Cost ($/day)	$2,500
Sub-contractor Materials Cost ($/day)	$500
Operations and Maintenance	Assumes 1/2 scale injection 4 years after the first year full injection, along with 1/2 scale injections after the 7th and 9th years
Soil Solidification	
Bin Length (feet):	19.71
Bin Width (feet):	19.82
Bin Height (feet):	12
Bin volume (cubic yards):	174
Target contamination limit for 100% removal (mg/kg)	20
Number of bins above target contamination limit	193
Volume of soil above target contamination limit (cubic yards):	33,509
Mixing Disposal Allowance (0% of soil mix volume in cubic yards)	0
Swell Factor	1.3
Density (tons/cubic yard)	1.45
Cement Mix (%)	10%
Number of wells to be abandoned:	6
Average depth of wells to be abandoned:	36
Soil Mixing can be Performed by Excavator with Attachment - no separate injection/mill required	
No waste stream generated	
Mix Design Study Cost	$40,000
Iron Introduction System	
Re-introduction trench length (feet)	280
Re-introduction trench depth (feet)	12
Re-introduction trench width (feet)	2
Stormwater Infiltration Gallery	
Re-introduction trench length (feet)	270
Re-introduction trench depth (feet)	12
Re-introduction trench width (feet)	2
Sediment Removal, Institutional Controls	Same as Alt. 1
Performance Monitoring	
Total Number of New Wells Installed:	10
Total Number of Existing Wells (after construction):	6
Average depth of new monitoring wells (feet):	25
Analytes:	Dissolved metals
Aquifer Sampling Frequency:	Quarterly for first 4 years, Semi-annual for next 6 years; annual thereafter
Monitoring Duration:	30 years
Pilot Test, JARPA, and Cleanup Action Plan	
Cost for Field Pilot Test (iron injection and introduction):	$60,000
JARPA	$60,000
Cost for Cleanup Action Plan	$30,000
Total:	$150,000

Notes:

Table D-3
Assumptions for Conceptual Design of Alternative 3
Soil Removal to Cleanup Levels, Short-Term Water Treatment, Upland Sediment Removal and Streambank Restoration, MNA and Institutional Controls

Feasibility Study - USG Puyallup
Puyallup, Washington

Component	Specifications
Soil Removal to Cleanup Level	
Three phases assumed: 1. shoring/dam along puyallup, main soil excavation, 2. Near Puyallup River Excavation, 3. Sediment Remova	
Total Quantities:	
Excavation Area (square feet):	138,000
Volume (bank cubic yards) excavated, stockpiled, tested:	82,160
Volume (bank cubic yards) transported, disposed - Non-Hazardous:	28,152
Volume (bank cubic yards) transported, disposed - Hazardous	0
Excavation average depth (feet):	16
Average depth to groundwater (feet):	13
Shoring (sheet pile or other) length (feet):	
Non-hazardous soil arsenic concentration (ppm):	Less than 500, greater than 20
Hazardous soil arsenic concentration (ppm):	Greater than 500
Number of wells to be abandoned:	12
Average depth of wells to be abandoned:	36
Disposal Site (non-hazardous):	Waste Management - Columbia Ridge, Subtitle D Landfill
Disposal Site (hazardous):	Waste Management - Columbia Ridge, Subtitle C Landfill
Imported (off-site) backfill (bank cubic yards) - above groundwater:	2,597
Shrikage	1.3 loose cubic yards to 1 bank cubic yard
Backfill conversion	1.75 tons earthen fill to 1 loose cubic yard
Imported (off-site) backfill (bank cubic yards) - below groundwater, quarry spalls:	25,555
Shrinkage - Quarry Spalls	1.15 loose cubic yards to 1 bank cubic yard
Backfill conversion - Quarry Spalls	1.5 tons rocky fill to 1 loose cubic yard
On-site backfill (cubic yards):	54,008
Phase 1 Main Soil Excavation Quantities:	
Excavation Area (square feet):	96,550
Volume (bank cubic yards) excavated, stockpiled, tested:	57,215
Volume (bank cubic yards) transported, disposed - Non-Hazardous:	20,106
Volume (bank cubic yards) transported, disposed - Hazardous	0
Excavation average depth (feet):	16
Average depth to groundwater (feet):	13
Shoring length (feet):	860
Shoring depth (feet):	45
Shoring surface area (sf):	38,700
Number of wells to be abandoned:	12
Average depth of wells to be abandoned:	36
Imported (off-site) backfill (bank cubic yards) - above groundwater:	2,597
Imported (off-site) backfill (bank cubic yards) - below groundwater, quarry spalls:	17,509
On-site backfill (cubic yards):	37,109
Phase 2 Near Puyallup River Excavation Quantities:	
Excavation Area (square feet):	41,450
Volume (bank cubic yards) excavated, stockpiled, tested:	24,563
Volume (bank cubic yards) transported, disposed - Non-Hazardous:	8,046
Volume (bank cubic yards) transported, disposed - Hazardous	0
Excavation average depth (feet):	16
Average depth to groundwater (feet):	13
Shoring length (feet):	450
Shoring depth (feet):	45
Shoring surface area (sf):	20,250
Number of wells to be abandoned:	2
Average depth of wells to be abandoned:	36
Imported (off-site) backfill (bank cubic yards) - above groundwater:	0
Imported (off-site) backfill (bank cubic yards) - below groundwater, quarry spalls:	8,046
On-site backfill (cubic yards):	16,517
Construction Dewatering for Above	
Average Dewatering Flow Rate (gpm)	240
Discharge Fees ($/gal)	$0.01
Duration (months)	12
Capital Cost for Packaged Arsenic Treatment System (double Severn Trent est. provided 2Aug13)	$470,000
Annual O&M for Above (double Severn Trent est. provided 2Aug13)	$150,600
Cost for equipment, materials, and labor for treatment system installation (double cost of Alt 2)	$120,000

Table D-3
Assumptions for Conceptual Design of Alternative 3
Soil Removal to Cleanup Levels, Short-Term Water Treatment, Upland Sediment Removal and Streambank Restoration, MNA and Institutional Controls

Feasibility Study - USG Puyallup
Puyallup, Washington

Component	Specifications
Short term water treatment	
Groundwater Extraction Well - casing construction (material):	PVC
Groundwater extraction well - casing diameter (inches):	4
Groundwater extraction well - depth (feet):	20
Groundwater extraction well - quantity (number):	6
Average total extracted groundwater flow rate (gpm):	10
Maximum arsenic concentration (ug/L):	4,000
Average arsenic concentration (ug/L):	950
Discharge requirement, arsenic (ug/L):	5
Average removal efficiency (%)	99.5%
# of days operating (number of days required to remove soil below water table)	1825
Sediment Removal, MNA, Institutional Controls	Same as Alt. 1
Permitting, JARPA, and Cleanup Action Plan	
Cost for Impacted Soil Delineation Investigation:	$0
Water Discharge Permit Plan, Review, and Fees:	$50,000
JARPA	$60,000
Cost for Cleanup Action Plan	$30,000
Total:	$140,000

Notes:
1. Extent of plume above cleanup levels is not fully defined. Assumptions have been made to delineate the extent of the contaminating exceeding site cleanup
2. Imported backfill for below the groundwater table is quarry spalls from an iron-rich rock.
3. Excavation cannot extend to edge of Puyallup River due to geotechnical stability concerns.

Table D-4
Cost Estimate for Alternative 1
Feasibility Study - USG Puyallup
Puyallup, Washington

Item	Quantity	Unit	Unit Cost	Cost	Comment
Soil Solidification					
Initial Capital Costs					
Direct Costs					
Clearing and Grubbing	1.80	acres	$ 9,500	$ 17,100	
Mix Design	1	ls	$ -	$ -	
Mobilization of Mixing Machine	0	ls	$ 75,000	$ -	Not Required
Disposal Allowance (0% of soil mixing volume)	0	tons	$ 52	$ -	Minimal Waste Generated
Soil Mixing	41,887	bcy	$ 40	$ 1,675,464	
Abandon Wells in Excavation Perimeter	6	wells	$ 2,000.00	$ 12,000	
			Subtotal =	$ 1,704,564	
Indirect-Contractor					
OH&P of Subcontractors (@20% of half capital costs)				$ 170,456	
General Conditions (@10%)				$ 170,456	
Other (@10%)				$ 170,456	
				$ 511,369	
			Subtotal =	$ 2,215,933	
Construction Contingency (@25%)				$ 553,983	
Contractor Fee (@15%)				$ 332,390	
Escalation (@2%)				$ 44,319	
				$ 930,692	
			Subtotal =	$ 3,146,625	
Indirect-Other					
Engineering (10% of total cost)				$ 314,662	
Project Management (12% of total cost)				$ 377,595	
Sales Tax (8.6% of half capital costs)				$ 135,305	
				$ 827,562	
			Total =	$ 3,974,187	
Operations, Maintenance, and Monitoring Cost					
Direct					This portion of alternative will require no maintenance
Operating and Maintenance Costs		ls	$ -	$ -	
Indirect					
Project Management (12% of total)	12	% of total		$ -	
			Total =	$ -	

Table D-4
Cost Estimate for Alternative 1
Feasibility Study - USG Puyallup
Puyallup, Washington

Item	Quantity	Unit	Unit Cost	Cost	Comment
Slurry Walls					
Capital Costs					
Direct					
Area of Slurry Wall	22,400	sf	$ 53.00	$ 1,187,200	from Means
Preparation	1	ea	$ 10,000	$ 10,000	
			Subtotal =	$ 1,197,200	
Indirect-Contractor					
OH&P of Subcontractors (@10%)				$ 119,720	
General Conditions (@10%)				$ 119,720	
Other (@10%)				$ 119,720	
				$ 359,160	
			Subtotal =	$ 1,556,360	
Construction Contingency (@25%)				$ 389,090	
Contractor Fee (@15%)				$ 233,454	
Escalation (@2%)				$ 31,127	
				$ 653,671	
			Subtotal =	$ 2,210,031	
Indirect-Other					
Engineering (10% of total cost)				$ 221,003	
Project Management (10% of total cost)				$ 221,003	
Sales Tax (8.6% of half capital cots)				$ 51,480	
				$ 493,486	
			Total =	$ 2,703,517	
Operations, Maintenance, and Monitoring Cost					
Direct					This portion of alternative will require no maintenance
Operating and Maintenance Costs		ls	$ -	$ -	
Indirect					
Project Management (12% of total)	12	% of total		$ -	
			Total =	$ -	

Table D-4
Cost Estimate for Alternative 1
Feasibility Study - USG Puyallup
Puyallup, Washington

Item	Quantity	Unit	Unit Cost	Cost	Comment
Permeable Reactive Barrier					
Initial Capital Costs					
Direct Costs					
Excavate PRB Trench	1,250	bcy	$ 8.56	$ 10,700	
Transporation and Disposal of Contaminated Soils	1,813	tons	$ 52	$ 94,250	
Zero Valent Iron	972	bcy	$ 264	$ 256,667	
Procure, Place, and Compact Backfill	632	tons	$ 25	$ 15,799	
Analytical Testing - Disposal (556 ton, 1.6:1)	4	samples	$ 255	$ 1,020	1 TCLP / Total per 400 ton
			Subtotal =	$ 378,435	
Indirect-Contractor					
OH&P of Subcontractors (@20% of half capital costs)				$ 37,844	
General Conditions (@10%)				$ 37,844	
Other (@10%)				$ 37,844	
				$ 113,531	
			Subtotal =	$ 491,966	
Construction Contingency (@25%)				$ 122,991	
Contractor Fee (@15%)				$ 73,795	
Escalation (@2%)				$ 9,839	
				$ 206,626	
			Subtotal =	$ 698,592	
Indirect-Other					
Engineering (10% of total cost)				$ 69,859	
Project Management (12% of total cost)				$ 83,831	
Sales Tax (8.6% of half capital costs)				$ 30,039	
				$ 183,730	
			Total =	$ 882,321	ZVI 10-year lifespan
Ongoing Costs					
Direct Costs					
Operating and Maintenance Costs	2	ls	$ 882,321	$ 1,764,642	For 30 years of groundwater treatment - Replace ZVI 2 times
Indirect Costs					
				$ -	
			Total =	$ 1,764,642	

Table D-4
Cost Estimate for Alternative 1
Feasibility Study - USG Puyallup
Puyallup, Washington

Item	Quantity	Unit	Unit Cost	Cost	Comment
Sediment Removal					
Initial Capital Costs					
Direct Costs					
TESC	1	ls	$ 10,000	$ 10,000	
Clearing and Grubbing	0.03	acres	$ 9,500	$ 294	
Excavation - Contaminated Soil	300	bcy	$ 24.00	$ 7,200	
Transportation and Disposal of Contaminated Soils	525	tons	$ 52.00	$ 27,300	<20mg/kg assumed Non-Hazardous
Imported Backfill Material	683	tons	$ 27.00	$ 18,428	
Place and Compact Backfill	390	bcy	$ 6.00	$ 2,340	
Analytical Testing - Perimeter (125 feet)	3	samples	$ 85	$ 255	1 per 50 perimeter feet
Analytical Testing - Bottom (1,250 sf)	5	samples	$ 85	$ 425	1 per 250 sf
Analytical Testing - Disposal (440, 1.6:1)	2	samples	$ 255	$ 510	1 TCLP / Total per 400 ton
Restoration - other	150	lf	$ 200	$ 30,000	
			Subtotal =	$ 96,752	
Indirect-Contractor					
OH&P of Subcontractors (@20% of half capital costs)				$ 9,675	
General Conditions (@10%)				$ 9,675	
Other (@10%)				$ 9,675	
				$ 29,026	
			Subtotal =	$ 125,777	
Construction Contingency (@25%)				$ 31,444	
Contractor Fee (@15%)				$ 18,867	
Escalation (@2%)				$ 2,516	
				$ 52,827	
			Subtotal =	$ 178,604	
Indirect-Other					
Engineering (10% of total cost)				$ 17,860	
Project Management (12% of total cost)				$ 21,432	
Sales Tax (8.6% of half capital costs)				$ 7,680	
				$ 46,973	
			Total =	$ 225,577	
Performance Monitoring					
Initial Capital Costs					
Direct Costs					
Install Monitoring Wells	10	wells	$ 1,361	$ 13,608	
Sampling / Field Staff	2	ls	$ 1,400	$ 2,800	14 hours @ $100 /hour: 2 times
Sample Analysis	32	samples	$ 100	$ 3,200	16 wells: 2 times per year
Instrumentation / Equipment	2	ls	$ 500	$ 1,000	
Vehicle	2	ls	$ 135	$ 270	
Expendable Suppies	2	ls	$ 250	$ 500	
Reporting	2	ls	$ 8,000	$ 16,000	
			Subtotal =	$ 37,378	
Indirect Costs					
Engineering (15% of total cost)				$ 5,607	
Project Management (12% of total cost)				$ 4,485	
Sales Tax (8.6% of half capital cots)				$ 1,607	
			Subtotal =	$ 11,699	
			Total =	$ 49,077	
			Total with 15% Contingency =	$ 56,439	
Operations, Maintenance, and Monitoring Cost					
Monitoring and Sampling Events					
Years 1 - 5 (two sampling events per year)	1	ls	$ 40,790	$ 40,790	Does not include monitoring well installation
Years 6 - 30 (one sampling event per year)	1	ls	$ 20,395	$ 20,395	
Indirect Costs					
Project Management (years 1 - 5)	12	% of total		$ 4,895	
Project Management (years 6 - 30)	12	% of total		$ 2,447	
			Total (Yr 1-5) =	$ 45,684	
			Total (Yr 6-30) =	$ 22,842	

Table D-4
Cost Estimate for Alternative 1
Feasibility Study - USG Puyallup
Puyallup, Washington

Item	Quantity	Unit	Unit Cost	Cost	Comment
Institutional Controls					
Initial Capital Costs					
Direct Costs					
Establish Restrictive Covenants and Conditional Point of Compliance	1	ls	$ 25,000	$ 25,000	
			Subtotal =	$ 25,000	
Indirect Costs					
Engineering (15% of total cost)				$ 3,750	
Project Management (12% of total cost)				$ 3,000	
Sales Tax (8.6% of half capital costs)				$ 1,075	
			Subtotal =	$ 7,825	
			Total =	$ 32,825	
			Total with 15% Contingency =	$ 37,749	
Operations, Maintenance, and Monitoring Cost					
Inspection and Maintenance of Restrictive Covenants	1	ls	$ 10,000	$ 10,000	
			Total =	$ 10,000	Includes PM, Contingency

Table D-5A
Cost Estimate for Alternative 2A

Feasibility Study - USG Puyallup
Puyallup, Washington

Item	Quantity	Unit	Unit Cost	Cost	Comment
Iron Compound injection					
Initial Capital Costs					
Direct Costs					
Miscellaneous Equipment	1	ls	5,000	$ 5,000	
Injection - Driller's Labor and Equipment	18	days	$ 2,500	$ 45,000	
Injection - Materials	18	days	$ 500	$ 9,000	
			Subtotal =	$ 59,000	
Indirect-Contractor					
OH&P of Subcontractors (@20% of half capital costs)				$ 5,900	
General Conditions (@10%)				$ 5,900	
Other (@10%)				$ 5,900	
				$ 17,700	
			Subtotal =	$ 76,700	
Construction Contingency (@25%)				$ 19,175	
Contractor Fee (@15%)				$ 11,505	
Escalation (@2%)				$ 1,534	
				$ 32,214	
			Subtotal =	$ 108,914	
Indirect-Other					
Engineering (10% of total cost)				$ 10,891	
Project Management (12% of total cost)				$ 13,070	
Sales Tax (8.6% of half capital costs)				$ 4,683	
				$ 28,644	
			Total =	$ 137,558	
Operations, Maintenance, and Monitoring Cost					
Iron Injection					
Years 2 - 5, 7, 9 (1/2 initial annual cost)	1	ls	$ 68,779	$ 68,779	
			Total =	$ 68,779	
Soil Solidification					
Initial Capital Costs					
Direct Costs					
Clearing and Grubbing	0.61	acres	$ 9,500	$ 5,757	
Mix Design	1	ls	$ 40,000	$ 40,000	
Mobilization of Mixing Machine	0	ls	$ 75,000	$ -	Not Required
Disposal Allowance (30% of soil mixing volume)	0	tons	$ 52	$ -	Minimal Waste Generated
Soil Mixing	11,459	bcy	$ 40	$ 458,365	
Abandon Wells in Excavation Perimeter	6	wells	$ 2,000.00	$ 12,000	
			Subtotal =	$ 516,122	
Indirect-Contractor					
OH&P of Subcontractors (@20% of half capital costs)				$ 51,612	
General Conditions (@10%)				$ 51,612	
Other (@10%)				$ 51,612	
				$ 154,837	
			Subtotal =	$ 670,959	
Construction Contingency (@25%)				$ 167,740	
Contractor Fee (@15%)				$ 100,644	
Escalation (@2%)				$ 13,419	
				$ 281,803	
			Subtotal =	$ 952,762	
Indirect-Other					
Engineering (10% of total cost)				$ 95,276	
Project Management (12% of total cost)				$ 114,331	
Sales Tax (8.6% of half capital costs)				$ 40,969	
				$ 250,576	
			Total =	$ 1,203,338	
Operations, Maintenance, and Monitoring Cost					
Direct Costs					This portion of alternative will require no maintenance
Operating and Maintenance Costs	1	ls		$ -	
Indirect Costs					
Project Management (12% of total)	12	% of total		$ -	
			Total =	$ -	

Table D-5A
Cost Estimate for Alternative 2A
Feasibility Study - USG Puyallup
Puyallup, Washington

Item	Quantity	Unit	Unit Cost	Cost	Comment
Stormwater Infiltration Trench					
Initial Capital Costs					
Direct Costs					
Percolation Testing	1	ls	$ 10,000	$ 10,000	
Excavate Re-Introduction Trench	240	bcy	$ 24.00	$ 5,760	
Transportation and Disposal of Contaminated soil	0	tons	$ 52.00	$ -	
Spread and lightly compact excavated soil in treatment foot print	312	bcy	$ 4.00	$ 1,248	
Import Backfill	312	bcy	$ 25.00	$ 7,800	assume higher cost for perc soil
Place and compact backfill for Re-Introduction Trench	588	tons	$ 6.00	$ 3,529	
Analytical Testing - Disposal Soils	1	samples	$ 255	$ 255	1 TCLP / Total per 400 ton
			Subtotal =	$ 28,592	
Indirect-Contractor					
OH&P of Subcontractors (@20% of half capital costs)				$ 2,859	
General Conditions (@10%)				$ 2,859	
Other (@10%)				$ 2,859	
				$ 8,578	
			Subtotal =	$ 37,169	
Construction Contingency (@25%)				$ 9,292	
Contractor Fee (@15%)				$ 5,575	
Escalation (@2%)				$ 743	
				$ 15,611	
			Subtotal =	$ 52,780	
Indirect-Other					
Engineering (10% of total cost)				$ 5,278	
Project Management (12% of total cost)				$ 6,334	
Sales Tax (8.6% of half capital costs)				$ 2,270	
				$ 13,881	
			Total =	$ 66,662	
Operations, Maintenance, and Monitoring Cost					
Direct Costs					
Operating and Maintenance Costs	1	ls	$ -	$ -	
Indirect Costs					
Project Management (12% of total)	12	% of total		$ -	
			Total =	$ -	

Table D-5A
Cost Estimate for Alternative 2A
Feasibility Study - USG Puyallup
Puyallup, Washington

Item	Quantity	Unit	Unit Cost	Cost	Comment
Iron Introduction System					
Initial Capital Costs					
Direct Costs					
Injection metering equipment, tank, piping	1	ls	$ 20,000.00	$ 20,000	
Excavate Re-Introduction Trench	249	bcy	$ 24.00	$ 5,973	
Transportation and Disposal of Contaminated soil	0	tons	$ 110.00	$ -	
Spread and lightly compact excavated soil in treatment foot print	324	bcy	$ 4.00	$ 1,294	
Import Backfill	324	bcy	$ 17.15	$ 5,549	
Place and compact backfill for Re-Introduction Trench	469	tons	$ 6.00	$ 2,815	
Analytical Testing - Disposal Soils	1	samples	$ 255	$ 255	1 TCLP / Total per 400 ton
			Subtotal =	$ 35,886	
Indirect-Contractor					
OH&P of Subcontractors (@20% of half capital costs)				$ 3,589	
General Conditions (@10%)				$ 3,589	
Other (@10%)				$ 3,589	
				$ 10,766	
			Subtotal =	$ 46,652	
Construction Contingency (@25%)				$ 11,663	
Contractor Fee (@15%)				$ 6,998	
Escalation (@2%)				$ 933	
				$ 19,594	
			Subtotal =	$ 66,246	
Indirect-Other					
Engineering (10% of total cost)				$ 6,625	
Project Management (12% of total cost)				$ 7,950	
Sales Tax (8.6% of half capital costs)				$ 2,849	
				$ 17,423	
			Total =	$ 83,669	
Operations, Maintenance, and Monitoring Cost					
Direct Costs					
Operating and Maintenance Costs	1	ls	$ 100,000	$ 100,000	
Indirect Costs					
Project Management (12% of total)	12	% of total		$ 12,000	
			Total =	$ 112,000	

Table D-5A

Cost Estimate for Alternative 2A

Feasibility Study - USG Puyallup
Puyallup, Washington

Item	Quantity	Unit	Unit Cost	Cost	Comment
Sediment Removal					
Initial Capital Costs					
Direct Costs					
TESC	1	ls	$ 10,000	$ 10,000	
Clearing and Grubbing	0.03	acres	$ 9,500.00	$ 294	
Excavation - Contaminated Soil	300	bcy	$ 24.00	$ 7,200	
Transporation and Disposal of Contaminated Soils	525	tons	$ 52.00	$ 27,300	<20mg/kg assumed Non-Hazardous
Imported Backfill Material	683	tons	$ 27.00	$ 18,428	1.5 ton : 1.3 lcy : 1 bcy
Place and Compact Backfill	390	tons	$ 6.00	$ 2,340	1.5 ton : 1.3 lcy : 1 bcy
Analytical Testing - Perimeter (125 feet)	3	samples	$ 85	$ 255	1 per 50 perimeter feet
Analytical Testing - Bottom (1,250 sf)	5	samples	$ 85	$ 425	1 per 250 sf
Analytical Testing - Disposal (440, 1.6:1)	2	samples	$ 255	$ 510	1 TCLP / Total per 400 ton
Restoration	150	lf	$ 200	$ 30,000	
			Subtotal =	$ 96,752	
Indirect-Contractor					
OH&P of Subcontractors (@20% of half capital costs)				$ 9,675	
General Conditions (@10%)				$ 9,675	
Other (@10%)				$ 9,675	
				$ 29,026	
			Subtotal =	$ 125,777	
Construction Contingency (@25%)				$ 31,444	
Contractor Fee (@15%)				$ 18,867	
Escalation (@2%)				$ 2,516	
				$ 52,827	
			Subtotal =	$ 178,604	
Indirect-Other					
Engineering (10% of total cost)				$ 17,860	
Project Management (12% of total cost)				$ 21,432	
Sales Tax (8.6% of half capital costs)				$ 7,680	
				$ 46,973	
			Total =	$ 225,577	
Operations, Maintenance, and Monitoring Cost					
Direct Costs					This portion of alternative will require no maintenance
Operating and Maintenance Costs	1	ls		$ -	
Indirect Costs					
Project Management (12% of total)	12	% of total		$ -	
			Total =	$ -	

Table D-5A
Cost Estimate for Alternative 2A

Feasibility Study - USG Puyallup
Puyallup, Washington

Item	Quantity	Unit	Unit Cost	Cost	Comment
Performance Monitoring					
Initial Capital Costs					
Direct Costs					
Install Monitoring Wells	10	wells	$ 1,361	$ 13,608	
Sampling / Field Staff	2	ls	$ 1,400	$ 2,800	14 hours @ $100 /hour: 2 times
Sample Analysis	32	sample	$ 100	$ 3,200	16 wells: 2 times per year
Instrumentation / Equipment	2	ls	$ 500	$ 1,000	
Vehicle	2	ls	$ 135	$ 270	
Expendable Suppies	2	ls	$ 250	$ 500	
Reporting	2	ls	$ 8,000	$ 16,000	
			Subtotal =	$ 37,378	
Indirect Costs					
Engineering (15% of total cost)				$ 5,607	
Project Management (12% of total cost)				$ 4,485	
Sales Tax (8.6% of half capital cots)				$ 1,607	
			Subtotal =	$ 11,699	
			Total =	$ 49,077	
			Total with 15% Contingency =	$ 56,439	
Operations, Maintenance, and Monitoring Cost					
Monitoring and Sampling Events					
Years 1 - 4 (four sampling events per year)	1	ls	$ 81,579	$ 81,579	Does not include monitoring well installation
Years 5-10 (two sampling events per year)	1	ls	$ 40,790	$ 40,790	
Years 11 - 30 (one sampling event per year)	1	ls	$ 20,395	$ 20,395	
Indirect Costs					
Project Management (years 1 - 4)	12	% of total		$ 9,790	
Project Management (years 5 - 10)	12	% of total		$ 4,895	
Project Management (years 11 - 30)	12	% of total		$ 2,447	
			Total (Yr 1-4) =	$ 91,369	
			Total (Yr 5-10) =	$ 45,684	
			Total (Yr 11-30) =	$ 22,842	
Institutional Controls					
Initial Capital Costs					
Direct Costs					
Establish Restrictive Covenants and Conditional Point of Compliance	1	ls	$ 25,000	$ 25,000	
			Subtotal =	$ 25,000	
Indirect Costs					
Engineering (15% of total cost)				$ 3,750	
Project Management (12% of total cost)				$ 3,000	
Sales Tax (8.6% of half capital cots)				$ 1,075	
			Subtotal =	$ 7,825	
			Total =	$ 32,825	
			Total with 15% Contingency =	$ 37,749	
Operations, Maintenance, and Monitoring Cost					
Inspection and Maintenance of Restrictive Covenants	1	ls	$ 10,000	$ 10,000	
			Total =	$ 10,000	Includes PM, Contingency

Table D-5B
Cost Estimate for Alternative 2B

Feasibility Study - USG Puyallup
Puyallup, Washington

Item	Quantity	Unit	Unit Cost	Cost	Comment
Iron Compound injection					
Initial Capital Costs					
Direct Costs					
Miscellaneous Equipment	1	ls	5,000	$ 5,000	
Injection - Driller's Labor and Equipment	18	days	$ 2,500	$ 45,000	
Injection - Materials	18	days	$ 500	$ 9,000	
			Subtotal =	$ 59,000	
Indirect-Contractor					
OH&P of Subcontractors (@20% of half capital costs)				$ 5,900	
General Conditions (@10%)				$ 5,900	
Other (@10%)				$ 5,900	
				$ 17,700	
			Subtotal =	$ 76,700	
Construction Contingency (@25%)				$ 19,175	
Contractor Fee (@15%)				$ 11,505	
Escalation (@2%)				$ 1,534	
				$ 32,214	
			Subtotal =	$ 108,914	
Indirect-Other					
Engineering (10% of total cost)				$ 10,891	
Project Management (12% of total cost)				$ 13,070	
Sales Tax (8.6% of half capital costs)				$ 4,683	
				$ 28,644	
			Total =	$ 137,558	
Operations, Maintenance, and Monitoring Cost					
Iron Injection					
Years 2 - 5, 7, 9 (1/2 initial annual cost)	1	ls	$ 68,779	$ 68,779	
			Total =	$ 68,779	
Soil Solidification					
Initial Capital Costs					
Direct Costs					
Clearing and Grubbing	0.61	acres	$ 9,500	$ 5,757	
Mix Design	1	ls	$ 40,000	$ 40,000	
Mobilization of Mixing Machine	0	ls	$ 75,000	$ -	Not Required
Disposal Allowance (30% of soil mixing volume)	0	tons	$ 52	$ -	Minimal Waste Generated
Soil Mixing	16,494	bcy	$ 40	$ 659,768	
Abandon Wells in Excavation Perimeter	6	wells	$ 2,000.00	$ 12,000	
			Subtotal =	$ 717,525	
Indirect-Contractor					
OH&P of Subcontractors (@20% of half capital costs)				$ 71,753	
General Conditions (@10%)				$ 71,753	
Other (@10%)				$ 71,753	
				$ 215,258	
			Subtotal =	$ 932,783	
Construction Contingency (@25%)				$ 233,196	
Contractor Fee (@15%)				$ 139,917	
Escalation (@2%)				$ 18,656	
				$ 391,769	
			Subtotal =	$ 1,324,551	
Indirect-Other					
Engineering (10% of total cost)				$ 132,455	
Project Management (12% of total cost)				$ 158,946	
Sales Tax (8.6% of half capital costs)				$ 56,956	
				$ 348,357	
			Total =	$ 1,672,908	
Operations, Maintenance, and Monitoring Cost					
Direct Costs					
Operating and Maintenance Costs	1	ls		$ -	This portion of alternative will require no maintenance
Indirect Costs					
Project Management (12% of total)	12	% of total		$ -	
			Total =	$ -	

Table D-5B
Cost Estimate for Alternative 2B

Feasibility Study - USG Puyallup
Puyallup, Washington

Item	Quantity	Unit	Unit Cost	Cost	Comment
Stormwater Infiltration Trench					
Initial Capital Costs					
Direct Costs					
Percolation Testing	1	ls	$ 10,000	$ 10,000	
Excavate Re-Introduction Trench	240	bcy	$ 24.00	$ 5,760	
Transportation and Disposal of Contaminated soil	0	tons	$ 52.00	$ -	
Spread and lightly compact excavated soil in treatment foot print	312	bcy	$ 4.00	$ 1,248	
Import Backfill	312	bcy	$ 25.00	$ 7,800	assume higher cost for perc soil
Place and compact backfill for Re-Introduction Trench	588	tons	$ 6.00	$ 3,529	
Analytical Testing - Disposal Soils	1	samples	$ 255	$ 255	1 TCLP / Total per 400 ton
			Subtotal =	$ 28,592	
Indirect-Contractor					
OH&P of Subcontractors (@20% of half capital costs)				$ 2,859	
General Conditions (@10%)				$ 2,859	
Other (@10%)				$ 2,859	
				$ 8,578	
			Subtotal =	$ 37,169	
Construction Contingency (@25%)				$ 9,292	
Contractor Fee (@15%)				$ 5,575	
Escalation (@2%)				$ 743	
				$ 15,611	
			Subtotal =	$ 52,780	
Indirect-Other					
Engineering (10% of total cost)				$ 5,278	
Project Management (12% of total cost)				$ 6,334	
Sales Tax (8.6% of half capital costs)				$ 2,270	
				$ 13,881	
			Total =	$ 66,662	
Operations, Maintenance, and Monitoring Cost					
Direct Costs					
Operating and Maintenance Costs	1	ls	$ -	$ -	
Indirect Costs					
Project Management (12% of total)	12	% of total		$ -	
			Total =	$ -	

Table D-5B
Cost Estimate for Alternative 2B

Feasibility Study - USG Puyallup
Puyallup, Washington

Item	Quantity	Unit	Unit Cost	Cost	Comment
Iron Introduction System					
Initial Capital Costs					
Direct Costs					
Injection metering equipment, tank, piping	1	ls	$ 20,000.00	$ 20,000	
Excavate Re-Introduction Trench	249	bcy	$ 24.00	$ 5,973	
Transportation and Disposal of Contaminated soil	0	tons	$ 110.00	$ -	
Spread and lightly compact excavated soil in treatment foot print	324	bcy	$ 4.00	$ 1,294	
Import Backfill	324	bcy	$ 17.15	$ 5,549	
Place and compact backfill for Re-Introduction Trench	469	tons	$ 6.00	$ 2,815	
Analytical Testing - Disposal Soils	1	sample	$ 255	$ 255	1 TCLP / Total per 400 ton
			Subtotal =	$ 35,886	
Indirect-Contractor					
OH&P of Subcontractors (@20% of half capital costs)				$ 3,589	
General Conditions (@10%)				$ 3,589	
Other (@10%)				$ 3,589	
				$ 10,766	
			Subtotal =	$ 46,652	
Construction Contingency (@25%)				$ 11,663	
Contractor Fee (@15%)				$ 6,998	
Escalation (@2%)				$ 933	
				$ 19,594	
			Subtotal =	$ 66,246	
Indirect-Other					
Engineering (10% of total cost)				$ 6,625	
Project Management (12% of total cost)				$ 7,950	
Sales Tax (8.6% of half capital costs)				$ 2,849	
				$ 17,423	
			Total =	$ 83,669	
Operations, Maintenance, and Monitoring Cost					
Direct Costs					
Operating and Maintenance Costs	1	ls	$ 100,000	$ 100,000	
Indirect Costs					
Project Management (12% of total)	12	% of total		$ 12,000	
			Total =	$ 112,000	

Table D-5B
Cost Estimate for Alternative 2B

Feasibility Study - USG Puyallup
Puyallup, Washington

Item	Quantity	Unit	Unit Cost	Cost	Comment
Sediment Removal					
Initial Capital Costs					
Direct Costs					
TESC	1	ls	$ 10,000	$ 10,000	
Clearing and Grubbing	0.03	acres	$ 9,500.00	$ 294	
Excavation - Contaminated Soil	300	bcy	$ 24.00	$ 7,200	
Transporation and Disposal of Contaminated Soils	525	tons	$ 52.00	$ 27,300	<20mg/kg assumed Non-Hazardous
Imported Backfill Material	683	tons	$ 27.00	$ 18,428	1.5 ton : 1.3 lcy : 1 bcy
Place and Compact Backfill	390	tons	$ 6.00	$ 2,340	1.5 ton : 1.3 lcy : 1 bcy
Analytical Testing - Perimeter (125 feet)	3	samples	$ 85	$ 255	1 per 50 perimeter feet
Analytical Testing - Bottom (1,250 sf)	5	samples	$ 85	$ 425	1 per 250 sf
Analytical Testing - Disposal (440, 1.6:1)	2	samples	$ 255	$ 510	1 TCLP / Total per 400 ton
Restoration	150	lf	$ 200	$ 30,000	
			Subtotal =	$ 96,752	
Indirect-Contractor					
OH&P of Subcontractors (@20% of half capital costs)				$ 9,675	
General Conditions (@10%)				$ 9,675	
Other (@10%)				$ 9,675	
				$ 29,026	
			Subtotal =	$ 125,777	
Construction Contingency (@25%)				$ 31,444	
Contractor Fee (@15%)				$ 18,867	
Escalation (@2%)				$ 2,516	
				$ 52,827	
			Subtotal =	$ 178,604	
Indirect-Other					
Engineering (10% of total cost)				$ 17,860	
Project Management (12% of total cost)				$ 21,432	
Sales Tax (8.6% of half capital costs)				$ 7,680	
				$ 46,973	
			Total =	$ 225,577	
Operations, Maintenance, and Monitoring Cost					
Direct Costs					This portion of alternative will require no maintenance
Operating and Maintenance Costs	1	ls		$ -	
Indirect Costs					
Project Management (12% of total)	12	% of total		$ -	
			Total =	$ -	

Table D-5B
Cost Estimate for Alternative 2B

Feasibility Study - USG Puyallup
Puyallup, Washington

Item	Quantity	Unit	Unit Cost	Cost	Comment
Performance Monitoring					
Initial Capital Costs					
Direct Costs					
Install Monitoring Wells	10	wells	$ 1,361	$ 13,608	
Sampling / Field Staff	2	ls	$ 1,400	$ 2,800	14 hours @ $100 /hour: 2 times
Sample Analysis	32	samples	$ 100	$ 3,200	16 wells: 2 times per year
Instrumentation / Equipment	2	ls	$ 500	$ 1,000	
Vehicle	2	ls	$ 135	$ 270	
Expendable Suppies	2	ls	$ 250	$ 500	
Reporting	2	ls	$ 8,000	$ 16,000	
			Subtotal =	$ 37,378	
Indirect Costs					
Engineering (15% of total cost)				$ 5,607	
Project Management (12% of total cost)				$ 4,485	
Sales Tax (8.6% of half capital cots)				$ 1,607	
			Subtotal =	$ 11,699	
			Total =	$ 49,077	
			Total with 15% Contingency =	$ 56,439	
Operations, Maintenance, and Monitoring Cost					
Monitoring and Sampling Events					
Years 1 - 4 (four sampling events per year)	1	ls	$ 81,579	$ 81,579	Does not include monitoring well installation
Years 5-10 (two sampling events per year)	1	ls	$ 40,790	$ 40,790	
Years 11 - 30 (one sampling event per year)	1	ls	$ 20,395	$ 20,395	
Indirect Costs					
Project Management (years 1 - 4)	12	% of total		$ 9,790	
Project Management (years 5 - 10)	12	% of total		$ 4,895	
Project Management (years 11 - 30)	12	% of total		$ 2,447	
			Total (Yr 1-4) =	$ 91,369	
			Total (Yr 5-10) =	$ 45,684	
			Total (Yr 11-30) =	$ 22,842	
Institutional Controls					
Initial Capital Costs					
Direct Costs					
Establish Restrictive Covenants and Conditional Point of Compliance	1	ls	$ 25,000	$ 25,000	
			Subtotal =	$ 25,000	
Indirect Costs					
Engineering (15% of total cost)				$ 3,750	
Project Management (12% of total cost)				$ 3,000	
Sales Tax (8.6% of half capital cots)				$ 1,075	
			Subtotal =	$ 7,825	
			Total =	$ 32,825	
			Total with 15% Contingency =	$ 37,749	
Operations, Maintenance, and Monitoring Cost					
Inspection and Maintenance of Restrictive Covenants	1	ls	$ 10,000	$ 10,000	
			Total =	$ 10,000	Includes PM, Contingency

Table D-5C
Cost Estimate for Alternative 2C

Feasibility Study - USG Puyallup
Puyallup, Washington

Item	Quantity	Unit	Unit Cost	Cost	Comment
Iron Compound injection					
Initial Capital Costs					
Direct Costs					
Miscellaneous Equipment	1	ls	5,000	$ 5,000	
Injection - Driller's Labor and Equipment	18	days	$ 2,500	$ 45,000	
Injection - Materials	18	days	$ 500	$ 9,000	
			Subtotal =	$ 59,000	
Indirect-Contractor					
OH&P of Subcontractors (@20% of half capital costs)				$ 5,900	
General Conditions (@10%)				$ 5,900	
Other (@10%)				$ 5,900	
				$ 17,700	
			Subtotal =	$ 76,700	
Construction Contingency (@25%)				$ 19,175	
Contractor Fee (@15%)				$ 11,505	
Escalation (@2%)				$ 1,534	
				$ 32,214	
			Subtotal =	$ 108,914	
Indirect-Other					
Engineering (10% of total cost)				$ 10,891	
Project Management (12% of total cost)				$ 13,070	
Sales Tax (8.6% of half capital costs)				$ 4,683	
				$ 28,644	
			Total =	$ 137,558	
Operations, Maintenance, and Monitoring Cost					
Iron Injection					
Years 2 - 5, 7, 9 (1/2 initial annual cost)	1	ls	$ 68,779	$ 68,779	
			Total =	$ 68,779	
Soil Solidification					
Initial Capital Costs					
Direct Costs					
Clearing and Grubbing	0.61	acres	$ 9,500	$ 5,757	
Mix Design	1	ls	$ 40,000	$ 40,000	
Mobilization of Mixing Machine	0	ls	$ 75,000	$ -	Not Required
Disposal Allowance (30% of soil mixing volume)	0	tons	$ 52	$ -	Minimal Waste Generated
Soil Mixing	33,515	bcy	$ 40	$ 1,340,600	
Abandon Wells in Excavation Perimeter	6	wells	$ 2,000.00	$ 12,000	
			Subtotal =	$ 1,398,357	
Indirect-Contractor					
OH&P of Subcontractors (@20% of half capital costs)				$ 139,836	
General Conditions (@10%)				$ 139,836	
Other (@10%)				$ 139,836	
				$ 419,507	
			Subtotal =	$ 1,817,864	
Construction Contingency (@25%)				$ 454,466	
Contractor Fee (@15%)				$ 272,680	
Escalation (@2%)				$ 36,357	
				$ 763,503	
			Subtotal =	$ 2,581,367	
Indirect-Other					
Engineering (10% of total cost)				$ 258,137	
Project Management (12% of total cost)				$ 309,764	
Sales Tax (8.6% of half capital costs)				$ 110,999	
				$ 678,900	
			Total =	$ 3,260,267	
Operations, Maintenance, and Monitoring Cost					
Direct Costs					This portion of alternative will require no maintenance
Operating and Maintenance Costs	1	ls		$ -	
Indirect Costs					
Project Management (12% of total)	12	% of total		$ -	
			Total =	$ -	

Table D-5C
Cost Estimate for Alternative 2C

Feasibility Study - USG Puyallup
Puyallup, Washington

Item	Quantity	Unit	Unit Cost	Cost	Comment
Stormwater Infiltration Trench					
Initial Capital Costs					
Direct Costs					
Percolation Testing	1	ls	$ 10,000	$ 10,000	
Excavate Re-Introduction Trench	240	bcy	$ 24.00	$ 5,760	
Transportation and Disposal of Contaminated soil	0	tons	$ 52.00	$ -	
Spread and lightly compact excavated soil in treatment foot print	312	bcy	$ 4.00	$ 1,248	
Import Backfill	312	bcy	$ 25.00	$ 7,800	assume higher cost for perc soil
Place and compact backfill for Re-Introduction Trench	588	tons	$ 6.00	$ 3,529	
Analytical Testing - Disposal Soils	1	sample	$ 255	$ 255	1 TCLP / Total per 400 ton
			Subtotal =	$ 28,592	
Indirect-Contractor					
OH&P of Subcontractors (@20% of half capital costs)				$ 2,859	
General Conditions (@10%)				$ 2,859	
Other (@10%)				$ 2,859	
				$ 8,578	
			Subtotal =	$ 37,169	
Construction Contingency (@25%)				$ 9,292	
Contractor Fee (@15%)				$ 5,575	
Escalation (@2%)				$ 743	
				$ 15,611	
			Subtotal =	$ 52,780	
Indirect-Other					
Engineering (10% of total cost)				$ 5,278	
Project Management (12% of total cost)				$ 6,334	
Sales Tax (8.6% of half capital costs)				$ 2,270	
				$ 13,881	
			Total =	$ 66,662	
Operations, Maintenance, and Monitoring Cost					
Direct Costs					
Operating and Maintenance Costs	1	ls	$ -	$ -	
Indirect Costs					
Project Management (12% of total)	12	% of total		$ -	
			Total =	$ -	

Table D-5C
Cost Estimate for Alternative 2C
Feasibility Study - USG Puyallup
Puyallup, Washington

Item	Quantity	Unit	Unit Cost	Cost	Comment
Iron Introduction System					
Initial Capital Costs					
Direct Costs					
Injection metering equipment, tank, piping	1	ls	$ 20,000.00	$ 20,000	
Excavate Re-Introduction Trench	249	bcy	$ 24.00	$ 5,973	
Transportation and Disposal of Contaminated soil	0	tons	$ 110.00	$ -	
Spread and lightly compact excavated soil in treatment foot print	324	bcy	$ 4.00	$ 1,294	
Import Backfill	324	bcy	$ 17.15	$ 5,549	
Place and compact backfill for Re-Introduction Trench	469	tons	$ 6.00	$ 2,815	
Analytical Testing - Disposal Soils	1	sample:	$ 255	$ 255	1 TCLP / Total per 400 ton
			Subtotal =	$ 35,886	
Indirect-Contractor					
OH&P of Subcontractors (@20% of half capital costs)				$ 3,589	
General Conditions (@10%)				$ 3,589	
Other (@10%)				$ 3,589	
				$ 10,766	
			Subtotal =	$ 46,652	
Construction Contingency (@25%)				$ 11,663	
Contractor Fee (@15%)				$ 6,998	
Escalation (@2%)				$ 933	
				$ 19,594	
			Subtotal =	$ 66,246	
Indirect-Other					
Engineering (10% of total cost)				$ 6,625	
Project Management (12% of total cost)				$ 7,950	
Sales Tax (8.6% of half capital costs)				$ 2,849	
				$ 17,423	
			Total =	$ 83,669	
Operations, Maintenance, and Monitoring Cost					
Direct Costs					
Operating and Maintenance Costs	1	ls	$ 100,000	$ 100,000	
Indirect Costs					
Project Management (12% of total)	12	% of total		$ 12,000	
			Total =	$ 112,000	

Table D-5C
Cost Estimate for Alternative 2C

Feasibility Study - USG Puyallup
Puyallup, Washington

Item	Quantity	Unit	Unit Cost	Cost	Comment
Sediment Removal					
Initial Capital Costs					
Direct Costs					
TESC	1	ls	$ 10,000	$ 10,000	
Clearing and Grubbing	0.03	acres	$ 9,500.00	$ 294	
Excavation - Contaminated Soil	300	bcy	$ 24.00	$ 7,200	
Transporation and Disposal of Contaminated Soils	525	tons	$ 52.00	$ 27,300	<20mg/kg assumed Non-Hazardous
Imported Backfill Material	683	tons	$ 27.00	$ 18,428	1.5 ton : 1.3 lcy : 1 bcy
Place and Compact Backfill	390	tons	$ 6.00	$ 2,340	1.5 ton : 1.3 lcy : 1 bcy
Analytical Testing - Perimeter (125 feet)	3	samples	$ 85	$ 255	1 per 50 perimeter feet
Analytical Testing - Bottom (1,250 sf)	5	samples	$ 85	$ 425	1 per 250 sf
Analytical Testing - Disposal (440, 1.6:1)	2	samples	$ 255	$ 510	1 TCLP / Total per 400 ton
Restoration	150	lf	$ 200	$ 30,000	
			Subtotal =	$ 96,752	
Indirect-Contractor					
OH&P of Subcontractors (@20% of half capital costs)				$ 9,675	
General Conditions (@10%)				$ 9,675	
Other (@10%)				$ 9,675	
				$ 29,026	
			Subtotal =	$ 125,777	
Construction Contingency (@25%)				$ 31,444	
Contractor Fee (@15%)				$ 18,867	
Escalation (@2%)				$ 2,516	
				$ 52,827	
			Subtotal =	$ 178,604	
Indirect-Other					
Engineering (10% of total cost)				$ 17,860	
Project Management (12% of total cost)				$ 21,432	
Sales Tax (8.6% of half capital costs)				$ 7,680	
				$ 46,973	
			Total =	$ 225,577	
Operations, Maintenance, and Monitoring Cost					
Direct Costs					This portion of alternative will require no maintenance
Operating and Maintenance Costs	1	ls		$ -	
Indirect Costs					
Project Management (12% of total)	12	% of total		$ -	
			Total =	$ -	

Table D-5C
Cost Estimate for Alternative 2C
Feasibility Study - USG Puyallup
Puyallup, Washington

Item	Quantity	Unit	Unit Cost	Cost	Comment
Performance Monitoring					
Initial Capital Costs					
Direct Costs					
Install Monitoring Wells	10	wells	$ 1,361	$ 13,608	
Sampling / Field Staff	2	ls	$ 1,400	$ 2,800	14 hours @ $100 /hour: 2 times
Sample Analysis	32	sample	$ 100	$ 3,200	16 wells: 2 times per year
Instrumentation / Equipment	2	ls	$ 500	$ 1,000	
Vehicle	2	ls	$ 135	$ 270	
Expendable Suppies	2	ls	$ 250	$ 500	
Reporting	2	ls	$ 8,000	$ 16,000	
			Subtotal =	$ 37,378	
Indirect Costs					
Engineering (15% of total cost)				$ 5,607	
Project Management (12% of total cost)				$ 4,485	
Sales Tax (8.6% of half capital cots)				$ 1,607	
			Subtotal =	$ 11,699	
			Total =	$ 49,077	
			Total with 15% Contingency =	$ 56,439	
Operations, Maintenance, and Monitoring Cost					
Monitoring and Sampling Events					
Years 1 - 4 (four sampling events per year)	1	ls	$ 81,579	$ 81,579	Does not include monitoring well installation
Years 5-10 (two sampling events per year)	1	ls	$ 40,790	$ 40,790	
Years 11 - 30 (one sampling event per year)	1	ls	$ 20,395	$ 20,395	
Indirect Costs					
Project Management (years 1 - 4)	12	% of total		$ 9,790	
Project Management (years 5 - 10)	12	% of total		$ 4,895	
Project Management (years 11 - 30)	12	% of total		$ 2,447	
			Total (Yr 1-4) =	$ 91,369	
			Total (Yr 5-10) =	$ 45,684	
			Total (Yr 11-30) =	$ 22,842	
Institutional Controls					
Initial Capital Costs					
Direct Costs					
Establish Restrictive Covenants and Conditional Point of Compliance	1	ls	$ 25,000	$ 25,000	
			Subtotal =	$ 25,000	
Indirect Costs					
Engineering (15% of total cost)				$ 3,750	
Project Management (12% of total cost)				$ 3,000	
Sales Tax (8.6% of half capital cots)				$ 1,075	
			Subtotal =	$ 7,825	
			Total =	$ 32,825	
			Total with 15% Contingency =	$ 37,749	
Operations, Maintenance, and Monitoring Cost					
Inspection and Maintenance of Restrictive Covenants	1	ls	$ 10,000	$ 10,000	
			Total =	$ 10,000	Includes PM, Contingency

Table D-6
Cost Estimate for Alternative 3

Feasibility Study - USG Puyallup
Puyallup, Washington

Item	Quantity	Unit	Unit Cost	Cost	Comment
Soil Removal To Cleanup Level					
Initial Capital Costs					
Direct Costs					
Phase 1 - Main Soil Excavation					need to check these volumes, tonnage, etc.
Clearing and Grubbing Excavation Area	2.22	acres	$ 9,500	$ 21,052	
Excavate Adjacent Clean Soil	37,109	bcy	$ 24.00	$ 890,616	
Excavation - Contaminated Soil	20,106	bcy	$ 24.00	$ 482,544	
Transportation and Disposal of Non-Hazardous Soils	39,207	tons	$ 52.00	$ 2,038,748	>20 mg/kg, <500 mg/kg assumed Non-Hazardous
Imported Backfill Material - Below GW	30,203	tons	$ 27.00	$ 815,482	1.5 tons : 1.15 lcy : 1 bcy
Place Backfill - Below GW	20,135	bcy	$ 6.00	$ 120,812	1.5 tons : 1.15 lcy : 1 bcy
Imported Backfill Material - Above GW	5,908	tons	$ 17.15	$ 101,325	1.75 tons : 1.3 lcy : 1 bcy
Place and Compact Backfill - Above GW	20,350	tons	$ 6.00	$ 122,099	1.75 tons : 1.3 lcy : 1 bcy (includes excavated 37,109 bcy clean material and 5,908 tons import)
Shoring	38,700	sf	$ 40.00	$ 1,548,000	
Abandon Wells in Excavation Perimeter	11	wells	$ 2,000.00	$ 22,000	
Analytical Testing - Perimeter (1,500 feet)	30	samples	$ 85	$ 2,550	1 per 50 perimeter feet
Analytical Testing - Bottom (96,550 sf)	39	samples	$ 85	$ 3,315	1 per 2500 sf
Analytical Testing - Disposal (34,953 ton, 1.6:1)	87	samples	$ 255	$ 22,185	1 TCLP / Total per 400 ton
Phase 2 - Excavation along Puyallup River					
Clearing and Grubbing Excavation Area	0.95	acres	$ 9,500	$ 9,025	
Excvavate Adjacent Clean Soil	16,517	bcy	$ 24.00	$ 396,408	
Excavation - Contaminated Soil	8,046	bcy	$ 24.00	$ 193,104	
Transportation and Disposal of Non-Hazardous Soils	15,690	tons	$ 52.00	$ 815,864	>20 mg/kg, <500 mg/kg assumed Non-Hazardous
Imported Backfill Material - Below GW	8,046	tons	$ 27.00	$ 217,242	1.5 tons : 1.15 lcy : 1 bcy
Place Backfill - Below GW	5,364	bcy	$ 6.00	$ 32,184	1.5 tons : 1.15 lcy : 1 bcy
Place and Compact Backfill - Above GW	11,153	bcy	$ 6.00	$ 66,918	1.75 tons : 1.3 lcy : 1 bcy
Shoring	20,250	sf	$ 40.00	$ 810,000	
Abandon Wells in Excavation Perimeter	2	wells	$ 2,000.00	$ 4,000	
Analytical Testing - Perimeter (725 feet)	15	samples	$ 85	$ 1,275	1 per 50 perimeter feet
Analytical Testing - Bottom (41,450 sf)	39	samples	$ 85	$ 3,315	1 per 2500 sf
Analytical Testing - Disposal (15,167 ton, 1.6:1)	38	samples	$ 255	$ 9,690	1 TCLP / Total per 400 ton
Dewatering for Both Phases - 6 months					
Materials (misc. electrical, mechanical)	2	ls	$ 60,000	$ 120,000	
Packaged Arsenic Treatment System	2	ls	$ 235,000	$ 470,000	
Operating and Maintenance Costs	1	ls	$ 40,000	$ 40,000	for 1 year
Replacement of Treatment Media	1	ls	$ 75,300	$ 75,300	for 1 year
Discharge Fees	62,899,200	gallons	$ 0.010	$ 628,992	assume Tacoma discharge fees for 1/2 year
			Subtotal =	$ 10,084,045	
Indirect-Contractor					
OH&P of Subcontractors (@20% of half capital costs)				$ 1,008,405	
General Conditions (@15%)				$ 1,512,607	
Other (@15%)				$ 1,512,607	
				$ 4,033,618	
			Subtotal =	$ 14,117,663	
Construction Contingency (@25%)				$ 3,529,416	
Contractor Fee (@15%)				$ 2,117,650	
Escalation (@2%)				$ 282,353	
				$ 5,929,419	
			Subtotal =	$ 20,047,082	
Indirect-Other					
Engineering (10% of total cost)				$ 2,004,708	
Project Management (12% of total cost)				$ 2,405,650	
Sales Tax (8.6% of half capital cots)				$ 862,025	
				$ 5,272,383	
			Total =	$ 25,319,465	
Operations, Maintenance, and Monitoring Cost					
Direct Costs					
Operating and Maintenance Costs		ls	$ -	$ -	This portion of alternative will require no maintenance
Indirect Costs					
Proejct Management (12% of total)	12	% of total		$ -	
			Total =	$ -	

Table D-6
Cost Estimate for Alternative 3
Feasibility Study - USG Puyallup
Puyallup, Washington

Item	Quantity	Unit	Unit Cost	Cost	Comment
Sediment Removal					
Initial Capital Costs					
Direct Costs					
TESC	1	ls	$ 10,000	$ 10,000	
Clearing and Grubbing	0.03	acres	$ 9,500.00	$ 294	
Excavation - Contaminated Soil	300	bcy	$ 24.00	$ 7,200	
Transportation and Disposal of Contaminated Soils	525	tons	$ 52.00	$ 27,300	<20mg/kg assumed Non-Hazardous
Imported Backfill Material	683	tons	$ 27.00	$ 18,428	1.5 ton : 1.3 lcy : 1 bcy
Place and Compact Backfill	390	tons	$ 6.00	$ 2,340	1.5 ton : 1.3 lcy : 1 bcy
Analytical Testing - Perimeter (125 feet)	3	samples	$ 85	$ 255	1 per 50 perimeter feet
Analytical Testing - Bottom (1,250 sf)	5	samples	$ 85	$ 425	1 per 250 sf
Analytical Testing - Disposal (440, 1.6:1)	2	samples	$ 255	$ 510	1 TCLP / Total per 400 ton
Restoration	150	lf	$ 200	$ 30,000	
			Subtotal =	$ 96,752	
Indirect-Contractor					
OH&P of Subcontractors (@20% of half capital costs)				$ 9,675	
General Conditions (@10%)				$ 9,675	
Other (@10%)				$ 9,675	
				$ 29,026	
			Subtotal =	$ 125,777	
Construction Contingency (@25%)				$ 31,444	
Contractor Fee (@15%)				$ 18,867	
Escalation (@2%)				$ 2,516	
				$ 52,827	
			Subtotal =	$ 178,604	
Indirect-Other					
Engineering (10% of total cost)				$ 17,860	
Project Management (12% of total cost)				$ 21,432	
Sales Tax (8.6% of half capital costs)				$ 7,680	
				$ 46,973	
			Total =	$ 225,577	
Operations, Maintenance, and Monitoring Cost					
Direct Costs					This portion of alternative will require no maintenance
Operating and Maintenance Costs	1	ls		$ -	
Indirect Costs					
Project Management (12% of total)	12	% of total		$ -	
			Total =	$ -	

Table D-6
Cost Estimate for Alternative 3
Feasibility Study - USG Puyallup
Puyallup, Washington

Item	Quantity	Unit	Unit Cost	Cost	Comment
Pump and Treat Water Treatment					
Initial Capital Costs					
Direct Costs					
Groundwater Extraction Well	6	each	$ 3,000.00	$ 18,000	
Pump, Electrical Service, and Controls	6	each	$ 3,000.00	$ 18,000	
Analytical Testing - Discharge Water	1	samples	$ 200	$ 200	1 per 100,000 gallons - Rushed Sample
			Subtotal =	$ 36,200	
Indirect-Contractor					
OH&P of Subcontractors (@20% of half of Capital Costs)				$ 3,620	
General Conditions (@10%)				$ 3,620	
Other (@10%)				$ 3,620	
				$ 10,860	
			Subtotal =	$ 47,060	
Construction Contingency (@25%)				$ 11,765	
Contractor Fee (@15%)				$ 7,059	
Escalation (@2%)				$ 941	
				$ 19,765	
			Subtotal =	$ 66,825	
Indirect-Other					
Engineering (15% of total cost)				$ 10,024	
Project Management (12% of total cost)				$ 8,019	
Sales Tax (8.6% of half capital cots)				$ 2,873	
				$ 20,916	
			Total =	$ 87,741	
Operations, Maintenance, and Monitoring Cost					
Direct Costs					
Operating and Maintenance Costs	1	ls	$ 40,000	$ 40,000	Yearly O&M costs - Rough Estimate
Replacement of Treatment Media	1	ls	$ 75,300	$ 75,300	120 gpm
Discharge Fees	63,072,000	gallons	$ 0.010	$ 630,720	Assumed City of Tacoma discharge fees and average flow of 120 gpm
Indirect Costs					
Project Management (12% of total)	12	% of total		$ 4,800	
			Total =	$ 750,820	
Monitored Natural Attenuation					
Initial Capital Costs					
Direct Costs					
Install Monitoring Wells	10	wells	$ 1,361	$ 13,608	
Sampling / Field Staff	2	ls	$ 1,400	$ 2,800	14 hours @ $100 /hour: 2 times
Sample Analysis	32	samples	$ 100	$ 3,200	16 wells: 2 times per year
Instrumentation / Equipment	2	ls	$ 500	$ 1,000	
Vehicle	2	ls	$ 135	$ 270	
Expendable Suppies	2	ls	$ 250	$ 500	
Reporting	2	ls	$ 8,000	$ 16,000	
			Subtotal =	$ 37,378	
Indirect Costs					
Engineering (15% of total cost)				$ 5,607	
Project Management (12% of total cost)				$ 4,485	
Sales Tax (8.6% of half capital cots)				$ 1,607	
			Subtotal =	$ 11,699	
			Total =	$ 49,077	
			Total with 15% Contingency =	$ 56,439	
Operations, Maintenance, and Monitoring Cost					
Monitoring and Sampling Events					
Years 1 - 5 (two sampling events per year)	1	ls	$ 40,790	$ 40,790	
Years 6 - 30 (one sampling event per year)	1	ls	$ 20,395	$ 20,395	
Indirect Costs					
Project Management (years 1 - 5)	12	% of total		$ 4,895	
Project Management (years 6 - 30)	12	% of total		$ 2,447	
			Total (Yr 1-5) =	$ 45,684	
			Total (Yr 6-30) =	$ 22,842	

Table D-6
Cost Estimate for Alternative 3
Feasibility Study - USG Puyallup
Puyallup, Washington

Item	Quantity	Unit	Unit Cost	Cost	Comment
Institutional Controls					
Initial Capital Costs					
Direct Costs					
Establish Restrictive Covenants and Conditional Point of Compliance	1	ls	$ 25,000	$ 25,000	
			Subtotal =	$ 25,000	
Indirect Costs					
Engineering (15% of total cost)				$ 3,750	
Project Management (12% of total cost)				$ 3,000	
Sales Tax (8.6% of half capital cots)				$ 1,075	
			Subtotal =	$ 7,825	
			Total =	$ 32,825	
			Total with 15% Contingency =	$ 37,749	
Operations, Maintenance, and Monitoring Cost					
Inspection and Maintenance of Restrictive Covenants	1	ls	$ 10,000	$ 10,000	
			Total =	$ 10,000	Includes PM, Contingency