FORD CANTY & ASSOCIATES, INC.
ENVIRONMENTAL SCIENTISTS & ENGINEERS

Revised Cleanup Criteria and Risk Assessment Work Plan

Wastewater Facilities Comprising the Closed-Loop System
Plant Site Area
Colstrip Steam Electric Station
Colstrip, Montana

Ford Canty Project No. 14-1006

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List of Acronyms

ABSd	Dermal Absorption Factor
ABSinh	Inhalation Absorption Factor
ADD	Average Daily Dose
AF	Adherence Factor
AOC	Administrative Order on Consent
AT	Averaging Time
ATc	Averaging Time – carcinogens
ATnc	Averaging Time – non-carcinogens
AUF	Area Use Factor
BCF	Bioconcentration Factor
BERA	Baseline Ecological Risk Assessment
bgs	below ground surface
BSL	Baseline Screening Levels
BTV	Background Threshold Value
BTAG	Biological Technical Assistance Group
BW	Body Weight
C	Concentration
Cal/EPA	California Environmental Protection Agency
CCME	Canadian Council of Ministers of the Environment
CCR	Coal Combustion Residuals
CCRA	Cleanup Criteria and Risk Assessment
CDC	Centers for Disease Control and Prevention
cm^2	centimeters squared
COI	Constituent of Interest
COPC	Chemicals of Potential Concern
CR	Contact Rate
DAF	Dilution Attenuation Factor
DEQ	Montana Department of Environmental Quality
DFSadj	age-adjusted dermal soil exposure factor for carcinogens
DFSMadj	age-adjusted dermal soil exposure factor for mutagenic carcinogens
EC	Exposure Concentration
EcoSSLs	Ecological Soil Screening Levels
ED	Exposure Duration
EF	Exposure Frequency
EPC	Exposure Point Concentration
ERA	Ecological Risk Assessment
EU	Exposure Unit
Ford Canty	Ford Canty & Associates, Inc.
FS	Fraction from the Source
g/g-d	grams per grams of body weight per day
GI ABS	Gastrointestinal Absorption Factor

List of Acronyms (Continued)

gpm	gallons per minute
HAZWOPER	Hazardous Waste Operations and Emergency Response
HEAST	Health Effects Assessment Summary Tables
HHRA	Human Health Risk Assessment
HHS	Human Health Standard
HQ	Hazard Quotient
Hydrometrics	Hydrometrics, Inc.
IEUBK	Integrated Uptake Biokinetic Model for Lead in Children
IFSadj	age-adjusted soil ingestion factor for carcinogens
IFSMadj	age-adjusted soil ingestion factor for mutagenic carcinogens
IRIS	Integrated Risk Information System
IRS	ingestion rate - soil
IUR	Inhalation Unit Risk
K_d	partition coefficient
Kg	kilograms
kg/d	kilograms per day
kg/kg-d	kilograms per kilograms of body weight per day
kg/mg	kilograms per milligram
LADD	Lifetime Average Daily Dose
LANL	Los Alamos National Laboratory
L/d	liters per day
LOAEL	Lowest Observed Adverse Effect Level
MCF	mass conversion factor
MCL	Maximum Contaminant Level
mg/cm^2	milligrams per centimeter squared
m^3/kg	cubic meters per kilogram
mg/kg	milligrams per kilogram
mg/kg-day	milligrams per kilogram per day
mg/L	milligrams per liter
mg/m^3	milligrams per cubic meter
MPC	Montana Power Company
NCEA	National Center for Environmental Assessment
Neptune	Neptune and Company, Inc.
NOAEL	No Observed Adverse Effect Level
OEHHA	Office of Environmental Health Hazard Assessment
OSHA	Occupational Safety and Health Administration
PbB	blood lead
PEF	Particulate Emission Factor
PPLM	PPL Montana, LLC
PPRTV	Provisional Peer Reviewed Toxicity Value
RAGS	Risk Assessment Guidance for Superfund
RBCA	Risk Based Corrective Action
RBSL	Risk Based Screening Level
RfC	Reference Concentration

List of Acronyms (Continued)

RfD	Reference Dose
RfD_i	Reference Dose – inhalation
RfD_o	Reference Dose – oral
RME	Reasonable Maximum Exposure
RSL	Regional Screening Level
SA	Surface Area
SC	Specific Conductance
SCEM	Site Conceptual Exposure Model
SES	Steam Electric Station
SF	Slope Factor
SLERA	Screening-level Ecological Risk Assessment
SOEP	Stage One Evaporation Pond
SPLP	Synthetic Precipitation Leaching Procedure
SSCL	Site Specific Cleanup Level
SSL	Soil Screening Level
STEP	Stage Two Evaporation Pond
Talen	Talen Montana, LLC
T&E	Threatened and Endangered
TRV	Toxicity Reference Value
UCL	Upper Confidence Limit
95 UCL	95 Percent Upper Confidence Limit
USEPA	United States Environmental Protection Agency
WECO	Western Energy Company
VF	Volatilization Factor
yr	year
µg/dl	micrograms per deciliter
µg/L	micrograms per liter

1.0 INTRODUCTION AND PURPOSE

Hydrometrics, Inc. (Hydrometrics), on behalf of Talen Montana, LLC (Talen), retained Ford Canty & Associates, Inc. (Ford Canty) and Neptune and Company, Inc. (Neptune) to prepare a Cleanup Criteria and Risk Assessment (CCRA) Work Plan for the Wastewater Facilities Comprising the Closed-Loop System at the Plant Site area, “the Plant Site,” of the Colstrip Steam Electric Station (SES), the “Facility”, located in Colstrip, Montana (see Figure 1).

A preliminary CCRA Work Plan was submitted to the Montana Department of Environmental Quality (DEQ) on behalf of Talen on October 1, 2015 (Ford Canty, 2015). It was developed following the guidance set forth in the Administrative Order on Consent (AOC) established by PPL Montana, LLC (PPLM; predecessor to Talen) and the DEQ (see Section 1.2 and Appendix A). The DEQ’s Comments on the preliminary CCRA Work Plan were received on December 1, 2015. One of DEQ’s main comments was that the Work Plan should follow DEQ’s new Risk Assessment Scope of Work, rather than the more general guidance provided in the AOC (DEQ, 2016). DEQ’s Risk Assessment Scope of Work includes various risk assessment pre-calculations prior to the final calculation of risks and cleanup criteria to be presented in the final risk assessment (DEQ, 2016). Ford Canty submitted comment responses on behalf of Talen on January 25, 2016. This revised CCRA Work Plan addresses and incorporates DEQ’s comments.

1.1 BACKGROUND

The Colstrip SES Facility is a zero-discharge facility. As such, there are no direct wastewater discharge points from the Plant Site to surface water. However, seepage losses from the process wastewater ponds (“ponds”) at the Plant Site appear to have migrated from the ponds to shallow groundwater. Facility-related wastewater constituents are anticipated to be largely derived from constituents that occur naturally in the coal formations. In addition, because the shallow groundwater gradient is toward East Fork Armells Creek (the “Creek”), which runs adjacent to and downstream of the Plant Site, wastewater constituents could potentially migrate to surface water and sediment in the Creek. To mitigate the seepage losses, numerous capture wells have been placed at the Plant Site that provide ongoing groundwater capture to control migration of Plant Site wastewater.

1.2 REGULATORY HISTORY

To address seepage losses from the Plant Site ponds and potential wastewater migration, PPLM and the DEQ entered into an AOC Regarding Impacts Related to Wastewater Facilities Comprising the Closed-Loop System at the Colstrip SES on August 3, 2012, (DEQ/PPLM Montana, 2012). It is important to note that the AOC addresses impacts related to wastewater and does not address other media (unless impacted by the wastewater).

As part of the AOC, PPLM committed to prepare Site Reports for the three Colstrip SES Areas, as follows: (1) the Plant Site, (2) the Stage One Evaporation Pond/ Stage Two Evaporation Pond (SOEP/STEP), and (3) the Units 3&4 Effluent Holding Pond (3&4 EHP) areas (see Figure 1 for a depiction of these areas). These site reports are the basis for further remedial activities under the AOC. A fourth category of reporting, involving area process wastewater pipeline spills or releases not included in one of the previously mentioned areas, and other miscellaneous areas that are mutually agreed upon by the parties to address in the AOC, was also defined. All past process wastewater spills and releases have fallen into one of the three areas defined earlier in this paragraph.

The work plan for human health and ecological risk assessments, as well as development of cleanup criteria, associated with the wastewater of first area of the Colstrip SES Facility, the Plant Site, is included within this report. The human health and ecological risk assessments and cleanup criteria for the wastewater associated with the remaining areas of the Colstrip SES Facility will be addressed in future documents.

The requirements of the AOC are provided in a detailed summary located in Appendix A. In summary, the AOC requires the CCRA Report to identify, at a minimum, the following (Article VI.B):

- Cleanup Criteria for the Constituents of Interest (COIs[1]);
- Identification of Transport Mechanisms for the COIs;
- Identification of potential receptors;
- Identification of exposure pathways; and
- If there are COIs, recommendation of additional site characterization needed to determine what, if any, human health or ecological risks are posed by releases from the Site.

Additionally, the AOC indicates that the CCRA Report shall also include the following.

- An assessment of the *(potential)* risk posed by COIs that exceed soil or water screening levels, as well as an evaluation of *(potential)* environmental and human health risks based on Cleanup Criteria (as defined in Article IV.G. of the AOC).

Lastly, the AOC indicates:

- If the CCRA identifies one or more COIs that exceed Cleanup Criteria, then remedial measures are necessary and a Remedy Evaluation Report shall be prepared.

1 *The AOC (MDEQ/PPLM, 2012; Article IV.F) defines COIs as those parameters found in soil, groundwater, or surface water that (1) result from Site operations and the wastewater facilities and (2) exceed background or unaffected reference area concentrations. The AOC subsequently defines the development of cleanup criteria for the COIs generally following the DEQ risk assessment process (DEQ, 2016). The DEQ refers to potential contaminants within their Risk Assessment Scope of Work (DEQ, 2016) as Chemicals of Potential Concern (COPCs). As part of the risk assessment process, parameters were screened against background concentrations, as well as other appropriate screening levels following the DEQ risk assessment process. As such, the terms COIs and COPCs have nearly synonymous definitions for the purposes of this revised CCRA and are, therefore, used interchangeably within this report for practicality.*

- If the CCRA does not identify COIs that exceed Cleanup Criteria, then remedial measures are not needed and there is no need for further action.

In general, the planned approach will be conducted in the following order of main tasks:

1. Identification of the COPCs/COIs
2. Human Health and Ecological Risk Assessments of the COPCs/COIs, as necessary
3. Identification of the Cleanup Criteria for the COPCs/COIs
4. Determination regarding the necessity of remedial measures

The purpose of this revised CCRA Work Plan is to describe the approach to conduct human health and ecological risk assessments, as well as cleanup criteria, associated with the wastewater of the Plant Site. Specifically, this CCRA Work Plan includes the requirements of the AOC, as well as the requests provided by the DEQ (2015, 2016). In other words, this revised CCRA Work Plan follows the planned approach to identify and provide the information listed in the AOC (Article VI.B) associated with the COIs/COPCs, Cleanup Criteria, and the Risk Assessment in a manner following the detailed requirements of the DEQ's Risk Assessment Scope of Work guidance (DEQ, 2016).

1.3 OVERVIEW OF DEQ'S HUMAN HEALTH RISK ASSESSMENT PROCESS

As previously described, the DEQ requested that the CCRA Work Plan include DEQ's new Risk Assessment Scope of Work guidance that includes various risk assessment pre-calculations in the work plan prior to the final calculation of risks and cleanup criteria that will be presented in the final CCRA (DEQ, 2016). The DEQ has defined the following as components required within a Risk Assessment Work Plan:

"The risk assessment work plan addresses both human health and ecological impacts and the fate and transport of contaminants through soils to groundwater. The risk assessment work plan must include the following information:

1. History and setting of the Facility, including demographic information
2. Data evaluation and selection of COPCs
   a. Data Summary
   b. Data Evaluation
   c. Selection of COPC(s) for each media
3. Human health risk assessment
   a. Exposure assessment
      i. Site conceptual exposure model
      ii. Potential receptors and exposure pathways
      iii. Exposure assumptions
      iv. Definitions of exposure areas and calculations of exposure point concentrations
      v. Calculations of chronic daily intakes
   b. Toxicity assessment
      i. Definitions of carcinogenic and non-carcinogenic risks

        ii. Carcinogenic slope factors and inhalation unit risks
        iii. Non-carcinogenic reference doses and reference concentrations
        iv. Uncertainties associated with toxicity assessment
    c. Risk characterization
        i. A description of how cancer risk estimates will be derived
        ii. A description of how non-carcinogenic hazard estimates will be derived
        iii. Evaluation of uncertainties
    d. Ecological risk assessment, including a description of how Site-Specific Cleanup Levels (SSCLs) based upon protection of ecological receptors will be calculated, if appropriate (for some sites this may only be a qualitative evaluation)
4. Fate and Transport Analysis
5. Description of how SSCLs will be developed
    a. Human health-based SSCLs
    b. SSCLs based on fate and transport analysis
    c. Ecological risk-based SSCLs (for some sites this may only be a qualitative evaluation)
6. Completed tables 1, 2, 3, 4, 5, and 6 of EPA's Risk Assessment Guidance for Superfund (RAGS) Part D.
7. The provision for submittal of a draft risk assessment work plan for DEQ review and a final risk assessment work plan that incorporates all DEQ comments."

2.0 FACILITY OPERATION, BACKGROUND AND DESCRIPTION

2.1 FACILITY OPERATION

The Colstrip SES, the Facility, is located in the city of Colstrip, within Rosebud County in the south central area of the State of Montana. The Facility consists of four units, Units 1 and 2 that are 333 megawatts each and Units 3 and 4 that are 805 megawatts each. Construction on Units 1 and 2 began in 1972 and they came on-line in the mid-1970s. Units 3 and 4 were constructed later; Unit 3 came on-line in 1983 and Unit 4 came on-line in 1985. Talen is the operator and an owner of the Facility, which is co-owned by PacifiCorp, Puget Sound Energy, Inc., Portland General Electric Company, Avista Corporation, and NorthWestern Corporation (Hydrometrics, 2015b).

The Facility generates electricity through the combustion of coal. Fly ash, a by-product of coal combustion, is removed by air scrubber systems to reduce emissions. Bottom ash collects at the bottom of the boiler. Fly ash, bottom ash, and Facility wastewaters contain constituents of the original coal. A closed-loop process water/scrubber system is used at the Facility to minimize impacts to water resources in the area. Ash and water based liquid wastes from the generating plants are impounded in ponds designed and constructed to control seepage losses. The Plant Site pond system includes ponds that serve all four generating units in various capacities. Fly ash disposal is not currently conducted on the Plant Site, but rather in holding ponds at two locations: (1) to the northwest of the Plant Site at the Units 1&2 SOEP/STEP and (2) to the east of the Plant Site at Units 3&4 EHP. Relatively minor amounts of fly ash deposited during previous operations remain in the Plant Site Units 1&2 Pond A. The pond system presently servicing Colstrip Units 1&2 has been in use since 1975 (Hydrometrics, 2015b).

Portions of the Plant Site pond system are presently being updated and retrofitted to meet the requirements of the new United States Environmental Protection Agency (USEPA) Coal Combustion Residuals (CCR) Final Rule that was signed into effect December 19, 2014.

2.2 PLANT SITE BOUNDARY

The Plant Site boundary was established and presented in the AOC to include (1) the active operations area, (2) pipelines in the area, and (3) areas influenced by the groundwater capture system. Some of the areas included in the Plant Site boundary are beyond the property line of areas owned by Talen. Figure 2 presents the boundary of the Plant Site.

2.2.1 Active Operations Area/Controlled Access Area

The active operations area of the Plant Site is a fenced, controlled access area. The active operations area of the Plant Site is owned by Talen, PacifiCorp, Puget Sound Energy, Inc., Portland General Electric Company, Avista Corporation, and NorthWestern Corporation. Figure 2 depicts the fencing at the Plant Site. For areas in Figure 2 where the fence appears open, gates are present that control access in that area.

2.2.2 Pipeline Areas/Uncontrolled Access Area

Various pipeline areas of the Plant Site are located outside the fenced area and, therefore, have uncontrolled access. The pipeline areas may or may not be owned by Talen (and co-owners), but are generally considered to be part of the Plant Site because of the presence of pipelines. An example is the northern tip of the Plant Site with areas owned by the City of Colstrip, that contains pipelines associated with Units 1 &2 (fly ash pipelines and return effluent pipelines).

2.2.3 Groundwater Capture Areas/Uncontrolled Access Area

Portions of the areas affected by the groundwater capture system are located outside the fenced area and, therefore, also have uncontrolled access. An example is a portion of the residential area (a trailer park) located on the southwestern corner of the Plant Site (see Figures 2 and 3) that was included within the Plant Site boundary because of the active groundwater capture occurring within that area.

2.3 PHYSICAL CHARACTERISTICS OF THE SITE

2.3.1 Regional Geology

Colstrip is located in the northern portion of the Powder River Basin, an asymmetrical basin oriented northwest to southeast. This structural basin is responsible for the general regional orientation of bedding. “In general, Fort Union Strata dip very gently (less than a few degrees) in easterly and southerly orientations from west to east across the coalfield, respectively. Locally, however, dips are steepened by high-angle faults that are present throughout much of the Colstrip area” (Roberts, et. al, 1999 as cited in Hydrometrics, 2015b).

Stratigraphy in the Colstrip area consists of, in descending order, the Fort Union Formation, Hell Creek/Lance Formation, Fox Hills Sandstone, and Bearpaw Shale. The Fort Union Formation is divided into three members; the upper Tongue River Member, the middle Lebo Shale Member, and the lower Tullock Member. The Tongue River Member is at the surface in the Colstrip area. The deeper Lebo Shale, and then the Tullock Members are exposed to the north. At Colstrip, the total thickness of the Fort Union Formation is about 650 feet.

The Fort Union Formation consists of alternating and intercalated deposits of shale, claystone, mudstone, siltstone, sandstone, carbonaceous shale and coal. The formation was deposited in a fluvial system of meandering, braided, and anastomosed streams near the basin center and by alluvial fans at the margins. The fluvial systems were typically oriented northeast-southwest. (Flores and Ethridge, 1985 as cited in Hydrometrics, 2015b).

- Anastomosing streams consist of multiple channels within a single drainage. Individual floodplains of an anastomosing system may include braided or meandering, or straight characteristics. Deposition typically occurs under low energy conditions near a local base level (Makaske, 2000 as cited in Hydrometrics, 2015b).
- Braided flow systems consist of a network of flow channels within a single floodplain or flow belt (Makaske, 2000 as cited in Hydrometrics, 2015b). These channels have multiple thalwegs that branch back and forth from single to multiple channels.

- Meandering streams consist of one or more individual channels that migrate back and forth across a single floodplain. Meandering channels consist of one thalweg.

Numerous coal seams are present in the Tongue River Member of the Fort Union Formation, the result of peat deposits which accumulated in swampy areas and channels. A tropical to sub-tropical climate resulted in thick peat deposits within the swamps and bogs (Nicols and others, 1989, Flores, R.M. and others, 1999 as cited in Hydrometrics, 2015b). Because of the depositional setting, the coal beds may pinch out laterally or stop abruptly. The main coal seams of interest near Colstrip are the sub-bituminous Rosebud (~ 24 feet thick) and McKay seams (~ 8-10 feet thick) which can economically be strip-mined. These two coal seams merge into a single seam on the west side of the Little Wolf Mountains near the Absolka Mine. The Rosebud Coal, however, is the only seam mined in the Colstrip SES Facility area due to quality of the McKay Seam which makes it currently undesirable for use in many coal-fired boilers. Both the Rosebud and McKay coals are generally cleated. That is, they contain natural vertical fracturing generally oriented perpendicular to the bedding plane.

The depositional setting results in numerous lateral facies changes within the sedimentary rock deposits. Channel sandstones often grade laterally into siltstones or shale (facies changes) resulting in preferential pathways for groundwater flow within the more permeable sandstone. Cementation, or the chemical binding of individual grains to one another, is highly variable within the units, mostly consisting of weak calcium carbonate cement although thin deposits with silica cementation also occur. Localized thin limestone beds may also exist.

Alluvium is present along many of the drainage bottoms. The most prominent deposit at the Colstrip SES Facility is along the Creek. At the west edge of the Plant Site area, alluvial deposits of clay, silt, sand and gravel reach thickness of 35 feet or more. A basal gravel, comprised of clinker, is often present in the alluvium. Clinker fragments are typically also found throughout finer-grained alluvial deposits.

The ancestral East Fork Armells Creek eroded through the shallow bedrock, including the Rosebud and McKay Coals, and in some places into the sub-McKay deposits. This results in groundwater flow from the eroded units into the alluvium. The Creek alluvium acts as a hydrologic sink in the vicinity of the Colstrip SES Facility. This “hydrologic sink” tends to collect groundwater that flows to the creek and serves to limit flow from one side of the creek to the other in shallow deposits.

As mentioned previously, the Rosebud Coal, and in some places, the McKay Coal has burned in the Colstrip area. This is most easily identified as red cap rock on hills around the region. Burning of the coal baked the overlying strata. As a result of the burning, the coal volume reduced either leaving a void for the overlying rock to collapse in or resulting in slow settling of the overlying rock into the space formerly held by the coal. The thermally altered rock is referred to as clinker or scoria. Collapse of the rock resulted in secondary porosity (fractures). Permeability varies but is typically very high and depends on the amount of fine grained sediments that have moved vertically into the available pore spaces, completeness of burning of the coal seam, and the degree and nature of fracturing. No clinker has been confirmed on the Plant Site proper.

Mining of the coal on the Plant Site has resulted in lateral heterogeneities. Strip mining of coal involves removing the overburden (sediments and rock overlying the coal), removing the coal, then backfilling the pit with the previously removed overburden. The resulting spoil material exhibits a wide range of permeability from very low to high. It also results in a higher vertical permeability when compared to the pre-mining permeability. (Section 2.3.2 presents additional information regarding permeability). Spoil is present over much of the southeastern part of the Plant Site (directly east of Units 1&2 Pond B and Units 1&2 Cooling Tower Blowdown Ponds, and Units 3&4 Bottom Ash Ponds). A minor amount of spoil is present directly southeast of the Units 1&2 Pond A.

2.3.2 Groundwater

Shallow groundwater flow directions at the Plant Site are locally changed by the operation of current capture systems (described in more detail below within this Section). Under non-pumping conditions, shallow groundwater flow is generally expected to mirror the topography with flow toward the Creek and discharging into the alluvium along the Creek. Under pumping conditions, overall shallow groundwater flow is locally diverted and interrupted by the capture systems.

Deep groundwater in the sub-McKay units generally flows to the northeast under a regional gradient with presumed discharge points located at various locations to the north.

It should be noted that lateral variations in groundwater flow conditions may exist near mine spoil. These variations are generally a function of lateral heterogeneities that exist at the site and local vertical heterogeneities. Spoil are replaced overburden following mining of each pit. Topsoil is removed during each cut through an open pit mine and then the disturbed soil from the subsequent adjacent pit is placed in the cut mined immediately prior to the active cut. This results in an interface of undisturbed stratigraphic rock adjacent to the excavated and replaced overburden (spoil) from the first mining cut.

Spoil typically has a higher overall vertical permeability than the undisturbed sedimentary rocks. This is due to the fact that low permeability layers, such as claystone, shale, or clayey siltstone are broken up during mining and are placed back into the pits in random order and orientation. This removes the lateral continuity of confining or semi-confining layers that tend to restrict downward flow. The effect is generally an increase in the overall hydraulic conductivity of the spoil as related to the undisturbed sedimentary rock which results in a thicker sequence of spoil that is capable of storing water (little restriction to vertical flow).

Materials (sedimentary rock, spoil, soil, sediments) with higher permeability tend to have flatter gradients the recharge source than materials with lower permeability, which tend to have steeper gradients. So, if the hydraulic conductivity of the spoil is higher than the adjacent deposits, the spoil will act as a drain. That is, the gradient near the edge of the adjacent materials will steepen near the lateral contact because the water is essentially “draining” into the higher permeable material. Conversely, if the spoil hydraulic conductivity is lower, an impediment to flow will occur at the contact. This will tend to result in an increase in the water levels in the more permeable material at, and immediately upgradient, of the contact. If the upgradient flow is traveling along a preferential pathway (a more permeable zone), then the groundwater in the more permeable material will tend to extend more laterally (perpendicular to groundwater flow direction) along the contact.

Spoil are present in the eastern portion of the Plant Site. In general, permeability of the spoil is similar to the adjacent bedrock. However, spoil with a higher permeability are present north and west of the Units 3&4 Bottom Ash Ponds. The higher permeability of the spoil in this area appears to be the result of backfilling affects (vertical variations in spoil permeability mentioned above). This occurs when backfill are placed in the previously mined pit and larger rock fragments roll to the bottom of the pit resulting in a coarser deposit. If the spaces between the coarser rock are not filled with fines, this results in a much higher localized permeability. As an example, this can result in a high yield (~50 gallons per minute [gpm]) of the Western Energy Company (WECO) well. The WECO well was installed to lower the groundwater level below a coal crusher at the Rosebud Mine. The well was advanced to the base of the mine spoil (60 feet below ground surface [bgs]) and five feet into the underlying interburden to a depth of 65 feet.

Several indicator parameters are used to evaluate potential process wastewater impacts to groundwater at the Colstrip SES Facility. These include specific conductance (SC), dissolved boron, chloride, sulfate, and the ratio of calcium to magnesium.

Existing groundwater capture systems in the areas where the highest concentrations of indicator parameters have been observed (both in the shallow units and in the McKay Coal) limit migration of impacted groundwater away from the Colstrip SES Facility. At the Plant Site, capture wells are located downgradient of the Units 1&2 B Pond, Units 1&2 Bottom Ash Ponds, Units 1&2 Sediment Retention Pond, North Cooling Tower Blowdown Pond C, and South Cooling Tower Blowdown Pond C. Additional capture wells are located at the former Brine Ponds, the former Unit 3&4 Drain Collection Pond, and Units 3&4 Bottom Ash Ponds. Consequently, the Plant Site capture wells are located between the various ponds and the Creek (see Figure 3). Capture wells are designed to capture shallow groundwater prior to it reaching the Creek.

It should be noted that a shallow groundwater divide is located just to the southeast of the Plant Site ponds. Groundwater in the shallow units in the southeastern part of the Plant Site flows to the east toward Cow Creek.

2.3.3 <u>Surface Water</u>

The nearest natural surface water is East Fork Armells Creek (the "Creek"). Regionally, the Creek is an intermittent stream, but it generally flows continuously through the town of Colstrip along the western edge of the Plant Site (see Figures 1, 2, and 3). However, flow in the creek may be diminished to zero during late summer and early fall. Flow directly upstream and downstream of Colstrip is observed only in response to storm water or precipitation runoff events.

At the Plant Site, the topography slopes downward from the Plant Site to the west/northwest toward the Creek. Colstrip SES is a zero-discharge facility, so there are no direct wastewater discharge points from the Plant to the Creek. Shallow groundwater from most of the Plant Site flows toward the northwest in the direction of the Creek, though as discussed previously, a series of capture wells control flow of groundwater to the Creek. There is also an area adjacent to the Units 3&4 Bottom Ash Ponds where groundwater flows toward the southeast. A series of capture wells is also present in this area.

The City of Colstrip sewage treatment ponds are located adjacent to the west bank of the Creek to the north and downstream of the Plant Site. Flows are measured for the Creek for the reach passing the treated sewage effluent ponds. The Creek is receiving water from the ponds based on increases in flow through the reach, field observations, and variations in water quality observed above and below the ponds. A public golf course (Ponderosa Butte) is located along the Creek downstream of the sewage treatment ponds. Treated water from the Colstrip wastewater treatment plant is pumped to an irrigation pond at the golf course. Water from the pond is used for golf course irrigation.

Surface water in the Creek varies in depth and flow rate throughout the year. In the area adjacent to the Plant Site and through the town of Colstrip, the Creek is generally shallow and slow moving with abundant emergent aquatic vegetation present during the summer months. In general, the creek gains flow through the town of Colstrip. Higher amounts of flow are gained directly downstream of the City of Colstrip Wastewater Treatment Ponds. During the summer months, the Creek also may gain flow in the area of the golf course as a result of irrigation. Note that flow in the Creek decreases directly downstream of the north end of the golf course as surface water infiltrates to groundwater. The variable water levels within the Creek likely limit the types and abundance of aquatic organisms.

2.4 DEMOGRAPHICS AND LAND USE

2.4.1 Demographics

As of the 2010 Census, the population of Colstrip was 2,214 people, which included 863 households and 622 families (United States Census Bureau, 2014). The Colstrip SES Facility employs approximately 360 people (PPL, 2014).

2.4.2 Past/Current Land Use

Colstrip was established in 1924 by Northern Pacific Railroad to provide coal for steam locomotives. Sub-bituminous coal was/is mined from the Fort Union Formation. In 1958, diesel fuel replaced coal to power the trains and the Montana Power Company (MPC) purchased the rights to the mine.

The Plant Site has been used as the location of a coal-fired power plant since the mid-1970's. A portion of the Plant Site was mined for coal prior to construction of the power plant units that commenced in 1972. In addition, soil, shallow bedrock, and coal were excavated from below the plant itself prior to construction.

The water supply for the Colstrip SES Facility and the town of Colstrip is Castle Rock Lake, which stores water pumped via a 30-mile pipeline from the Yellowstone River located to the north. Groundwater near the Plant Site is not currently used as drinking water. Domestic wells are not present in the Plant Site area. As a conservative measure, PPLM facilitated the connection of private properties with wells in the Units 1&2 SOEP/STEP Area to the City of Colstrip water supply; but, again, domestic wells are not present in the Plant Site area. In the Plant Site area, shallow groundwater is not used for irrigation or livestock watering.

Surface water (i.e., East Fork Armells Creek) is currently used for livestock (horses) watering in the northern tip of the Plant Site.

Figure 4 depicts current land uses at the Plant Site area, including the uses of the uncontrolled access areas.

2.4.3 Future Use

The site is reasonably anticipated to remain as the location of a coal-fired power plant well into in the future. The associated land use activities in the town can also be reasonably anticipated to remain into the future.

In the future, groundwater is not anticipated to be used as drinking water because domestic wells are not present in the Plant Site area. In addition, PPLM previously facilitated the connection of private properties with wells to the City of Colstrip water supply in the Units 1&2 SOEP/STEP area as a conservative measure. Future drilling of the domestic wells in the Plant Site area is not anticipated to be allowed. In the Plant Site area, shallow groundwater is not anticipated to be used for irrigation or livestock watering.

In the future, surface water (i.e., East Fork Armells Creek) is anticipated to be used for livestock watering in the northern tip of the Plant Site.

3.0 RISK ASSESSMENT GUIDELINES

As previously described in Section 1.0, the DEQ requested that the CCRA Work Plan include DEQ's new Risk Assessment Scope of Work guidance, which includes various risk assessment pre-calculations prior to the final calculation of risks and cleanup criteria that will be presented in the final risk assessment (DEQ, 2016). As such, this report, the CCRA Work Plan, presents numerous preliminary steps in both human health and ecological risk assessments. Following DEQ guidance, a full Human Health Risk Assessment (HHRA) and Ecological Risk Assessment (ERA) will be prepared following DEQ's review of this CCRA Work Pan.

3.1 HUMAN HEALTH RISK ASSESSMENT

The methods used to conduct the preliminary HHRA steps presented within this Work Plan are based on both USEPA guidance (USEPA, 1989, 2001, 2009b et al.) and DEQ guidance (DEQ, 2009, 2016). The framework for a HHRA is presented in "Risk Assessment Guidance for Superfund (RAGS), Volume I, Human Health Evaluation Manual (Part A; USEPA, 1989) and consist of the following six main steps:

- Conceptual Site Exposure Model (also referred to as the Site Conceptual Exposure Model [SCEM] by DEQ) – during this step, contaminant sources, affected environmental media, release and transport mechanisms, potential human receptors and exposure pathways to the COPCs are identified for current and future site conditions.

- Data Evaluation and Selection of COPCs – during this step, the analytical data are evaluated for usability in the HHRA. In addition, the data are grouped by location and medium and COPCs are selected for each applicable site media.

- Exposure Assessment – during this step, exposures for identified potentially complete exposure pathways to the COPCs are quantified. Exposure Point Concentrations (EPCs) are estimated, generally using a statistical approach, for each of the COPCs in each media. Pathway-specific intakes are estimated using human exposure parameters for the current and future potential human receptors.

- Toxicity Assessment – during this step, toxicity values that characterize potential adverse health effects for the COPCs are compiled.

- Risk Characterization – during this step, information from the previous steps is used to characterize potential risks to human health associated with exposure to COPCs. Both potential cancer risks and non-cancer hazard indices are evaluated.

- Uncertainly Analysis - during this final step, the major uncertainties associated with the risks are evaluated.

Following DEQ guidance, generally the first four steps were conducted and are presented within this Work Plan:

- SCEM
- Data Evaluation and Selection of COPCs
- Exposure Assessment
- Toxicity Assessment

After DEQ's review and approval of this CCRA Work Plan, the HHRA will be completed by conducting the final two steps:

- Risk Characterization
- Uncertainty Analysis

The data, assumptions, and calculations associated with each of the four steps are provided in Appendix B of this Work Plan in RAGS Part D tabular format (USEPA, 2001).

3.2 ECOLOGICAL RISK ASSESSMENT

Montana DEQ follows the 8-Step Ecological Risk Assessment (ERA) process developed by USEPA and detailed in *Ecological Risk Assessment Process for Superfund: Process for Designing and Conducting Ecological Risk Assessments, Interim Final* (USEPA, 1997) and *Guidelines for Ecological Risk Assessment* (USEPA, 1998). Montana DEQ recognizes that not all sites will need to utilize the full 8-Step process identified by USEPA, and has further tailored the process to identify four different levels of ecological risk assessment based on site location, activities, habitats, and chemicals potentially present at the Site (DEQ, 2016). The simplest of these, a Level 1 ERA, is for sites where no long-term ecological habitat is present, and simply requires documentation of site conditions (e.g., lack of ecological habitat) and consideration of future site use. The most complex, a Level 4 ERA, is for sites that represent critical ecological habitat, and requires the implementation of the full 8-Step Process.

Steps 1 and 2 of the USEPA process represent the screening phase of the ecological risk assessment. Step 1 is the Screening Level Problem Formulation and Ecological Effects Evaluation to identify site ecological receptors, exposure pathways, endpoints for evaluation, and ecological toxicity information, while Step 2 provides the Screening-level Exposure Estimates and Risk Calculations. The screening-level ecological risk assessment (SLERA) for the Plant Site is included as part of this CCRA Work Plan. Steps 3 through 8 comprise the baseline ecological risk assessment (BERA), though an informal "Step 3a", in which the list of COPCs identified in Step 2 is refined prior to development of the BERA problem formulation, is often included as part of the SLERA. The steps of the BERA are:

- Step 3: BERA Problem Formulation
- Step 4: Study Design and Data Quality Objectives
- Step 5: Field Verification of Sampling Design
- Step 6: Site Investigation
- Step 7: Risk Characterization
- Step 8: Risk Management

Because of the presence of aquatic and wetland features (East Fork Armells Creek) at the Plant Site, the CCRA Work Plan assumes that, at a minimum, a Level 3 Ecological Risk Assessment is required, with the results of the SLERA determining the need for a Level 4 Assessment.

4.0 SITE CONCEPTUAL EXPOSURE MODEL

A Site Conceptual Exposure Model (SCEM) was prepared as the first step to identify the contaminant sources, affected environmental media, release and transport mechanisms, potential human receptors, exposure pathways under the current and reasonably anticipated future uses of the Plant Site (see also Sections 2.4.2 and 2.4.3 above). The SCEM is presented as Figure 5.

4.1 SOURCES OF FACILITY CHEMICALS AND AFFECTED ENVIRONMENTAL MEDIA

The following potential sources of chemicals from Plant Site wastewater were identified:

- Water based liquid wastes (wastewater) that seeped from the Colstrip SES Facility ponds at the Plant Site.

- Water based liquid slurry waste (wastewater) that was accidentally released from pipeline spills in the northern tip of the Plant Site area.

- Water based liquid waste (storm water) that was collected in a ponding area near the Facility main gate, where a low area exists that overflow from the storm water canal could potentially pool.

- (Although not a source directly from Plant Site wastewater) - background-related chemicals in geological strata, such as rock, coal, spoils, previously burned coal seams, which may be leaching chemicals into groundwater.

Seepage from the Colstrip SES Facility ponds was assumed to have primarily affected groundwater. Creek water and sediments were assumed to have been affected secondarily via groundwater migration and diffuse seepage. The pipeline spills were assumed to have primarily affected soil and secondarily affected creek water and sediments via over land flow. The storm water ponding area was assumed to have primarily affected soil.

Background-related chemicals in geological strata were assumed to have primarily affected groundwater and surface water. The area upstream of Colstrip and the Plant Site has undergone extensive coal mining which has the potential to affect the quality of both the surface water (i.e., East Fork Armells Creek) and the alluvial groundwater that both flow into the Plant Site area. In addition, activities associated with the upstream coal mining, such as road maintenance of the mine haul roads, access roads, and local highways, may also affect the quality of the surface water and alluvial groundwater at the Plant Site.

Wind suspension from the impacted soil areas in the Plant Site area was assumed to have the potential to affect outdoor air (particulates) in the spill areas and the storm water ponding area.

The potential chemicals within the water based liquid wastes were evaluated using several data sources, but primarily the following:

- The Plant Site Report, prepared as a requirement of the AOC, summarizes numerous investigations that have been conducted at the Plant Site relating to ponds, spills associated with the pipelines, or changes in water quality identified in operational groundwater monitoring (Hydrometrics, 2015b). Table 3-2 of the Plant Site Report (Hydrometrics, 2015b) contains a list of the reports, dates of the reports, and short summaries of the work conducted and findings of the investigations or studies.

- The Synoptic Run data that included both surface water data and, selectively, sediment data over a period of several years (Hydrometrics, 2016b).

- The soil investigation data from identified pipeline release areas and a storm water collection area (Hydrometrics, 2016a).

4.1.1 Anthropogenic Chemical Sources

The AOC addresses impacts related to the Colstrip SES Facility wastewater and does not address other media (unless impacted by the wastewater). As such, contaminants that have the potential to be present in the Plant Site area that originated from sources other than the wastewater system, such as highway maintenance, residential lawn maintenance, or upgradient mining areas, and for which little or no data are available, were not assessed within the CCRA Work Plan. However, it should be noted that contaminants in East Fork Armells Creek upgradient of the Plant Site were considered background concentrations for the Creek. The source of such upstream chemicals are unknown, but may be present as a result of upgradient mining activities.

4.2 CHEMICAL RELEASE AND TRANSPORT MECHANISMS

Chemical releases and transport mechanisms are depicted in Figure 5, the SCEM. Primary chemical releases occurred by the following mechanisms:

- Pond seepage
- Pipeline releases
- Background-related geologic strata leaching, including upstream mining areas, and leaching/erosion from other anthropogenic background sources

In general, releases were assumed to have been potentially transported through migration to soil, groundwater, and East Fork Armells Creek.

The specific chemical transport pathways identified for the Plant Site and the identified transport mechanisms (i.e., migration) are discussed in the following sections. It should be noted that the AOC (Article VI.B) requires the CCRA Report to identify transport mechanisms for the COIs/COPCs.

4.2.1 Pond Seepage and Groundwater Migration

Seepage losses from the process ponds at the Plant Site have historically impacted shallow groundwater. However, numerous capture wells have been placed at the Plant Site downgradient of the process ponds and act as ongoing groundwater capture systems to limit migration of impacted groundwater. The capture system continues to be evaluated and upgraded to ensure migration is limited to the extent practicable. Additional groundwater capture wells have been added as recently as this year (2016).

4.2.2 Surface and Groundwater

Shallow groundwater near East Fork Armells Creek and the surface water of East Fork Armells Creek are anticipated to be in direct communication. In the area of the pond seepage losses, contaminants could have been transported to surface water in solution in the shallow groundwater. Again, at present, an ongoing groundwater capture system limits migration of groundwater to surface water.

In the area of two surface spills (two pipeline releases near the treated sewage effluent ponds), released liquid waste entered surface water (East Fork Armell's Creek) releasing contaminants to the surface water (see Section below for additional information).

4.2.3 Surface Releases to Soil (Pipeline Releases and Subsequent Remediation, and Storm Water)

Three surface releases have occurred in the uncontrolled access area of the Plant Site (Hydrometrics 2015b). All three spills occurred in the northern tip of the Plant Site from pipeline releases and all three were remediated. One spill occurred near the Power Road Overpass, while the other two occurred near the Treated Sewage Effluent Ponds. Per the request of DEQ, additional soil sampling was conducted by Hydrometrics at the spill areas in 2016 (Hydrometrics, 2016a). The three surface releases are summarized below:

- September 18, 1998 – MPC Units 1 and 2 Fly Ash Pipeline near the Treated Sewage Effluent Ponds

  Approximately 80,000 gallons of fly ash slurry were released from a leak in the pipeline. Approximately 16,000 gallons of slurry may have flowed into East Fork Armell's Creek. MPC placed two flow obstacles in the creek to create areas of slow moving water to promote slurry settling and minimize migration. MPC also constructed a berm to divert the flow of slurry from entering the creek and constructed a containment pond. Lastly, MPC removed approximately 329 cubic yards of soil and fly ash from the ground, from a stockpiled area, and from the creek (Hydrometrics, 1998).

  East Fork Armell's Creek has numerous meanders in area of the release (south of the Treated Sewage Effluent ponds). At the time of the release, confirmation soil samples were collected verifying fly ash removal. Fly ash slurry was released to East Fork Armell's Creek and assumed to have migrated downstream at least to some extent.

Numerous synoptic run sampling events of the Creek have been performed since the spill. As requested by the DEQ (2015), additional surface and subsurface soil samples were collected in the area of this former spill and remediated area in April 2016 (Hydrometrics, 2016a).

- March 13, 2000 – PPLM Units 1 and 2 Fly Ash Pipeline near the Power Road Overpass

  Approximately 400 gallons of fly ash slurry water were released from a leak in the pipeline. Approximately 200 gallons were recovered (pumped from a low area) and 30 cubic yards of soil and fly ash were hauled from the site and disposed in the Evaporation Holding Ponds. The majority, if not all of the spilled liquid, was believed to be recovered (PPLM, 2000).

  The location of this spill is not immediately adjacent to East Fork Armell's Creek. Slurry water was not reported to have reached the Creek; rather, the slurry ponded in a low area from which it was pumped. Migration of the spill was assumed to have penetrated in the soil and, therefore, impacted soil was excavated. It is unlikely that significant migration was associated with this spill. As requested by the DEQ (2015), additional surface and subsurface soil samples were collected in the area of this former spill and remediated area in April 2016 (Hydrometrics, 2016a).

- March 29, 2000 – PPLM Units 1 and 2 Effluent pipeline near the Treated Sewage Effluent Ponds

  Approximately 122,500 gallons of return liquid were released from a leak in the pipeline at nearly the same location as the 1998 spill. Containment measures had been previously installed in 1999, but ~9,000 gallons of returned liquid breached the measures. An estimated 114,000 gallons of return liquid were recovered from the containment pond and another 159,000 gallons of impacted water were recovered from the Creek. Water quality of the Creek after cleanup was indicative of background water quality. As requested by the DEQ (2015), additional surface and subsurface soil samples were collected in the area of this former spill and remediated area in April 2016 (Hydrometrics, 2016a).

During the additional soil sampling event in April 2016 of the former spill sites described above, an area at which storm water has the potential to pond was also sampled. The storm water ponding area is located near the main gate in an area immediately north of the railroad tracks near its intersection with Willow Avenue. Surface and near surface soil samples were collected in this area in April 2016 (Hydrometrics, 2016a).

4.2.4 Wind Suspension (Fugitive Dust)

In the remediated surface spill areas and the storm water ponding area at the Plant Site, the potential exists for wind to suspend dry soil impacted with COPCs from liquid waste, if present, into the air as particulates (fugitive dust).

4.3 POTENTIALLY EXPOSED HUMAN RECEPTORS

Potential human receptors at the Plant Site were identified that may potentially be exposed to contamination from the Colstrip SES Facility that originated from wastewater releases (see also Figure 5, the SCEM). Potential human receptors were limited to individuals who may potentially be exposed at the Plant Site area outside of the active operations area and, therefore, beyond the controlled access (fenced) areas. Figure 2 depicts the fence line/controlled access areas of the Plant Site.

Within the active operations/controlled access area, current potential exposures to workers would predominantly fall under the Occupational Safety and Health Administration (OSHA). At present, Talen has a robust worker safety program, including awareness training, spill response training, Hazardous Waste Operations and Emergency Response (HAZWOPER) training (for select employees), etc. As such, potential human exposures within the active operations/controlled access area are presently managed through Talen's worker safety program and were not addressed under the CCRA Work Plan.

Figure 4 identifies current land uses and areas at the Plant Site at which receptors could potentially be exposed. Generally, the western side of the Plant Site, along the southern and eastern edges of the town of Colstrip, contains areas outside the controlled access areas of the active operations with potential exposures to receptors from waste water releases. Current and reasonably anticipated future uses of the uncontrolled access areas of the Plant Site were considered when identifying potential receptors. The following table presents the identified potential human receptors:

Table 4-1 Receptors Identified and Evaluated in the CCRA Work Plan

Land Use	Receptor	On-Site*	
		Current	Future
Residential	Resident (Adult and Child)	X	X
Industrial	Outdoor Worker	X	X
Construction	Construction Worker	X	X
Recreational Receptor (Hunter)	Adult and Child	X	X

Notes:
On-Site* Potential receptors on the uncontrolled access areas of the Plant Site, i.e., outside of the controlled-access (fenced) areas, but within the Plant Site boundary.

- Adult and Child Residents (adults and children residing in the uncontrolled access areas of the Plant Site, e.g., the trailer park located along the Creek on the western side of the Plant Site).
- Adult Industrial Outdoor Workers (adults working outdoors in the uncontrolled access areas of the Plant Site, e.g., the sewage treatment plant or the dog pound located in the northern most tip of the Plant Site).

- Adult Construction Workers (adults performing construction work in the uncontrolled access areas of the Plant Site, e.g., trench workers).

- Recreational Users (adults and children recreating in the uncontrolled access areas of the Plant Site, specifically in the area south of the sewage treatment plant where previous pipeline releases have occurred. This area is used recreationally, particularly by archery hunters).

4.4 POTENTIALLY COMPLETE EXPOSURE PATHWAYS

USEPA guidance (USEPA, 1989) defines a complete exposure pathway as consisting of four elements:

- A source and mechanism of chemical release
- A retention or transport medium (or media in cases involving transfer of chemicals)
- A point of potential human contact with the contaminated medium (referred to as an exposure point)
- An exposure route (such as ingestion or inhalation) at the contact point

An exposure pathway is considered complete when it has all four factors. Designation of an exposure pathway as complete indicates that human exposure is possible, but does not necessarily mean that exposure will occur, or that exposure will occur at the levels estimated in this report. When any one of the factors is missing in the pathway, it is considered incomplete. Incomplete exposure pathways do not pose a health hazard and were not evaluated further. A key step of the exposure analysis was to determine whether there were any plausible routes of human exposure to COPCs at the Plant Site.

The SCEM for the Plant Site summarizes the information on sources of COPCs, affected environmental media, COPC release and transport mechanisms, potentially exposed receptors, and potential exposure pathways for each potential receptor (see Figure 5). Figure 5 includes information on both human and ecological receptors and exposure pathways. The discussion of the SCEM presented in this Section is limited to potential human exposures to the Site. Ecological pathways and exposures are discussed in Section 10 of this Work Plan.

Potentially complete exposure pathways associated with surface soil in the former spill areas and creek sediments within East Fork Armells Creek were identified in the SCEM:

- Surface Soil
    - Incidental ingestion
    - Dermal contact

- Creek sediments
    - Incidental ingestion
    - Dermal contact

It should be noted that inhalation of surface soil particulates (i.e., fugitive dust) was eliminated as a surface soil exposure pathway because no COPCs were identified in surface soil.

Potentially complete exposure pathways associated with groundwater and surface water were identified for the Plant Site area and selected for comparison with DEQ-7 standards (DEQ, 2012):

- Surface water
    - Ingestion
    - Dermal contact

- Shallow groundwater
    - Dermal contact

- Deeper groundwater
    - Ingestion of groundwater is not currently a complete pathway because no domestic groundwater wells are present in the Plant Site area. However, ingestion of groundwater was evaluated per the request of the DEQ to evaluate the potential need for institutional/land use controls that would be intended to prevent potential future exposure to groundwater. To achieve adequate volume/production, domestic groundwater wells would need to be drilled into deep geologic layers several hundred feet below surface, such as the Sub-McKay. The alluvium has not been targeted at the Colstrip SES for domestic groundwater wells.

Bioconcentration of surface water COPCs in fish tissue was not identified as an exposure pathway because East Fork Armells Creek does not sustain a fish population that would provide for recreational fishing.

The basis for identifying each exposure pathway as complete or incomplete is summarized in Tables B-1.1 through B-1.4 of Appendix B (i.e., RAGS Part D Table 1).

5.0 HUMAN HEALTH DATA EVALUATION, DATA GROUPING, AND CHEMICALS OF POTENTIAL CONCERN

Within this section, the process used to evaluate and group the analytical data for both quantitative and qualitative evaluation in this CCRA Work Plan is presented. This section also discusses the process used to identify and refine the list of COPCs.

5.1 EVALUATION OF SITE DATA

Data were available from the following media:

- Surface water (East Fork Armells Creek)
- Sediment (East Fork Armells Creek)
- Soil (associated with remediated areas of former pipeline releases and a storm water ponding area all located in the northern tip of the Plant Site Area)
- Groundwater

Potential sources of contaminants were identified and discussed in Section 4.1.

The available surface water, sediment, soil, and groundwater data for the Plant Site were reviewed and used in the identification of Exposure Units (EUs) and COPCs.

5.1.1 Description of an Exposure Unit

A location at which a human receptor may be exposed to a medium, such as soil, sediment, surface water or groundwater, is referred to as an Exposure Unit (EU). EUs were defined using the following information:

- Plant Site Land Use (specifically in the uncontrolled access areas, see Figure 4)
- Identified Potential Receptors (see Figure 5)
- Potential Chemical Releases and Migration from the Facility Wastewater System
- Available Site Data

The identified EUs for the Plant Site area are presented in Table 5-1 below and depicted in Figure 6.

Table 5-1 Exposure Units

Exposure Unit	Description
EU 1	East Fork Armells Creek in the Plant Site area (surface water and sediments)
EU 2	Former Spill Site near Power Road (soil)
EU 3	Former Spills Site near the Treated Effluent Sewage Lagoons (soil)
EU 4	Storm Water Ponding Area near the intersection of the railroad tracks and Willow Avenue (soil)
EU 5	Groundwater in the uncontrolled access Plant Site Area with the (unlikely) potential to be used as a potable water source in the future

5.1.2 Description of Data used in the HHRA, by Exposure Unit

Data for each of the EUs are described in the Table 5-2 below. The human health risk assessment data are summarized in Tables B-2.1 through B-2.6 (RAGS Part D Table 2) located in Appendix B. In addition, data tables of the data used in the risk assessment are presented in Appendix C.

Table 5-2 Data Description by Exposure Unit

Exposure Unit	Media	Sample Locations	Sampling Dates	Description
EU1 East Fork Armells Creek Plant Site Area	Surface Water	AR-5, AR-4, AR-3, NSTP, and AR-2 (Figure 7; Tables C-1 & C-2, Appendix C)	Spring 2014 through Fall 2015	Synoptic Run Sampling Data collected from 4 sampling events in spring and fall 2014 and spring and fall 2015. The sampling points are located in East Fork Armells Creek in the Plant Site Area.
	Sediment			
EU 2 Former Spill Site near Power Road	Soil	BH-29 through BH-32 (Figure 8; Table C-3, Appendix C)	April 2016	Soil samples collected from various intervals from surface to 6 feet bgs
EU 3 Former Spill Site near Sewage Lagoons	Soil	BH-33 through BH-69, and BH-73 (Figure 9; Table C-4, Appendix C)	April 2016	Soil samples collected from various intervals from surface to 7 feet bgs
EU 4 Storm Water Ponding Area	Soil	BH-70 through BH-72 (Figure 10; Table C-5, Appendix C)	April 2016	Soil samples collected from various surface intervals from surface to 2 feet bgs
EU 5 Groundwater Plant Site Area	Groundwater	Groundwater wells 15D, 66D, 80D, 95D, 99D, 103D, 110D (Figure 11; Table C-6, Appendix C)	2014 and 2015 groundwater data	Groundwater samples collected in the Plant Site area, as well as an appropriate geologic layer at locations that could potentially be used for drinking water wells in the future

Surface water and sediment data were limited to the previous two years (i.e., 2014 and 2015) for the following reasons:

(1) As a flowing surface water body, East Fork Armells Creek is expected to be very dynamic. COPC concentrations in surface water and sediment are expected to change frequently.

(2) The effectiveness of the capture well system is evaluated regularly with additional capture wells added, as needed. Capture wells have been added as recently as this year (2016) that function to improve and further limit migration of groundwater that has seeped from the process ponds toward the creek.

(3) Comprehensive Synoptic Run data sets were available for this time period.

Soil data were limited to the investigation of the remediated former spill areas and the storm water ponding area conducted in April 2016 (Hydrometrics, 2016).

Groundwater data were limited to samples collected from wells in the uncontrolled access area of the Plant Site at locations which, through professional judgment, could potentially be used for the placement of future domestic wells (see Figure 11). The groundwater data were also limited to a deep formation (the Sub-McKay), which is the geologic formation that would have sufficient volume/production to support domestic wells. Furthermore, groundwater data were limited to the previous two years (i.e., 2014 and 2015) because recent improvements to the capture well system (as recently as this year, 2016) are expected to have improved groundwater quality by further limiting migration of groundwater that seeps from the process ponds.

5.1.3 Reference/Background Samples

Upstream surface water background data were available from the recently updated Baseline Screening Levels (BSLs) for the Colstrip SES (Neptune, 2016). In addition to the BSLs, surface water samples were also compared to the closest upstream background sampling point, AR-12, during the same sampling period as the EU 1 surface water data (i.e., 2014 and 2015 data).

Sediment data was also available from the upstream background sampling point, AR-12. Sediment samples were compared to the sediment data collected from AR-12 during the same sampling period as the EU 1 sediment data (i.e., 2014 and 2015 data).

Soil background data, referred to as the Background Threshold Values (BTVs) for Inorganics in Montana Soils, were available from DEQ (Project Report Background Concentrations of Inorganic Constituents in Montana Surface Soils, 2013). In addition, specific data collected during the background concentration study from background sampling point MBSI-29-01, which is located approximately 8.5 miles west of Colstrip, were used to compare to the EU2, EU3, and EU4 soil data.

Groundwater background data were available from the recently updated BSLs for the Colstrip SES (Neptune, 2016).

5.2 DATA GROUPING

Data were grouped by each EU (e.g., EU1 data were grouped separately from EU2 data) and sample medium (e.g., surface water data were grouped separately from sediment data). Data for soil were not grouped by depth interval because screening of the soil data did not identify any human health COPCs in soil.

5.3 IDENTIFYING HUMAN HEALTH COPCS

Data were screened using the flow charts and screening process described by the DEQ (2016). Data were also screened against background concentrations described in Section 5.1.3. Specifically, data for each media were screened as summarized in Table 5-3 below to identify COPCs.

Table 5-3 Summary of Screening Values and Human Health COPCs

Media	Screening Values	Identified Human Health COPCs/ Rationale
Surface Water	• DEQ-7 Human Health Standards (DEQ, 2012) • Colstrip SES Surface Water BSLs (Neptune, 2016) • Nearest Upstream Background Data Point (AR-12)	Manganese / above screening levels (DEQ-7 and Background)
Sediments	• Residential and Industrial USEPA Regional Screening Levels (RSLs; following the DEQ screening process in which non-carcinogenic RSLs are reduced by a factor of 10 to account for cumulative health effects, [DEQ,2016]) • Nearest Upstream Background Data Point (AR-12) • BTVs for Inorganics in Montana Soils (DEQ, 2013) • Background Screening Levels in soil – Colstrip Area data point (DEQ, 2013)	Manganese/ above screening levels (RSLs and Background)
Soil	• Residential and Industrial EPA RSLs (following the DEQ screening process in which non-carcinogenic RSLs are reduced by a factor of 10 to account for cumulative health effects, [DEQ,2016]) • BTVs for Inorganics in Montana Soils (DEQ, 2013) • Background Screening Level in soil – Colstrip Area data point (DEQ, 2013)	None
Groundwater	• DEQ-7 Human Health Standards (DEQ, 2012) • Colstrip SES Groundwater BSL (Neptune, 2016)	None

Data screening is presented in Tables B-2.1 through B-2.6 (RAGS Part D Table 2) located in Appendix B. The COPC column flags chemicals with either a "Y" for yes or an "N" for no. The chemicals flagged with an "N" were excluded from further human health risk evaluation.

If surface water or groundwater chemicals were flagged with a "Y" in the COPC column, they were identified as COPCs. Following DEQ guidance (2016), surface water and groundwater COPCs will be evaluated qualitatively in the risk evaluation. Sections 9.1 and 9.2 present additional information regarding the comparison of surface water and groundwater concentrations to DEQ-7 standards.

If sediments or soil chemicals were flagged with a "Y" in the COPC column, they were identified as COPCs and retained for quantitative risk evaluation. For the human health portion of the risk evaluation, sediments and soil were compared to direct contact screening levels (i.e., 1/10th the residential and industrial USEPA Regional Screening Level (RSLs; USEPA, 2016a) following DEQ's screening process; 2016) to identify potential human health COPCs.

5.3.1 Special Considerations for Groundwater COPCs

It should be noted that groundwater data in the uncontrolled access area of the Plant Site are regularly compared to the groundwater BSLs to evaluate water quality trends at the site. New monitoring wells are installed, as necessary, to further evaluate hydrologic conditions, including water quality, or to better delineate areas of impacts. Water quality data are compared to BSLs as part of the evaluation process. Beyond the comparison with BSLs, new well water quality is evaluated for the presence of process water indicator parameters (chemical constituents that may be concentrated in the process waters). Capture wells are placed in areas that have been interpreted to have potentially been impacted or have been impacted by process waters. Additional groundwater capture wells are routinely added, as necessary, to improve the effectiveness of the system based water quality trends, potentiometric maps analysis, capture zone analysis, well yield, and/or to replace damaged or otherwise failing wells. The groundwater BSLs are not clean-up levels, but are used as one criteria for evaluating capture well or monitoring well data when baseline specific data are not available.

5.4 IDENTIFYING LEACHING COPCS

Soil chemicals were also compared to the USEPA Soil Screening Levels (SSLs) for groundwater protection (USEPA, 2016) that were modified following the DEQ Soil Screening Process (DEQ, 2016) to identify leaching COPCs. If soil chemicals were flagged with a "Y" in the Leaching COPC column, they were identified as a potential leaching COPC. Two chemicals, barium and lead, were identified as possible leaching COPCs (see Table B-2.4 in Appendix B). However, after a more detailed data comparison, these chemicals were not identified as leaching COPCs. Please see Section 9.3 for additional information regarding leaching COPCs.

6.0 HUMAN HEALTH EXPOSURE ASSESSMENT

The Human Health Exposure Assessment provides a description of the potential human health exposure to wastewater-related chemicals in the uncontrolled access areas of the Plant Site, including exposure routes, magnitudes, frequencies, and durations for both current and future Facility use. The exposure assessment identifies the reasonable maximum exposures (RME) that are reasonably expected to occur at the uncontrolled access areas of the Plant Site area (USEPA, 1989). Potential human receptors and complete exposure pathways were presented in Section 4.0, Site Conceptual Exposure Model. The identified COPCs were presented in Section 5.0, Human Health Data Evaluation, Data Grouping, and Chemicals of Potential Concern.

6.1 EXPOSURE POINTS AND EXPOSURE POINT CONCENTRATIONS

Present and anticipated future land use and human activity patterns are used to identify potential exposure points for human receptors and contaminated media. The exposure point is the location at which a human receptor might contact contaminated media. Potential exposures to identified COPCs are assumed to occur uniformly throughout each exposure point (or EU).

The concentration of a COPC at an exposure point is referred to as an Exposure Point Concentration (EPC). The description of the approach used to statistically assess the data and calculate EPCs is included in Appendix D. Tables B-3.1 through B-3.4 in Appendix B present EPC data.

One COPC was identified in surface water and one in sediment within the five EUs defined for the uncontrolled access area of the Plant Site. Both COPCs were manganese.

Following DEQ Guidance (2016), the COPC in surface water will be evaluated qualitatively in the final CCRA. Within this CCRA Work Plan, manganese in surface water is compared to DEQ-7 values.

The COPC in sediment, manganese, will be evaluated quantitatively. Within this CCRA Work Plan, average daily doses for potential receptors were estimated.

6.1.1 Particulate Emission Models

To calculate airborne concentrations of particulates (fugitive dust), soil EPCs of COPCs are divided by the particulate emission factor (PEF). The PEF is defined as a nonchemical-specific value that relates chemical concentrations in soil to airborne concentrations that may be inhaled (USEPA, 2012). The USEPA default PEF, 1.36×10^9 cubic meters per kilogram (m^3/kg), is based on emissions associated with wind erosion.

COPCs were not identified in areas where soil was sampled (EU2, EU3, and EU4) and, therefore, particulate emission modeling was not necessary for these three EUs. In EU1, particulate releases from (dried) streambank sediments were assumed to be incomplete because significant vegetation is present along the East Fork Armells Creek that overhangs the bank and extends into the stream covering bank sediments.

6.2 CHEMICAL INTAKE ESTIMATES

Calculations of the non-carcinogenic average daily dose (ADD) and the carcinogenic lifetime average daily doses (LADD) for the HHRA are performed for complete exposure pathways using the equations available from the USEPA (1989, 2004, and 2009b). Numerous updates have been made to the intake equations and exposure parameters since the initial publication of USEPA's Risk Assessment Guidance for Superfund, Volume 1, Human Health Evaluation Manual, Part A (RAGS; USEPA, 1989), including, but not limited to, those listed below:

- Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment, 2004).

- Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part F, Supplemental Guidance for Inhalation Risk Assessment, 2009b).

- Exposure Factors Handbook: 2011 Edition.

- Human Health Evaluation Manual, Supplemental Guidance: Update of Standard Default Exposure Factors, 2014.

In addition, DEQ has specific guidance for risk assessments available on their web-page (DEQ, 2016).

The EPCs, scenario-specific assumptions, and intake parameters are used to estimate exposures (or intakes), which are expressed in terms of milligrams of chemical per kilogram body weight per day (mg/kg-day). Intakes are calculated for the RME, which is the highest exposure reasonably expected to occur.

The USEPA (1989) defines the generic equation for calculating human non-carcinogenic ADDs as follows:

$$Average\ Daily\ Dose\ (ADD) = \frac{C \times CR \times EF\ X\ ED}{BW \times ATnc}$$

where:

C	=	COPC concentration
CR	=	contact rate (amount of contact with impacted media per time)
EF	=	exposure frequency
ED	=	exposure duration
BW	=	body weight of the receptor
ATnc	=	averaging time (period over which the exposure is averaged)

The USEPA (1989) defines the generic equation for calculating human carcinogenic LADDs as follows:

$$Lifetime\ Average\ Daily\ Dose\ (LADD) = \frac{C \times CR \times EF \times ED}{BW \times ATc}$$

where:

C	=	COPC concentration
CR	=	contact rate (amount of contact with impacted media per time)
EF	=	exposure frequency
ED	=	exposure duration
BW	=	body weight of the receptor
ATc	=	averaging time carcinogens (lifetime)

Pathway-specific variations of the generic equations are used for non-carcinogenic COPCs and carcinogenic COPCs to calculate intakes. The pathway specific variations are discussed in the following sections and presented in Table B-4 located in Appendix B.

6.2.1 Incidental Ingestion of Soil for Non-Carcinogens

For non-carcinogenic ADD posed by incidental ingestion of soil, the childhood exposure is evaluated as it is considered to be protective of adult exposures (DEQ, 2016).

The ADD for incidental soil ingestion for non-carcinogenic COPCs is calculated as follows:

$$ADDsoil\ ing = \frac{Cs \times IRSc\ \times GI\ ABS\ \times FS\ \times\ EF\ \times\ ED\ \times MCF}{BWc\ \times\ ATnc}$$

where:

Cs	=	COPC EPC concentration in soil (kilogram [kg])
IRSc	=	ingestion rate soil (child; milligrams per day [mg/day])
GI ABS	=	gastrointestinal absorption factor (unitless)
FS	=	fraction from the source (unitless)
EF	=	exposure frequency (days/year [yr])
ED	=	exposure duration (yrs)
MCF	=	mass conversion factor (1 x 10^{-6} kilograms per milligram [kg/mg])
BWc	=	body weight (child; kg)
ATnc	=	averaging time non-carcinogens (ED in days)

ADD calculations for incidental ingestion of soil impacted with non-carcinogenic COPCs (i.e., manganese) were calculated for the various receptors (See Table presented in Section 6.2.10).

6.2.2 Incidental Ingestion of Soil for Carcinogens and Mutagenic Carcinogens

For carcinogenic LADD posed by incidental ingestion of soil, an age-adjusted ingestion factor is used because the soil ingestion rate is different for children and adults (DEQ, 2016). The exposure duration includes both six years of early childhood (ages one to six) and 20 years of childhood to adulthood (ages seven to 26). The age-adjusted soil ingestion factor for carcinogens (IFSadj) and the age-adjusted soil ingestion factor for mutagenic carcinogens (IFSMadj) are calculated by the equations presented below.

The age-adjusted soil ingestion factor for carcinogens is calculated as follows:

$$IFSadj = \frac{IRSc \times EDc}{BWc} + \frac{IRSa \times EDa}{BWa}$$

where:

IFSadj	=	age-adjusted soil ingestion factor for carcinogens (mg-yr/kg-day)
IRSc	=	ingestion rate of soil ages 1-6 (mg/day])
IRSa	=	ingestion rate of soil ages 7-26 (mg/day)
EDc	=	exposure duration during ages 1-6 (yr)
EDd	=	exposure duration during ages 7-26 (yr)
BWc	=	average body weight from ages 1-6 (kg)
BWa	=	average body weight from ages 7-26 (kg)

The age-adjusted soil ingestion factor for mutagenic carcinogens is calculated as follows:

$$IFSMadj = \frac{IRS_{0-2} \times ED_{0-2} \times 10}{BW_{0-2}} + \frac{IRS_{2-6} \times ED_{2-6} \times 3}{BW_{2-6}} + \frac{IRS_{6-16} \times ED_{6-16} \times 3}{BW_{6-16}} + \frac{IRS_{16-26} \times ED_{16-26} \times 1}{BW_{6-16}}$$

where:

IFSMadj	=	age-adjusted soil ingestion factor for mutagenic carcinogens (mg-yr/kg-day)
IRSage	=	ingestion rate of soil for various ages (mg/day)
EDage	=	exposure duration for various ages (yr)
BWage	=	average body weight for various ages (kg)

The age-adjusted soil ingestion factor for carcinogens is 105 mg-yr/kg-day. The age-adjusted soil ingestion factor for mutagenic carcinogens is 477 mg-yr/kg-day (DEQ, 2016).

Using the age-adjusted soil ingestion factors, the LADD for incidental soil ingestion for residential soils is calculated as follows:

$$LADDsoil\ ing = \frac{Cs \times IFSadj\ or\ IFSMadj \times GI\ ABS\ \times FS\ \times\ EF\ \times MCF}{ATc}$$

where:

Cs = COPC EPC concentration in Soil (milligrams/kilogram [mg/kg])
IFSadj = age-adjusted soil ingestion factor for carcinogens (mg-yr/kg-day)
IFSMadj= age-adjusted soil ingestion factor for mutagenic carcinogens (mg-yr/kg-day)
GI ABS = gastrointestinal absorption factor (unitless)
EF = exposure frequency (days/yr)
MCF = mass conversion factor (1×10^{-6} kg/mg)
ATc = averaging time carcinogens (lifetime; days)

Neither carcinogenic nor mutagenic COPCs in soil or sediment were identified for the uncontrolled access areas of the Plant Site. As such, LADD calculations for incidental ingestion of soil impacted with carcinogenic or mutagenic COPCs were not necessary.

6.2.3 Dermal Absorption of Soil/Sediment for Non-Carcinogens

For non-carcinogenic ADD posed by dermal absorption of soil/sediment, the childhood exposure is evaluated as it is considered to be protective of adult exposures (DEQ, 2016).

The ADD for dermal absorption of soil/sediment is calculated as follows:

$$ADDsoil\ dermal = \frac{Cs \times ABS\ \times SAc\ \times AF \times FS\ \times\ EF\ \times\ ED\ \times MCF}{BWc\ \times\ ATnc}$$

where:

Cs = COPC EPC concentration in soil (kg)
ABS = dermal absorption factor (unitless)
SAc = exposed skin surface area (child, square centimeters [cm^2])
AF = soil to skin adherence factor (milligrams per square centimeters [mg/cm^2])
FS = fraction from the source (unitless)
EF = exposure frequency (days/yr)
ED = exposure duration (yrs)
MCF = mass conversion factor (1×10^{-6} kg/mg)
BWc = body weight (child; kg)
ATnc = averaging time non-carcinogens (ED in days)

ADD calculations for dermal absorption of soil impacted with non-carcinogenic COPCs (i.e., manganese) were calculated for the various receptors (See Table presented in Section 6.2.10).

6.2.4 Dermal Absorption of Soil/Sediment for Carcinogens and Mutagenic Carcinogens

For carcinogenic LADD posed by dermal absorption of soil/sediments, an age-adjusted dermal exposure factor is used because the dermal exposure is expected to be different for children and adults (DEQ, 2016). The exposure duration includes both six years of early childhood (ages one to six) and 20 years of childhood to adulthood (ages seven to 26). The age-adjusted dermal soil exposure factor for carcinogens (DFSadj) and the age-adjusted dermal soil exposure factor for mutagenic carcinogens (DFSMadj) are calculated by the equations presented below.

The recommended age-adjusted dermal soil exposure factor for carcinogens is calculated as follows:

$$DFSadj = \frac{SAc \times AFc \times EDc}{BWc} + \frac{SAa \times AFa \times EDa}{BWa}$$

where:

DFSadj	=	age-adjusted dermal exposure factor for carcinogens (mg-yr/kg-day)
SAc	=	exposed skin surface area ages 1-6 (cm^2/day)
SAa	=	exposed skin surface area ages 7-26 (cm^2/day)
AFc	=	skin adherence factor ages 1-6 (mg/cm^2)
AFa	=	skin adherence factor ages 7-26 (mg/cm^2)
EDc	=	exposure duration ages 1-6 (years)
EDa	=	exposure duration ages 7-26 (years)
BWc	=	body weight ages 1-6 (kg)
BWa	=	body weight ages 7-26 (kg)

The age-adjusted dermal soil exposure factor for mutagenic carcinogens is calculated as follows:

$$DFSMadj = \frac{SA_{0-2} \times AF_{0-2} \times EF_{0-2} \times ED_{0-2} \times 10}{BW_{0-2}} + \frac{SA_{2-6} \times AF_{2-6} \times EF_{2-6} \times ED_{2-6} \times 3}{BW_{2-6}} + \frac{SA_{6-16} \times AF_{6-16} \times EF_{6-16} \times ED_{6-16} \times 3}{BW_{6-16}} + \frac{SA_{16-26} \times AF_{16-26} \times EF_{16-26} \times ED_{16-26} \times 1}{BW_{6-16}}$$

where:

DFSMadj	= age-adjusted dermal soil exposure factor for mutagenic carcinogens (mg-yr/kg-day)
SAage	= exposed skin surface area for various ages (cm^2/day)
AFage	= skin adherence factor for various ages (mg/cm^2)
EDage	= exposure duration for various ages (years)
BWage	= body weight for various ages (kg)

The DFSadj for carcinogens is 295 mg-yr/kg-day. The DFSMadj for mutagenic carcinogens is 1,224 mg-yr/kg-day (DEQ, 2016).

Based on the age-adjusted dermal factor for soil/sediment calculated above, the carcinogenic dermal absorbed dose for residential soil is calculated as follows:

$$LADDsoil\ dermal = \frac{CS\ \times DFSadj\ or\ DFSMadj \times ABS\ \times FS\ \times EF\ \times\ MCF}{ATc}$$

where:

CS = COPC EPC in soil (mg/kg)
DFSadj = age-adjusted dermal soil exposure factor for carcinogens (mg-yr/kg-event)
DFSMadj = age-adjusted dermal soil exposure factor for mutagenic carcinogens (mg-yr/kg-event)
ABS = dermal absorption factor (unitless)
EF = exposure frequency (days/yr)
MCF = mass conversion factor ($1x10^{-6}$ kg/mg)
ATc = averaging time for carcinogens (lifetime, days)

Neither carcinogenic nor mutagenic COPCs in soil or sediment were identified for the uncontrolled access areas of the Plant Site. As such, LADD calculations for dermal absorption of soil impacted with carcinogenic or mutagenic COPCs were not necessary.

6.2.5 Inhalation of Volatiles or Fugitive Dust Particles

Chemical intake estimates for the inhalation of volatiles and fugitive dust particles are calculated following USEPA RAGS Part F guidance (2009b), in which an Exposure Concentration (EC) is calculated to evaluate inhalation of volatiles and fugitive dust particles.

To calculate intakes associated with the inhalation of COPCs (either volatiles or fugitive dust particles), the following equations are used:

$$EC = \frac{Cair\ \times\ ABSinh\ \times\ ET\ \times EF \times ED}{ATnc\ or\ ATc}$$

And:

$$Cair = \frac{Csoil}{PEF}$$

$$Cair = \frac{Csoil}{VF}$$

where:

EC	=	exposure concentration (milligram per cubic meter [mg/m^3])
Cair	=	COPC EPC in air (mg/m^3)
ABSinh	=	inhalation absorption factor (unitless)
ET	=	exposure time (hours/day)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (yrs)
ATc	=	averaging time for carcinogens (hours)
ATnc	=	averaging time for non-carcinogens (hours)
Csoil	=	COPC EPC in soil (mg/kg)
PEF	=	particulate emission factor (m^3/kg)
VF	=	chemical specific volatilization factor for volatiles (unitless)

COPCs were not identified in areas where soil was sampled (EU2, EU3, and EU4) and, therefore, particulate emission modeling was not necessary for these three EUs. In EU1, particulate releases from (dried) streambank sediments were assumed to be incomplete because significant vegetation is present along the East Fork Armells Creek that overhangs the bank and extends into the stream covering bank sediments.

6.2.6 Lead Exposures

Lead exposures are not evaluated by standard estimates representing a dose-response assessment. Rather, lead exposures are typically evaluated in terms of the increase in blood lead (PbB) concentrations following exposures. Blood lead models are available from the USEPA to evaluate this exposure (USEPA, 2009a). The first model is the Integrated Uptake Biokinetic Model for Lead in Children (IEUBK), which incorporates the Centers for Disease Control and Prevention's (CDC) recommendation that children do not have more than a five percent (5%) probability that their PbB concentration will exceed 10 micrograms per deciliter (µg/dl). This level was assumed to be protective of adults, as well, in the second model, the Adult Lead Model. These models were used to establish the USEPA RSLs for lead for residential exposures (i.e., children) of 400 mg/kg and for industrial exposure (i.e., adults) of 800 mg/kg.

Recently, the CDC has lowered their recommendation indicating that children should not have more than a 5% probability that their PbB concentration will exceed 5 µg/dl. The USEPA blood lead models have not, yet, been revised to accommodate CDC's updated blood lead recommendation. However, the models may still be run using the lower PbB concentration. The DEQ typically requests that blood lead modeling be conducted using both of the CDC blood lead recommendations. Running the IEUBK using the new lower CDC blood lead recommendation (and default values) results in a residential lead screening level of 153 mg/kg.

Lead was not identified as a COPC in soil or sediment in the uncontrolled access areas of the Plant Site. As such, blood lead modeling will not be conducted.

6.2.7 General Exposure Assumptions

Human exposure assumptions were based on USEPA and DEQ guidance. For the most part, the exposure parameters recommended by DEQ (and largely based on USEPA guidance) were used (DEQ, 2016). Several of the exposure parameters recommended by DEQ include conditions, such as climate, specific to Montana. The exposure parameters are presented in Table B-4 located in Appendix B.

6.2.7.1 Exposure Time, Frequency, and Duration

The total extent of an exposure is defined by the exposure time, exposure frequency, and the exposure duration. The exposure time is limited to the inhalation pathway and is generally defined in hours per day. However, as previously described, the inhalation pathway was found to be incomplete for the EUs in the Plant Site and, therefore, was not evaluated (i.e., no surface soil COPCs were identified that could contribute to fugitive dust emissions).

The exposure frequency is the number of days per year when exposure occurs. Exposure frequencies for the various receptors are as follows:

- The exposure frequency for residential receptors was assumed to be 270 days per year, which assumes three months of snow cover and a two-week vacation (DEQ, 2016).

- The exposure frequency for industrial receptors was assumed to be 187 days per year, which assumes a standard five-day work week, three months of snow cover, and a two-week vacation (DEQ, 2016).

- The exposure frequency for construction worker receptors was assumed to be 124 days per year, which assumes four months of excavation (DEQ, 2016).

- The exposure duration for recreational user receptors was assumed to be 16 days per year based on professional judgment (i.e., an eight-week hunting season and an EU visitation of two times per week).

The exposure duration is the total number of years over which an exposure occurs. Exposure durations for the various receptors are as follows:

- The exposure durations for the adult and child residential receptors were assumed to be 20 years and 6 years, respectively (DEQ, 2016). However, when calculating intakes for an exposure to a non-carcinogenic COPC, DEQ guidance indicates the child exposure scenario (i.e., exposure duration of 6 years years) should be evaluated because it is assumed to be protective of the adult exposure scenario. When calculating intakes for an exposure to a carcinogenic COPC, DEQ guidance indicates a combined adult and child scenario should be evaluated (i.e., exposure duration of 26 years, DEQ, 2016).

- The exposure duration for an industrial receptor was assumed to be 25 years (DEQ, 2016).

- The exposure duration for a construction worker receptor was assumed to be one year (DEQ, 2016).

- The exposure durations for the adult and child recreational receptors were assumed to be 20 years and 6 years, respectively (DEQ, 2016). However, when calculating intakes for an exposure to a non-carcinogenic COPC, DEQ guidance indicates the child exposure scenario (i.e., exposure duration of 6 years years) should be evaluated because it is assumed to be protective of the adult exposure scenario. When calculating intakes for an exposure to a carcinogenic COPC, DEQ guidance indicates a combined adult and child scenario should be evaluated (i.e., exposure duration of 26 years, DEQ, 2016).

6.2.7.2 Body Weight

Default body weights of 80 kilograms for adults and 15 kilograms for children were used in the assessment (USEPA, 2014; DEQ, 2016).

6.2.7.3 Averaging Time

For non-cancer health effects, the averaging time is equal to the exposure duration (in years) multiplied by 365 days per year (USEPA, 1989). The averaging time for cancer risk estimation is the number of days in a 78-year lifetime or 28,470 days (DEQ, 2016). The averaging time for oral and dermal exposures is expressed in days, while the averaging time for inhalation exposures is express in hours.

Non-cancer COPCs were identified in the EUs associated with the uncontrolled access areas of the Plant Site. As such, averaging times calculated as the exposure duration (in years) multiplied by 365 days per year were used in the intake calculations.

6.2.8 Pathway-Specific Exposure Factors

Pathway-specific exposure factors, which are unique to each exposure pathway, are summarized in Table B-4 (RAGS Table 4) located in Appendix B. Professional judgment was used to define exposure factors for which neither the USEPA nor the DEQ has established specific exposure assumptions.

6.2.8.1 Exposure Parameters for Incidental Ingestion of Soil and Sediment

Receptors may be exposed to COPCs in soil and sediment through inadvertent, or incidental, soil ingestion. Parameters specific to the soil and sediment ingestion pathway include the following:

1. the amount of soil/sediment incidentally ingested (mg/day).

2. the fraction of the ingested contaminated soil/sediment that is absorbed into the body as it passes through the human gastrointestinal tract, which is referred to as the gastrointestinal absorption factor (GI ABS), or the relative bioavailability, or bioaccessibility (unitless).

3. the fraction of the ingestion rate that is from the contaminated soil/sediment, as opposed to other outdoor areas (e.g., a child resident is expected to spend only a portion of his outdoor time playing in contaminated sediment, Fraction from the Source, FS, unitless).

Incidental sediment ingestion rates for the various receptors are presented below. The FS components were based on professional judgment.

- Adult Resident – 100 mg/day with a FS (contaminated sediment) of 0.1 (i.e., assumed sediment ingestion to be one-tenth of all incidental soil ingestion).

- Child Resident – 200 mg/day with a FS (contaminated sediment) of 0.25 (i.e., assumed sediment ingestion to be one-quarter of all incidental soil ingestion).

- Industrial Worker – 100 mg/day with a FS (contaminated sediment) of 0.1 (i.e., assumed sediment ingestion to be one-tenth of all incidental soil ingestion).

- Construction Worker – 330 mg/day with a fraction ingested from the source (contaminated sediment) of 0.5 (i.e., assumed sediment ingestion to be one-half of all incidental soil ingestion).

- Recreational Receptor (adult) - 165 mg/day with a FS (contaminated sediment) of 0.1 (i.e., assumed sediment ingestion to be one-tenth of all incidental soil ingestion).

- Recreational Receptor (child) - 200 mg/day with a FS (contaminated sediment) of 0.1 (i.e., assumed sediment ingestion to be one-tenth of all incidental soil ingestion).

The exposure assumptions for assessing incidental sediment ingestion, including rationales for selection of values, are summarized in Table B-4 located in Appendix B.

It should be noted that no soil COPCs were identified. One COPC, manganese, was identified in sediment. A GI ABS for manganese is available from the USEPA (2016a) of 0.04, which was used in the intake calculations (see Table 6-1 below).

Table 6-1 Gastrointestinal Absorption Factor

COPC	Gastrointestinal Absorption Factor	Reference
Manganese	0.04	USEPA, 2016a

6.2.8.2 Exposure Parameters for Dermal Contact with Soil and Sediment

Receptors may be exposed to COPCs through dermal absorption from direct contact with contaminated soil or sediment. The dermal intake is an estimated absorbed dose (i.e., the amount of the COPC that crosses the skin and subsequently enters the human bloodstream). Parameters specific to the soil and sediment dermal pathway include the following:

1. the skin surface area (amount of skin in contact with the soil/sediment, cm^2).

2. amount of soil/sediment that adheres to the skin (adherence factor, AF, unitless).

3. the chemical-specific dermal absorption factor (ABSd, unitless).

4. the fraction of the contaminated sediment, as opposed to other outdoor areas (e.g., a child resident is expected to spend only a portion of his outdoor time playing in contaminated sediment, the FS, unitless).

Dermal exposure parameters for the various receptors are presented below. The FS components were based on professional judgment.

- The adult resident receptor was assumed to have 6,032 square centimeters (cm^2) of exposed skin surface area, a soil to skin AF of 0.07 milligrams per square centimeter (mg/ cm^2), and a FS of 0.1.

- The child resident receptor was assumed to have 2,373 cm^2 of exposed skin surface area, a soil to skin AF of 0.2 mg/ cm^2, and a FS of 0.25.

- The industrial worker receptor was assumed to have 3,527 cm^2 of exposed skin surface area, a soil to skin AF of 0.12 mg/ cm^2, and a FS of 0.1.

- The construction worker receptor was assumed to have 3,527 cm^2 of exposed skin surface area, a soil to skin AF of 0.3 mg/ cm^2, and a FS of 0.5.

- The adult recreational receptor was assumed to have 3,527 cm^2 of exposed skin surface area, a soil to skin AF of 0.12 mg/ cm^2, and a FS of 0.1.

- The child recreational receptor was assumed to have 2,373 cm^2 of exposed skin surface area, a soil to skin AF of 0.2 mg/ cm^2, and a FS of 0.1.

The exposure assumptions for assessing dermal exposures, including rationales for selection of values, are summarized in Table B-4 located in Appendix B.

The USEPA indicates that dermal exposures to sediments should be treated the same as dermal exposures to soil. The USEPA indicates that adherence factors are perhaps the most uncertain parameter in estimating dermal exposures to sediments, but does not provide AFs specific to sediments (USEPA, 2004).

No soil COPCs were identified for the uncontrolled access areas of the Plant Site. One COPC, manganese, was identified in sediment. A dermal absorption factor for manganese is not available from the USEPA (2016a) and, therefore, following USEPA guidance was assumed to be one (100%, see Table 6-2 below).

Table 6-2 Dermal Absorption Factor

COPC	Dermal Absorption Factor	Reference
Manganese	NA	USEPA, 2016a

NA - not available, assumed to be 1.0.

6.2.8.3 Exposure Parameters for Inhalation of Volatile Chemicals and Particulate Chemicals

Receptors may be exposed to COPCs by inhaling volatile chemicals in the air or inhaling chemicals sorbed to particulates. Parameters specific to the inhalation pathway include the following:

1. the PEF (m^3/kg).
2. the chemical-specific Volatilization Factor (VF, unitless).
3. the fraction of the inhalation that is from the contaminated soil/sediment, as opposed to other outdoor areas (FS, unitless).
4. the chemical-specific fraction of the inhaled COPC that is absorbed into the body through the lungs, referred to as the Inhalation Absorption Factor (ABSinh, unitless).

No volatile COPCs were identified and, therefore, chemical intakes were not estimated for inhalation of volatile chemicals. No soil COPCs were identified and, therefore, chemical intakes were not estimated for inhalation of particulates.

Particulate releases from (dried) streambank sediments were assumed to incomplete because significant vegetation is present along the East Fork Armells Creek that overhangs the bank and extends into the stream. As such, chemical intakes were not estimated for inhalation of particulate chemicals.

6.2.9 Exposure Point Concentrations/ 95 UCLs

Exposure Point Concentrations (also referred to as 95th Upper Confidence Limits on the mean [95 UCLs]) were calculated for the COPC, manganese, in two media, sediment and surface water. Please see Appendix D for the Statistical Summary. Table 6-3 below presents the EPCs.

Table 6-3 Exposure Point Concentrations (95 UCLs)

COPC	Media	Minimum Value	Maximum Value	Average	EPC (95 UCL)
Manganese	Sediment (mg/kg)	412	5,910	1,939	2,662
	Surface Water (mg/L)	0.059	12.0	1.4	3.74

6.2.10 Human Exposure Assessment Summary and Calculated Average Daily Doses

The human exposure assessment is summarized below.

One sediment COPC was identified in EU1, manganese, which is a non-carcinogen. The identified exposure pathways were incidental ingestion and dermal contact with sediment. As such, chemical intakes were calculated for exposure to manganese in sediment via the incidental ingestion and dermal contact pathways (see Table 6-4 below).

No soil COPCs were identified in the five EUs of the Plant Site.

One surface water COPC was identified in EU1, manganese. Chemical intakes were not calculated. Rather, following DEQ guidance (2016), the concentrations were compared to DEQ-7 values (see Section 9.1).

No groundwater COPCs were identified in the uncontrolled access area of the Plant Site within the Sub-McKay geologic unit, which would be the geologic layer suitable for potential future domestic wells (i.e., the geologic layer that could support volume/production).

Table 6-4 Average Daily Doses

COPC	Receptor	EPC (mg/kg)	ADD (mg/kg-day)	RfD (mg/kg-day)
Manganese (non-carcinogen)	Current/Future Child Resident	2,662	1.6E-02	2.4E-02
	Current/Future Industrial Worker		7.2E-04	
	Current/Future Construction Worker		6.0E-03	
	Current/Future Child Recreational Receptor (hunter)		3.7E-04	

7.0 TOXICITY ASSESSMENT

The Toxicity Assessment follows the USEPA recommended approach (USEPA, 1989, et al). The toxicity assessment identifies, as necessary, the Reference Doses (RfDs), the Reference Concentrations (RfCs), cancer Slope Factors (SFs), and Inhalation Unit Risks (IURs) that will be used to evaluate adverse non-cancer health effects and cancer risks. Toxicity values for COPCs follows the hierarchy of human health toxicity (USEPA, 2003a), which is also recommended by DEQ (2016), as described below:

1. USEPA's Integrated Risk Information System (IRIS). IRIS is an on-line database that presents the latest EPA-approved RfDs, RfCs, SFs, and IURs as well as uncertainty and modifying factors (USEPA, 2016b). The toxicity values available from IRIS are recognized as USEPA-wide consensus information.

2. USEPA's Provisional Peer Reviewed Toxicity Values (PPRTV) Database. Similar to IRIS, the PPRTVs are USEPA-approved RfDs, RfCs, SFs, and IURs that have undergone peer review and recognized as consensus information (USEPA, 2013b).

3. Other USEPA and non-USEPA toxicity values, such as:

    a. USEPA's Health Effects Assessment Summary Tables (HEAST; USEPA, 1997).
    b. USEPA's National Center for Environmental Assessment (NCEA) papers, which are chemical-specific references (USEPA, 2013b)
    c. California Environmental Protection Agency's (Cal/EPA) Office of Environmental Health Hazard Assessment (OEHHA) on-line database, which contains approved, peer-reviewed toxicity criteria (Cal/EPA OEHHA, 2016)

7.1 REFERENCE DOSES AND REFERENCE CONCENTRATIONS

Non-carcinogen RfDs and RfCs will be used in the final CCRA to estimate the risks of a receptor developing non-cancer health hazards as a result of exposure to concentrations (i.e., EPCs) of identified non-cancer COPCs. An RfD is an estimate of a daily exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of harmful effects (USEPA, 1989). An RfD has an uncertainty that spans perhaps an order of magnitude (USEPA, 1989). RfDs are chemical-specific and expressed as milligrams per kilogram-day (mg/kg-day). Oral RfDs are typically used to assess dermal exposures in the absence of route-specific dermal RfDs (USEPA, 1989). RfCs are used to assess inhalation exposures and are expressed in units of milligrams per cubic meter (mg/m^3; USEPA, 2009b).

Relevant human and animal studies for each COPC are used to derive the RfDs and RfCs. Specifically, measured or observed No Observed Adverse Effect Levels (NOAEL) are typically used in the derivation, which corresponds to the dose that can be administered without inducing observable adverse effects. If A NOAEL cannot be established, the Lowest Observed Adverse Effect Level (LOAEL) is used, which corresponds the lowest daily dose administered that induces an observable adverse effect (the "critical effect").

Chronic RfDs and RfCs were used in the toxicity assessment, as few subchronic RfDs and RfCs are available. Chronic RfDs and RfCs are intended for chronic exposures (i.e., exposures greater than seven years). Subchronic RfDs and RfCs are intended for subchronic exposures (i.e., exposures less than seven years). Using chronic RfDs and RfCs for all exposure durations, which for this assessment ranged from one to 25 years, is expected to result in conservative estimates of potential human health hazards.

Because NOAELs and LOAELs are typically established based on experimental animal studies, uncertainty factors are applied to be protective of human health. Uncertainty factors usually occur in multiples of 10 and account for the following:

- Extrapolation of data from animals to humans, known as interspecies extrapolation.
- Variation in human sensitivity to the toxic effect of the COPC, known as intraspecies extrapolation.
- Derivation of a chronic RfD based on subchronic data, rather than chronic data.
- Derivation of an RfD based on the LOAEL, rather than the NOAEL.

Modifying factors between 0 and 10 may also be applied in addition to uncertainty factors to accommodate for other additional uncertainty factors.

A summary of the non-cancer toxicity information is presented in Table B-5 (RAGS Part D Table 5) located in Appendix B.

One non-carcinogenic COPC, manganese, was identified in sediment and surface water. The following RfD was identified for manganese (Table 7-1).

Table 7-1 COPC Reference Dose

COPC	RfD (mg/kg-day)	Source	Reference
Manganese	2.4E-02	IRIS*	USEPA, 2016b

IRIS* - The IRIS RfD is 0.14 mg/kg-day; however, the IRIS explanatory text recommends using a modifying factor of three when calculating risks associated with non-food sources because of a number of uncertainties, resulting in an RfD of 0.024 mg/kg-day.

7.2 SLOPE FACTORS AND INHALATION UNIT RISKS

The USEPA (1989) defines a carcinogenic slope factor (SF) as a plausible upper-bound estimate of the probability of a response per unit intake of a chemical over a lifetime. Carcinogenic Slope Factors and Inhalation Unit Risks (IURs) are used in the HHRA to estimate upper-bound lifetime probabilities of a receptor developing cancer as a result of exposure to concentrations (i.e., EPCs) of identified carcinogenic COPCs. SFs and IURs are upper-bound estimates, approximating a 95 UCL on the increased cancer risk from lifetime exposure to a carcinogenic COPC (USEPA, 1989).

Carcinogenic COPCs are typically classified into one of five groups:

- Group A, a known human carcinogen
- Groups B1 and B2, a probable human carcinogen
- Group C, a possible human carcinogen

- Group D, chemicals that cannot be classified due to lack of data
- Group E, no evidence of human carcinogenicity

No carcinogenic COPCs were identified for the uncontrolled access areas of the Plant Site.

7.3 ROUTE-TO-ROUTE EXTRAPOLATION

Because toxicity criteria were not available for the dermal exposure route, route-to-route extrapolations of oral toxicity criteria were used to evaluate dermal exposures for the identified COPC.

7.4 TOXICITY PROFILE - MANGANESE

Manganese is a naturally occurring metal that makes up about 0.10 percent of the earth's crust. Manganese is typically found combined with other substances, such as oxygen, sulfur, or chlorine. Manganese is also found in anthropogenic organic compounds, such as pesticides (maneb and mancozeb) and a fuel additive known as methylcyclopentadienyl manganese tricarbonyl.

Manganese is also an essential trace element that is nutritionally necessary for good health. Manganese nutritional requirements are typically satisfied through the diet with minor contributions arising from water and air. Manganese can be found in several food items, including grains, cereals, and tea. The National Research Council recommends a dietary allowance of 2-5 mg/day of manganese for an adult human for a safe and adequate intake.

If humans are exposed on a prolonged basis to elevated concentrations, manganese can elicit a variety of serious toxic responses with the central nervous system being the primary target. Headache, insomnia, disorientation, anxiety, lethargy, and memory loss are initial symptoms. With continued exposure, the initial symptoms progress to include motor disturbances, tremors, and difficulty in walking. These motor difficulties are similar to those seen with Parkinsonism and are often irreversible. This combination of symptoms is a disease called "manganism."

No human cancer data are available for manganese. The USEPA weight-of-evidence classification is D, not classifiable as to human carcinogenicity, based on no evidence in humans and inadequate evidence in animals. However, some conflicting data exists on possible carcinogenesis in mice (USEPA 2016a, 2016b).

The toxicity criteria used in the HHRA to quantify risks for exposure to manganese are summarized in Table B-5 in Appendix B. This table includes information on the primary target organ, and the uncertainty and modifying factors associated with toxicity criteria used to evaluate systemic (noncancer) effects.

7.5 UNCERTAINTIES ASSOCIATED WITH TOXICITY ASSESSMENT

A modifying factor of three was used in the development of the oral RfD (non-diet) for manganese because of a number of IRIS-identified uncertainties (USEPA, 2016b). Additional uncertainties associated with the Toxicity Assessment will be identified within the final CCRA.

8.0 RISK CHARACTERIZATION

For complete exposure pathways, risk characterization will be performed in the final CCRA to combine the exposure and toxicity assessments to produce quantitative estimates of potential health risks associated with the COPCs.

8.1 CHARACTERIZATION OF CANCER RISKS

Carcinogenic risk can be described as the probability over a receptor's lifetime of developing cancer from an exposure to cancer-causing compounds. All individuals have a risk of developing cancer because of a genetic predisposition or other causes non-related to exposure to cancer-causing compounds at a USEPA- or DEQ-regulated facility. The DEQ (2016) indicates that any person has approximately a one in three chance of developing some type of cancer over their lifetime. "Excess lifetime cancer risk" is the additional cancer risk over this "background" probability. The DEQ (2016) defines "excess lifetime cancer risk" as the additional risk that someone might have of getting cancer if that person is exposed to site-related cancer-causing compounds.

Potential cancer risks estimates will be calculated according to the USEPA (1989) equation as presented below:

$$Incremental\ Lifetime\ Cancer\ = LADD\ \times SF$$

where:

LADD	=	Lifetime Average Daily Dose
SF	=	Cancer Slope Factor

Incremental lifetime cancer risk probabilities will be compared to the acceptable risk levels. The USEPA has established an acceptable incremental lifetime cancer risk range of 10^{-4} to 10^{-6} (i.e., one in ten thousand to one in one million; USEPA, 1991). However, the DEQ (2016) has established an acceptable incremental lifetime cancer risk probability of 10^{-5} (i.e., one in one hundred thousand). As such, incremental lifetime cancer risk probabilities will be compared to 10^{-5} as a not to exceed value.

Because no carcinogenic or carcinogenic mutagenic COPCs were identified, cancer risk probabilities will not be calculated in the final CCRA.

8.2 CHARACTERIZATION OF NONCANCER HEALTH HAZARDS

Non-carcinogenic health hazards can be described as the potential of a receptor developing non-cancer health concerns around the time of an exposure to non-cancer causing compounds.

Non-cancer hazard quotients (HQ) will be calculated according to the USEPA (1989) equation as presented below:

$$Hazard\ Quotient\ (HQ) = \frac{ADD}{RfDi\ or\ RfDo}$$

where:

ADD	=	Average Daily Dose
RfD_i	=	inhalation Reference Dose
RfD_o	=	oral Reference Dose

HQ's that affect the same target organ are summed together to form the Hazard Index. The non-cancer hazard index is based on a comparison of the estimated site-related dose to the USEPA acceptable dose. The USEPA (2001) has indicated that a hazard index of less than 1.0 indicates an acceptable potential for non-cancer health hazards (USEPA, 2001). Similarly, the DEQ (2016) has indicated that a total hazard index for non-carcinogenic compounds may not exceed 1.0 for each target organ. As such, the hazard indices will be compared to 1.0 as a not-to-exceed value.

Hazard quotients for the various receptors for the one non-carcinogenic COPC will be calculated in the CCRA.

8.3 EVALUATION OF UNCERTAINTIES

Uncertainties associated with Risk Characterization will be identified within the CCRA. Uncertainties in the risk characterization are expected to originate from a cumulative effect of the uncertainties in the Exposure Assessment, the Toxicity Assessment, and the Characterization of Risk.

8.4 RISK ASSESSMENT GUIDANCE FOR SUPERFUND PART D TABLES

Following DEQ Guidance (DEQ, 2016), the table format from RAGS Part D are used for the risk assessment tables. The Risk Assessment Work Plan includes RAGS Part D Tables 1 through 6, which are included in Appendix B.

9.0 COMPARISON OF DATA TO MEDIUM-SPECIFIC STANDARDS AND SCREENING LEVELS

9.1 COMPARISON OF SURFACE WATER COPC CONCENTRATIONS TO DEQ-7 VALUES

DEQ guidance (2016) indicates surface water concentrations of COPCs should be compared to DEQ-7 values, rather than being quantitatively evaluated in the HHRA. DEQ-7 (2012) indicates that for metals, total recoverable concentrations (excluding aluminum) should be used in the comparison. Surface water concentrations were compared to DEQ-7 values and are presented in Table 2.1 (RAGS Table 2) in Appendix B. Following guidance (DEQ, 2012), if a DEQ-7 Human Health Standard (HHS) was not available, the Maximum Contaminant Level (MCL) was used. If an MCL was not available, the USEPA Tapwater RSL (Traditional RSL Tables) was used. Through this comparison, one contaminant, manganese, was identified as a surface water human health COPC as summarized in Table 9-1 below.

Table 9-1 Comparison of Surface Water COPC Concentrations

COPC	Minimum Value (mg/L)	Maximum Value (mg/L)	Average (mg/L)	95 UCL (mg/L)	BSL (mg/L)	DEQ-7 (Tapwater RSL, mg/L)
Manganese	0.059	12.0	1.4	3.74	1.6	0.43

The minimum, maximum, average and 95th Upper Confidence Limit on the mean (95 UCL) manganese concentrations exceeded the Tapwater RSL for manganese of 0.43 milligrams per liter (mg/L). Neither a DEQ-7 HHS, nor an MCL was available for manganese. East Fork Armells Creek is not used as a potable drinking water source.

The maximum and 95 UCL manganese concentrations exceeded the BSL of 1.6 mg/L for manganese (Neptune, 2016) and the Tapwater RSL. See Appendix D for the statistical summary.

It should be noted that arsenic was not identified as a surface water human health COPC. Although the maximum concentration of arsenic in surface water of 0.054 mg/L exceeded the DEQ-7 value (the MCL) of 0.010 mg/L, it was nearly an identical concentration as measured in the immediate upstream sample location (AR-12) of 0.053 mg/L. As such, arsenic concentrations measured in East Fork Armells Creek in the area adjacent to the Plant Site appear to have originated from an upstream source and; therefore, arsenic was not selected as a surface water COPC. Arsenic is included in the statistical analysis presented in Appendix D.

9.2 COMPARISON OF GROUNDWATER COPC CONCENTRATIONS TO DEQ-7 VALUES

DEQ guidance (2016) indicates groundwater concentrations should be compared to DEQ-7 standards, rather than being quantitatively evaluated in the human health risk assessment. DEQ-7 (2012) indicates that for metals, dissolved concentrations (i.e., the portion that passes through a 0.45 micron filter) should be used in the comparison. Following guidance (DEQ, 2012), if a DEQ-7 HHS was not available, the MCL was used. If an MCL was not available, the USEPA Tapwater RSL (Traditional RSL Tables) was used.

Several groundwater wells (i.e., 15D, 66D, 80D, 95D, 99D, 103D, 110D) were identified as wells in the uncontrolled access area of the Plant Site that were within a geologic layer that could potentially be used for in the future as a potable water source (EU5). The wells are depicted on Figure 11. Data available from these wells (boron and selenium) were compared to DEQ-7 standards. Based on this comparison, no groundwater COPCs were identified.

Selenium was not detected at concentrations above the laboratory reporting limit in the groundwater samples. Boron was detected in all the wells. The boron groundwater concentrations did not exceed the DEQ-7 standard (i.e., the tapwater RSL). In one of the wells, 110D, the measured boron concentrations were greater than the BSL for boron (Neptune, 2016). However, the 95 UCL calculated from the groundwater data did not exceed the BSL (see Appendix D for the statistical results). The comparison of the groundwater data is summarized in Table 9-2 below.

Table 9-2 Comparison of Groundwater COPC Concentrations

Chemical	Minimum Value (mg/L)	Maximum Value (mg/L)	Average (mg/L)	95 UCL (1) (mg/L)	BSL (mg/L)	DEQ-7 (Tapwater RSL, mg/L)
Boron	0.3	1.9	0.75	1.09	1.3	4.0

(1) Please see Appendix D, Statistical Summary.

9.3 COMPARISON OF LEACHING COPCS TO USEPA SSLS FOR GROUNDWATER PROTECTION

Soil chemicals were also compared to the USEPA Soil Screening Levels (SSLs) for groundwater protection (USEPA, 2016) that were modified following the DEQ Soil Screening Process (DEQ, 2016) to identify leaching COPCs. Two potential leaching COPCs were identified from the comparison, which was in EU3 (former spills area near the sewage lagoons) in the shallow soil intervals (i.e., 0 to six inches), as summarized in Table 9-3 below.

Table 9-3 Comparison of Barium and Lead Concentrations

Chemical	Minimum Value (mg/kg)	Maximum Value (mg/kg)	Average(1) (mg/kg)	95 UCL(2) (mg/kg)	BTV (mg/kg)	USEPA SSL for Groundwater Protection (mg/kg)
Barium	96.3	1,130 (BH-54) Re-analysis 1,050	204	301.8	429	421
Lead	9.5	504 (BH-56) Re-analysis 18.8	21	47.8	29.8	140

(1) Average of all soil samples (i.e., all soil depths).

(2) Please see Appendix D, Statistical Summary, 95 UCL for samples in the 0-6" soil depth.

Although barium was measured at a concentration of 1,130 mg/kg (BH-54) that exceeded the USEPA SSL for Groundwater Protection of 421 mg/kg, it was not selected as a leaching COPC for the following reasons:

- Of the remaining 88 data points in EU3, only the re-analysis of the BH-54 sample and the sample from BH-73 exceeded the USEPA SSL for barium (as modified per DEQ, 2016). The concentration in BH-73 of 429 mg/kg matched the BTV for barium in Montana soils and just slightly exceeded the USEPA SSL of 421 mg/kg.
- The barium concentration in BH-54 in the 12”-24” soil interval (218 mg/kg) was approximately five times lower than the concentration measured in the 0-6” interval. The concentration in this interval, collected directly below the 0-6” soil interval sample, did not exceed the USEPA SSL and demonstrated that barium is not leaching through the soil column.
- Barium exceedances are limited to the 0-6” soil interval and appear very limited in area. For example, barium concentrations in BH-59, which is located approximately 20 feet to the southeast of BH-54, ranged from 153 mg/kg to 240 mg/kg (all below the USEPA SSL).
- The BTV for barium in Montana soils of 429 mg/kg exceeds the USEPA SSL (as modified per DEQ, 2016).
- The 95 UCL for barium in the 0-6” soil depth of EU3 was 301.8 mg/kg, which was below the USEPA SSL for barium (see Appendix D for the statistical summary).

Although lead was measured at a concentration of 504 mg/kg (BH-56) that exceeded the USEPA SSL for Groundwater Protection of 140 mg/kg, it was not selected as a leaching COPC for the following reasons:

- The sample was re-analyzed resulting in a lead concentration of 18.8 mg/kg. As such, the concentration of 504 mg/kg was possibly a laboratory error, or represented a “nugget effect” within a very small soil volume (i.e., within the sample aliquot).
- The remaining 88 data points in EU3 did not exceed the USEPA SSL for lead (as modified per DEQ, 2016). The remaining data ranged from 9.5 mg/kg to 124 mg/kg.
- The 95 UCL for lead in the 0-6” soil depth of EU3 was 47.8 mg/kg, which was below the USEPA SSL for lead (see Appendix D for the statistical summary).

10.0 ECOLOGICAL RISK ASSESSMENT

The Ecological Risk Assessment (ERA) was prepared by Neptune and Company, Inc. The ERA was conducted following USEPA guidance (USEPA, 1993, 1997b, 1998 et al.) and DEQ guidance (DEQ, 2009, 2016).

The ERA focuses on potential exposure to COPCs in surface water and sediment in East Fork Armells Creek adjacent to the Plant Site and extending downstream as far as Power Road, and exposure to soil in three areas along the Creek north of the Plant Site, as shown in Figure 6 and detailed in the Interim Response Action Work Plan for Soil Sampling at Historic Release Sites along East Fork Armells Creek (Hydrometrics, 2016a). Potential ecological risk associated with sediment and water within the ponds at the Plant Site will be addressed as part of the closure process for those ponds. Potential risk associated with East Fork Armells Creek sediment and surface water downstream of Power Road will be assessed as part of the CCRA Work Plan for the Units 1 & 2 SOEP and STEP area.

Initially, a screening-level ecological risk assessment (SLERA) is presented as part of this CCRA Work Plan to conservatively rule out further evaluation of constituents and media that do not pose an ecological risk. The SLERA represents Steps 1 and 2 of the USEPA ecological risk assessment process (USEPA, 1997b). Any constituents that remain following the initial SLERA were carried to the screening refinement, informally known as Step 3A of the USEPA ecological risk assessment process. If COPCs remain following screening refinement, a baseline ecological risk assessment (BERA) may be necessary.

The BERA replaces the conservative assumptions used in the SLERA with more realistic, site-specific exposure assumptions, and may include direct evaluation of Creek sediment and water toxicity in the form of bioassays and comparison of site benthic communities with those in unimpacted reference areas. Identification of appropriate reference areas within the Creek is problematic because upstream of the Plant Site the Creek becomes intermittent, and flowing water is not present year round. Portions of the Creek where water is intermittent are not appropriate for comparison to areas with permanent water because the physical properties and biotic communities will not be comparable between the two areas.

Baseline Screening Levels (BSLs) for surface water in East Fork Armells Creek were developed by Neptune and Company (2016) based on four upstream locations that were deemed similar to the physical conditions present adjacent to the Plant Site. The SLERA and screening-refinement were conducted with existing synoptic run data for the Creek. Synoptic run sediment data for the SLERA were collected in Spring and Fall 2014 and Spring and Fall 2015. Synoptic run surface water data used in the SLERA were collected seasonally, and data collected in 2014 and 2015 are used to represent current conditions within the Creek.

10.1 ECOLOGICAL EXPOSURE ASSESSMENT

The Ecological Exposure Assessment provides a description of the environmental exposure to releases or threatened releases of wastewater COPCs from the ponds at the Plant Site based upon the current use of the Facility and adjacent properties and any reasonably anticipated future uses of the Facility and adjacent properties. The Ecological Exposure Assessment was prepared following DEQ and USEPA guidance as described in the following sections.

10.1.1 Ecological Site Conceptual Exposure Model

An ecological Site Conceptual Exposure Model (SCEM) was prepared as the first step in the Exposure Assessment. The ecological SCEM identifies the ecological exposures associated with the Creek, as well as the Facility-specific contaminant sources, release mechanisms, transport routes and media, and potential receptors. The preliminary ecological exposures assessed in the SLERA are presented in the SCEM (Figure 5).

10.1.2 Assessment Endpoints, Measures of Effect, and Exposure Pathways

Ecological assessment endpoints represent the ecological values to be protected at the Facility. Potential receptors for the SLERA were selected based on a site visit conducted in July 2014 and information obtained from the Montana Natural Heritage Program. Receptors, include the plants, animals and components of the environment (e.g., habitats, populations, communities) that may potentially be exposed to contamination in East Fork Armells Creek and adjacent soil areas. Exposure pathways are identified in the SCEM (Figure 5). Preliminary assessment endpoints for the SLERA and screening refinement included:

- Protection of populations of aquatic plants exposed to surface water and sediment in East Fork Armells Creek.
- Protection of benthic invertebrate communities exposed to surface water and sediment in East Fork Armells Creek.
- Protection of populations of riparian birds and mammals exposed to surface water and sediment in East Armells Creek.
- Protection of populations of soil invertebrates exposed to upland soil in the soil historic release areas.
- Protection of populations of plants exposed to upland soil in the soil historic release areas.
- Protection of populations of terrestrial birds and mammals exposed to upland soil in the historic release areas.

Ecological risk assessments focus on the protection of populations of organisms, except when the potential exists for threatened and endangered (T&E) species to occur at the Facility. Protection of individuals of T&E species is a goal of the ERA if such species are known or suspected to occur. Information on the potential for T&E species to be present along the Creek was obtained from the Montana Natural Heritage Program. According to the Species of Concern list updated on 6/23/2015, there are 45 animal species of concern in Rosebud County. Of these, only one, the Pallid Sturgeon, is listed as endangered. The Pallid Sturgeon occurs in large rivers, and would not occur in East Fork Armells Creek. A second species, the Yellow-billed Cuckoo, is listed as threatened in the portion of its range that includes the State of Montana. The Yellow-billed Cuckoo inhabits prairie riparian forests and may utilize streamside cottonwoods during migration, but trees are likely too sparse in the area of East Fork Armells Creek and the Plant Site to support breeding yellow-billed cuckoos. A third species, Sprague's Pipit, is a candidate species for listing. Sprague's Pipit inhabits open grassland with no trees or shrubs, and may occur on open grassland portions of the plant site, but would not be expected along East Fork Armell's Creek. Two other species, Bald Eagle and Golden Eagle, receive protection under the Bald and Golden Eagle Protection Act. Bald Eagles normally stay near large bodies of water, while Golden Eagles prefer open country. Of the two, Golden eagles are more likely to occur on the Plant Site, where they would be expected to feed on a variety of small mammals in the open grasslands. Utilization of East Fork Armells Creek by Bald and Golden Eagles is expected to be minimal. Any exposure to East Fork Armells Creek water and sediment is expected to be limited to surface water ingestion.

According to information obtained from the Montana Natural Heritage Program's Wetland's Mapper (http://geoinfo.msl.mt.gov/home/msdi/wetlands), the following delineated wetland occur within the study area:

- Upstream sampling location AR-12 is adjacent to Riparian Lotic Scrub-shrub wetland.
- East Armells Creek between sampling location AR-4 and AR-3 includes Palustrine Aquatic Bed Semi-permanently Flooded wetland, and Palustrine Emergent Seasonally Flooded wetland.
- Sampling location AR-5 is located in Palustrine Emergent Seasonally Flooded wetland.
- The area between location AR-3 and Power Road contains Palustrine Emergent Seasonally Flooded wetland.

Measures of Effect describe how assessment endpoints will be evaluated to determine whether potential risk exists to a specific assessment endpoint. Measures of Effect for the SLERA and screening refinement include:

- Comparison of Creek surface water concentrations to chronic aquatic life standards published in Montana DEQ-7.
- Comparison of Creek sediment concentrations to USEPA Region 3 Biological Technical Assistance Group (BTAG) freshwater sediment screening benchmarks.
- Comparison of soil concentrations to EPA Ecological Soil Screening Levels (EcoSSLs) or other ecological soil screening benchmarks if EPA EcoSSLs have not been derived for a given constituent.

- Comparison of soil, sediment, and surface water concentrations to appropriate background or reference areas that are not impacted by Plant Site wastewater system operations.

Additional Measures of effect for a baseline ecological risk assessment, if necessary, include:

- Food chain modeling to terrestrial birds and mammals utilizing upland soil areas and the Creek as a source of food and drinking water, and comparison of average daily doses to toxicity reference values (TRVs). Food-chain models will be constructed for the following representative receptors that may forage in upland soil areas and/or the Creek:
    - Raccoon (*Procyon lotor*), representative of omnivorous mammals utilizing East Fork Armells Creek.
    - Common yellowthroat (*Geothlypis trichas*), representative of insectivorous birds utilizing East Fork Armells Creek.
    - Great blue heron (*Ardea herodias*), representative of piscivorous birds utilizing East Fork Armells Creek.
    - Ord's kangaroo rat (*Dipodomys ordii*), representative of herbivorous mammals utilizing upland soil areas at the Plant Site.
    - Masked shrew (*Sorex cinereus*), representative of insectivorous mammals utilizing upland soil areas at the Plant Site.
    - Lark sparrow (*Chondestes grammacus*), representative of herbivorous birds utilizing upland soil areas at the Plant Site.
    - Sprague's pipit (*Anthus spragueii*), representative of insectivorous birds utilizing upland soil areas at the Plant Site.

Food chain modeling to terrestrial receptors utilizing the creek as a food/water source was included as part of the BERA because these receptors have exposures across multiple media (soil, sediment, and water).

Following the SLERA and screening refinement, the list of assessment endpoints and the SCEM were refined based upon the results of the screening-level assessment. Current and reasonably anticipated future uses of adjacent properties were considered when identifying potential receptors and exposure pathways.

East Fork Armells Creek within the investigation area is a generally slow-moving creek containing permanent water and in places, abundant emergent vegetation. Wetland areas are present in and adjacent to the Creek within the investigation area. Delineated wetland types include Riparian Lotic Scrub-shrub, Palustrine Aquatic Bed Semi-permanently Flooded wetland, and Palustrine Emergent Seasonally Flooded wetland. East Fork Armells Creek and its immediate environs provide habitat for aquatic and terrestrial plants, aquatic and benthic invertebrates, and small fish. The utility of the creek as a drinking water source for wildlife is uncertain due to the high concentrations of cations and dissolved solids, which make the water in the creek more akin to saltwater than freshwater. These high levels of cations and dissolved solids occur in all areas of the creek, including areas upstream of the site, and are likely the result of mining activities in the region. However, for risk assessment purposes it is assumed that the creek is used by wildlife as a drinking water source. Terrestrial habitats adjacent to the Creek, including the three soil spill areas evaluated in this work plan, are comprised of grasslands with scattered shrubs. These provide habitat for a variety of birds and small mammals. Some of the surrounding grasslands on and adjacent to the Plant Site are fenced to allow grazing by cattle and horses. Therefore, ecological exposure pathways are considered complete for all trophic levels to surface water, sediment, and soil. Ecological exposure pathways to groundwater are considered incomplete. Complete exposure pathways for each receptor group are shown in Table 10-1.

Table 10-1 Ecological Exposure Pathways

Ecological Receptor	Exposure Pathway				
	Root Uptake	Dermal Contact	Surface Water Ingestion	Soil/Sediment Ingestion	Food-chain Ingestion
Benthic Invertebrates/Fish	NA	1°	1°	1°	2°
Soil Invertebrates	NA	1°	NA	1°	2°
Aquatic Plants / Terrestrial Plants	1°	2°	NA	NA	NA
Terrestrial Mammals	NA	2°	1°	2°	1°
Terrestrial Birds	NA	2°	1°	2°	1°

1° = Primary or major pathway
2° = Secondary or minor pathway
N/A = Insignificant or Incomplete Pathway

10.1.3 Exposure Assumptions

Ecological exposure scenarios are identified based on the current and reasonably anticipated future Facility use (and adjacent areas), the potential receptors, and complete exposure pathways. For the SLERA, conservative exposure assumptions are used to ensure that risk is not underestimated. These assumptions include:

- An Area Use Factor (AUF) of 1 (i.e., an organism gets 100% of its exposure from East Fork Armells Creek)
- 100% bioavailability of chemical constituents in sediment and surface water
- Use of No Adverse Effects Level (NOAEL) screening levels and TRVs

For the BERA food chain modeling of dose to birds and mammals exposed to soil and Creek surface water and sediments, more realistic exposure assumptions are used to represent exposure. Organism body weights, food ingestion rates, and water ingestion rates for use in the food-chain modeling are shown in Tables 10-2 and 10-3 below. Because no biotic tissue has been analyzed to provide estimates of contaminant concentrations in the food chain, estimates of bioaccumulation into food/prey items were selected from available literature.

Bioaccumulation factors used to estimate contaminant concentrations in food items are shown in Tables 10-4 and 10-5. For contaminants in East Fork Armells Creek, concentrations in aquatic plants and benthic invertebrates are estimated based on bioaccumulation from sediment. Concentrations in fish tissue are estimated based on bioconcentration from surface water.

Table 10-2 Food Chain Modeling Exposure Parameters For East Fork Armells Creek Receptors

Parameter	Value	Source
Raccoon		
Body Weight (kg)	6	Average of the sample mean from studies reporting weights of adult raccoons, reported in Wildlife Exposure Factors Handbook (USEPA, 1993).
Food Ingestion Rate (kg/d dry wt.)	0.3	Calculated using allometric equation for All Mammals (Equation 3-7) from Wildlife Exposure Factors Handbook (USEPA 1993).
Water Ingestion Rate (L/d)	0.5	Based on water ingestion rate of 0.083 grams per grams of body weight per day (g/g-d) as reported in Wildlife Exposure Factors Handbook (USEPA, 1993)
Incidental Sediment Ingestion Rate (k/d dry wt)	0.03	Beyer et al., 1994.
Fraction Plants in Diet (unitless)	0.4	A study of raccoons in bottomland riparian habitat found that plant material made up ~40% of the raccoon diet when averaged across all four seasons, ranging from less than 5% in spring to ~60% in fall and winter (Llewellyn and Uhler as reported in USEPA 1993). Raccoon diets in Spring, Summer, and Fall are dominated by fruits and nuts (Tesky, 1995).
Fraction Invertebrates in Diet (unitless)	0.5	A study of raccoons in bottomland riparian habitat found that invertebrates made up ~50% of the raccoon diet when averaged across all four seasons, ranging from ~25% in fall and winter to 82% in spring (Llewellyn and Uhler as reported in USEPA 1993). According to Tesky (1995), Spring is the only time of year when animal material comprises more than 50% of raccoons diet, with small invertebrates the most important animal foods consumed by raccoons.
Fraction Fish in Diet (unitless)	0.1	A study of raccoons in bottomland riparian habitat found that fish and other vertebrates made up ~10% of the raccoon diet when averaged across all four seasons, ranging from ~3% in fall to 16% in winter and spring (Llewellyn and Uhler as reported in USEPA 1993). In summer, this category also includes eggs of nesting birds, particularly waterfowl eggs in regions of the northern great plains (Tesky 1995).
Area Use Factor	1	An AUF of 1 is used to be protective of all omnivorous mammals for which the raccoon serves as a surrogate.
Common Yellowthroat		
Body Weight (kg)	0.01	Mean of all adult body weights from Guzy and Ritchison, 1999.
Food Ingestion Rate (kg/d dry wt.)	0.0033	Calculated using allometric equation for passerine birds (Equation 3-4) in Wildlife Exposure Factors Handbook (USEPA, 1993).
Water Ingestion Rate (L/d)	0.0028	Based on water ingestion rate of 0.28 g/g-d as reported in Wildlife Exposure Factors Handbook (USEPA, 1993)
Incidental Sediment Ingestion Rate (k/d dry wt)	0.000066	Calculated as 2% of total ingestion rate
Fraction Invertebrates in Diet (unitless)	1	Diet assumed to be 100% invertebrates to be protective of all insectivorous birds utilizing the Creek
Area Use Factor	1	The AUF of 1 is applied to each individual area within East Fork Armells Creek, assuming that individual common yellowthroats defend territories in the wetland portions of each area.

Table 10-2. Food Chain Modeling Exposure Parameters For East Fork Armells Creek Receptors (continued)

Great Blue Heron Exposure Parameters		
Body Weight (kg)	2.336	Mean of all adult body weights reported in Wildlife Exposure Factors Handbook (USEPA, 1993).
Food Ingestion Rate (kg/d dry wt.)	0.105	Total Ingestion of 0.105 kg/d (dry weight) based on ingestion rate of 0.18 kg/kg-d (kilograms per kilograms of body weight per day; wet weight) from Wildlife Exposure Factors Handbook (USEPA, 1993) adjusted for body weight and converted to dry weight by assuming average of 75% moisture in prey items.
Water Ingestion Rate (L/d)	0.105	Based on water ingestion rate of 0.045 g/g-d as reported in Wildlife Exposure Factors Handbook (USEPA, 1993)
Incidental Sediment Ingestion Rate (k/d dry wt)	0.002	Calculated as 2% of total ingestion rate
Fraction Fish in Diet	1	The four studies listed in USEPA (1993) report the diet of the great blue heron as comprised of 94 to 100% fish, with invertebrates, amphibians, birds and mammals comprising the non-fish portion of the diet. For the purposes of evaluating risk to piscivores, the great blue heron will be assumed to have a diet of 100% fish from East Fork Armells Creek.
Area Use Factor	1	The AUF of 1 is applied to each individual area within East Fork Armells Creek. Great Blue Herons have been reported to forage in areas as small as 1.5 acres.

Table 10-3 Food Chain Modeling Exposure Parameters For Plant Site Soil Area Receptors

Ord's Kangaroo Rat (mammalian herbivore)		
Body Weight (kg)	0.052	Mean adult body mass reported in Garrison and Best, 1990.
Food Ingestion Rate (kg/d dry wt.)	0.0058	Calculated using allometric equation for rodents (Equation 3-8) in Wildlife Exposure Factors Handbook (USEPA, 1993)
Water Ingestion Rate (L/d)	0.007	Calculated using allometric equation for mammals (Equation 3-17) in Wildlife Exposure Factors Handbook (USEPA, 1993)
Incidental Soil Ingestion Rate (k/d dry wt)	0.0058	Calculated as 10% of total ingestion
Fraction Plants in Diet	1	Diet assumed to be 100% plant material to be protective of all herbivorous mammals utilizing the upland soil areas
Area Use Factor	1	
Masked Shrew (mammalian insectivore)		
Body Weight (kg)	0.004	Recommended value for masked shrew from Warrington, P.D. 2001.
Food Ingestion Rate (kg/d dry wt.)	0.00325	Recommended value for masked shrew from Warrington, P.D. 2001.
Water Ingestion Rate (L/d)	0.0005	Recommended value for masked shrew from Warrington, P.D. 2001.
Incidental Soil Ingestion Rate (k/d dry wt)	0.000325	Calculated as 10% of total ingestion
Fraction Invertebrates in Diet	1	Assumed to be 100% to be protective of all insectivorous mammals
Area Use Factor	1	
Lark Sparrow (avian herbivore)		
Body Weight (kg)	0.0289	Mean adult weight from four studies reported in Martin and Parrish (2000)
Food Ingestion Rate (kg/d dry wt.)	0.00694	Calculated using allometric equation for passerine birds (Equation 3-4) in Wildlife Exposure Factors Handbook (USEPA, 1993).
Water Ingestion Rate (L/d)	0.005	Calculated using allometric equation for birds (Equation 3-15) in Wildlife Exposure Factors Handbook (USEPA, 1993)
Incidental Soil Ingestion Rate (k/d dry wt)	0.00014	Calculated as 2% of total ingestion
Fraction Plants in Diet	0.75	Martin and Parrish, 2000
Fraction Invertebrates in Diet	0.25	Martin and Parrish, 2000
Area Use Factor	1	
Spraque's Pipit (avian insectivore)		
Body Weight (kg)	0.02375	Mean of 343 territorial males and breeding females reported in Davis et al., 2014.
Food Ingestion Rate (kg/d dry wt.)	0.00588	Calculated using allometric equation for passerine birds (Equation 3-4) in Wildlife Exposure Factors Handbook (USEPA, 1993).
Water Ingestion Rate (L/d)	0.005	Calculated using allometric equation for birds (Equation 3-15) in Wildlife Exposure Factors Handbook (USEPA, 1993)
Incidental Soil Ingestion Rate (k/d dry wt)	0.00012	Calculated as 2% of total ingestion
Fraction Invertebrates in Diet	1	According to Davis et al. (2014) diet consists of a wide array of arthropods with a small amount of plant matter. For risk assessment purposes, 100% invertebrate ingestion is assumed
Area Use Factor	1	

Table 10-4 Bioaccumulation Factors for Metals in Soil

	Soil to Plant BAF	Soil to Invertebrate BAF	Soil to Flesh BAF
Arsenic[1]	$B_i = 0.03752 * Soil_j$	$\ln(B_i) = 0.706 * \ln(Soil_j) - 1.421$	$\ln(B_i) = 0.8188 * \ln(Soil_j) - 4.8471$
Barium[1]	$B_i = 0.156 * Soil_j$	$B_i = 0.091 * Soil_j$	$B_i = C_{diet} * 0.0075$
Boron[2]	$B_i = 4.0 * Soil_j$	$B_i = 1 * Soil_j$ (Default)	$B_i = 0.000817 * Soil_j$
Cadmium[1]	$\ln(B_i) = 0.546 * \ln(Soil_j) - 0.475$	$\ln(B_i) = 0.795 * \ln(Soil_j) + 2.114$	$\ln(B_i) = 0.4723 * \ln(Soil_j) - 1.2571$
Chromium[1]	$B_i = 0.041 * Soil_j$	$B_i = 0.306 * Soil_j$	$\ln(B_i) = 0.7338 * \ln(Soil_j) - 1.4599$
Lead[1]	$\ln(B_i) = 0.561 * \ln(Soil_j) - 1.328$	$\ln(B_i) = 0.807 * \ln(Soil_j) - 0.218$	$\ln(B_i) = 0.4422 * \ln(Soilj) + 0.0761$
Manganese[1]	$B_i = 0.079 * Soil_j$	$\ln(B_i) = 0.682 * \ln(Soil_j) - 0.809$	$B_i = 0.0205 * Soil_j$
Mercury[2]	$B_i = 0.663 * Soil_j$	$B_i = 3.933 * Soil_j$	$B_i = 0.49 * Soil_j$
Selenium[1]	$\ln(B_i) = 1.104 * \ln(Soilj) - 0.677$	$\ln(B_i) = 0.733 * \ln(Soil_j) - 0.075$	$\ln(B_i) = 0.3764 * \ln(Soil_j) - 0.4158$

[1] Bioaccumulation factors from USEPA EcoSSL guidance documents (USEPA, 2003c)
[2] Bioaccumulation factors from LANL EcoRisk Database (LANL, 2014)

Table 10-5 Bioaccumulation / Bioconcentation Factors for Metals in Sediment / Surface Water

	Bioaccumulation / Bioconcentration Factor		
	Sediment – Plant [1]	Sediment – Invert [1]	Surface Water – Fish [2]
Arsenic	$B_i = 0.0375 *$ Sediment	$B_i = 0.236 *$ Sediment	$B_i = 44 *$ Surface Water
Barium	$B_i = 0.156 *$ Sediment	$B_i = 0.091 *$ Sediment	$B_i = 129 *$ Surface Water [3]
Beryllium	$B_i = 0.01 *$ Sediment	$B_i = 0.045 *$ Sediment	$B_i = 19 *$ Surface Water
Boron	$B_i = 4.0 *$ Sediment	$B_i = 1 *$ Sediment (Default)	$B_i = 0.3 *$ Surface Water [4]
Cadmium	$B_i = 0.833 *$ Sediment	$B_i = 14.26 *$ Sediment	$B_i = 64 *$ Surface Water
Chromium	$B_i = 0.041 *$ Sediment	$B_i = 0.1607 *$ Sediment	$B_i = 16 *$ Surface Water
Copper	$B_i = 0.288 *$ Sediment	$B_i = 0.6364 *$ Sediment	$B_i = 36 *$ Surface Water
Lead	$B_i = 0.58 *$ Sediment	$B_i = 0.225 *$ Sediment	$B_i = 49 *$ Surface Water
Manganese	$B_i = 0.15 *$ Sediment	$B_i = 0.0605 *$ Sediment	$B_i = 600 *$ Surface Water [5]
Mercury	$B_i = 0.663 *$ Sediment	$B_i = 3.933 *$ Sediment	$B_i = 5500 *$ Surface Water
Nickel	$B_i = 0.372 *$ Sediment	$B_i = 0.778 *$ Sediment	$B_i = 47 *$ Surface Water
Selenium	$B_i = 0.7 *$ Sediment	$B_i = 0.99 *$ Sediment	$B_i = 4.8 *$ Surface Water
Thallium	$B_i = 0.004 *$ Sediment	$B_i = 0.0541 *$ Sediment	$B_i = 119 *$ Surface Water
Vanadium	$B_i = 0.0055 *$ Sediment	$B_i = 0.042 *$ Sediment	$B_i = 1 *$ Surface Water (default)
Zinc	$B_i = 0.88 *$ Sediment	$B_i = 3.78 *$ Sediment	$B_i = 47 *$ Surface Water

[1] Sediment – Plant and Sediment – Invert bioaccumulation factors obtained from LANL EcoRisk Database (LANL, 2014).
[2] Bioconcentration factor based on ratio of dissolved concentration in water to wet weight concentration in fish tissue. Fish tissue wet weight concentration is converted to dry weight in the food chain models by dividing wet weight concentration by 0.25 (assuming moisture content of 75%). Unless otherwise noted, wet weight values obtained from DEQ-7.
[3] BCF for Barium from ATSDR, 2007
[4] BCF for Boron from CCME, 2009.
[5] BCF for Manganese from Karlsson et al., 2002

10.1.4 Ecological Exposure Areas and Exposure Point Concentrations

The exposure area for the ERA is defined as East Fork Armells Creek adjacent to and extending downstream of the Plant Site as far as Power Road. The Creek downstream of Power Road will be evaluated as part of the ERA for Units 1 &2 SOEP and STEP Area. The Plant Site ERA also includes the three soil areas detailed in the Interim Response Action Work Plan for Soil Sampling at Historic Release Sites along East Fork Armells Creek (Hydrometrics, 2016a).

For the initial screening-level assessment, the maximum concentration of each COPC in sediment, surface water, and soil is used. Refinement of the SLERA and the BERA utilized a 95 UCL EPC to represent more realistic exposure integrated across the exposure area. Because the creek extends across a relatively large area, 95 UCL EPCs in the BERA were calculated differently for the raccoon, which has relatively large home range/foraging area, versus the common yellowthroat and great blue heron, which have relatively small foraging areas. For the raccoon, the 95 UCL was calculated across all sampling locations in the Creek included in this investigation (AR-5, AR-4, AR-3, AR-2SF, AR-1), while 95 UCL EPCs for common yellowthroat and great blue heron were calculated for each sampling location. Thus, the 95 UCLs for the widely ranging raccoon encompass spatial and temporal variability across the creek, while the EPCs for the smaller ranging receptors encompass only temporal variability at each sampling location.

The 95 UCLs for soil were calculated across all soil sampling locations because the soil areas represent a much smaller areal extent than Creek sediment and water. Statistical and graphical summaries of the data to support EPC calculations are presented in Appendix D. Details of the 95 UCL calculations for surface water, soil, and groundwater are presented in Appendix D. For certain data sets with small sample sizes, the calculated 95 UCL may exceed the maximum reported concentration. In those instances, the maximum value was used in lieu of the 95 UCL. Exposure units and type of EPC used for each line of evidence in the SLERA and BERA are shown in Table 10-6.

Table 10-6 Exposure Units for Plant Site Ecological Risk Assessment

Receptor	Ecological Exposure Unit	Exposure Medium	EPC
SLERA			
Aquatic Plants	East Fork Armells Creek	Surface Water	Maximum
Aquatic Plants and Animals	East Fork Armells Creek	Sediment	Maximum
Terrestrial Plants and Animals	Soil Areas 1 – 3 (Combined)	Soil	Maximum
BERA			
Aquatic Plants and Animals	East Fork Armells Creek	Surface Water	95 UCL (all locations)
		Sediment	95 UCL (all locations)
Terrestrial Plants	Soil Areas 1 – 3 (Combined)	Soil	95 UCL (all locations)
Terrestrial Invertebrates	Soil Areas 1 – 3 (Combined)	Soil	95 UCL (all locations)
Terrestrial Omnivorous Mammals	Soil Areas 1 – 3 (Combined)	Soil	95 UCL (all locations)
		Food Chain	Bioaccumulation based on Soil 95 UCL
	East Fork Armells Creek	Surface Water	95 UCL (all locations)
		Sediment	95 UCL (all locations)
		Food Chain	Bioaccumulation based on Sediment/Water 95 UCLs
Terrestrial Insectivorous Birds	Soil Areas 1 – 3 (Combined)	Soil	Bioaccumulation based on Soil 95 UCL
		Food Chain	95 UCL (all locations)
	East Fork Armells Creek	Surface Water	95 UCL (each location)
		Sediment	95 UCL (each location)
		Food Chain	Bioaccumulation based on Sediment 95UCL
Aquatic/Terrestrial Piscivorous Birds	Soil Areas 1 – 3 (Combined)	Soil	95 UCL (all locations)
		Food Chain	Bioaccumulation based on Soil 95 UCL
	East Fork Armells Creek	Surface Water	95 UCL (each location)
		Sediment	95 UCL (each location)
		Food Chain	Bioconcentration based on Surface Water 95 UCL

10.2 ECOLOGICAL TOXICITY ASSESSMENT

The Toxicity Assessment for the COPCs identified for East Fork Armells Creek follows the USEPA recommended approach (USEPA, 1997b, 1998). Surface water screening values were chosen to represent chronic criteria for protection of aquatic life as published in DEQ-7, and sediment screening values were selected from freshwater sediment screening criteria recommended by

USEPA Region 3 BTAG. Historically, there has been less water and sediment toxicity information available for boron than for many of the other inorganic constituents. The Canadian Council of Ministers of the Environment (CCME) has summarized existing information and developed water quality guidelines for the protection of aquatic life (CCME, 2009), and the CCME guidelines are used to assess boron in East Fork Armells Creek.

Surface water and sediment screening levels used in the SLERA are shown in Table 10-7. Soil screening criteria represent EcoSSLs developed by the USEPA. Alternative sources of screening values, such as the EcoRisk Database developed by Los Alamos National Laboratory (LANL), were used when the primary sources listed above lack screening values for a given COPC. Soil screening levels for plants, invertebrates and wildlife are shown in Table 10-8. The screening level selected for preliminary COPC determination is the lowest value among plant, invertebrate, and wildlife values. Screening levels used in the SLERA represent NOAEL toxicity values, while the BERA will consider both NOAEL and LOAEL toxicity values. TRVs for evaluation of dose to upper-trophic level birds and mammals likewise represent NOAEL values for screening and NOAEL and LOAEL values for screening refinement and the BERA. TRVs were selected from available sources, including those derived by USEPA as part of the Ecological Soil Screening Level Guidance (USEPA, 2003c), and Los Alamos National Laboratory (LANL, 2014). NOAEL TRVs for use in food chain modeling are presented in Table 10-9, and LOAEL TRVs are presented in table 10-10.

Table 10-7 Ecological Screening Criteria For Protection Of Aquatic Life

	Surface Water Screening Level (ug/L)	Source [1]	Surface Water BSL (ug/L)	Sediment Screening Level (mg/kg)	Source [1]
Trace Metals					
Arsenic	150	DEQ-7	17	9.8	Region 3
Barium	4	Region 3	NA	150	LANL ER Db
Beryllium	0.66	Region 3	NA	NA	NA
Boron	1500	CCME, 2009	880	NA	NA
Cadmium	0.097 (hardness adjustable)	DEQ-7	2	0.99	Region 3
Chromium (III)	27.7 (hardness adjustable)	DEQ-7	50	43.4	Region 3
Copper	2.85 (hardness adjustable)	DEQ-7	100	31.6	Region 3
Lead	0.545 (hardness adjustable)	DEQ-7	60	35.8	Region 3
Manganese	120	Region 3	1,600	460	Region 3
Mercury	0.91	DEQ-7	1	0.18	Region 3
Nickel	16.1 (hardness adjustable)	DEQ-7	21.7	22.7	Region 3
Selenium	5	DEQ-7	10	2	Region 3
Thallium	0.8	Region 3	NA	NA	NA
Vanadium	20	Region 3	100	NA	NA
Zinc	37 (hardness adjustable)	DEQ-7	290	121	Region 3
Common Ions					
Calcium	116,000	Region 3	369,000	NA	NA
Chloride	230,000	National AWQC	228,000	NA	NA
Fluoride	2120 (hardness adjustable)	Region 3	320	NA	NA
Magnesium	82,000	Region 3	495,000	NA	NA
Potassium	53,000	Region 3	17,300	NA	NA
Sodium	680,000	Region 3	234,000	NA	NA
Sulfate	NA	NA	2,260,000	NA	NA

1 DEQ-7 = Montana Numeric Water Quality Standards, Chronic Aquatic Life Standards (DEQ, 2012)
Region 3 = USEPA Region 3 Ecological Screening Benchmarks for Freshwater and Freshwater Sediment, published 2006. Obtained from https://www.epa.gov/risk/biological-technical-assistance-group-btag-screening-values on 4/30/2016
CCME, 2009 = Canadian Water Quality Guidelines for Protection of Aquatic Life: Boron; In: Canadian environmental quality guidelines, 2009, Canadian Council of Ministers of the Environment, Winnipeg
LANL ER Db = TRVs obtained from Los Alamos National Laboratory EcoRisk Database (LANL, 2014)
Surface Water BSL from Neptune and Company (2016)

Table 10-8 Ecological Soil Screening Levels for Plants, Invertebrates and Wildlife

	Plant Soil Screening Level (mg/kg)	Source [1]	Invert. Soil Screening Level (mg/kg)	Source [1]	Wildlife Soil Screening Level [2] (mg/kg)	Source [1]	BTV [3]
Arsenic	18	EPA EcoSSL	6.8	LANL ER Db	43	EPA EcoSSL	22.5
Barium	110	LANL ER Db	330	EPA EcoSSL	2000	EPA EcoSSL	429
Boron	36	LANL ER Db	NA	NA	2	LANL ER Db	NA
Cadmium	32	EPA EcoSSL	140	EPA EcoSSL	0.36	EPA EcoSSL	0.7
Chromium (III)	NA	NA	NA	NA	26	EPA EcoSSL	41.7
Lead	120	EPA EcoSSL	1700	EPA EcoSSL	11	EPA EcoSSL	29.8
Manganese	220	EPA EcoSSL	450	EPA EcoSSL	4000	EPA EcoSSL	880
Mercury	34	LANL ER Db	0.05	LANL ER Db	0.013	LANL ER Db	NA
Selenium	0.52	EPA EcoSSL	4.1	EPA EcoSSL	0.63	EPA EcoSSL	0.7

1 EPA EcoSSL = TRVs obtained from EPA Ecological Soil Screening Levels documents (USEPA, 2003c, 2005a-e, 2007a-b)
LANL ER Db = TRVs obtained from Los Alamos National Laboratory EcoRisk Database (LANL, 2014)
2 Wildlife Soil Screening Level represents the minimum soil screening value for birds and mammals
3 BTV = Montana Background Threshold Value from Hydrometrics (2013)

Table 10-9 NOAEL Toxicity Reference Values For Wildlife Food Chain Models

	Mammalian NOAEL TRV (mg/kg/d)	Source [1]	Avian NOAEL TRV (mg/kg/d)	Source [1]
Arsenic	1.04	EPA EcoSSL	2.24	EPA EcoSSL
Barium	51.8	EPA EcoSSL	73.5	LANL ER Db
Beryllium	0.532	LANL ER Db	NA	LANL ER Db
Boron	28	LANL ER Db	2.92	LANL ER Db
Cadmium	0.77	EPA EcoSSL	1.47	EPA EcoSSL
Chromium (III)	2.4	EPA EcoSSL	2.66	EPA EcoSSL
Copper	5.6	EPA EcoSSL	4.05	EPA EcoSSL
Lead	4.7	EPA EcoSSL	1.63	EPA EcoSSL
Manganese	51.5	EPA EcoSSL	179	EPA EcoSSL
Mercury	1.41	LANL ER Db	0.019	LANL ER Db

Nickel	1.7	EPA EcoSSL	6.71	EPA EcoSSL
Selenium	0.143	EPA EcoSSL	0.29	EPA EcoSSL
Thallium	0.0071	LANL ER Db	0.35	LANL ER Db
Vanadium	4.16	EPA EcoSSL	0.344	EPA EcoSSL
Zinc	75.4	EPA EcoSSL	66.1	EPA EcoSSL

[1] EPA EcoSSL = TRVs obtained from EPA Ecological Soil Screening Levels documents (USEPA, 2003c, 2005a-e, 2007a-b), LANL ER Db = TRVs obtained from Los Alamos National Laboratory EcoRisk Database (LANL, 2014)

Table 10-10 LOAEL Toxicity Reference Values for BERA Food Chain Modeling

	Mammalian LOAEL TRV (mg/kg/d)	Source [1]	Avian LOAEL TRV (mg/kg/d)	Source [1]
Arsenic	1.66	LANL ER Db	22.4	LANL ER Db
Barium	518	LANL ER Db	131	LANL ER Db
Beryllium	5.32	LANL ER Db	NA	NA
Boron	280	LANL ER Db	14.5	LANL ER Db
Cadmium	7.7	LANL ER Db	14.7	LANL ER Db
Chromium (III)	24	LANL ER Db	26.6	LANL ER Db
Copper	9.34	LANL ER Db	12.1	LANL ER Db
Lead	8.9	LANL ER Db	3.26	LANL ER Db
Manganese	515	LANL ER Db	1790	LANL ER Db
Mercury	14.1	LANL ER Db	0.19	LANL ER Db
Nickel	3.4	LANL ER Db	67.1	LANL ER Db
Selenium	0.215	LANL ER Db	0.579	LANL ER Db
Thallium	0.071	LANL ER Db	3.5	LANL ER Db
Vanadium	8.31	LANL ER Db	0.688	LANL ER Db
Zinc	754	LANL ER Db	661	LANL ER Db

[1] LANL ER Db = TRVs obtained from Los Alamos National Laboratory EcoRisk Database (LANL, 2014)

10.3 ECOLOGICAL RISK CHARACTERIZATION

For complete pathways, risk characterization will be performed in the final CCRA to combine the exposure and toxicity assessments to produce quantitative estimates of potential ecological risks associated with the COPCs.

Ecological risk assessments generally characterize risk based on direct toxicity of COPCs. Unlike the human health risk characterization, ecological risk characterization does not calculate carcinogenic risk directly. Ecological risk is concerned primarily with risk to populations, and the life-span of most ecological receptors is not long enough for cancer endpoints to pose population level effects.

The potential for direct toxicity of COPCs to ecological receptors will be evaluated through calculation of hazard quotients. For screening of sediment and surface water data for the protection of aquatic life, and screening of soil data for protection of plants, soil invertebrates, and wildlife, hazard quotients will be calculated as follows:

$$\boldsymbol{Hazard\ Quotient} = \frac{\boldsymbol{EPC}}{\boldsymbol{Media\ Specific\ Screening\ Level}}$$

where:

EPC = media-specific exposure concentration

In the BERA, potential risk to birds and mammals using the East Fork Armells Creek area and Plant Site soil areas will be assessed through calculation of hazard quotients based upon the average daily food chain dose to the organisms identified in Tables 10-2 and 10-3:

$$\boldsymbol{Hazard\ Quotient} = \frac{\boldsymbol{ADD}}{\boldsymbol{TRV}}$$

where:

ADD = average daily dose (mg/kg-d)
TRV = toxicity reference value (mg/kg-d)

The average daily dose is calculated as follows:

$$\boldsymbol{ADD} = \frac{\sum(\boldsymbol{C_i} * \boldsymbol{IR_i}) * \boldsymbol{AUF}}{\boldsymbol{BW}}$$

where:

ADD = average daily dose (mg/kg-d)
C_i = concentration of chemical in media “i” (mg/kg)
IR_i = organism-specific ingestion rate of media “I” (mg/kg-d)
AUF = Area Use Factor (unitless)
BW = organism body weight (kg)

10.3.1 Screening-Level Ecological Risk Characterization

*10.3.1.1 **Preliminary Screening of COPCs***

Preliminary COPCs for the East Armells Creek exposure unit and the soil areas exposure unit were determined by comparing maximum detected concentrations in sediment, surface water and soil to the ecological screening levels presented in Section 10.2. Background or reference concentrations of metals were also factored into the determination of preliminary COPCs. A site-specific background data set for soil has not been developed, therefore Background Threshold Values for Montana surface soils were used for comparison (DEQ/Hydrometrics, 2013). BSLs for surface water (Neptune and Company, 2016) were used to represent conditions in East Fork Armells Creek upstream of the Plant Site. No background data set was available for Creek sediment, so a qualitative comparison of downstream sediment concentrations was made to concentrations at upstream location AR-12. No constituents in sediment were eliminated as potential COPCs based on the comparison to location AR-12.

In East Fork Armells Creek sediment, two metals, arsenic and manganese, had maximum detected concentrations exceeding sediment screening levels. Sediment screening levels were not available for beryllium, boron, thallium, and vanadium, and maximum concentrations of each of these downstream of the Plant Site exceeded their concentrations at upstream location AR-12. Because sediment screening levels were not available for these metals, decisions on their status as COPCs in the Creek will be based on the results of the surface water screening.

Mercury was not detected in any of the 16 East Fork Armells Creek samples, nor was it detected at upstream location AR-12. Results of the initial sediment screening are shown in Table 10-11. Based on the initial screening, arsenic and manganese are the only two constituents in sediment retained as potential sediment COPCs, and are evaluated further in the screening refinement.

Preliminary ecological screening results for thirteen metals and six common cations in East Fork Armells Creek surface water are presented in Table 10-12. Two metals, boron and manganese, and two cations, calcium and magnesium, had maximum observed concentrations greater than ecological screening levels and BSLs. These four potential COPCs are retained for further evaluation in the screening refinement for surface water. The maximum concentration of vanadium in surface water exceeded the ecological screening level, but was less than the BSL for vanadium, therefore vanadium was not retained as a potential COPC. Beryllium was not detected in any of the eighteen surface water samples, but the maximum reporting limit was greater than the ecological screening. Beryllium is discussed further in the SLERA uncertainty discussion.

Sulfate, which does not have an ecological screening level, had a maximum concentration greater than the BSL. Sulfate exceeded its BSL in only one of nineteen surface water samples. The observed concentrations of sulfate, in conjunction with levels of calcium, magnesium, and total dissolved solids are indicative of the saline nature of the surface water in East Fork Armells Creek. Sulfate in particular has a laxative effect when consumed by animals, and can cause diarrhea in livestock when present in drinking water. A number of studies have evaluated the suitability of water bodies as drinking water sources based on concentrations of total dissolved solids and sulfate in the water. Information published by Montana State University (Bauder, 1998) suggests that East Fork Armells Creek surface water is marginally suitable as a drinking water source for livestock, with the possible exception of poultry (Table 10-13).

Ecological screening of metals concentrations in soil was divided into shallow depth (0 - 6 inches), and mid-depth (12 – 24 inches). All ecological receptors included in this evaluation (plants, invertebrates, birds, mammals) are considered to have potential exposure to soils in the shallow depth. Only plants, soil invertebrates, and burrowing mammals are considered to have direct contact with soils in the mid-depth horizon. The ecological screening results for shallow soils are presented in Table 10-14. Screening results for mid-depth soils are presented in Table

10-15. Soil screening levels in Table 10-15 have been adjusted to reflect only the receptor groups that have direct contact with mid-depth soils.

In the shallow soils barium, lead and selenium had maximum concentrations exceeding ecological soil screening levels and Montana surface soil BTVs. No Montana BTV was available for boron. Previous studies of boron in the western U.S. found background concentrations ranging from less than 20 mg/kg to 300 mg/kg, with an estimated arithmetic mean concentration of 29 mg/kg (Shaklette and Boerngen, 1984). Maximum concentrations of barium, lead and selenium also exceeded mean western U.S. background levels as reported by Shaklette and Boerngen (1984). Barium, boron, lead and selenium are retained for evaluation in screening refinement. Arsenic, cadmium, chromium, and manganese had maximum concentrations exceeding soil screening levels, but were less than Montana surface soil BTVs. Therefore arsenic, cadmium, chromium, and manganese are not considered soil COPCs. Mercury was not detected in any soil samples, but had maximum reporting limits greater than screening levels. Mercury is discussed further in the SLERA uncertainty discussion. In mid-depth soils boron, lead and selenium had maximum concentrations exceeding ecological soil screening levels and Montana surface soil BTVs. These three constituents are retained for evaluation in screening refinement. Arsenic, barium, cadmium, chromium and manganese had maximum concentrations exceeding soil screening levels, but less than or equal to Montana surface soil BTVs and are not considered COPCs in mid-depth soils. As in shallow soils, mercury was not detected in any mid-depth soil samples, but had maximum reporting limits greater than screening levels, and is discussed further in the SLERA uncertainty discussion.

Table 10-11 Ecological Screening of East Fork Armells Creek Sediment – Plant Site Area

Analyte	Detects / Samples	Maximum (mg/kg)	Location	Upstream Concentration (AR-12)	Ecological Screening Level (mg/kg)	Hazard Quotient	COPC?	Reason
Arsenic	16/16	12.6	AR-5	2.9	9.8	1.3	Yes	HQ > 1
Beryllium	16/16	0.37	AR-4	0.27	NA	NA	(1)	No ESL, Exceeds Upstream Conc.
Boron	16/16	19.9	AR-3	17.8	NA	NA	(1)	No ESL, Exceeds Upstream Conc.
Cadmium	9/16	0.25	AR-4	0.14	0.99	0.25	No	HQ < 1
Copper	16/16	11.7	AR-3	7.4	31.6	0.4	No	HQ < 1
Lead	16/16	12.8	AR-4	4.71	35.8	0.4	No	HQ < 1
Manganese	16/16	5910	AR-5	700	460	13	Yes	HQ > 1
Mercury	0/16	ND	NA	ND	0.18	NA	No	Not Detected
Nickel	16/16	9.4	AR-4	6.5	22.7	0.5	No	HQ < 1
Selenium	12/16	1.1	AR-5	0.3	2	0.55	No	HQ < 1
Thallium	11/16	0.35	AR-2	0.07	NA	NA	(1)	No ESL, Exceeds Upstream Conc.
Vanadium	16/16	16.8	AR-5	12	NA	NA	(1)	No ESL, Exceeds Upstream Conc.
Zinc	16/16	76.2	AR-4	127	121	0.6	No	HQ < 1

(1) No ecological screening levels are available for these constituents in sediment. Determination of COPC status for these constituents is based on results of surface water screening in Table 10-13

Table 10-12 Ecological Screening of East Fork Armells Creek Surface Water – Plant Site Area

Analyte	Detects / Samples	Maximum (ug/L)	BSL (ug/L)	Ecological Screening Level (ug/L)	HQ	COPC?	Reason
Arsenic	13/18	54	17	150	0.36	No	HQ < 1
Beryllium	0/18	<1	NA	0.66	< 1.5	Yes	Not Detected, DL > ESL
Boron	18/18	2200	880	1500	1.5	Yes	HQ > 1, Max > BSL
Cadmium	2/18	0.08	2	0.75*	0.11	No	HQ < 1
Copper	4/18	25	100	30.5*	0.82	No	HQ < 1
Lead	4/18	18	60	18.6*	0.97	No	HQ < 1
Manganese	18/18	12,000	1,600	120	100	Yes	HQ > 1, Max > BSL
Mercury	0/8	<0.1	1	0.91	< 0.1	No	HQ < 1
Nickel	12/18	28	21.7	168*	0.17	No	HQ < 1
Selenium	4/18	4	10	5	0.8	No	HQ < 1
Thallium	0/18	<0.5	NA	0.8	< 0.62	No	HQ < 1
Vanadium	2/18	50	100	20	2.5	No	Max less than BSL
Zinc	5/18	190	290	387*	0.5	No	HQ < 1
Calcium	20/20	397,000	369,000	116,000	3.4	Yes	HQ > 1, Max > BSL
Chloride	20/20	125,000	228,000	230,000	0.54	No	HQ < 1
Fluoride	20/20	400	320	7450*	0.05	No	HQ < 1
Magnesium	20/20	501,000	495,000	82,000	6.1	Yes	HQ > 1, Max > BSL [1]
Potassium	20/20	43,000	17,300	53,000	0.81	No	HQ < 1
Sodium	20/20	348,000	234,000	680,000	0.51	No	HQ < 1
Sulfate	19/19	2,800,000	2,260,000	NA	NA	Yes	No ESL. Max > BSL

* Ecological Screening Level adjusted for the maximum allowable hardness of 400 mg/L, per DEQ-7. BSL values represents the Baseline Screening Level for Surface Water from Neptune and Company, 2016.

[1] The maximum magnesium concentration differs from the BSL by 1.2%, which is within the limit of analytical reproducibility. However, in the interest of conservatism, magnesium is retained for further evaluation in the screening refinement.

Table 10-13 Evaluation of East Fork Armells Creek Water Quality for Livestock

	Total Dissolved Solids			Sulfate		
	Range (mg/L)	Mean (SD) (mg/L)	Livestock Water Quality[1]	Range (mg/L)	Mean (SD) (mg/L)	Livestock Water Quality[2]
Spring 2014	3100 - 3530	3277 (182)	Marginally safe. Satisfactory for all except poultry	1870 - 2080	1950 (92.7)	Marginal
Fall 2014	3510 - 4070	3862 (244)	Marginally safe. Satisfactory for all except poultry	1960 - 2350	2170 (160)	Marginal
Spring 2015	2450 - 2570	2507 (61.3)	Satisfactory for all	1310 - 1450	1397 (61.8)	Marginal
Fall 2015	1570 - 4540	2882 (1250)	Marginally safe. Satisfactory for all except poultry at levels over 3000 mg/L)	616 - 2800	1639 (906)	Marginal

[1] From Bauder, 1998

[2] USDA-ARS Poster, online at http://www.ars.usda.gov/SP2UserFiles/Place/30300000/Research/WATERQUALITYMKP6-09.pdf

Table 10-14 Ecological Screening of Soil Areas 1, 2, and 3 – Shallow Depth

Analyte	Detects / Samples	Maximum (mg/kg)	Ecological Soil Screening Level (mg/kg)	Background Threshold Value[1] (mg/kg)	HQ	COPC?	Reason
Arsenic	44/44	7.90	6.8	22.5	1.2	No	Max Less than BTV
Barium	44/44	1,090	110	429	9.9	Yes	HQ > 1, Max > BTV
Boron	44/44	68.2	2	NA	34	Yes	HQ > 1, No Background value
Cadmium	36/44	0.64	0.36	0.7	1.8	No	Max Less than BTV
Chromium (III)	44/44	30.8	26	41.7	1.2	No	Max Less than BTV
Lead	44/44	261	11	29.8	23.7	Yes	HQ > 1, Max > BTV
Manganese	44/44	497	220	880	2.3	No	Max Less than BTV
Mercury	0/44	<0.1	0.013	NA	< 7.7	Yes	Not detected, DL > ESL
Selenium	44/44	1.25	0.52	0.7	2.4	Yes	HQ > 1, Max > BTV

[1] Background values represent Background Threshold Values for Montana Surface Soils from DEQ/Hydrometrics, 2013.

Table 10-15 Ecological Screening of Soil Areas 1, 2, and 3 – Mid-Depth

Analyte	Detects / Samples	Maximum (mg/kg)	Minimum Soil Screening Level for Plants, Invertebrates, and Burrowing Mammals (mg/kg)	Background Threshold Value[1] (mg/kg)	HQ	COPC?	Reason
Arsenic	43/43	6.8	6.8	22.5	1.0	No	Max Less than BTV
Barium	43/43	237	110	429	2.2	No	Max Less than BTV
Boron	43/43	35.3	36	NA	0.98	Yes	HQ = 1, No Background value
Cadmium	34/43	0.71	0.36	0.7	2	No	Max = BTV
Chromium (III)	43/43	32.3	34	41.7	1.2	No	Max Less than ESL and BTV
Lead	43/43	73.9	56	29.8	1.3	Yes	HQ > 1, Max > BTV
Manganese	43/43	491	220	880	2.2	No	Max Less than BTV
Mercury	0/43	<0.1	0.05	NA	< 7.7	Yes	Not detected, DL > ESL
Selenium	43/43	1.20	0.52	0.7	2.3	Yes	HQ > 1, Max > BTV

[1] Background values represent Background Threshold Values for Montana Surface Soils from DEQ/Hydrometrics, 2013.

10.3.1.2 <u>Ecological Screening Refinement Results</u>

The refinement of the initial Plant Site ecological screening results encompasses two steps. The first step replaces the use of the maximum concentration as the EPC with the 95 UCL concentration to represent a more realistic exposure scenario for ecological receptors. The use of the 95 UCL as the EPC is a more realistic exposure scenario for receptors that move across the area, because COPC concentrations are variable spatially across the site, and in the case of surface water, temporally variable as well. Calculation of the 95 UCLs for each media is detailed in Appendix D.

The second step of the refinement process is applied to the soil data only. In the second step, maximum and 95 UCL COPC concentrations are compared to an expanded list of screening levels specific for each of the eight receptor groups used in the derivation of EPA EcoSSLs (plants, soil invertebrates, herbivorous mammals, insectivorous mammals, carnivorous mammals, herbivorous birds, insectivorous birds, carnivorous birds). This allows for a more focused evaluation of potential risk to specific receptor groups in the BERA.

Comparison of 95 UCL Exposure Point Concentrations to Ecological Screening Levels

<u>Sediment</u>
Two metals, arsenic and manganese, had maximum concentrations in East Fork Armells Creek sediment exceeding ecological screening benchmarks, and were carried forward to screening refinement. The 95 UCL concentration of arsenic across the Plant Site portion of East Fork Armells Creek was less than the arsenic screening level. The 95 UCL concentration of manganese in Creek sediment exceeded the ecological screening level. Concentrations of manganese exceeded the ecological screening level at all locations, including upstream location AR-12. Manganese is retained as a COPC in sediment for further evaluation in the BERA. Arsenic is not carried forward as a COPC to the BERA because 95 UCL concentrations are not indicative of potential risk to sediment biota. Results of the 95 UCL comparisons to sediment screening levels are presented in Table 10-16.

<u>Surface water</u>
Two metals (boron and manganese) and two common cations (calcium and magnesium) had maximum concentrations in surface water exceeding their respective screening benchmarks. The 95 UCL for boron across the Plant Site portion of East Armells Creek was less than the ecological screening level for boron in surface water. The 95 UCL concentrations of manganese, calcium, and magnesium exceeded their respective surface water screening levels. Results of the surface water screening refinement are presented in Table 10-17. Manganese is retained as a COPC for further evaluation in the BERA because 95 UCL concentrations indicate that potential risk exists to aquatic receptors. Boron is not carried forward to the BERA as a COPC, as 95 UCL concentrations are not indicative of potential risk to aquatic biota. Calcium and magnesium elevated due to chemistry of the water, not indicative of toxicity, but negates classification as fresh water. Calcium and magnesium will be discussed further in the uncertainty discussion of the BERA. Although their concentrations exceed freshwater screening levels, the elevated nature of these constituents, as well as high levels of total dissolved solids, water hardness, and concentrations of other cations such as sodium and potassium, suggest that East Fork Armells

Creek does not meet the definition of a fresh water body. As previously noted, concentrations of TDS and common cations are elevated across the creek, including upstream location AR-12, and are likely the result of regional mining activities.

Soil

Four metals, barium, boron, lead, and selenium, were carried forward to screening refinement from the initial screening step because maximum concentrations in surface soil exceeded. The 95 UCL concentrations of all four of these metals exceeded the minimum ecological screening levels (Table 10-18). Barium, boron, lead and selenium are evaluated further in the expanded soil screening to determine which receptors are at potential risk from these constituents in surface soil, and to focus the BERA evaluation.

In addition, boron, cadmium, lead and selenium were retained for screening refinement in mid-depth soils (12 – 24" bgs). The comparison to 95 UCLs (Table 10-19) shows that 95 UCL concentrations of selenium exceed the surface soil screening level for selenium, while 95 UCL concentrations of boron, cadmium, and lead were below their respective screening benchmarks. As stated in Section 10.4.1, soil screening levels for the mid-depth soils were limited to receptors that may have direct contact with mid-depth soils, specifically plants, soil invertebrates, and burrowing mammals (insectivorous or herbivorous). Selenium is evaluated further in the expanded soil screening to determine which receptors are at potential risk from this constituent in mid-depth soil, and to focus the BERA evaluation to those receptors.

Table 10-16 Comparison of 95 UCLs to Sediment Screening Levels

Analyte	Detects / Samples	95 UCL (mg/kg)	Upstream Concentration (AR-12)	Ecological Screening Level (mg/kg)	Hazard Quotient	COPC?
Arsenic	16/16	5.58	2.9	9.8	0.57	No, HQ < 1
Manganese	16/16	2667	700	460	5.8	Yes, HQ > 1

Table 10-17 Comparison of 95 UCLs to Surface Water Screening Levels

Analyte	Detects / Samples	95 UCL (ug/L)	BSL	Ecological Screening Level (ug/L)	HQ	Reason
Boron	15/15	1,284	880	1500	0.86	No, HQ < 1
Manganese	15/15	3,740	1,600	120	31	HQ > 1
Calcium	17/17	312,000	369,000	116,000	2.7	HQ > 1
Magnesium	17/17	373,000	495,000	82,000	4.5	HQ > 1

Table 10-18 Comparison of 95 UCLs to Soil Screening Levels – Shallow Only

Analyte	Detects / Samples	95 UCL (mg/kg)	Minimum Ecological Soil Screening Level (mg/kg)	Hazard Quotient	Surface Soil (0-6” bgs) COPC?
Barium	44/44	279	110	2.5	Yes, HQ > 1
Boron	44/44	17.1	2	8.6	Yes, HQ > 1
Lead	44/44	43.7	11	4.0	Yes, HQ > 1
Selenium	44/44	0.58	0.52	1.1	Yes, HQ > 1

Table 10-19 Comparison of 95 UCLs to Soil Screening Levels – Mid-depth Only

Analyte	Detects / Samples	95 UCL (mg/kg)	Minimum Ecological Soil Screening Level plants, inverts, burrowing mammals (mg/kg)	Hazard Quotient	Subsurface Soil (12 – 24” bgs) COPC?
Boron	43/43	13.8	36	0.38	No, HQ < 1
Cadmium	43/43	0.304	0.36	0.84	No, HQ < 1
Lead	43/43	21.1	56	0.38	No, HQ < 1
Selenium	43/43	0.63	0.52	1.2	Yes, HQ > 1

Expanded Screening of Soil COPCs

In deriving ecological soil screening levels for metals, both USEPA (2003c) and LANL (2014) modeled doses to multiple trophic levels and feeding guilds, and then selected the most sensitive trophic receptor as the basis for the soil screening level. The receptor group/trophic levels evaluated include plants, invertebrates, herbivorous mammals, herbivorous birds, insectivorous mammals, insectivorous birds, carnivorous mammals, and carnivorous birds. To assist in focusing the BERA to those receptors most at potential risk, the expanded screening compares the ecological screening levels for all eight receptor categories to the 95 UCL concentrations in soil. The expanded screening for barium, boron, lead, and selenium in surface soil are shown in Tables 10-20 through 10-23, respectively. The expanded screening for selenium in mid-depth soil is presented in Table 10-24. The expanded screening shows that 95 UCL concentrations of barium in surface soil exceed only NOAEL-based screening levels for plants. 95 UCL concentrations of boron in surface soil exceed NOAEL screening levels for herbivorous birds and insectivorous birds. 95 UCL lead concentrations in surface soil exceed NOAEL screening levels for insectivorous birds, and 95 UCL selenium concentrations in surface soil exceed screening levels for plants and insectivorous mammals. In mid-depth soil, 95 UCL concentrations of selenium exceed NOAEL screening benchmarks for plants and insectivorous mammals. The list of COPCs and the associated endpoints retained for evaluation in the BERA are summarized in Table 10-25.

Table 10-20 Expanded Screening of Barium in Shallow Soil (0 – 6")

Screening-level Receptor	Ecological Soil Screening Level (mg/kg)	Maximum Concentration in Surface Soil (mg/kg)	Number of Detects in Surface Soil Exceeding Eco-SSL	95 UCL Concentration in Surface Soil (mg/kg)	Does 95 UCL Concentration in Surface Soil Exceed Soil Screening Level?
Plants	110	1090	43	279	Yes
Soil Invertebrates	330	1090	4	279	No
Herbivorous Birds	NA	1090	NA	279	NA
Insectivorous Birds	NA	1090	NA	279	NA
Carnivorous Birds	NA	1090	NA	279	NA
Herbivorous Mammals	3200	1090	0	279	No
Insectivorous Mammal	2000	1090	0	279	No
Carnivorous Mammals	9100	1090	0	279	No

Table 10-21 Expanded Screening of Boron in Shallow Soil (0 – 6")

Screening-level Receptor	Ecological Soil Screening Level (mg/kg)	Maximum Concentration in Surface Soil (mg/kg)	Number of Detects in Surface Soil Exceeding Eco-SSL	95 UCL Concentration in Surface Soil (mg/kg)	Does 95 UCL Concentration in Surface Soil Exceed Soil Screening Level?
Plants	36	68.2	2	17.1	No
Soil Invertebrates	NA	68.2	NA	17.1	NA
Herbivorous Birds	2	68.2	44	17.1	Yes
Insectivorous Birds	7.5	68.2	39	17.1	Yes
Carnivorous Birds	43	68.2	1	17.1	NA
Herbivorous Mammals	68	68.2	1	17.1	No
Insectivorous Mammal	120	68.2	0	17.1	No
Carnivorous Mammals	21,000	68.2	0	17.1	No

Table 10-22 Expanded Screening of Lead in Shallow Soil (0 – 6")

Screening-level Receptor	Ecological Soil Screening Level (mg/kg)	Maximum Concentration in Surface Soil (mg/kg)	Number of Detects in Surface Soil Exceeding Eco-SSL	95 UCL Concentration in Surface Soil (mg/kg)	Does 95 UCL Concentration in Surface Soil Exceed Soil Screening Level?
Plants	120	261	2	43.7	No
Soil Invertebrates	1,700	261	0	43.7	No
Herbivorous Birds	46	261	3	43.7	No
Insectivorous Birds	11	261	44	43.7	Yes
Carnivorous Birds	510	261	0	43.7	No
Herbivorous Mammals	1,200	261	0	43.7	No
Insectivorous Mammal	56	261	2	43.7	No
Carnivorous Mammals	460	261	0	43.7	No

Table 10-23 Expanded Screening of Selenium in Shallow Soil (0 – 6")

Screening-level Receptor	Ecological Soil Screening Level (mg/kg)	Maximum Concentration in Surface Soil (mg/kg)	Number of Detects in Surface Soil Exceeding Eco-SSL	95 UCL Concentration in Surface Soil (mg/kg)	Does 95 UCL Concentration in Surface Soil Exceed Soil Screening Level?
Plants	0.52	1.25	12	0.58	Yes
Soil Invertebrates	4.1	1.25	0	0.58	No
Herbivorous Birds	2.2	1.25	0	0.58	No
Insectivorous Birds	1.2	1.25	1	0.58	No
Carnivorous Birds	83	1.25	0	0.58	No
Herbivorous Mammals	2.7	1.25	0	0.58	No
Insectivorous Mammal	0.63	1.25	7	0.58	No
Carnivorous Mammals	2.8	1.25	0	0.58	No

Table 10-24 Expanded Screening of Selenium in Mid-depth Soil (12 – 24")

Screening-level Receptor	Ecological Soil Screening Level (mg/kg)	Maximum Concentration in Mid-depth Soil (mg/kg)	Number of Detects in Mid-depth Soil Exceeding Eco-SSL	95%UCL Concentration in Mid-depth Soil (mg/kg)	Does 95 UCL Concentration in Mid-depth Soil Exceed Soil Screening Level?
Plants	0.52	1.2	20	0.63	Yes
Soil Invertebrates	4.1	1.2	0	0.63	No
Herbivorous Birds	2.2	1.2	0	0.63	No
Insectivorous Birds	1.2	1.2	1	0.63	No
Carnivorous Birds	83	1.2	0	0.63	No
Herbivorous Mammals	2.7	1.2	0	0.63	No
Insectivorous Mammal	0.63	1.2	13	0.63	Yes
Carnivorous Mammals	2.8	1.2	0	0.63	No

Table 10-25 COPCs and Endpoints for Evaluation in the BERA

	Aquatic Life	Omnivorous Mammals	Piscivorous Birds	Herbivorous Birds	Insectivorous Birds	Carnivorous Birds	Herbivorous Mammals	Insectivorous Mammals	Carnivorous Mammals	Plants	Soil Invertebrates
Sediment and Surface Water											
Manganese	X	X	X		X						
Surface Soil											
Barium										X	
Boron				X	X						
Lead					X						
Selenium										X	
Mid-depth Soil											
Selenium								X		X	

10.3.2 Baseline Ecological Risk Characterization

Based on the results of the SLERA and COPC refinement steps, manganese is carried forward to the BERA for further evaluation in East Fork Armells Creek sediment and surface water, and barium, boron, lead, and selenium are retained for further evaluation in Plant Site soils. Specific ecological receptor groups evaluated for each chemical in each media are summarized in Table 10-25. As discussed in Section 10.1.2, Assessment Endpoints, Measures of Effect, and Exposure Pathways, the BERA risk characterization involves calculation of average daily doses of COPCs to wildlife potentially exposed to Creek sediment and surface water, and Plant Site soils. The BERA risk characterization also includes consideration of LOAEL toxicity levels in addition to NOAEL levels. LOAEL-based aquatic life criteria for manganese were derived by LANL in the EcoRisk Database (LANL, 2014). BERA risk characterization for aquatic organisms in East Fork Armells Creek will be based on the LOAEL thresholds of 2,300 micrograms per liter (ug/L) for surface water, and 1,100 mg/kg for sediment. Risk characterization to wildlife utilizing the creek will be based on the average daily doses of manganese to piscivorous birds, insectivorous birds, and omnivorous mammals, as shown in Tables 10-26 to 10-28, respectively.

Risk characterization for plants exposed to barium and selenium in soil will be based on the LOAEL toxicity values of 260 mg/kg for barium, and 3.0 mg/kg for selenium (LANL, 2014). Risk characterization for potentially at-risk wildlife exposed to boron, lead, and selenium in soil will be based on the calculated average daily doses presented in Tables 10-29 through 10-32 for insectivorous birds, herbivorous mammals, and insectivorous mammals, respectively.

10.3.3 Evaluation of Uncertainties

Uncertainties associated with Risk Characterization will be identified within the BERA. Uncertainties in the risk characterization will originate from a cumulative effect of the uncertainties in the Exposure Assessment, the Toxicity Assessment, and the Characterization of Risk, including lack of toxicity information for certain chemicals, uncertainties in exposure parameters, including site use, and uncertainties associated with deriving exposure point concentrations for specific chemicals and organisms given the spatial and temporal variability observed in the data. Depending on the results of the BERA, additional studies may be conducted to reduce uncertainties associated with the risk assessment. Additional studies could include assessments of aquatic life in the Creek or vegetation assessment of surrounding soil areas.

Table 10-26 Food Chain Model Dose Calculations for Great Blue Heron as Surrogate for Piscivorous Birds

	Analyte	95 UCL Sediment Conc. (mg/kg dw)	95 UCL Water Conc (mg/L), unfiltered	Modeled Fish Conc (mg/kg dry wt)	Fish Ingestion Rate (kg/d)	Sediment Ingestion Rate (kg/d)	Water Ingestion Rate (L/d)	Body Weight (kg)	AUF	Average Daily Dose (mg/kg-d)	NOAEL TRV (mg/kg-d)	LOAEL TRV (mg/kg-d)
Whole Creek	Manganese	2667	3.74	11220	0.105	0.0021	0.105	2.336	1	507	179	1790
AR-5	Manganese	5214	10.1	30300	0.105	0.0021	0.105	2.336	1	1370	179	1790
AR-4	Manganese	924.5	0.43	1290	0.105	0.0021	0.105	2.336	1	58.8	179	1790
AR-3	Manganese	2876	2.88	8640	0.105	0.0021	0.105	2.336	1	391	179	1790
AR-2SF	Manganese	3586	1.99	5970	0.105	0.0021	0.105	2.336	1	272	179	1790

Table 10-27 Food Chain Model Dose Calculations for Common Yellowthroat as Surrogate for Insectivorous Birds

	Analyte	95 UCL Sediment Conc. (mg/kg dw)	95 UCL Water Conc. (mg/L), total	Modeled Invertebrate Conc (mg/kg dw)	Invertebrate Ingestion Rate (kg/d)	Sediment Ingestion Rate (kg/d)	Water Ingestion Rate (L/d)	Body Weight (kg)	AUF	Average Daily Dose (mg/kg-d)	NOAEL TRV (mg/kg-d)	LOAEL TRV (mg/kg-d)
Whole Creek	Manganese	2667	3.74	161.3535	0.0033	0.000066	0.0028	0.01	1	71	179	1790
AR-5	Manganese	5214	10.1	315.447	0.0033	0.000066	0.0028	0.01	1	141	179	1790
AR-4	Manganese	924.5	0.43	55.93225	0.0033	0.000066	0.0028	0.01	1	24.7	179	1790
AR-3	Manganese	2876	2.88	173.998	0.0033	0.000066	0.0028	0.01	1	77.2	179	1790
AR-2SF	Manganese	3586	1.99	216.953	0.0033	0.000066	0.0028	0.01	1	95.8	179	1790

Table 10-28 Food Chain Model Dose Calculations for Raccoon as Surrogate for Omnivorous Mammals

	Analyte	95 UCL Sediment Conc. (mg/kg dw)	95 UCL Water Conc (mg/L), total	Modeled Plant Conc (mg/kg dry wt)	Modeled Invertebrate Conc (mg/kg dry wt)	Modeled Fish Conc (mg/kg dry wt)	Plant Ingestion Rate (kg/d)	Invert. Ingestion Rate (kg/d)	Fish Ingestion Rate (kg/d)	Sediment Ingestion Rate (kg/d)	Water Ingestion Rate (L/d)	Body Weight (kg)	AUF
Whole Creek	Manganese	2667	3.74	400	161.4	11220	0.12	0.15	0.03	0.03	0.5	6	1

Table 10-28 (continued)

		Average Daily Dose (mg/kg-d)	NOAEL TRV (mg/kg-d)	LOAEL TRV (mg/kg-d)
Whole Creek	Manganese	81.8	51.5	515

Table 10-29 Food Chain Model Dose Calculations for Sprague's Pipit as Surrogate for Insectivorous Birds

Analyte	95 UCL Soil Conc. (mg/kg dw)	95 UCL Water Conc. (mg/L), total	Modeled Invertebrate Conc (mg/kg dw)	Invertebrate Ingestion Rate (kg/d)	Soil Ingestion Rate (kg/d)	Water Ingestion Rate (L/d)	Body Weight (kg)	AUF	Average Daily Dose (mg/kg-d)	NOAEL TRV (mg/kg-d)	LOAEL TRV (mg/kg-d)
Boron	17.1	1.284	17.1	0.00588	0.00012	0.005	0.02375	1	4.59	2.92	14.5
Lead	43.7	0.018	16.9	0.00588	0.00012	0.005	0.02375	1	4.42	1.62	3.26

Table 10-30 Food Chain Model Dose Calculations form Lark Sparrow as Surrogate for Herbivorous Birds

Analyte	95 UCL Soil Concentration (mg/kg dw)	95 UCL Water Concentration (mg/L), total	Modeled Plant Conc (mg/kg dry wt)	Modeled Invert Conc (mg/kg dry wt)	Plant Ingestion Rate (kg/d)	Invert. Ingestion Rate (kg/d)	Soil Ingestion Rate (kg/d)	Water Ingestion Rate (L/d)	Body Weight (kg)	AUF	Average Daily Dose (mg/kg-d)	NOAEL TRV (mg/kg-d)	LOAEL TRV (mg/kg-d)
Boron	17.1	1.284	68.4	17.1	0.005205	0.001735	0.00014	0.005	0.0289	1	13.65	2.92	14.5

Table 10-31 Food Chain Model Dose Calculations for Ord's Kangaroo Rat as Surrogate for Herbivorous Mammals

Analyte	95 UCL Water Concentration (mg/L), total	95 UCL Soil Concentration (mg/kg dw)	Modeled Plant Conc (mg/kg dry wt)	Plant Ingestion Rate (kg/d)	Soil Ingestion Rate (kg/d)	Water Ingestion Rate (L/d)	Body Weight (kg)	AUF	Average Daily Dose (mg/kg-d)	NOAEL TRV (mg/kg-d)	LOAEL TRV (mg/kg-d)
Selenium	0.004	0.63	0.305	0.013	0.0013	0.0005	0.052	1	0.092	0.143	0.215

Table 10-32 Food Chain Model Dose Calculations for Masked Shrew as Surrogate for Insectivorous Mammals

Analyte	95 UCL Water Concentration (mg/L), total	95 UCL Soil Concentration (mg/kg dw)	Modeled Invertebrate Conc (mg/kg dw)	Invertebrate Ingestion Rate (kg/d)	Soil Ingestion Rate (kg/d)	Water Ingestion Rate (L/d)	Body Weight (kg)	AUF	Average Daily Dose (mg/kg-d)	NOAEL TRV (mg/kg-d)	LOAEL TRV (mg/kg-d)
Selenium	0.004	0.63	0.661217801	0.00325	0.000325	0.0005	0.004	1	0.589	0.143	0.215

11.0 FATE AND TRANSPORT ANALYSIS

The AOC (Article VI.B) requires the CCRA Report to identify transport mechanisms for the COIs (COPCs). In Section 4.2 Chemical Releases and Transport Mechanisms, various transport mechanisms were discussed that largely consisted of the following:

- Seepage losses from the process ponds that are presently mitigated by an extensive capture well system. Comprehensive groundwater sampling is conducted regularly to evaluate groundwater quality trends and evaluate the effectiveness of the capture well system. Groundwater analytical results are compared to the BSLs as part of this evaluation. The groundwater BSLs are not clean-up levels, but are used as one criteria for evaluating capture well or monitoring well data when baseline specific data are not available.

- Historical surface releases to soil (pipeline releases and subsequent remediation).

If fate and transport modeling is necessary, DEQ (2008) divides potential site data needs into the following four categories based on characteristics of the contaminated site and the identified COPCs:

1. Soil characteristics
2. Hydrogeological characteristics
3. Source characteristics, and
4. Chemical biodegradation.

Based on the identified COPCs, fate and transport modeling does not appear to be necessary for the uncontrolled access area of the Plant Site.

A fate and transport analysis of COPCs potentially leaching through the soil column was performed through the comparison of soil chemicals (i.e., metals) to the USEPA SSLs for Groundwater Protection (USEPA, 2016) that were modified following the DEQ Soil Screening Process (DEQ, 2016). Leaching COPCs were not identified through this analysis (see Section 9.3).

12.0 CALCULATION OF SITE-SPECIFIC CLEANUP LEVELS

This section describes the process for developing Site-Specific Cleanup Levels (SSCLs), which will follow five steps:

1. Calculate Acceptable Human Health SSCLs
2. Calculate Acceptable Ecological SSCLs
3. Calculate EU-specific Soil Screening Levels for Leaching to Groundwater
4. Identify the Appropriate Background Concentrations
5. Compare the Concentrations Calculated and Identified in the First Four Steps to Determine Final SSCLs

The methods to be used to calculate the SSCLs are described in the sections below.

12.1 HUMAN HEALTH SSCLS

If necessary, human health SSCLs will be calculated by adjusting the risk equations used in the HHRA (see Sections 6.0 and 8.0) with the incorporation of acceptable target risks and target hazard indices.

Carcinogenic COPCs were not identified for the Plant Site. If present, SSCLs for carcinogenic COPCs would be developed by dividing the DEQ acceptable cumulative cancer risk of 1×10^{-5} by the number of COPCs to establish a target risk (DEQ, 2016). The target risk can then be used to calculate SSCLs for the COPC carcinogens.

One non-carcinogenic COPC was identified for the Plant Site. Consequently, a SSCL for this one COPC can be calculated using the USEPA and DEQ acceptable target hazard index of 1.0. If more than one non-carcinogenic COPC were identified, the acceptable target hazard index of 1.0 would be divided by the number of non-cancer COPCs with same target organ or critical effect to establish target hazard indices (DEQ, 2016). The target hazard indices would then be used to calculate SSCLs for the non-carcinogenic COPCs.

12.2 ECOLOGICAL SSCLS

In the event that unacceptable risk to individual specific ecological receptors is determined, risk-based clean-up levels for ecological receptors will be derived for each assessment endpoint determined to be at risk. For the site-specific food chain receptors, soil and sediment remediation goals are set by back-calculating the soil or sediment concentration that through bioaccumulation and ingestion result in doses to the organism that are equal to the LOAEL TRVs. The area of contamination exceeding the remedial goals can then be evaluated spatially to determine the likelihood that population-level risk is expected. Because site-specific toxicity testing has not been conducted on site soil, sediment, or water, preliminary remedial goals for plants and invertebrates exposed to these media will be set based on the range of literature LOAEL values appropriate for plants and invertebrates present at the site. These preliminary remedial goals may be modified during any remedial planning phase by conducting site-specific toxicity testing to establish dose-response relationships for site plants and invertebrates. In the event that site-specific toxicity testing is needed, the remediation goal will be established as a specified percentile of the dose-response curve (e.g., EC20, the concentration causing adverse effect to 20% of test organisms) in agreement with DEQ and stakeholders.

12.3 LEACHING TO GROUDWATER SSCLS

To develop leaching to groundwater SSCLs, a decision process is available that typically involves the following:

- The USEPA Synthetic Precipitation Leaching Procedure (SPLP; SW-846 Method 1312) results, which quantify the site-specific mobility and partitioning of metals in site soils.

- Site-specific Dilution Attenuation Factor (DAFs) or the DEQ default DAF of 10 are used and the SPLP results were developed for the leaching-to-groundwater SSCLs for each EU (DEQ, 2016).

- Site-specific partition coefficient (K_d) values.

However, leaching COPCs were not identified for the uncontrolled access area of the Plant Site and, therefore, leaching to groundwater SSCLs will not be calculated.

12.4 IDENTIFICATION OF APPROPRIATE BACKGROUND CONCENTRATIONS

SSCLs will not be developed at concentrations that are more stringent that background concentrations per the AOC (DEQ/PPLM, 2012). Appropriate background concentrations will be identified for comparison to the SSCLs. Numerous background concentrations have been identified, which are discussed in Section 5.1.3 and presented in Tables B-2.1 through B-2.6 (RAGS Part D Table 2) located in Appendix B. Appropriate background concentrations will be further refined, as necessary.

12.5 DETERMINE FINAL SSCLS

If necessary, the calculated SSCLs will be compared to the appropriate background concentrations to identify the final SSCLs.

13.0 RAGS PART D TABLES

Following DEQ guidance (2016), USEPA RAGS PART D Tables 1-6 were prepared as part of this CCRA Work Plan and are presented in Appendix B.

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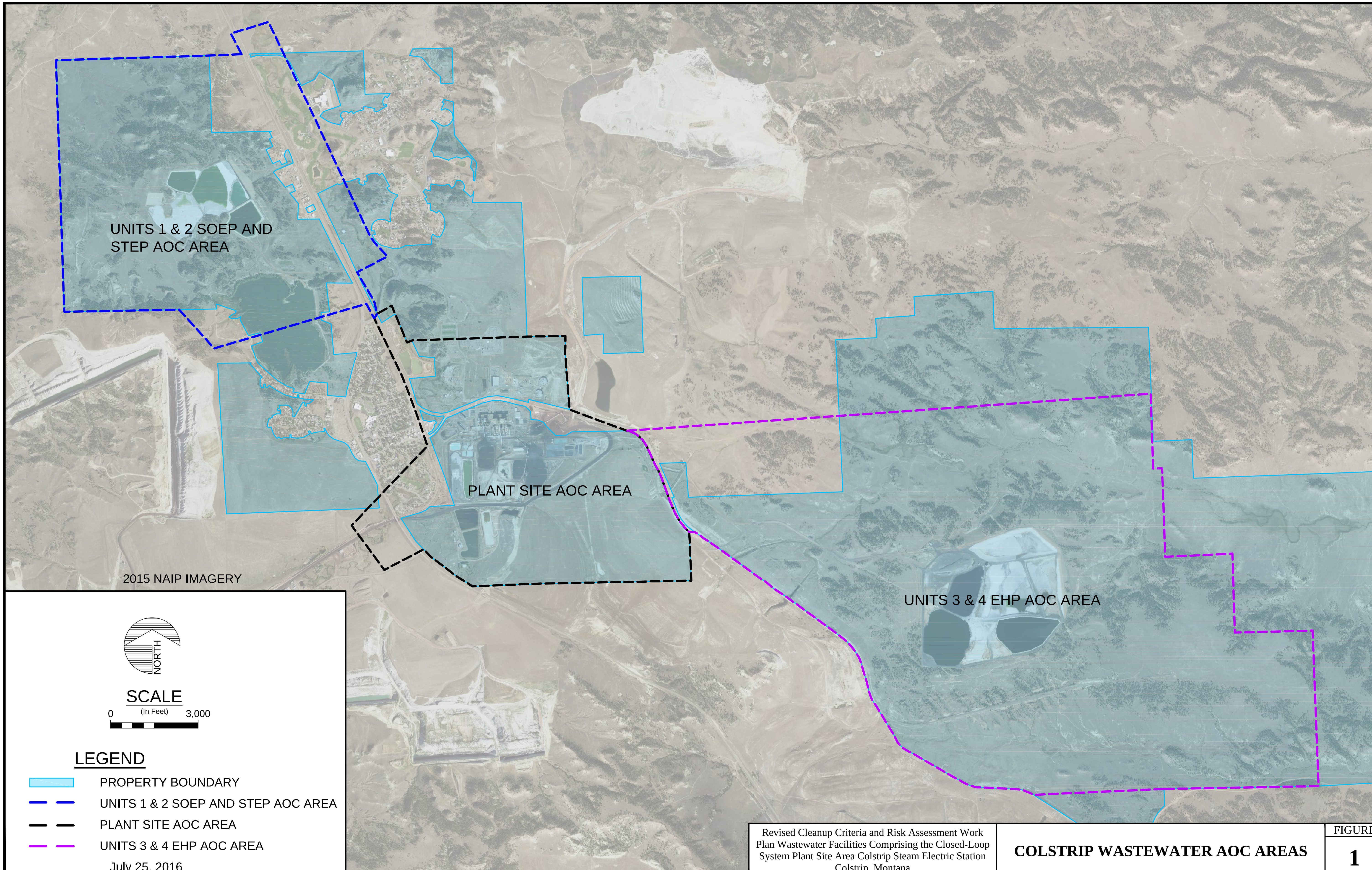
FIGURES



Revised Cleanup Criteria and Risk Assessment Work Plan Wastewater Facilities Comprising the Closed-Loop System Plant Site Area Colstrip Steam Electric Station Colstrip, Montana

COLSTRIP WASTEWATER AOC AREAS

FIGURE

1

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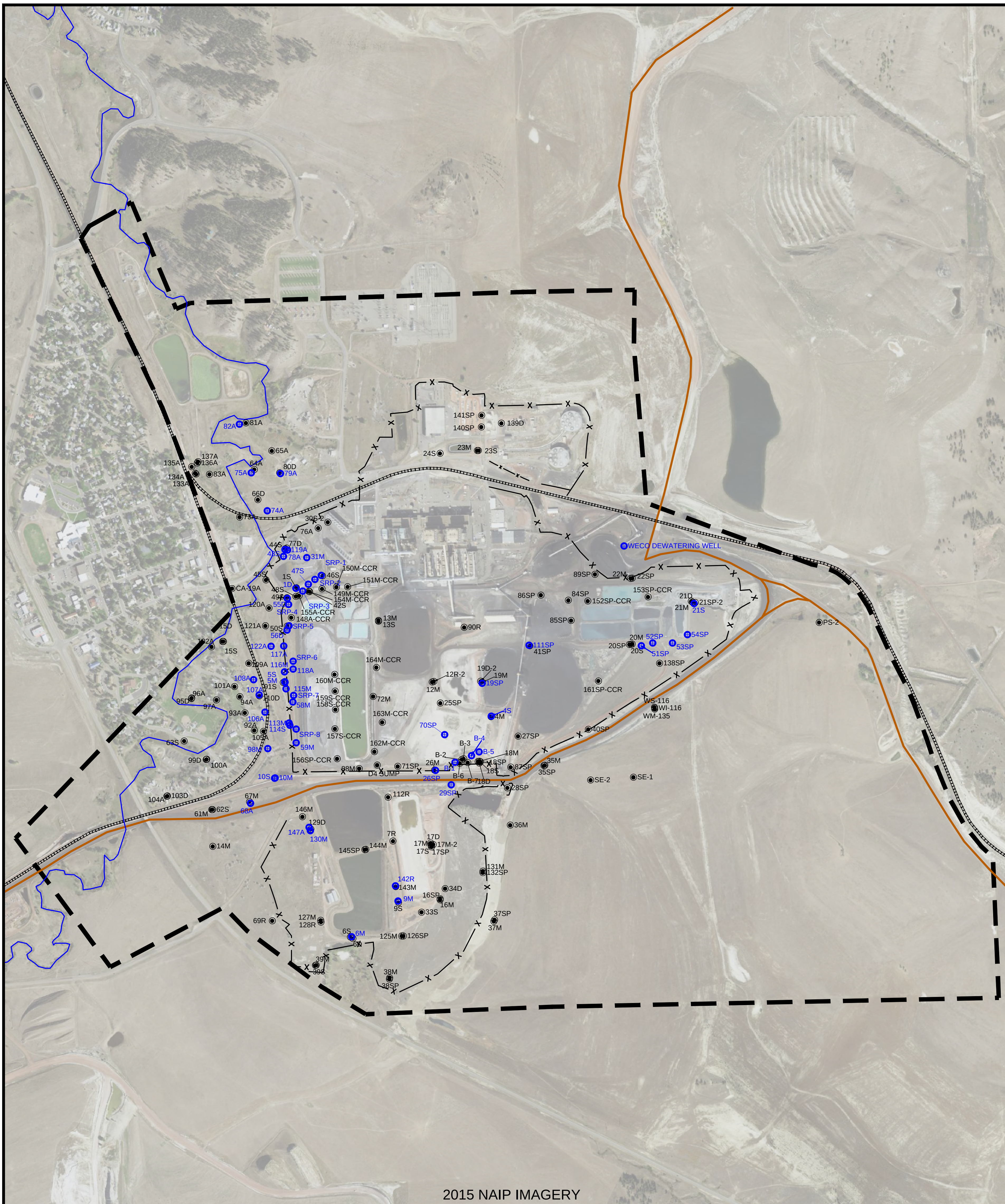

LEGEND

ROSEBUD MINE HAUL ROAD (RESTRICTED ACCESS)

RAIL ROAD

FENCELINE

PLANT SITE AOC BOUNDARY

EAST FORK ARMELLS CREEK

NORTH

SCALE

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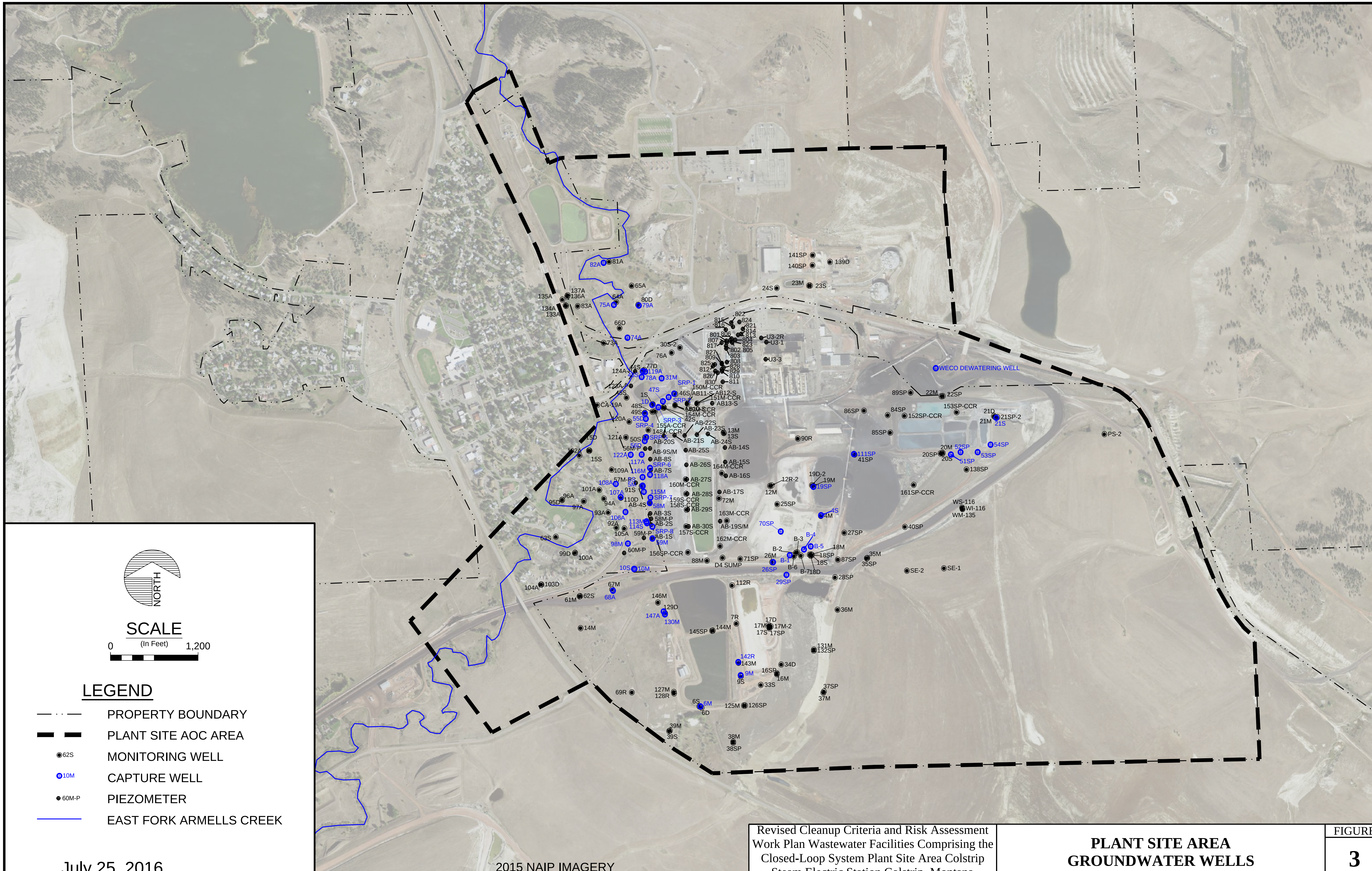
Revised Cleanup Criteria and Risk Assessment Work Plan Wastewater Facilities Comprising the Closed-Loop System Plant Site Area Colstrip Steam Electric Station Colstrip, Montana	PLANT SITE AREA AND FENCELINE	FIGURE 2



Revised Cleanup Criteria and Risk Assessment Work Plan Wastewater Facilities Comprising the Closed-Loop System Plant Site Area Colstrip Steam Electric Station Colstrip, Montana

PLANT SITE AREA GROUNDWATER WELLS

FIGURE 3

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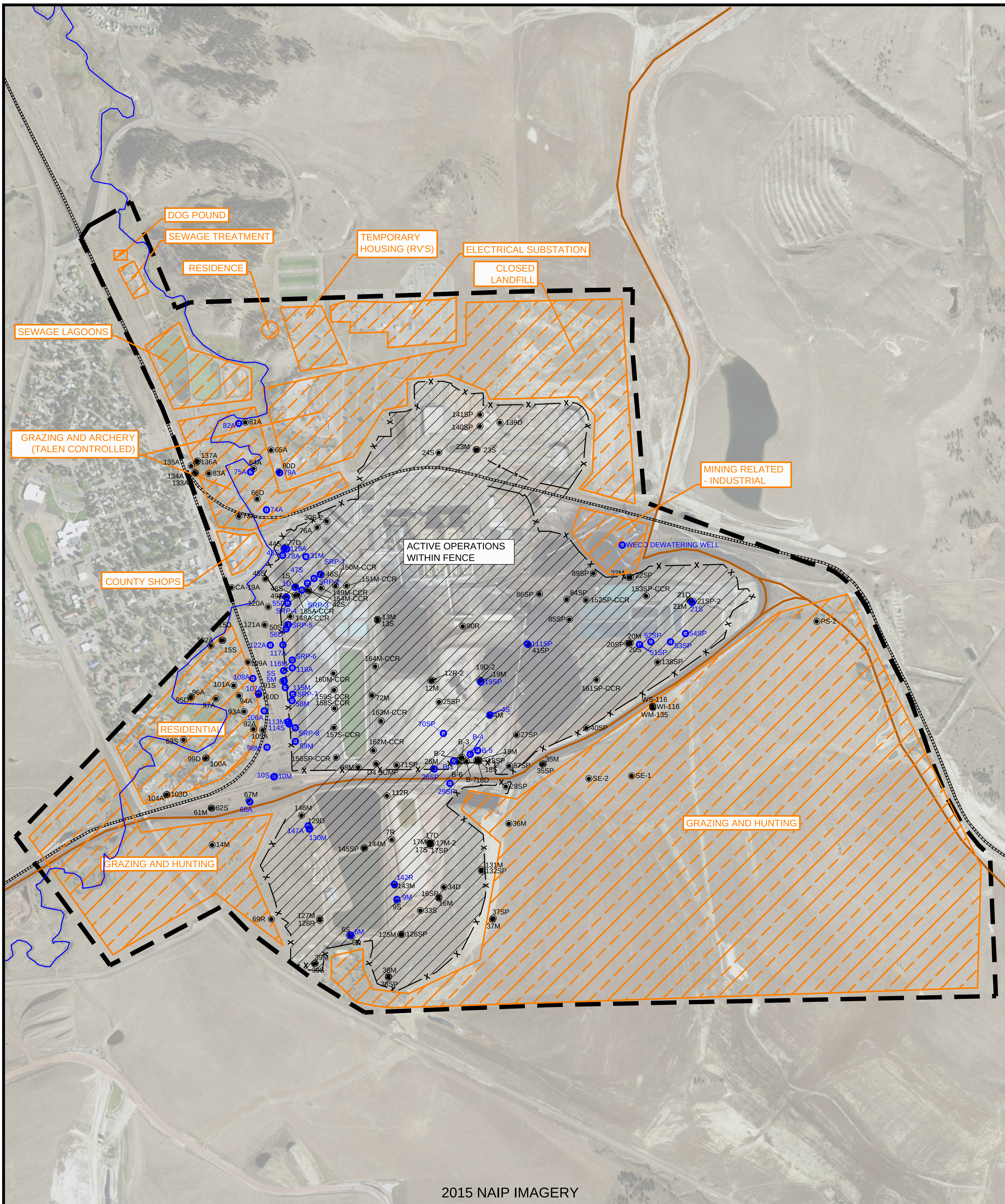

LEGEND

ROSEBUD MINE HAUL ROAD (RESTRICTED ACCESS)

RAIL ROAD

FENCELINE (ACTIVE OPERATIONS WITHIN FENCE)

PLANT SITE AOC BOUNDARY

EAST FORK ARMELLS CREEK

ACTIVE OPERATIONS WITHIN FENCE

OTHER AREAS

NORTH

SCALE
0 (In Feet) 1200

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July 25, 2016	Revised Cleanup Criteria and Risk Assessment Work Plan Wastewater Facilities Comprising the Closed-Loop System Plant Site Area Colstrip Steam Electric Station Colstrip, Montana	PLANT SITE AREA AND CURRENT LAND USE	FIGURE 4

Primary Source	Primary Release Mechanism	Secondary Source	Secondary Release Mechanism	Media	Exposure Pathway	Current and Future Residents (Adult and Child)	Current and Future Industrial Outdoor Workers	Current and Future Construction Worker	Current and Future Recreational User	Terrestrial Ecological	Aquatic Ecological
						Current/Future Land Use					
						Human Receptors				Ecological Receptors	
Water Based Liquid	Pipeline	Surface Soil	None	Surface Soil	Ingestion	O (1)	•	•	•	•	O
					Dermal	O (1)	•	•	•	•	O
			Migration	East Fork Armells Creek Sediments	Ingestion	O (1)	•	•	•	•	•
					Dermal	O (1)	•	•	•	•	•
				East Fork Armells Creek Surface Water	Ingestion	O (1)	~	~	~	•	~
					Dermal	O (1)	~	~	~	†	~
			Wind	Outdoor Air (Particulates)	Inhalation	O (1)	•	•	•	†	O
	Pond Seepage	Groundwater	None	Groundwater	Ingestion	~	O	~	O	O	O
					Dermal	~	O	~	O	O	O
			Migration	East Fork Armells Creek Sediments	Ingestion	•	•	•	•	•	•
					Dermal	•	•	•	•	†	•
				East Fork Armells Creek Surface Water	Ingestion	~	~	~	~	•	~
					Dermal	~	~	~	~	†	~
Background Geology	Leaching	Groundwater	None	Groundwater	Ingestion	~	O	~	O	O	O
					Dermal	~	O	~	O	O	O
			Migration	East Fork Armells Creek Sediments	Ingestion	•	•	•	•	•	•
					Dermal	•	•	•	•	†	•
				East Fork Armells Creek Surface Water	Ingestion	~	~	~	~	†	~
					Dermal	~	~	~	~	†	~

Notes:
- • Potentially complete exposure pathway; evaluated quantitatively
- ~ Potentially complete exposure pathway; evaluated qualitatively by comparison to DEQ-7
- † Minor pathway, not quantitatively evaluated
- O Incomplete exposure pathway
- (1) Spill areas not located in a residential area

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Revised Cleanup Criteria and Risk Assessment Work Plan Wastewater Facilities Comprising the Closed-Loop System Plant Site Area Colstrip Steam Electric Station Colstrip, Montana

PRELIMINARY SITE CONCEPTUAL EXPOSURE MODEL

FIGURE 5

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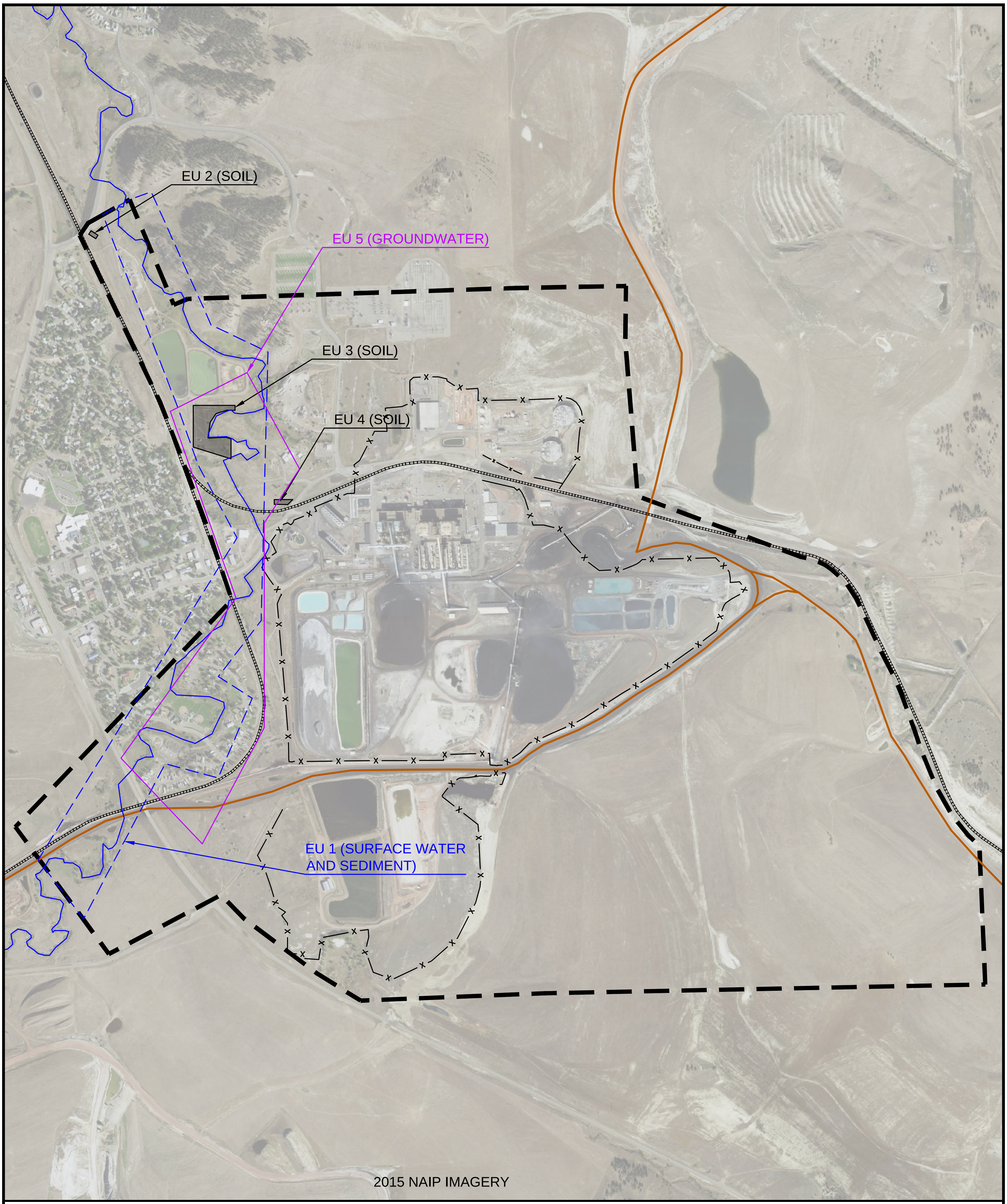

LEGEND

ROSEBUD MINE HAUL ROAD (RESTRICTED ACCESS)	PLANT SITE AOC BOUNDARY
RAILROAD	EAST FORK ARMELLS CREEK
—x— FENCE (CHAIN-LINK WITH BARBED WIRE TOP)	EU EXPOSURE UNIT

NORTH

SCALE

0 (In Feet) 1200

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Revised Cleanup Criteria and Risk Assessment Work Plan Wastewater Facilities Comprising the Closed-Loop System Plant Site Area Colstrip Steam Electric Station Colstrip, Montana	**PLANT SITE EXPOSURE UNITS**	FIGURE **6**

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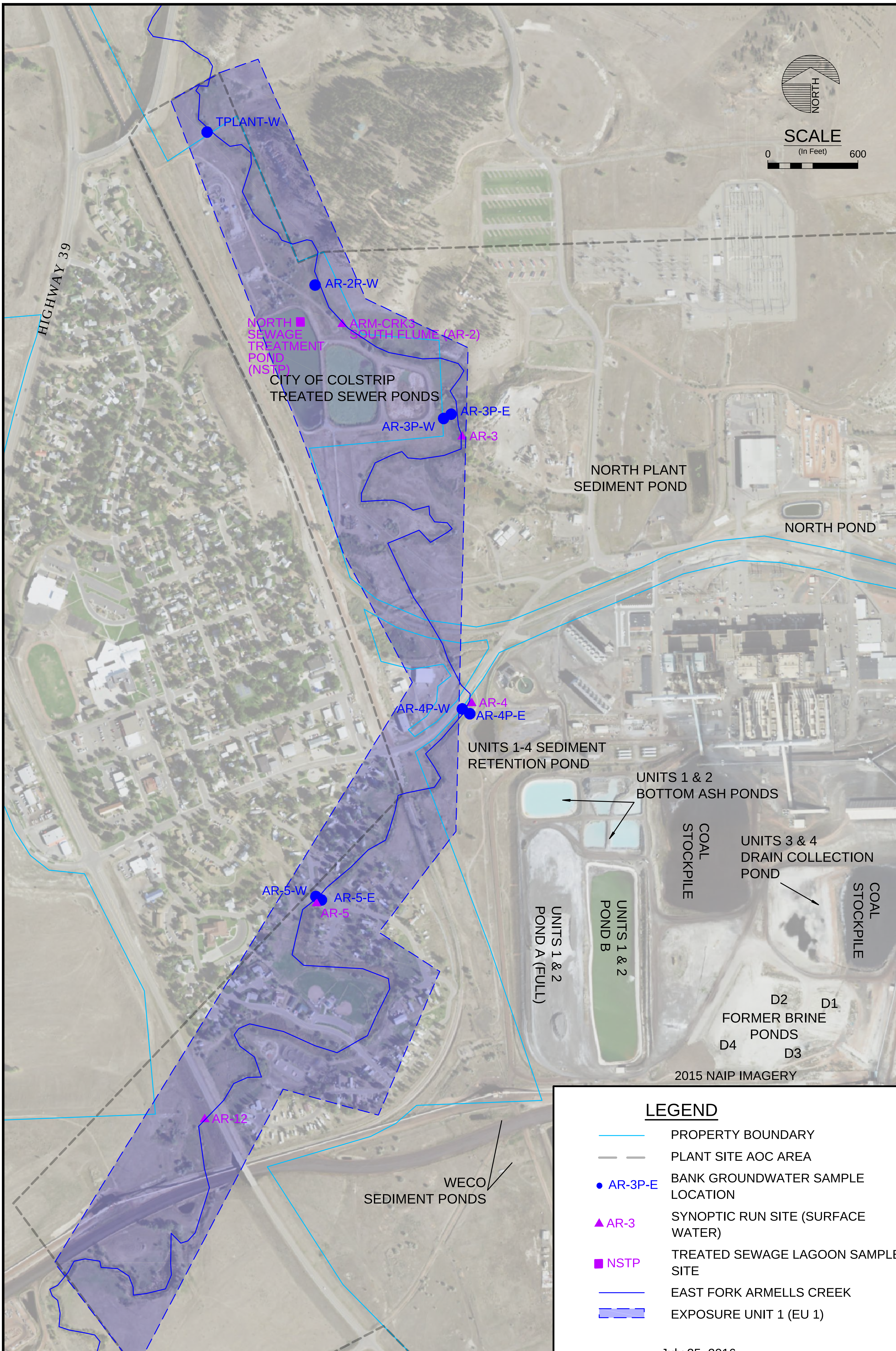

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Revised Cleanup Criteria and Risk Assessment Work Plan Wastewater Facilities Comprising the Closed-Loop System Plant Site Area Colstrip Steam Electric Station Colstrip, Montana

PLANT SITE EAST FORK ARMELLS CREEK SYNOPTIC RUN SAMPLING SITES (EU 1)

FIGURE
7

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LEGEND

OT-1 ◉	MONITORING WELL
● BH-29	SHALLOW SAMPLE LOCATION (0-0.5' & 1-2')
● BH-30	DEEP SAMPLE LOCATION (0-0.5', 1-2', & 5-7')
———	EXPOSURE UNIT 3 (EU 3)

July 25, 2016

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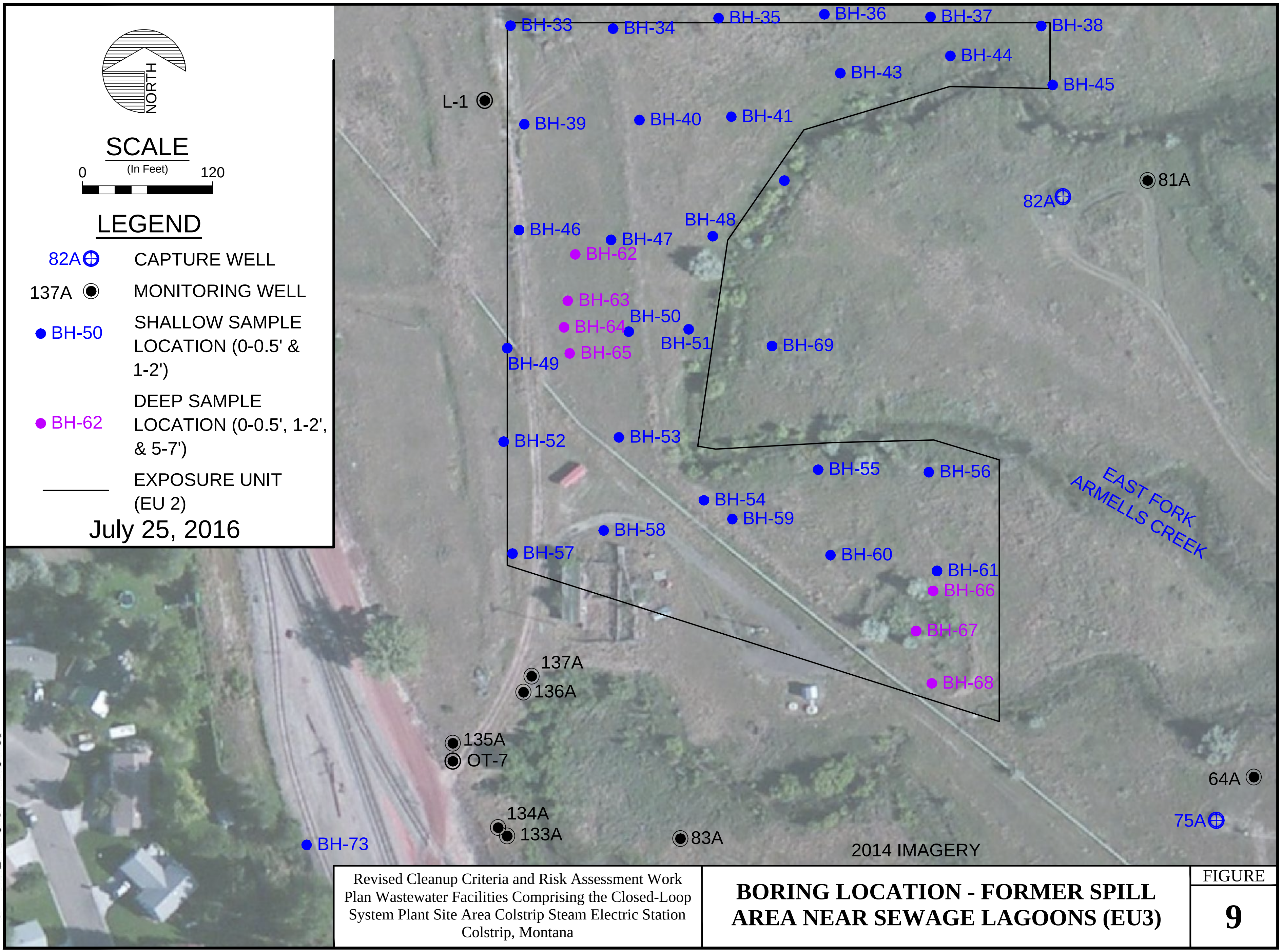
Revised Cleanup Criteria and Risk Assessment Work Plan Wastewater Facilities Comprising the Closed-Loop System Plant Site Area Colstrip Steam Electric Station Colstrip, Montana

BORING LOCATIONS - FORMER POWER ROAD SPILL AREA (EU2)

FIGURE **8**



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Hydrometrics, Inc.
Consulting Scientists and Engineers

Revised Cleanup Criteria and Risk Assessment Work Plan Wastewater Facilities Comprising the Closed-Loop System Plant Site Area Colstrip Steam Electric Station Colstrip, Montana	**BORING LOCATION - FORMER SPILL AREA NEAR SEWAGE LAGOONS (EU3)**	FIGURE **9**

UPDATE TIME: 12:31 PM
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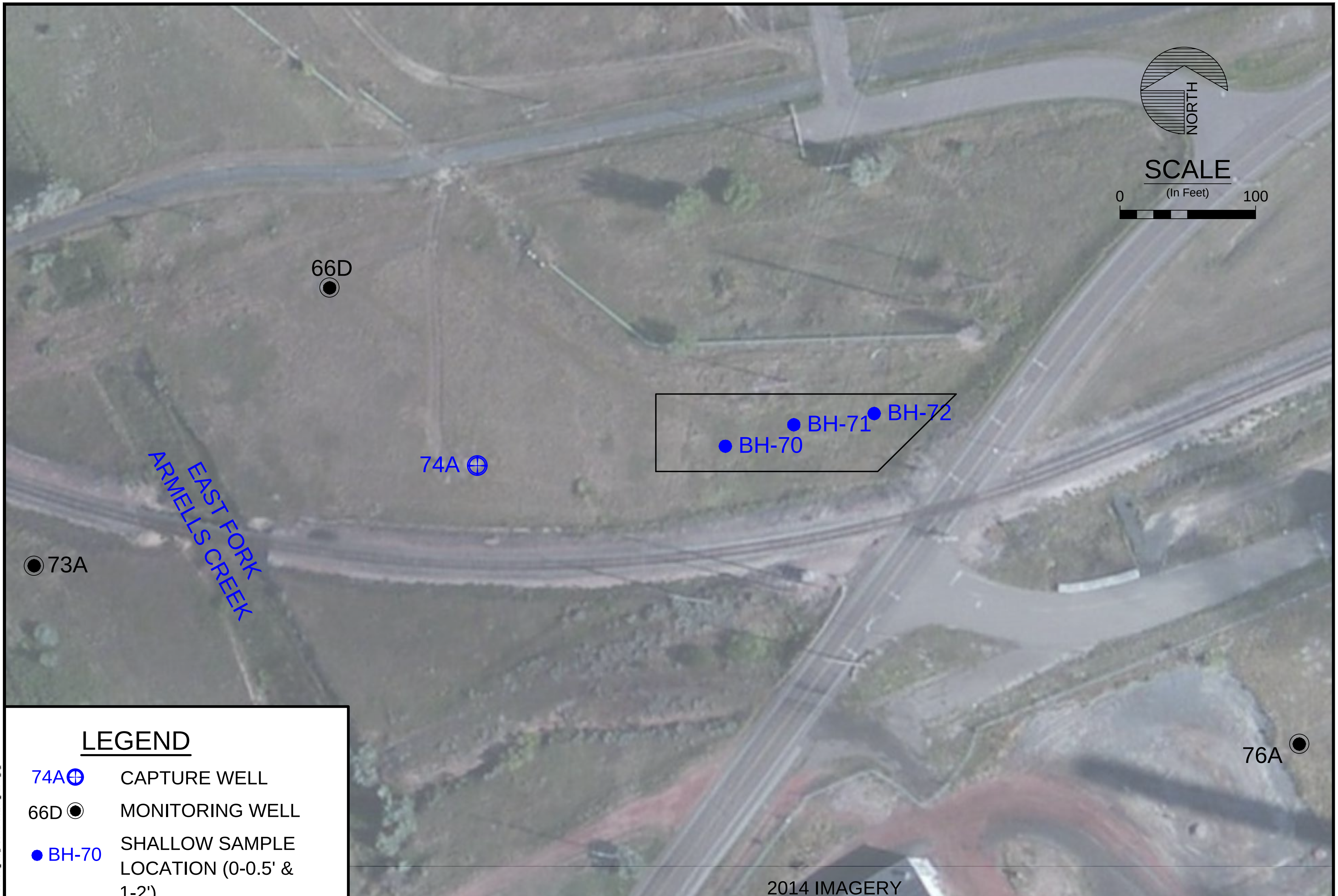

LEGEND

74A ⊕ CAPTURE WELL

66D ◉ MONITORING WELL

● BH-70 SHALLOW SAMPLE LOCATION (0-0.5' & 1-2')

EXPOSURE UNIT 4 (EU 4)

July 25, 2016

Hydrometrics, Inc.
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Revised Cleanup Criteria and Risk Assessment Work Plan Wastewater Facilities Comprising the Closed-Loop System Plant Site Area Colstrip Steam Electric Station Colstrip, Montana

BORING LOCATIONS - STORM WATER PONDING AREA (EU 4)

FIGURE **10**

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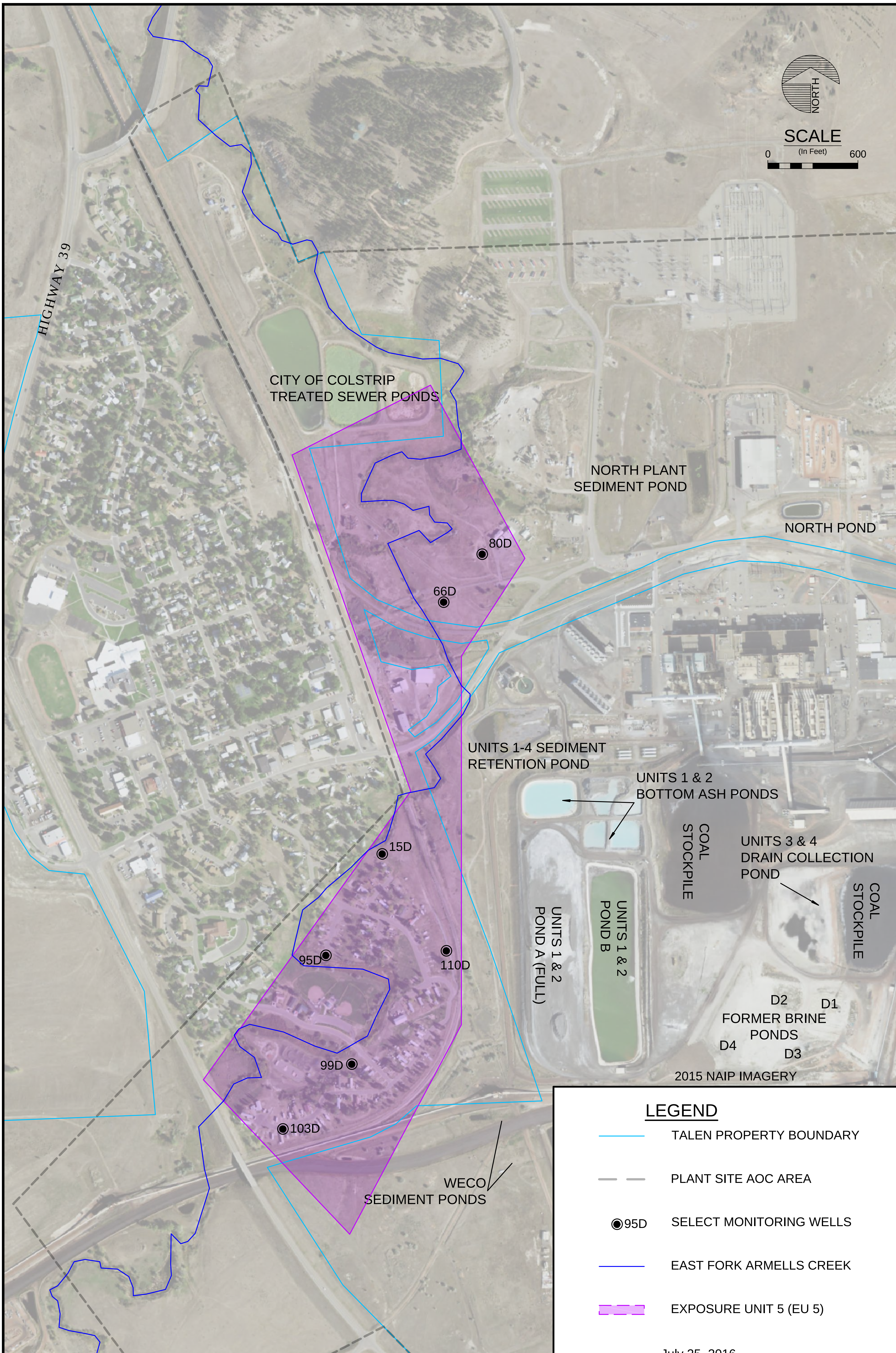

Hydrometrics, Inc.
Consulting Scientists and Engineers

Revised Cleanup Criteria and Risk Assessment Work Plan Wastewater Facilities Comprising the Closed-Loop System Plant Site Area Colstrip Steam Electric Station Colstrip, Montana

GROUNDWATER WELLS
EXPOSURE UNIT 5 (EU 5)

FIGURE
11

APPENDIX A

Administrative Order on Consent Summary

A. SUMMARY OF THE ADMINSTRATIVE ORDER ON CONSENT

The proposed approach for the selection of the Constituents of Interest (COIs) is presented in the following sections.

A.1 AOC DEFINITION OF COI

The AOC (MDEQ/PPLM, 2012; Article IV.F) defines Constituents of Interest (COI) as those parameters found in soil, groundwater, or surface water that (1) result from Site operations and the wastewater facilities and (2) exceed background or unaffected reference area concentrations.

A.2 AOC HUMAN HEALTH RISK ASSESSMENT DISCUSSION

The AOC (MDEQ/PPLM, 2012; Article IV.B) indicates that the CCRA Report shall also include the following:

- An assessment of the *(potential)* risk posed by COIs that exceed soil or water screening levels
- An evaluation of *(potential)* environmental and human health risks based on Cleanup Criteria (as defined in Article IV.G. of the AOC and presented in Section 4.0 above).

A.3 AOC DEFINITION OF CLEANUP CRITERIA

The AOC (MDEQ/PPLM, 2012; Article IV.G) defines the following Cleanup Criteria for the COIs:

1. For each COI in ground or surface water, except for the evaluation for ecological receptors, the applicable standard contained in the most current version of Circular DEQ-7 Montana Numeric Water Quality Standards ("DEQ-7"), the USEPA maximum contaminant level, the risk-based screening level contained in the most current version of Montana Risk-Based Guidance for Petroleum Releases, *whichever* is more stringent; and, for COIs for which there is not a DEQ-7 standard, a maximum contaminant level, or a risk-based screening level contained in the Montana Risk-Based Guidance for Petroleum Releases, the tap water screening level contained in the most current version of USEPA Regional Screening Levels for Chemical Constituents at Superfund Sites, except that no criterion may be more stringent than the background or unaffected reference areas concentrations; and

2. For each COI in ground or surface water that may impact an ecological receptor, an acceptable ecological risk determined using the most current versions of standard USEPA ecological risk assessment guidance if the criteria set pursuant to (1) above are not adequate to protect ecological receptors, except that no criterion may be more stringent than the background or unaffected reference areas concentrations;

3. For each COI in soil, the more stringent of:

   (a) A cumulative human health risk of 1 x 10^{-5} for carcinogens or a cumulative hazard index of 1 for non-carcinogenic COIs, except that no criterion may be more stringent than the background or unaffected reference areas concentrations;

   (b) An acceptable ecological risk, determined using the most current versions of standard USEPA ecological risk assessment guidance if the criteria set pursuant to (a) above are not adequate to protect ecological receptors, except that no criterion may be more stringent than the background or unaffected reference areas concentrations; or

   (c) The risk-based screening level contained in the most current version of Montana Risk-Based Guidance for Petroleum Releases, except that no criterion may be more stringent than the background or unaffected reference areas concentrations.

A.3.1 Groundwater Cleanup Criteria

According to the AOC, the Cleanup Criteria for each groundwater COI, except for the evaluation for ecological receptors, is the most stringent of the following:

- The applicable standard contained in the most current version of Circular DEQ-7 Montana Numeric Water Quality Standards ("DEQ-7"). It should be noted, in addition, that the MDEQ considers the DEQ-7 Standards to be clean-up values for groundwater, rather than screening levels (MDEQ, 2014).

- The EPA maximum contaminant level (MCL)

- The risk-based screening level (RBSL) contained in the most current version of Montana Risk-Based Guidance for Petroleum Releases

In addition, for COIs for which there is not a DEQ-7 standard, a maximum contaminant level, or a risk-based screening level contained in the Montana Risk-Based Guidance for Petroleum Releases, the cleanup criteria will be the tap water screening level contained in the most current version of the USEPA Regional Screening Levels (RSLs) for Chemical Constituents at Superfund Sites. No cleanup criterion, however, may be more stringent than the background or unaffected reference areas concentrations.

A.3.2 Surface Water Cleanup Criteria

According to the AOC, the Cleanup Criteria for each COI in surface water, except for the evaluation for ecological receptors, is the most stringent of the following:

- The applicable standard contained in the most current version of the DEQ-7 Circular. It should be noted, in addition, that the MDEQ considers the DEQ-7 Standards to be clean-up values for groundwater, rather than screening levels (MDEQ, 2014).
- The USEPA MCL.
- The RBSL contained in the most current version of Montana Risk-Based Guidance for Petroleum Releases.

In addition, for COIs for which there is not a DEQ-7 standard, a MCL, or a RBSL contained in the Montana Risk-Based Guidance for Petroleum Releases, the cleanup criteria will be the tap water screening level contained in the most current version of the EPA RSLs for Chemical Constituents at Superfund Sites. No cleanup criterion, however, may be more stringent than the background or unaffected reference areas concentrations. Note also, that some special cases may exist due to geospatial variations, in which ambient water at one site is naturally above background screening levels. Such cases will require examination on an individual basis in conjunction with the MDEQ.

A.3.3 Soil Cleanup Criteria

According to the AOC, the cleanup criteria for each COI in soil (soil data is available for areas of surface releases and sediment data is available for the Creek) is the most stringent of the following:

(a) A cumulative human health risk of 1×10^{-5} for carcinogens or a cumulative hazard index of 1 for non-carcinogenic constituents of interest, except that no criterion may be more stringent than the background or unaffected reference areas concentrations;

(b) An acceptable ecological risk, determined using the most current versions of standard USEPA ecological risk assessment guidance if the criteria set pursuant to (a) above are not adequate to protect ecological receptors, except that no criterion may be more stringent than the background or unaffected reference areas concentrations; or

(c) The risk-based screening level contained in the most current version of Montana Risk-Based Guidance for Petroleum Releases, except that no criterion may be more stringent than the background or unaffected reference areas concentrations.

Note: The AOC does not specifically define sediment cleanup criteria separately from soil cleanup criteria. However, according to DEQ guidance (2016), sediment concentrations should be compared to the following ecological screening levels.

- USEPA Region 3 Biological Technical Assistance Group (BTAG) Freshwater Sediment Screening Benchmarks.

APPENDIX B

USEPA RAGS Part D Tables 1 through 6

Table B-1.1 USEPA RAGS Part D Table 1 , Selection of Exposure Pathways for Surface Water
Human Health Risk Assessment
Wastewater Facilities Comprising the Closed Loop System
Plant Site Area, Colstrip Steam Electric Station, Colstrip Montana

Scenario Timeframe	Medium	Exposure Medium	Exposure Point	Receptor Population	Receptor Age	Exposure Route	Type of Analysis	Rational for Selection or Exclusion of Exposure Path
Current and Future	Surface Water	Surface Water	EU 1 East Fork Armells Creek Plant Site Area	Resident	Adult and Child	Dermal and Incidental Ingestion	Qual.	East Fork Armells Creek runs through the residential area southwest of the Plant Site.
				Industrial Outdoor Worker	Adult		Qual.	In the commercial/industrial areas of the Creek, industrial outdoor workers may be exposed (e.g., sewage treatment plant area).
				Construction Worker	Adult		Qual.	In the residential and commercial/industrial areas of Creek, construction work may occur.
				Recreational User	Adult and Child		Qual.	Adults and children may use the creek recreationally. Particularly children may play in the Creek. The creek, however, does not support a fishing resource.

Notes:

EU Exposure unit
RAGS Risk Assessment Guidance for Superfund
Qual. Qualitative; this scenario qualitatively assessed through comparison to DEQ-7 values.
Quant. Quantitative; this scenario was quantitatively assessed in the human health risk assessment
USEPA United States Environmental Protection Agency

Table B-1.2 USEPA RAGS Part D Table 1 , Selection of Exposure Pathways for Sediment
Human Health Risk Assessment
Wastewater Facilities Comprising the Closed Loop System
Plant Site Area, Colstrip Steam Electric Station, Colstrip Montana

Scenario Timeframe	Medium	Exposure Medium	Exposure Point	Receptor Population	Receptor Age	Exposure Route	Type of Analysis	Rational for Selection or Exclusion of Exposure Path
Current and Future	Sediment	Sediment	EU 1 East Fork Armells Creek Plant Site Area	Resident	Adult and Child	Dermal and Incidental Ingestion	Quan.	East Fork Armells Creek runs through the residential area southwest of the Plant Site.
				Industrial Outdoor Worker	Adult		Quan.	In the commercial/industrial areas of the Creek, industrial outdoor workers may be exposed (e.g., sewage treatment plant area).
				Construction Worker	Adult		Quan.	In the residential and commercial/industrial areas of Creek, construction work may occur.
				Recreational User	Adult and Child		Quan.	Adults and children may use the creek recreationaly. Particularly children may play in the Creek.
Current and Future	Sediment	Sediment	EU 1 East Fork Armells Creek	Resident	Adult and Child	Inhalation	None	Sediments within East Fork Armells Creek are saturated in the Exposure Unit with significant vegetation along the streambanks. As such, inhalation via fugitive dust emissions are unlikely making it an incomplete pathway.
				Industrial Outdoor Worker	Adult		None	
				Construction Worker	Adult		None	
				Recreational User	Adult and Child		None	

Notes:

EU	Exposure unit
RAGS	Risk Assessment Guidance for Superfund
Qual.	Qualitative; this scenario qualitatively assessed through comparison to DEQ-7 values.
Quant.	Quantitative; this scenario was quantitatively assessed in the human health risk assessment
USEPA	United States Environmental Protection Agency

Table B-1.3 USEPA RAGS Part D Table 1 , Selection of Exposure Pathways for Soil
Human Health Risk Assessment
Wastewater Facilities Comprising the Closed Loop System
Plant Site Area, Colstrip Steam Electric Station, Colstrip Montana

Scenario Timeframe	Medium	Exposure Medium	Exposure Point	Receptor Population	Receptor Age	Exposure Route	Type of Analysis	Rational for Selection or Exclusion of Exposure Path
Current and Future	Soil	Soil	EUs 2 thru 4 Former Spill Areas Plant Site Area	Resident	Adult and Child	Dermal and Incidental Ingestion	None	The former spill areas are not located within the residential area of the Plant Site Area.
				Industrial Outdoor Worker	Adult		Quan.	In the commercial/industrial areas of the Creek, industrial outdoor workers may be exposed (e.g., sewage treatment plant area).
				Construction Worker	Adult		Quan.	Construction work may occur in the former spill areas.
				Recreational User	Adult and Child		Quan.	Adults and children may recreationally use the former spill areas.
Current and Future	Soil	Soil	EUs 2 thru 4 Former Spill Areas Plant Site Area	Resident	Adult and Child	Inhalation of Soil Particulates	None	The former spill areas are not located within the residential area of the Plant Site Area.
				Industrial Outdoor Worker	Adult		None	Surface and subsurface soil COPCs were not identified In the remediated spill sites and storm water ponding area.
				Construction Worker	Adult		None	
				Recreational User	Adult and Child		None	

Notes:

EU	Exposure unit
RAGS	Risk Assessment Guidance for Superfund
Qual.	Qualitative; this scenario qualitatively assessed through comparison to DEQ-7 values.
Quant.	Quantitative; this scenario was quantitatively assessed in the human health risk assessment
USEPA	United States Environmental Protection Agency

Table B-1.4 USEPA RAGS Part D Table 1 , Selection of Exposure Pathways for Groundwater
Human Health Risk Assessment
Wastewater Facilities Comprising the Closed Loop System
Plant Site Area, Colstrip Steam Electric Station, Colstrip Montana

Scenario Timeframe	Medium	Exposure Medium	Exposure Point	Receptor Population	Receptor Age	Exposure Route	Type of Analysis	Rational for Selection or Exclusion of Exposure Path
Current and Future	Groundwater	Groundwater	EU 5 Groundwater Plant Site Area	Resident	Adult and Child	Ingestion	Qual.	Although groundwater is not currently used as a potable water source, no current restrictions prevent groundwater from being used as drinking water.
				Industrial Outdoor Worker	Adult		Qual.	Although groundwater is not currently used as a potable water source, no current restrictions prevent groundwater from being used as drinking water.
				Construction Worker	Adult		None	Construction workers do not have groundwater access and, thus, there is no potential exposure for these receptors.
				Recreational User	Adult and Child		None	Recreational users do not have groundwater access and, thus, there is no potential exposure for these receptors.

Notes:

EU	Exposure unit
RAGS	Risk Assessment Guidance for Superfund
Qual.	Qualitative; this scenario qualitatively assessed through comparison to DEQ-7 values.
Quant.	Quantitative; this scenario was quantitatively assessed in the human health risk assessment
USEPA	United States Environmental Protection Agency

Table B-2.1 USEPA RAGS Part D Table 2, Data Summary for Surface Water, EU1, mg/L
Human Health Risk Assessment
Wastewater Facilities Comprising the Closed Loop System
Plant Site Area, Colstrip Steam Electric Station, Colstrip, Montana

Exposure Unit	Surface Water Sampling Locations	CAS Number	Chemical	Data Time Range	Minimum [6] Concentration/ Location/ Date	Maximum [6] Concentration/ Location/Date	Detection Frequency [6]	Range of Detection Limits for Non-Detects	Most Recent Concentration Maximum/ Location/ Date	Maximum Background Concentration/ AR-12 / Date	Most Recent Background Concentration/ AR-12/ Date	Background Screening Level	Screening Value DEQ-7	COPC? (Y/N)	Rationale for Selection or Deletion
EU 1 East Fork Armells Creek	AR-2 to AR-5	7429-90-5	Aluminum Dissolved	4/7/2014 - 10/16/2014 [1]	<0.009 AR-3, AR-4 10/16/2014	0.019 NSTP 10/16/2014	3/9	<0.009 to <0.05	0.019 NSTP 10/16/2014 [1]	0.015 AR-12 10/16/2014	0.015 AR-12 10/16/2014 [1]	34.3	No HHS[2] NC 2,000 Tap Water RSL	No	BSL BB
EU 1 East Fork Armells Creek	AR-2 to AR-5	7429-90-5	Aluminum Total	4/7/2014 - 10/15/2015	<0.009 AR-5 3/18/2015	11.2 AR-5 10/14/15	16/19	<0.009 to <0.05	11.2 AR-5 10/14/15	22.8 AR-12 10/14/2015	22.8 AR-12 10/14/2015	34.3	No HHS[2] NC 2,000 Tap Water RSL	No	BSL BB
EU 1 East Fork Armells Creek	AR-2 to AR-5	7440-38-2	Arsenic Total	4/7/2014 - 10/15/2015	<0.001 several	0.054 AR-5 10/14/2015	14/19	<0.001	0.054 AR-5 10/14/2015	0.053 AR-12 10/14/2015	0.053 AR-12 10/14/2015	0.017	0.010 [3] C	No	Background conc in AR-12 and maximum concentration ~ same (0.053 and 0.054 mg/l, respectively.
EU 1 East Fork Armells Creek	AR-2 to AR-5	7440-41-7	Beryllium Total	4/7/2014 - 10/15/2015	<0.001 several	<0.002 several	0/19	<0.001 to <0.002	<0.001 several 10/14/2015	0.001 AR-12 10/14/2015	0.001 AR-12 10/14/2015	NA	0.004[2] C	No	All ND DL is BSL
EU 1 East Fork Armells Creek	AR-2 to AR-5	7440-42-8	Boron Total	4/7/2014 - 10/15/2015	0.62 NSTP 4/7/2014	2.2 AR-5 10/14/2015	19/19	NA	2.2 AR-5 10/14/2015	1.0 AR-12 10/14/2015	1.0 AR-12 10/14/2015	0.88	No HHS[2] NC 4.0 Tapwater RSL	No	No HHS (DEQ-7) BSL
EU 1 East Fork Armells Creek	AR-2 to AR-5	7440-43-9	Cadmium Total	4/7/2014 - 10/15/2015	<0.00003 several	0.00007 NSTP 3/18/2015	1/14	<0.00003 to <0.001	<0.001 10/14/2015	<0.001 AR-12 10/14/2015	<0.001 AR-12 10/14/2015	0.002	0.005 [3] NC	No	High % of ND BSL BB
EU 1 East Fork Armells Creek	AR-2 to AR-5	7440-50-8	Copper Total	4/7/2014 - 10/15/2015	0.003 NTSP 10/16/2014	0.025 AR-5 10/14/2015	5/19	<0.002 to <0.005	0.025 AR-5 10/14/2015	0.028 AR-12 10/14/2015	0.028 AR-12 10/14/2015	0.1	1.3 [4] NC	No	BB BSL
EU 1 East Fork Armells Creek	AR-2 to AR-5	7439-92-1	Lead Total	4/7/2014 - 10/15/2015	0.0018 AR-2 10/16/2014	0.018 AR-5 10/14/2015	4/19	<0.0003 to <0.001	0.018 AR-5 10/14/2015	0.024 AR-12 10/14/2015	0.024 AR-12 10/14/2015	0.06	0.015 [3] C	No	BB
EU 1 East Fork Armells Creek	AR-2 to AR-5	7439-96-5	Manganese Total	4/7/2014 - 10/15/2015	0.059 NSTP, 10/16/2014 AR-5, 3/18/2015 NSTP,10/14/2015	12.0 AR-5 10/14/2015	19/19	NA	12.0 AR-5 10/14/2015	4.83 AR-12 10/14/2015	4.83 AR-12 10/14/2015	1.6	No HHS[2] NC 0.43 Tap Water RSL	Y	ASL AB

Exposure Unit	Surface Water Sampling Locations	CAS Number	Chemical	Data Time Range	Minimum [6] Concentration/ Location/ Date	Maximum [6] Concentration/ Location/Date	Detection Frequency [6]	Range of Detection Limits for Non-Detects	Most Recent Concentration Maximum/ Location/ Date	Maximum Background Concentration/ AR-12 / Date	Most Recent Background Concentration/ AR-12/ Date	Background Screening Level	Screening Value DEQ-7	COPC? (Y/N)	Rationale for Selection or Deletion
EU 1 East Fork Armells Creek	AR-2 to AR-5	7439-97-6	Mercury Total	4/7/2014 - 10/15/2015	<0.00005	0.00005 NSTP 10/16/2014	1/19	<0.00005 to <0.0001	<0.0001 10/14/2015	<0.0002 AR-12	<0.0002 AR-12 10/14/2015	0.001	0.00005 [4] NC	N	High % of ND BB
EU 1 East Fork Armells Creek	AR-2 to AR-5	7440-02-0	Nickel Total	4/7/2014 - 10/15/2015	<0.002 several	0.028 AR-5 10/14/2015	13/19	<0.002 to <0.005	0.028 AR-5 10/14/2015	0.065 AR-12 10/14/2015	0.065 AR-12 10/14/2015	0.0217	0.1 [5] NC	N	BB BSL
EU 1 East Fork Armells Creek	AR-2 to AR-5	7782-49-2	Selenium Total	4/7/2014 - 10/15/2015	<0.0006 several	0.004 AR-5 10/14/2015	4/19	<0.0006 to <0.001	0.004 AR-5 10/14/2015	<0.002 AR-12 10/14/2015	<0.002 AR-12 10/14/2015	0.01	0.050 [3] NC	N	BB BSL
EU 1 East Fork Armells Creek	AR-2 to AR-5	7447-24-6	Strontium Total	4/7/2014 - 10/15/2015	1.16 NSTP 4/7/2014	8.87 AR-5 10/14/2015	19/19	NA	8.87 AR-5 10/14/2015	11.1 AR-12 10/14/2015	11.1 AR-12 10/14/2015	NA	4.0 [5] NC	N	BB
EU 1 East Fork Armells Creek	AR-2 to AR-5	7440-28-0	Thallium Total	4/7/2014 - 10/15/2015	<0.0003	<0.0005	0/19	<0.0003 to <0.0005	<0.0005 10/14/2015	0.0006 AR-12	0.0006 AR-12 10/14/2015	NA	0.00024 [4] NC	N	All ND BB
EU 1 East Fork Armells Creek	AR-2 to AR-5	7440-62-2	Vanadium Total	4/7/2014 - 10/15/2015	<0.01 several	0.05 AR-5 10/14/2015	2/19	<0.01	0.05 AR-5 10/14/2015	0.17 AR-12 10/14/2015	0.17 AR-12 10/14/2015	0.1	No HHS[2] NC 0.086 Tap Water RSL	N	High % of ND BB BSL
EU 1 East Fork Armells Creek	AR-2 to AR-5	7440-66-6	Zinc Total	4/7/2014 - 10/15/2015	<0.008 several	0.19 AR-5 10/14/2015	6/19	<0.008 to <0.01	0.19 AR-5 10/14/2015	0.74 AR-12 10/14/2015	0.74 AR-12 10/14/2015	0.29	2.0 [5] NC	N	BB BSL

Notes:

DEQ-7	Screening Levels are based on DEQ-7 values (DEQ, 2012) and DEQ guidance if DEQ-7 values are not available (DEQ, 2016). DEQ-7 values are total recoverable concentrations in surface water (DEQ, 2012).
Background Screening Level	Background Screening Levels for Colstrip Steam Electric Station (Neptune 2016)
Neptune 2016	Final Report on Updated Background Screening Levels, Plant Site, 1&2 SOEP and STEP, and 3&4 EHP, Colstrip Steam Electric Station, Colstrip, Montana.
(1)	Dissolved concentrations not measured during 2015 sampling events.
(2)	No Human Health Standard (HHS) available from DEQ-7 and no MCL available. Tap Water RSL (traditional tables) was used as the screening value (DEQ, 2016).
(3)	DEQ-7, Human Health Surface Water, based on the MCL
(4)	DEQ-7, Human Health Surface Water, based on Priority Pollutant (PP) Criteria
(5)	DEQ-7, Human Health Surface Water, based on health advisory (HA) from EPA's "Drinking Water Standards and Health Advisories" October 1996
(6)	Minimum and maximum concentrations and detection frequencies may differ in comparison to the Statistical Analysis (App D) as samples were averaged with their duplicates in the statistical analysis.

Definitions:

AB	Above Background
ASL	Above Screening Level
BB	Below background
BSL	Below screening level
C	Carcinogen
CAS	Chemical Abstract Service
COPC	Chemical of Potential Concern
DL	Detection Level
mg/l	milligrams per liter
NA	Not Analyzed
NC	Non-Carcinogen
ND	Non-detect
HHS	Human Health Standard

Table B-2.2 USEPA RAGS Part D Table 2, Data Summary for Sediment, EU1, mg/kg
Human Health Risk Assessment
Wastewater Facilities Comprising the Closed Loop System
Plant Site Area, Colstrip Steam Electric Station, Colstrip, Montana

Exposure Unit	Sediment Sampling Locations	CAS Number	Chemical	Data Time Range	Minimum [2] Concentration/ Location/ Date	Maximum [2] Concentration/ Location/Date	Detection Frequency [2]	Range of Detection Limits for Non-Detects	Most Recent Concentration Maximum/ Location/ 10/15/2015	Maximum Background Concentration/ AR-12 / Date	Most Recent Background Concentration/ AR-12/ 10/15/2015	RSLs - Carcinogens Residential Industrial	RSLs - Non-carcinogens Residential Industrial 1/10th	BTV for Inorganics in Montana Soils	Background Screening Level [1] Colstrip Area	COPC? (Y/N)	Rationale for Selection or Deletion
EU 1 East Fork Armells Creek	AR-2 to AR-5	7429-90-5	Aluminum	4/7/2014 - 10/15/2015	1,020 AR-5 4/8/2014	5,490 AR-4 10/15/2015	16/16	NA	5,490 AR-4	9,840 4/25/2007	4,120	NS	7,700 110,000	25,941	8,650	N	BSL BB
EU 1 East Fork Armells Creek	AR-2 to AR-5	7440-38-2	Arsenic	4/7/2014 - 10/15/2015	1.0 AR-2 4/8/2014	12.6 AR-5 10/16/2014	16/16	NA	3.9 AR-3	6.4 4/25/2007	2.2	NA	NS	22.5	8	N	BSL
EU 1 East Fork Armells Creek	AR-2 to AR-5	7440-41-7	Beryllium	4/7/2014 - 10/15/2015	0.05 AR-5 4/8/2014	0.37 AR-4 3/19/2015	16/16	NA	0.32 AR-4	0.59 4/25/2007	0.22	NS	16 230	1.1	0.5	N	BSL BB
EU 1 East Fork Armells Creek	AR-2 to AR-5	7440-42-8	Boron	4/7/2014 - 10/15/2015	4.4 AR-4 3/19/2015	19.9 AR-3 4/8/2014	16/16	NA	16.4 AR-5	49.0 4/25/2007	17.8	NS	1,600 23,000	Not Available	Not Available	N	BSL BB
EU 1 East Fork Armells Creek	AR-2 to AR-5	7440-43-9	Cadmium	4/7/2014 - 10/15/2015	0.08 AR-5 3/19/2015 10/15/2015	0.25 AR-4 10/15/2015	9/16	<0.05	0.25 AR-4	0.31 4/25/2007	0.14	NS	7.1 98	0.7	0.2	N	BSL BB
EU 1 East Fork Armells Creek	AR-2 to AR-5	7440-50-8	Copper	4/7/2014 - 10/15/2015	2 AR-5 4/8/2014	11.7 AR-3 3/19/2015	16/16	NA	10.3 AR-4	16.3 4/25/2007	6.4	NS	310 4,700	165	9.2	N	BSL BB
EU 1 East Fork Armells Creek	AR-2 to AR-5	7439-92-1	Lead	4/7/2014 - 10/15/2015	2.3 AR-5 4/8/2014 AR-2 4/8/2015	12.8 AR-4 10/15/2015	16/16	NA	12.8 AR-4	4.71 10/16/2014	NS	400 800	NS	29.8	9.7	N	BSL
EU 1 East Fork Armells Creek	AR-2 to AR-5	7439-96-5	Manganese	4/7/2014 - 10/15/2015	412 AR-4 3/19/2015	5,910 AR-5 10/16/2014	16/16	NA	2,060 AR-3	1,090 4/25/2007	637	NS	180 2,600	880	234	Y	ASL
EU 1 East Fork Armells Creek	AR-2 to AR-5	7439-97-6	Mercury	4/7/2014 - 10/15/2015	ND	ND	0/16	<0.02 to <0.1	ND	0.02 4/25/2007	ND	NS	1.1 4.6	<0.05	<0.05	N	ND
EU 1 East Fork Armells Creek	AR-2 to AR-5	7440-02-0	Nickel	4/7/2014 - 10/15/2015	2.3 AR-5 4/18/2014	9.4 AR-4 10/15/2015	16/16	NA	6.2 AR-2	15.4 4/25/2007	6.5	NS	150 2,200	31.4	8.4	N	BSL BB
EU 1 East Fork Armells Creek	AR-2 to AR-5	7782-49-2	Selenium	4/7/2014 - 10/15/2015	0.3 AR-4 4/8/2014 10/16/2014 3/19/2015	1.1 AR-5 3/19/2015	12/16	<0.02	0.5 AR-5	0.3 10/16/2014	ND	NS	39 580	0.7	0.3	N	BSL
EU 1 East Fork Armells Creek	AR-2 to AR-5	7440-24-6	Strontium	4/7/2014 - 10/15/2015	119 AR-4 10/16/2014	1,040 AR-3 10/16/2014	16/16	NA	412 AR-4	663 4/25/2007	354	NS	4,700 70,000	Not Available	Not Available	N	BSL
EU 1 East Fork Armells Creek	AR-2 to AR-5	7440-28-0	Thallium	4/7/2014 - 10/15/2015	0.08 AR-4 10/15/2015	0.35 AR-2 10/16/2014	11/16	<0.05	0.17 AR-2	0.07 10/16/2014	ND	NS	0.078 1.2	0.41	0.13	N	NB

Exposure Unit	Sediment Sampling Locations	CAS Number	Chemical	Data Time Range	Minimum (2) Concentration/ Location/ Date	Maximum (2) Concentration/ Location/Date	Detection Frequency (2)	Range of Detection Limits for Non-Detects	Most Recent Concentration Maximum/ Location/ 10/15/2015	Maximum Background Concentration/ AR-12 / Date	Most Recent Background Concentration/ AR-12/ 10/15/2015	RSLs - Carcinogens Residential Industrial	RSLs - Non-carcinogens Residential Industrial 1/10th	BTV for Inorganics in Montana Soils	Background Screening Level (1) Colstrip Area	COPC? (Y/N)	Rationale for Selection or Deletion
EU 1 East Fork Armells Creek	AR-2 to AR-5	7440-62-2	Vanadium	4/7/2014 - 10/15/2015	4.1 AR-5 4/8/2014	16.8 AR-5 10/16/2014	16/16	NA	13 AR-4	12 3/19/2015	9.9	NS	39 580	52.6	15.6	N	BSL
EU 1 East Fork Armells Creek	AR-2 to AR-5	7440-66-6	Zinc	4/7/2014 - 10/15/2015	14.9 AR-5 4/8/2014	112 AR-5 10/16/2014	16/16	NA	32.4 AR-4	127 10/16/2014	44.9	NS	2,300 35,000	118	32	N	BSL BB

Notes:

(1) Background Concentrations for Inorganic Constituents in Montana Surface Soil, specifically sampling point MBSI-29-01 located 8.5 miles west of Colstrip (DEQ, 2013).

(2) Minimum and maximum concentrations and detection frequencies may differ in comparison to the Statistical Analysis (App D) as samples were averaged with their duplicates in the statistical analysis.

DEQ, 2013 Project Report Background Concentrations of Inorganic Constituents in Montana Surface Soils. Prepared for DEQ by Hydrometrics, Inc. Available on-line at http://deq.mt.gov/StateSuperfund/background.mcpx September.

Definitions:

ASL	Above Screening Level
BB	Below Background
BSL	Below Screening Level
BTV	Background Threshold Value for Inorganics in Montana Soils (DEQ, 2013)
CAS	Chemical Abstract Service
COPC	Chemical of Potential Concern
NA	Not Applicable
NB	Near Background Concentration, maximum concentration near background concentration, and contaminant not specific to wastewater.
ND	Not Detected
NS	No Standard
RSL	USEPA Regional Screening Level May 2016

Table B-2.3 USEPA RAGS Part D Table 2, Data Summary for Soil, Former Spill Area near Power Road, EU2, mg/kg
Human Health Risk Assessment
Wastewater Facilities Comprising the Closed Loop System
Plant Site Area, Colstrip Steam Electric Station, Colstrip, Montana

Exposure Unit	Sampling Location	CAS Number	Chemical	Date	Depth Range	Minimum (4) Concentration/ Location/Depth	Maximum (4) Concentration/ Location/Depth	Detection Frequency (4)	Range of Detection Limits for Non-Detects	RSLs - Carcinogens Residential Industrial	RSLs - Non-carcinogens Residential Industrial 1/10th	BTV for Inorganics in Montana Soils	Background Screening Level (3) Colstrip Area	COPC? (Y/N)	Rationale for Selection or Deletion	Protection of Groundwater SSL (1)	Leaching COPC Flag (Y/N)
EU 2 Spill Area Power Rd	BH-29 to BH-32	7440-38-2	Arsenic	4/15/2016	0 to 7 feet	5.1 BH-32 12-24 inches	6.8 BH-29 12-24 inches	11/11	NA	NA	NS	22.5	8	N	BSL	22.5 (2)	N
EU 2 Spill Area Power Rd	BH-29 to BH-32	7440-39-3	Barium	4/15/2016	0 to 7 feet	137 BH-31 0 to 6 inches BH-32	270 BH-29 0 to 6 inches	11/11	NA	NS	1,500 22,000	429	120	N	BSL	421	N
EU 2 Spill Area Power Rd	BH-29 to BH-32	7440-42-8	Boron	4/15/2016	0 to 7 feet	6.6 BH-31 0 to 6 inches	11.7 BH-29 0 to 6 inches	11/11	NA	NS	1,600 23,000	Not Available	Not Available	N	BSL	130	N
EU 2 Spill Area Power Rd	BH-29 to BH-32	7440-43-9	Cadmium	4/15/2016	0 to 7 feet	0.34 BH-32 0 to 6 inches	0.71 BH-29 12 to 24 inches	10/11	<0.05	NS	7.1 98	0.7	0.2	N	BSL	NS	N
EU 2 Spill Area Power Rd	BH-29 to BH-32	7440-47-3	Chromium	4/15/2016	0 to 7 feet	24.1 BH-31 0 to 6 inches	33.9 BH-29 0 to 6 inches	11/11	NA	NS	12,000 180,000	41.7	12.2	N	BSL	4×10^{8}	N
EU 2 Spill Area Power Rd	BH-29 to BH-32	7439-92-1	Lead	4/15/2016	0 to 7 feet	15.3 BH-32 6 to 7 feet	73.9 BH-30 12 to 24 inches	11/11	NA	NS	400 800	29.8	9.7	N	BSL	140	N
EU 2 Spill Area Power Rd	BH-29 to BH-32	7439-97-6	Mercury	4/15/2016	0 to 7 feet	ND	ND	0/11	<0.1	NS	1.1 4.6	<0.05	<0.05	N	BSL	1.0	N
EU 2 Spill Area Power Rd	BH-29 to BH-32	7782-49-2	Selenium	4/15/2016	0 to 7 feet	0.4 BH-30 0 to 6 inches 12 to 24 inches 5 to 6 feet BH-31 0 to 6 inches 12 to 24 inches BH-32 0 to 6 inches 12 to 24 inches	0.6 BH-29 0 to 6 inches BH-32 6 to 7 feet	11/11	NA	NS	39 580	0.7	0.3	N	BSL	2.6	N

Notes:

(1) Value derived following DEQ Soil Screening Process, Part 2 - Leaching to Groundwater, 2016

(2) Background Threshold Value for arsenic in Montana was used rather than SSL based on MCL

(3) Background Concentrations for Inorganic Constituents in Montana Surface Soil, specifically sampling point MBSI-29-01 located 8.5 miles west of Colstrip (DEQ, 2013).

(4) Minimum and maximum concentrations and detection frequencies may differ in comparison to the Statistical Analysis (App D) as samples were averaged with their duplicates in the statistical analysis.

DEQ, 2013 Project Report Background Concentrations of Inorganic Constituents in Montana Surface Soils. Prepared for DEQ by Hydrometrics, Inc. Available on-line at http://deq.mt.gov/StateSuperfund/background.mcpx September.

Definitions:

ASL	Above Screening Level
BB	Below Background
BSL	Below Screening Level
BTV	Background Threshold Value for Inorganics in Montana Soils (DEQ, 2013)
CAS	Chemical Abstract Service
COPC	Chemical of Potential Concern
MCL	Maximum Contaminant Level
mg/kg	milligram per kilogram
NA	Not Applicable
ND	Not Detected
NS	No Standard
RSL	USEPA Regional Screening Level May 2016
SSL	USEPA Soil Screening Level for Groundwater Protection May 2016

Table B-2.4 USEPA RAGS Part D Table 2, Data Summary for Soil, Former Spills near Sewage Treatment Lagoons, EU3, mg/kg
Human Health Risk Assessment
Wastewater Facilities Comprising the Closed Loop System
Plant Site Area, Colstrip Steam Electric Station, Colstrip, Montana

Exposure Unit	Sampling Location	CAS Number	Chemical	Date	Depth Range	Minimum (6) Concentration/ Location/Depth	Maximum (6) Concentration/ Location/Depth	Detection Frequency (6)	Range of Detection Limits for Non-Detects	RSLs - Carcinogens Residential Industrial	RSLs - Non-carcinogens Residential Industrial $1/10^{th}$	BTV for Inorganics in Montana Soils	Background Screening Level (3) Colstrip Area	COPC? (Y/N)	Rationale for Selection or Deletion	Protection of Groundwater SSL (1)	Leaching COPC Flag (Y/N)
EU 3 Spill Site Sewage Lagoons	BH-33 to BH-69, BH-73	7440-38-2	Arsenic	4/13/2016 to 4/15/2016	0 to 7 ft	4.7 BH-33 0 to 6 inches	7.9 BH-62 0 to 6 inches	83/83	NA	NA	NS	22.5	8	N	BSL	22.5 (2)	N
EU 3 Spill Site Sewage Lagoons	BH-33 to BH-69, BH-73	7440-39-3	Barium	4/13/2016 to 4/15/2016	0 to 7 ft	96.3 BH-33 12 to 24 inches	1,130 BH-54 0 to 6 inches	83/83	NA	NS	1,500 22,000	429	120	N	BSL	421	Y (5)
EU 3 Spill Site Sewage Lagoons	BH-33 to BH-69, BH-73	7440-42-8	Boron	4/13/2016 to 4/15/2016	0 to 7 ft	5.9 BH-63 0 to 6 inches	68.5 BH-54 0 to 6 inches	83/83	NA	NS	1,600 23,000	Not Available	Not Available	N	BSL	130	N
EU 3 Spill Site Sewage Lagoons	BH-33 to BH-69, BH-73	7440-43-9	Cadmium	4/13/2016 to 4/15/2016	0 to 7 ft	0.07 BH-35 0 to 6 inches	0.57 BH-54 0 to 6 inches	71/83	<0.05	NS	7.1 98	0.7	0.2	N	BSL	NS	N
EU 3 Spill Site Sewage Lagoons	BH-33 to BH-69, BH-73	7440-47-3	Chromium	4/13/2016 to 4/15/2016	0 to 7 ft	11.9 BH-56 0 to 6 inches	34.0 BH-65 6 to 7 feet	83/83	NA	NS	12,000 180,000	41.7	12.2	N	BSL	4×10^8	N
EU 3 Spill Site Sewage Lagoons	BH-33 to BH-69, BH-73	7439-92-1	Lead	4/13/2016 to 4/15/2016	0 to 7 ft	9.47 BH-61 12 to 24 inches	504 BH-56 0 to 6 inches	83/83	NA	NS	400 800	29.8	9.7	N (4)	ASL	140	Y (4)
EU 3 Spill Site Sewage Lagoons	BH-33 to BH-69, BH-73	7439-97-6	Mercury	4/13/2016 to 4/15/2016	0 to 7 ft	ND	ND	0/83	<0.1	NS	1.1 4.6	<0.05	<0.05	N	ND BSL	1.0	N
EU 3 Spill Site Sewage Lagoons	BH-33 to BH-69, BH-73	7782-49-2	Selenium	4/13/2016 to 4/15/2016	0 to 7 ft	0.3 BH-56 12 to 24 inches BH-66 6 to 7 feet BH-68 4.5 to 5.5 feet	1.3 BH-54 0 to 6 inches	83/83	NA	NS	39 580	0.7	0.3	N	BSL	2.6	N

Notes:

(1) Value derived following DEQ Soil Screening Process, Part 2 - Leaching to Groundwater, 2016

(2) Background Threshold Value for arsenic in Montana was used rather than SSL based on MCL

(3) Background Concentrations for Inorganic Constituents in Montana Surface Soil, specifically sampling point MBSI-29-01 located 8.5 miles west of Colstrip (DEQ, 2013).

(4) Although lead was flagged as a possible Leaching COPC, it was ultimately not identified as a leaching COPC based on more detailed data comparisons (please see Section 9.3 for further discussion).

(5) Although barium was flagged as a possible Leaching COPC, it was ultimately not identified as a leaching COPC based on more detailed data comparisons (please see Section 9.3 for further discussion).

(6) Minimum and maximum concentrations and detection frequencies may differ in comparison to the Statistical Analysis (App D) as samples were averaged with their duplicates in the statistical analysis.

DEQ, 2013 Project Report Background Concentrations of Inorganic Constituents in Montana Surface Soils. Prepared for DEQ by Hydrometrics, Inc. Available on-line at http://deq.mt.gov/StateSuperfund/background.mcpx September.

Definitions:

ASL	Above Screening Level
BB	Below Background
BSL	Below Screening Level
BTV	Background Threshold Value for Inorganics in Montana Soils (DEQ, 2013)
CAS	Chemical Abstract Service
COPC	Chemical of Potential Concern
MCL	Maximum Contaminant Level
NA	Not Applicable
ND	Not Detected
NS	No Standard
RSL	USEPA Regional Screening Level May 2016
SSL	USEPA Soil Screening Level for Groundwater Protection May 2016

Table B-2.5 USEPA RAGS Part D Table 2, Data Summary for Soil, Stormwater Ponding Area, EU4, mg/kg
Human Health Risk Assessment
Wastewater Facilities Comprising the Closed Loop System
Plant Site Area, Colstrip Steam Electric Station, Colstrip, Montana

Exposure Unit	Sampling Location	CAS Number	Chemical	Date	Depth Range	Minimum (4) Concentration/ Location/Depth	Maximum (4) Concentration/ Location/Depth	Detection Frequency (4)	Range of Detection Limits for Non-Detects	RSLs - Carcinogens Residential Industrial	RSLs - Non-carcinogens Residential Industrial 1/10th	BTV for Inorganics in Montana Soils	Background Screening Level (3)	COPC? (Y/N)	Rationale for Selection or Deletion	Protection of Groundwater SSL (1)	Leaching COPC Flag (Y/N)
EU 4 Storm Water	BH-70 to BH-72	7440-38-2	Arsenic Total	4/13/2016	0 to 24 inches	5.4 BH-70 12 to 24 inches	6.9 BH-72 0 to 6 inches	7/7	NA	NA	NS	22.5	8	N	BSL	22.5 (2)	N
EU 4 Storm Water	BH-70 to BH-72	7440-39-3	Barium Total	4/13/2016	0 to 24 inches	119 BH-72 0 to 6 inches	188 BH-72 12 to 24 inches	7/7	NA	NS	1,500 22,000	429	120	N	BSL	421	N
EU 4 Storm Water	BH-70 to BH-72	7440-42-8	Boron Total	4/13/2016	0 to 24 inches	9.8 BH-70 12 to 24 inches	35.3 BH-72 12 to 24 inches	7/7	NA	NS	1,600 23,000	Not Available	Not Available	N	BSL	130	N
EU 4 Storm Water	BH-70 to BH-72	7440-43-9	Cadmium Total	4/13/2016	0 to 24 inches	0.39 BH-70 0 to 6 inches	0.39 BH-70 0 to 6 inches	1/7	<0.05	NS	7.1 98	0.7	0.2	N	BSL	NS	N
EU 4 Storm Water	BH-70 to BH-72	7440-47-3	Chromium Total	4/13/2016	0 to 24 inches	18.7 BH-71 12 to 24 inches	25.2 BH-72 0 to 6 inches	7/7	NA	NS	12,000 180,000	41.7	12.2	N	BSL	4×10^8	N
EU 4 Storm Water	BH-70 to BH-72	7439-92-1	Lead Total	4/13/2016	0 to 24 inches	11 BH-71 12 to 24 inches	18 BH-70 0 to 6 inches BH-72 0 to 6 inches	7/7	NA	NS	400 800	29.8	9.7	N	BSL	140	N
EU 4 Storm Water	BH-70 to BH-72	7439-97-6	Mercury Total	4/13/2016	0 to 24 inches	ND	ND	0/7	<0.1	NS	1.1 4.6	<0.05	<0.05	N	ND BSL	1.0	N
EU 4 Storm Water	BH-70 to BH-72	7782-49-2	Selenium Total	4/13/2016	0 to 24 inches	0.5 BH-70 0 to 6 inches 12 to 24 inches BH-71 0 to 6 inches 12 to 24 inches BH-72 0 to 6 inches	0.6 BH-72 12 to 24 inches	7/7	NA	NS	39 580	0.7	0.3	N	BSL	2.6	N

Notes:

(1) Value derived following DEQ Soil Screening Process, Part 2 - Leaching to Groundwater, 2016
(2) Background Threshold Value for arsenic in Montana was used rather than SSL based on MCL
(3) Background Concentrations for Inorganic Constituents in Montana Surface Soil, specifically sampling point MBSI-29-01 located 8.5 miles west of Colstrip (DEQ, 2013).
(4) Minimum and maximum concentrations and detection frequencies may differ in comparison to the Statistical Analysis (App D) as samples were averaged with their duplicates in the statistical analysis.
DEQ, 2013 Project Report Background Concentrations of Inorganic Constituents in Montana Surface Soils. Prepared for DEQ by Hydrometrics, Inc. Available on-line at http://deq.mt.gov/StateSuperfund/background.mcpx September.

Definitions:

ASL	Above Screening Level
BB	Below Background
BSL	Below Screening Level
BTV	Background Threshold Value for Inorganics in Montana Soils (DEQ, 2013)
CAS	Chemical Abstract Service
COPC	Chemical of Potential Concern
MCL	Maximum Contaminant Level
mg/kg	milligrams per kilogram
NA	Not Applicable
ND	Not Detected
NS	No Standard
RSL	USEPA Regional Screening Level May 2016
SSL	USEPA Soil Screening Level for Groundwater Protection 2016

Table B-2.6 USEPA RAGS Part D Table 2, Data Summary for Groundwater, EU5, mg/L
Human Health Risk Assessment
Wastewater Facilities Comprising the Closed Loop System
Plant Site Area, Colstrip Steam Electric Station, Colstrip, Montana

Exposure Unit	Chemical	CAS Number	Data Time Range	Minimum Concentration	Maximum Concentration	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Background Screening Level (1)	Screening Level DEQ-7	COPC? (Y/N)
Bedrock Groundwater (Formation Suitable for Potential Future Domestic Groundwater Wells). Data from wells 15D, 66D, 80D, 95D, 99D, 103D, 110D.											
EU5	Boron Dissolved	7440-42-8	4/7/2014 to 5/6/2015	0.3	1.9	Well 110D	21/21	NA	1.3	No HHS (2) NC 4.0 Tapwater RSL	N (3)
EU5	Selenium Dissolved	7782-49-2	4/7/2014 to 5/6/2015	<0.005	<0.005	NA	0/21	<0.005	0.005	0.050 (4) NC	N

Notes:

DEQ-7	Screening Levels are based on DEQ-7 values (DEQ, 2012) and DEQ guidance if DEQ-7 values are not available (DEQ, 2016). DEQ-7 values are dissolved concentrations in groundwater (DEQ, 2012).
Neptune 2016	Final Report on Updated Background Screening Levels, Plant Site, 1&2 SOEP and STEP, and 3&4 EHP, Colstrip Steam Electric Station, Colstrip, Montana.
(1)	Background Screening Levels for Colstrip Steam Electric Station (Neptune 2016)
(2)	No Human Health Standard (HHS) available from DEQ-7 and no MCL available. Tap Water RSL (traditional tables) was used as the screening value (DEQ, 2016).
(3)	The maximum concentration exceeded the Background Screening Level, but did not exceed the screening level. The 95% UCL for boron was calculated (1.09 mg/l), which was below both the Background Screening Level and the Screening Level (See discussion in Section 9.2 and Appendix D for statistical results).
(4)	DEQ-7, Human Health Surface Water, based on the MCL
(5)	Minimum and maximum concentrations and detection frequencies may differ in comparison to the Statistical Analysis (App D) as samples were averaged with their duplicates in the statistical analysis.

Definitions:

BB	Below Background
BSL	Below Screening Level
COPC	Chemical of Potential Concern
HHS	Human Health Standard
MCL	Maximum Contaminant Level
NA	Not Applicable
NC	Non-carcinogen
ND	Not Detected
RSL	USEPA Regional Screening Level May 2016

Table B-3.1 USEPA RAGS Part D Table 3, Exposure Point Concentration Summary, Surface Water, mg/L
Human Health Risk Assessment
Wastewater Facilities Comprising the Closed Loop System
Plant Site Area, Colstrip Steam Electric Station, Colstrip, Montana

Scenario Timeframe:	Current/Future
Medium:	Surface Water
Exposure:	Incidental Ingestion/ Dermal

Exposure Unit	Chemicals of Potential Concern	Detection Frequency (4)	Number of High Censored Results	Average	95 UCL Distribution	Maximum Concentration (4)	Exposure Point Concentration			Screening Level
							Value	Statistic	Method	
EU 1 East Fork Armells Creek Surface Water (1)	Manganese Total	15/15	0	1.4	non-parametric	12.0	3.74	95 UCL	BCa bootstrap (3)	No HHS(2) NC 0.43 Tap Water RSL

Notes:

(1) Surface water exposures evaluated qualitatively through comparison to DEQ-7 Values (see Section 9.1).

(2) No Human Health Standard (HHS) available from DEQ-7 and no MCL available.

(3) See Appendix D for UCL method justification.

(4) Minimum and maximum concentrations and detection frequencies may differ in comparison to the Data Summary Tables (RAGS Table 2) as samples were averaged with their duplicates in the statistical analysis.

Table B-3.2 USEPA RAGS Part D Table 3, Exposure Point Concentration Summary, Sediment, mg/kg
Human Health Risk Assessment
Wastewater Facilities Comprising the Closed Loop System
Plant Site Area, Colstrip Steam Electric Station, Colstrip, Montana

Scenario Timeframe:	Current/Future
Medium:	Sediment
Exposure:	Incidental Ingestion/ Dermal

Exposure Unit	Depth Interval (feet bgs)	Chemicals of Potential Concern	Detection Frequency [2]	Number of High Censored Results	Average	95 UCL Distribution	Maximum Concentration [2]	Exposure Point Concentration		
								Value	Statistic	Method
EU1 East Fork Armells Creek Sediment	Surface	Manganese	16/16	0	1,940	non- parametric	5910	2,667	95 UCL	BCa bootstrap [1]

Notes:

(1) See Appendix D for UCL method justification.

(2) Minimum and maximum concentrations and detection frequencies may differ in comparison to the Data Summary Tables (RAGS Table 2) as samples were averaged with their duplicates in the statistical analysis.

Table B-3.3 USEPA RAGS Part D Table 3, Exposure Point Concentration Summary, Sediment
Human Health Risk Assessment
Wastewater Facilities Comprising the Closed Loop System
Plant Site Area, Colstrip Steam Electric Station, Colstrip, Montana

Scenario Timeframe:	Current/Future
Medium:	Soil
Exposure:	Incidental Ingestion/Dermal/ Inhalation

Exposure Unit	Depth Interval (feet bgs)	Chemicals of Potential Concern	Detection Frequency (1)	Number of High Censored Results	Average	95 UCL Distribution	Maximum Concentration (1)	Exposure Point Concentration		
								Value	Statistic	Method
EU2-EU4	No COPCs identified for soil (samples collected from 3 spill areas and a stormwater collection area).									

Notes:

(1) Minimum and maximum concentrations and detection frequencies may differ in comparison to the Data Summary Tables (RAGS Table 2) as samples were averaged with their duplicates in the statistical analysis.

Table B-3.4 USEPA RAGS Part D Table 3, Exposure Point Concentration Summary, Groundwater, mg/L
Human Health Risk Assessment
Wastewater Facilities Comprising the Closed Loop System
Plant Site Area, Colstrip Steam Electric Station, Colstrip, Montana

Scenario Timeframe:	Future
Medium:	Groundwater
Exposure:	Ingestion

Exposure Unit	Chemicals of Potential Concern	Detection Frequency (2)	Number of High Censored Results	Mean	95 UCL Distribution	Maximum Concentration (2)	Exposure Point Concentration		
							Value	Statistic	Method
EU 5 East Fork Armells Creek Plant Site Area Groundwater (1)	No COPCs identified for groundwater.								

Notes:

(1) Groundwater exposures evaluated qualitatively through comparison to DEQ-7 Values (see Section 9.2).

(2) Minimum and maximum concentrations and detection frequencies may differ in comparison to the Data Summary Tables (RAGS Table 2) as samples were averaged with their duplicates in the statistical analysis.

Table B-4 USEPA RAGS PART D TABLE 4, VALUES USED FOR DAILY INTAKE, RME SEDIMENT EXPOSURE
Human Health Risk Assessment
Wastewater Facilities Comprising the Closed Loop System
Plant Site Area, Colstrip Steam Electric Station, Colstrip, Montana

Scenario Timeframe:	Current/Future
Medium:	Sediment
Exposure:	Incidental Ingestion, Dermal

Exposure Route	Receptor Population	Receptor Age	Exposure Unit	Parameter Code	Parameter Definition	Value	Units	Rationale/Reference	Intake Equation/Model Name
Ingestion	Resident	Adult	EU1 East Fork Armells Creek Plant Site Area	CS	Chemical Concentration	EPC	mg/kg	The RAGS Part D Table 3 series for each EU documents the rationale	ADD (noncarcinogen) Intake (mg/kg-day) = (CS x IRS x GIABS x FS x EF x ED x MCF) / (BW x AT-NC) LADD (carcinogen) Intake (mg/kg-day) = (CS x IFSadj x GIABS x FS x EF) / (AT-C)
				IRS	Ingestion Rate - Soil	100	mg/day	USEPA 2014, DEQ 2016	
				IFSadj	Age-Adjusted Soil Ingestion Factor (combined child/adult)	105	mg-yr/ kg-day	DEQ 2016	
				GI ABS	Gastrointestinal Absorption Factor	chemical-specific	unitless	USEPA 2016a	
				FS	Fraction Ingested from the Source	0.1	unitless	Professional judgment. Assumes contact with sediment one-tenth of outdoor contacts.	
				EF	Exposure Frequency	270	days/year	Assumes 3 months of snow cover or frozen ground and a 2-week vacation (DEQ 2016).	
				ED	Exposure Duration	20	years	Upperbound time estimate for residing in one location (USEPA 2014, DEQ 2016)	
				MCF	Mass Conversion Factor	1.00E-06	kg/mg	Not applicable	
				BW	Body Weight	80	kg	USEPA 2014, DEQ 2016	
				AT-C	Averaging Time - Cancer	28,470	days	78 years x 365 days/year (DEQ 2016)	
				AT-NC	Averaging Time - Noncancer	7,300	days	ED x 365 days/year (DEQ 2016)	
Ingestion	Resident	Child	EU1 East Fork Armells Creek Plant Site Area	CS	Chemical Concentration	EPC	mg/kg	The RAGS Part D Table 3 series for each EU documents the rationale	ADD (noncarcinogen) Intake (mg/kg-day) = (CS x IRS x GIABS x FS x EF x ED x MCF) / (BW x AT-NC) LADD (carcinogen) Intake (mg/kg-day) = (CS x IFSadj x GIABS x FS x EF) / (AT-C)
				IRS	Ingestion Rate - Soil	200	mg/day	USEPA 2014, DEQ 2016	
				IFSadj	Age-Adjusted Soil Ingestion Factor (combined child/adult)	105	mg-yr/ kg-day	DEQ 2016	
				GI ABS	Gastrointestinal Absorption Factor	chemical-specific	unitless	USEPA 2016a	
				FS	Fraction Ingested from the Source	0.25	unitless	Professional judgment. Assumes contact with sediment one-quarter of outdoor contacts.	
				EF	Exposure Frequency	270	days/year	Assumes 3 months of snow cover or frozen ground and a 2-week vacation (DEQ 2016).	
				ED	Exposure Duration	6	years	Upperbound time estimate for residing in one location and childhood exposure duration (USEPA 2014, DEQ 2016)	
				MCF	Mass Conversion Factor	1.00E-06	kg/mg	Not applicable	
				BW	Body Weight	15	kg	USEPA 2014, DEQ 2016	
				AT-C	Averaging Time - Cancer	28,470	days	78 years x 365 days/year (DEQ 2016)	
				AT-NC	Averaging Time - Noncancer	2,190	days	ED x 365 days/year (DEQ 2016)	

Exposure Route	Receptor Population	Receptor Age	Exposure Unit	Parameter Code	Parameter Definition	Value	Units	Rationale/Reference	Intake Equation/Model Name
Ingestion	Industrial Worker	Adult	EU1 East Fork Armells Creek Plant Site Area	CS	Chemical Concentration	EPC	mg/kg	The RAGS Part D Table 3 series for each EU documents the rationale	Intake (mg/kg-day) = (CS x IRS x GIABS x FS x EF x ED x MCF) / (BW x AT)
				IRS	Ingestion Rate - Soil	100	mg/day	USEPA 2014, DEQ 2016	
				GI ABS	Gastrointestinal Absorption Factor	chemical-specific	unitless	USEPA 2016	
				FS	Fraction Ingested from the Source	0.1	unitless	Professional judgment. Assumes contact with sediment one-tenth of outdoor contacts.	
				EF	Exposure Frequency	187	days/year	Assumes a standard 5-day work week, 3 months of snow cover or frozen ground, and a 2-week vacation (DEQ 2016).	
				ED	Exposure Duration	25	years	USEPA 2014, DEQ 2016	
				MCF	Mass Conversion Factor	1.00E-06	kg/mg	Not applicable	
				BW	Body Weight	80	kg	USEPA 2014, DEQ 2016	
				AT-C	Averaging Time - Cancer	28,470	days	78 years x 365 days/year (DEQ 2016)	
				AT-NC	Averaging Time - Noncancer	9,125	days	ED x 365 days/year (DEQ 2016)	
Ingestion	Construction Worker	Adult	EU1 East Fork Armells Creek Plant Site Area	CS	Chemical Concentration	EPC	mg/kg	The RAGS Part D Table 3 series for each EU documents the rationale	Intake (mg/kg-day) = (CS x IRS x GIABS x FS x EF x ED x MCF) / (BW x AT)
				IRS	Ingestion Rate - Soil	330	mg/day	USEPA 2004, DEQ 2016	
				GI ABS	Gastrointestinal Absorption Factor	chemical-specific	unitless	USEPA 2016	
				FS	Fraction Ingested from the Source	0.5	unitless	Professional judgment. Assumes open excavation involves the creek and one-half of contacts are with sediments.	
				EF	Exposure Frequency	124	days/year	Assumes four months of open excavation (DEQ 2016)	
				ED	Exposure Duration	1	years	USEPA 2004, DEQ 2016	
				MCF	Mass Conversion Factor	1.00E-06	kg/mg	Not applicable	
				BW	Body Weight	80	kg	USEPA 2014	
				AT-C	Averaging Time - Cancer	28,470	days	78 years x 365 days/year (DEQ 2016)	
				AT-NC	Averaging Time - Noncancer	365	days	ED x 365 days/year (DEQ 2016)	
Ingestion	Recreational Receptor (Hunter)	Adult	EU1 East Fork Armells Creek Plant Site Area	CS	Chemical Concentration	EPC	mg/kg	The RAGS Part D Table 3 series for each EU documents the rationale	Intake (mg/kg-day) = (CS x IRS x GIABS x FS x EF x ED x MCF) / (BW x AT)
				IRS	Ingestion Rate - Soil	50	mg/day	Professional judgment. One-half the soil ingestion rate residential exposure.	
				GI ABS	Gastrointestinal Absorption Factor	chemical-specific	unitless	USEPA 2016a	
				FS	Fraction Ingested from the Source	0.1	unitless	Professional judgment. Assumes contact with sediment one-tenth of outdoor contacts during recreational use, such as hunting.	
				EF	Exposure Frequency	16	days/year	Professional Judgment. Based on length of hunting season (8 weeks during September and October) with a visitation rate of 2X per week.	
				ED	Exposure Duration	20	years	Upperbound time estimate for residing in one location (USEPA 2014, DEQ 2016)	
				MCF	Mass Conversion Factor	1.00E-06	kg/mg	Not applicable	
				BW	Body Weight	80	kg	USEPA 2014	
				AT-C	Averaging Time - Cancer	28,470	days	78 years x 365 days/year (DEQ 2016)	
				AT-NC	Averaging Time - Noncancer	7,300	days	ED x 365 days/year (DEQ 2016)	

Exposure Route	Receptor Population	Receptor Age	Exposure Unit	Parameter Code	Parameter Definition	Value	Units	Rationale/Reference	Intake Equation/Model Name
Ingestion	Recreational Receptor (Hunter)	Child	EU1 East Fork Armells Creek Plant Site Area	CS	Chemical Concentration	EPC	mg/kg	The RAGS Part D Table 3 series for each EU documents the rationale	Intake (mg/kg-day) = (CS x IRS x GIABS x FS x EF x ED x MCF) / (BW x AT)
				IRS	Ingestion Rate - Soil	200	mg/day	USEPA 2014, DEQ 2016	
				GI ABS	Gastrointestinal Absorption Factor	chemical-specific	unitless	USEPA 2016a	
				FS	Fraction Ingested from the Source	0.1	unitless	Professional judgment. Assumes contact with sediment one-tenth of outdoor contacts during recreational use, such as hunting.	
				EF	Exposure Frequency	16	days/year	Professional Judgment. Based on length of hunting season (8 weeks during September and October) with a visitation rate of 2X per week.	
				ED	Exposure Duration	6	years	Upperbound time estimate for residing in one location and childhood exposure duration (USEPA 2014, DEQ 2016)	
				MCF	Mass Conversion Factor	1.00E-06	kg/mg	Not applicable	
				BW	Body Weight	15	kg	USEPA 2014, DEQ 2016	
				AT-C	Averaging Time - Cancer	28,470	days	78 years x 365 days/year (DEQ 2016)	
				AT-NC	Averaging Time - Noncancer	2,190	days	ED x 365 days/year (DEQ 2016)	

Dermal	Resident	Adult	EU1 East Fork Armells Creek Plant Site Area	CS	Chemical Concentration	EPC	mg/kg	The RAGS Part D Table 3 series for each EU documents the rationale	ADD (noncarcinogens) (mg/kg-day) = (CS x ABS x SA x AF x FS x EF x ED x MCF) / (BW x AT) LADD (carcinogens) Intake (mg/kg-day) = (CS x DFadj x GIABS x FS x EF x MCF) / (AT-C)
				ABS	Dermal Absorption Factor	Chemical-specific	unitless	USEPA 2016a	
				SA	Exposed Skin Surface Area	6,032	cm^2	USEPA 2014, DEQ 2016	
				AF	Soil to Skin Adherence Factor	0.07	mg/cm^2	USEPA 2014, DEQ 2016	
				FS	Fraction from the Source	0.1	unitless	Professional judgment. Assumes contact with sediment one-tenth of outdoor contacts.	
				EF	Exposure Frequency	270	days/year	Assumes 3 months of snow cover or frozen ground and a 2-week vacation (DEQ 2016).	
				ED	Exposure Duration	20	years	Upperbound time estimate for residing in one location (USEPA 2014, DEQ 2016)	
				MCF	Mass Conversion Factor	1.00E-06	kg/mg	Not applicable	
				BW	Body Weight	80	kg	USEPA 2014, DEQ 2016	
				AT-C	Averaging Time - Cancer	28,470	days	78 years x 365 days/year (DEQ 2016)	
				AT-NC	Averaging Time - Noncancer	7,300	days	ED x 365 days/year (DEQ 2016)	
Dermal	Resident	Child	EU1 East Fork Armells Creek Plant Site Area	CS	Chemical Concentration	EPC	mg/kg	The RAGS Part D Table 3 series for each EU will document the rationale	Intake (mg/kg-day) = (CS x ABS x SA x AF x FS x EF x ED x MCF) / (BW x AT)
				ABS	Dermal Absorption Factor	Chemical-specific	unitless	USEPA 2016a	
				SA	Exposed Skin Surface Area	2,373	cm^2	DEQ 2016	
				AF	Soil to Skin Adherence Factor	0.2	mg/cm^2	USEPA 2014, DEQ 2016	
				FS	Fraction from the Source	0.25	unitless	Professional judgment. Assumes contact with sediment one-quarter of outdoor contacts.	
				EF	Exposure Frequency	270	days/year	Assumes 3 months of snow cover or frozen ground and a 2-week vacation (DEQ 2016).	
				ED	Exposure Duration	6	years	Upperbound time estimate for residing in one location and childhood exposure duration (USEPA 2014, DEQ 2016)	
				MCF	Mass Conversion Factor	1.00E-06	kg/mg	Not applicable	
				BW	Body Weight	15	kg	USEPA 2014, DEQ 2016	
				AT-C	Averaging Time - Cancer	28,470	days	78 years x 365 days/year (DEQ 2016)	
				AT-NC	Averaging Time - Noncancer	2,190	days	ED x 365 days/year (DEQ 2016)	

Exposure Route	Receptor Population	Receptor Age	Exposure Unit	Parameter Code	Parameter Definition	Value	Units	Rationale/Reference	Intake Equation/Model Name
Dermal	Industrial Worker	Adult	EU1 East Fork Armells Creek Plant Site Area	CS	Chemical Concentration	EPC	mg/kg	The RAGS Part D Table 3 series for each EU will document the rationale	Intake (mg/kg-day) = (CS x ABS x SA x AF x FS x EF x ED x MCF) / (BW x AT)
				ABS	Dermal Absorption Factor	Chemical-specific	unitless	USEPA 2016a	
				SA	Exposed Skin Surface Area	3,527	cm^2	DEQ 2016	
				AF	Soil to Skin Adherence Factor	0.12	mg/cm^2	USEPA 2014, DEQ 2016	
				FS	Fraction from the Source	0.1	unitless	Professional judgment. Assumes contact with sediment one-tenth of outdoor contacts.	
				EF	Exposure Frequency	187	days/year	Assumes a standard 5-day work week, 3 months of snow cover or frozen ground, and a 2-week vacation (DEQ 2016).	
				ED	Exposure Duration	25	years	USEPA 2014, DEQ 2016	
				MCF	Mass Conversion Factor	1.00E-06	kg/mg	Not applicable	
				BW	Body Weight	80	kg	USEPA 2014, DEQ 2016	
				AT-C	Averaging Time - Cancer	28,470	days	78 years x 365 days/year (DEQ 2016)	
				AT-NC	Averaging Time - Noncancer	9,125	days	ED x 365 days/year (DEQ 2016)	
Dermal	Construction Worker	Adult	EU1 East Fork Armells Creek Plant Site Area	CS	Chemical Concentration	Sample Result	mg/kg	The RAGS Part D Table 3 series for each EU will document the rationale	Intake (mg/kg-day) = (CS x ABS x SA x AF x FS x EF x ED x MCF) / (BW x AT)
				ABS	Dermal Absorption Factor	Chemical-specific	unitless	USEPA 2016a	
				SA	Exposed Skin Surface Area	3,527	cm^2	DEQ 2016	
				AF	Soil to Skin Adherence Factor	0.3	mg/cm^2	DEQ 2016	
				FS	Fraction from the Source	0.5	unitless	Professional judgment. Assumes open excavation involves the creek and one-half of contacts are with sediments.	
				EF	Exposure Frequency	124	days/year	Assumes four months of open excavation (DEQ 2016)	
				ED	Exposure Duration	1	years	USEPA 2004, DEQ 2016	
				MCF	Mass Conversion Factor	1.00E-06	kg/mg	Not applicable	
				BW	Body Weight	80	kg	USEPA 2014, DEQ 2016	
				AT-C	Averaging Time - Cancer	28,470	days	78 years x 365 days/year (DEQ 2016)	
				AT-NC	Averaging Time - Noncancer	365	days	ED x 365 days/year (DEQ 2016)	
Dermal	Recreational Receptor (Hunter)	Adult	EU1 East Fork Armells Creek Plant Site Area	CS	Chemical Concentration	Sample Result	mg/kg	The RAGS Part D Table 3 series for each EU documents the rationale	Intake (mg/kg-day) = (CS x ABS x SA x AF x FS x EF x ED x MCF) / (BW x AT)
				ABS	Dermal Absorption Factor	Chemical-specific	unitless	USEPA 2016a	
				SA	Exposed Skin Surface Area	3,527	cm^2	Professional judgment. Assume similar exposed skin surface as industrial worker.	
				AF	Soil to Skin Adherence Factor	0.2	mg/cm^2	Professional judgment. Assume similar to residential exposure (USEPA 2014)	
				FS	Fraction from the Source	0.1	unitless	Professional judgment. Assumes contact with sediment one-tenth of outdoor contacts during recreational use, such as hunting.	
				EF	Exposure Frequency	16	days/year	Professional Judgment. Based on length of hunting season (8 weeks during September and October) with a visitation rate of 2X per week.	
				ED	Exposure Duration	20	years	Upperbound time estimate for residing in one location (USEPA 2014, DEQ 2016)	
				MCF	Mass Conversion Factor	1.00E-06	kg/mg	Not applicable	
				BW	Body Weight	80	kg	USEPA 2014, DEQ 2016	
				AT-C	Averaging Time - Cancer	28,470	days	78 years x 365 days/year (DEQ 2016)	
				AT-NC	Averaging Time - Noncancer	7,300	days	ED x 365 days/year (DEQ 2016)	

Exposure Route	Receptor Population	Receptor Age	Exposure Unit	Parameter Code	Parameter Definition	Value	Units	Rationale/Reference	Intake Equation/Model Name
Dermal	Recreational Receptor (Hunter)	Child	EU1 East Fork Armells Creek Plant Site Area	CS	Chemical Concentration	Sample Result	mg/kg	The RAGS Part D Table 3 series for each EU documents the rationale	Intake (mg/kg-day) = (CS x ABS x SA x AF x FS x EF x ED x MCF) / (BW x AT)
				ABS	Dermal Absorption Factor	Chemical-specific	unitless	USEPA 2016a	
				SA	Exposed Skin Surface Area	2,373	cm^2	Professional judgment. Assume similar exposed skin surface as residential child.	
				AF	Soil to Skin Adherence Factor	0.2	mg/cm^2	USEPA 2014	
				FS	Fraction from the Source	0.1	unitless	Professional judgment. Assumes contact with sediment one-tenth of outdoor contacts during recreational use, such as hunting.	
				EF	Exposure Frequency	16	days/year	Professional Judgment. Based on length of hunting season (8 weeks during September and October) with a visitation rate of 2X per week.	
				ED	Exposure Duration	6	years	Upperbound time estimate for residing in one location and childhood exposure duration (USEPA 2014, DEQ 2016)	
				MCF	Mass Conversion Factor	1.00E-06	kg/mg	Not applicable	
				BW	Body Weight	15	kg	USEPA 2014, DEQ 2016	
				AT-C	Averaging Time - Cancer	28,470	days	78 years x 365 days/year (DEQ 2016)	
				AT-NC	Averaging Time - Noncancer	2,190	days	ED x 365 days/year (DEQ 2016)	

References:

DEQ 2016 DEQ Remediation Division, State Superfund FAQs. Available on-line at: https://deq.mt.gov/Land/statesuperfund/frequentlyaskedquestions.

USEPA 2004 Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment), Final. EPA/540/R/99/005 OSWER 9285.7-02EP PB99-963312, July.

USEPA 2014 Human Health Evaluation Manual, Supplemental Guidance: Update of Standard Default Exposure Factors, OSWER Directive 9200.1-120, February.

USEPA 2016a Regional Screening Levels for Chemical Contaminants at Superfund Sites. May. Available on-line at https://www.epa.gov/risk/regional-screening-levels-rsls.

Definitions:

cm^2	square centimeter
DEQ	Montana Department of Environmental Quality
EPC	exposure point concentration
kg	kilogram
kg/mg	kilogram per milligram
mg/cm^2	milligram per square centimeter
mg/day	milligram per day
mg/kg-day	milligram per kilogram per day
mg/kg	milligram per kilogram
RAGS	Risk Assessment Guidance for Superfund
RME	reasonable maximum exposure
USEPA	United States Environmental Protection Agency

Table B-5 USEPA RAGS PART D TABLE 5, FEDERAL NON-CANCER TOXICITY DATA - ORAL / DERMAL
Human Health Risk Assessment
Wastewater Facilities Comprising the Closed Loop System
Plant Site Area, Colstrip Steam Electric Station, Colstrip, Montana

Chemical of Potential Concern	Chronic / Subchronic	Oral RfD		Oral Absorption Efficiency for Dermal [1]	Gastro-intestinal Absorption Factor [2]	Absorbed RfD for Dermal		Primary Target Organ(s) [3]	Combined Uncertainty/Modifying Factors	Oral Reference Dose	
		Value	Units			Value	Units			Source(s)	Date(s)
Manganese[4]	Chronic	2.4 E-02 [5]	mg/kg-day	100%	4%	2.4E-02	mg/kg-day	Central Nervous System	1	IRIS [5]	May 2016

Notes:

RfD Reference Dose
IRIS Integrated Risk Information System
mg/kg-day milligrams per kilogram-day

(1) Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment), July 2004. If not available, assumed to be 100%. The absorbed dermal RfD is derived by multiplying the oral RfD by the oral absorption efficiency. A manganese dermal ABS is not available (USEPA, 2016); therefore, 100% was assumed.

(2) Gastrointestinal Absorption Factor as presented in the USEPA RSL Tables (USEPA, 2016). The manganese RfD was modified from the IRIS value due to uncertainties discussed in the IRIS file associated with non-diet manganese vs. diet manganese (USEPA 2016).

(3) Primary target(s) listed are those associated with the critical effect(s) on which the RfD was based.

(4) The toxicity value for manganese excludes dietary contribution.

(5) The IRIS RfD is 0.14 mg/kg-day; however, the IRIS explanatory text recommends using a modifying factor of 3 when calculating risks associated with non-food sources because of a number of uncertainties, leading to an RfD of 0.024 mg/kg-day.

Table B-6 USEPA RAGS PART D TABLE 5, FEDERAL CANCER TOXICITY DATA - ORAL / DERMAL
Human Health Risk Assessment
Wastewater Facilities Comprising the Closed Loop System
Plant Site Area, Colstrip Steam Electric Station, Colstrip, Montana

Chemical of Potential Concern	Oral Cancer Slope Factor		Oral Absorption Efficiency for Dermal	Absorbed Cancer Slope Factor for Dermal		Weight of Evidence / Cancer Guidance Description	Oral Cancer Slope Factor	
	Value	Units		Value	Units		Source(s)	Date(s)
No carcinogenic COPCs identified.								

APPENDIX C

Data Used in the Risk Assessment

Table C-1
Colstrip Plant Site Area, EU1
Surface Water Data Used in the HHRA (Total Metals)
2014 and 2015

Sample Location	Date	Al mg/L	As mg/L	Be mg/L	B mg/L	Cd mg/L	Cu mg/L	Pb mg/L	Mn mg/L	Hg mg/L	Ni mg/L	Se mg/L	Sr mg/L	Tl mg/L	V mg/L	Zn mg/L
AR-12	4/8/2014	< 0.05 0.10	0.001	< 0.001	0.63	< 0.0005	< 0.002	< 0.0003	0.198	< 0.00005	0.002	< 0.001	6.23	< 0.0003	< 0.01	< 0.008
AR-5	4/8/2014	< 0.05 < 0.05	< 0.001	< 0.001	0.75	< 0.0005	< 0.002	< 0.0003	0.278	< 0.00005	< 0.002	< 0.001	6.28	< 0.0003	< 0.01	< 0.008
AR-4	4/8/2014	< 0.05 0.07	< 0.001	< 0.002	0.78	< 0.0005	< 0.002	< 0.0003	0.426	< 0.00005	< 0.002	< 0.001	6.21	< 0.0003	< 0.01	< 0.008
AR-3	4/8/2014	< 0.05 < 0.05	<0.001	< 0.001	1.15	< 0.0005	< 0.002	< 0.0003	0.281	< 0.00005	0.005	< 0.001	6.69	< 0.0003	< 0.01	<0.008
NSTP	4/8/2014	<0.05 0.17	0.006	<0.001	0.62	<0.0005	<0.002	<0.0003	0.09	<0.00005	0.004	<0.001	1.16	<0.0003	<0.01	0.009
AR-2SF	4/8/2014	< 0.05 0.06	< 0.001	< 0.001	1.28	< 0.0005	< 0.002	< 0.0003	0.366	< 0.00005	0.005	< 0.001	6.19	< 0.0003	< 0.01	< 0.008
AR-12	10/16/2014	0.015 0.038	0.002	< 0.002	0.72	--	< 0.002	< 0.0003	0.167	< 0.00005	< 0.002	< 0.001	7.95	< 0.0003	< 0.01	< 0.008
AR-5	10/16/2014	0.01 0.014	0.001	< 0.002	0.96	--	< 0.002	< 0.0003	0.146	< 0.00005	0.003	< 0.001	8.32	< 0.0003	< 0.01	< 0.008
AR-4	10/16/2014	< 0.009 0.029	0.001	< 0.002	0.99	--	< 0.002	< 0.0003	0.104	< 0.00005	0.002	< 0.001	8.13	< 0.0003	< 0.01	< 0.008
AR-3	10/16/2014	< 0.009 0.020	0.001	< 0.002	1.22	--	< 0.002	< 0.0003	0.221	< 0.00005	0.003	< 0.001	7.03	< 0.0003	< 0.01	< 0.008
NSTP	10/16/2014	0.019 0.133	0.006	<0.002	0.94	--	0.003	<0.0003	0.059	0.00005	0.005	<0.001	1.3	<0.0003	<0.01	0.011
AR-2SF	10/16/2014	0.011 1.59	0.002	< 0.002	1.38	--	0.004	0.0018	1.34	< 0.00005	0.008	< 0.001	6.3	< 0.0003	< 0.01	0.013
AR-12	3/19/2015	-- 0.019	0.001	< 0.002	0.41	< 0.00003	< 0.002	< 0.0003	0.078	< 0.00005	< 0.002	< 0.001	6.33	< 0.0003	< 0.01	< 0.008
AR-5	3/19/2015	-- < 0.009	0.002	< 0.002	0.51	< 0.00003	< 0.002	< 0.0003	0.059	< 0.00005	< 0.002	< 0.001	6.29	< 0.0003	< 0.01	< 0.008
AR-4	3/19/2015	-- 0.072	0.001	< 0.002	0.51	< 0.00003	< 0.002	< 0.0003	0.073	< 0.00005	< 0.002	< 0.001	5.88	< 0.0003	< 0.01	< 0.008
AR-3	3/19/2015	-- 0.066	0.002	< 0.002	0.66	< 0.00003	< 0.002	< 0.0003	0.133	< 0.00005	< 0.002	0.002	5.78	< 0.0003	< 0.01	< 0.008
NSTP	3/19/2015	-- 1.26	0.005	< 0.002	0.72	0.00007	0.004	0.002	0.151	<0.00005	0.006	0.001	1.17	< 0.0003	< 0.01	0.018
AR-2SF	3/19/2015	-- 0.01	< 0.001	< 0.002	0.77	< 0.00003	< 0.002	< 0.0003	0.223	< 0.00005	0.003	0.001	5.67	< 0.0003	< 0.01	< 0.008
AR-12	10/15/2015	-- 22.8	0.053	0.001	1	<0.001	0.028	0.024	4.83	<0.002	0.065	<0.002	11.1	0.0006	0.17	0.74
AR-5	10/15/2015	-- 11.2	0.054	< 0.001	2.2	<0.001	0.025	0.018	12.0	< 0.0001	0.028	0.004	8.87	<0.0005	0.05	0.19
AR-4	10/15/2015	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
AR-3	10/15/2015	-- 2.49	0.021	< 0.001	1.24	<0.001	0.008	0.008	3.39	< 0.0001	0.009	< 0.0006	5.26	< 0.0005	0.02	0.05
NSTP	10/15/2015	-- 0.11	0.007	<0.001	0.96	<0.001	<0.005	<0.001	0.059	<0.0001	<0.005	<0.0006	1.38	<0.0005	< 0.01	<0.01
AR-2SF	10/15/2015	-- 0.6	0.003	< 0.001	1.62	<0.001	<0.005	<0.001	2.03	< 0.0001	0.006	<0.0006	6.42	<0.0005	< 0.01	< 0.01

Notes:
Al First number is the dissolved concentration; the second number is the total concentration
mg/L milligrams per liter
Regional Screening Level
United States Environmental Protection Agency

Table C-2
Colstrip Plant Site Area, EU1
Sediment Data Used in the HHRA
2014 and 2015

Sample Location	Date	Al mg/kg	As mg/kg	Be mg/kg	B mg/kg	Cd mg/kg	Cu mg/kg	Pb mg/kg	Mn mg/kg	Hg mg/kg	Ni mg/kg	Se mg/kg	Sr mg/kg	Tl mg/kg	V mg/kg	Zn mg/kg
AR-12	4/8/2014	2930	1.4	0.13	13.5	0.08	5.1	3.5	268	< 0.02	5.0	< 0.2	166	< 0.05	6.6	37.8
AR-5	4/8/2014	1020	2.9	0.05	12.3	< 0.05	2	2.3	1040	< 0.02	2.3	0.7	180	< 0.05	4.1	14.9
AR-4	4/8/2014	4850	2.8	0.25	11.3	< 0.05	8.9	8.38	605	< 0.02	7.7	0.3	157	0.08	9.8	76.2
AR-3	4/8/2014	2310	5.6	0.16	19.9	< 0.05	6.4	3.92	2040	< 0.02	4.8	0.3	199	0.06	7.1	43.6
AR-2SF	4/8/2014	1510	1.0	0.08	11.3	< 0.05	3.0	2.3	3910	< 0.02	4.2	< 0.2	222	0.06	7.2	18.9
AR-12	10/16/2014	4980	2.8	0.2	15.8	< 0.05	7.4	4.71	534	< 0.1	6.2	0.3	313	0.07	12	127
AR-5	10/16/2014	1150	12.6	0.06	19.4	< 0.05	6.1	2.89	5910	< 0.1	2.4	0.5	568	< 0.05	16.8	112
AR-4	10/16/2014	4580	4.2	0.25	10	< 0.05	7.8	8.22	520	< 0.1	6.9	0.3	119	0.08	12.6	38.4
AR-3	10/16/2014	3170	5.3	0.19	19.2	< 0.05	9.4	6.65	2390	< 0.1	6.3	0.5	1040	0.08	12.2	35.7
AR-2SF	10/16/2014	3840	3.3	0.23	16.4	0.18	8.2	5.52	1940	< 0.1	6.1	0.4	315	0.35	11.1	30.9
AR-12	3/19/2015	4030	2.9	0.27	8.1	0.11	6.3	4.17	700	< 0.1	4.7	0.2	227	0.06	8.4	78
AR-5	3/19/2015	2110	2.8	0.15	18	0.08	5	4.36	1370	< 0.1	3.9	1.1	353	< 0.05	6.1	27
AR-4	3/19/2015	5150	5.1	0.37	4.4	0.16	8.6	7.83	412	< 0.1	7.9	0.3	156	0.08	12.1	50
AR-3	3/19/2015	3850	3.2	0.3	11	0.18	11.7	7.78	2970	< 0.1	8.8	0.5	652	0.11	9.8	46
AR-2SF	3/19/2015	3290	2.2	0.24	6.6	0.18	7.9	4.96	1750	< 0.1	5.4	0.3	302	0.28	7.2	27
AR-12	10/15/2015	4120	2.2	0.22	17.8	0.14	6.4	4.68	637	< 0.1	6.5	< 0.2	354	< 0.05	9.9	44.9
AR-5	10/15/2015	1650	3	0.11	16.4	0.08	3.8	3.47	1860	< 0.1	3.9	0.5	349	< 0.05	7	17.7
AR-4	10/15/2015	5490	2	0.32	15.4	0.25	10.3	12.8	986	< 0.1	9.4	< 0.2	412	0.06	13	32.4
AR-3	10/15/2015	1740	3.9	0.15	12.5	0.12	5.9	7.02	2060	< 0.1	4.8	< 0.2	281	< 0.05	5.4	18.3
AR-2SF	10/15/2015	2980	1.5	0.21	13.6	0.18	8.7	5.43	1270	< 0.1	6.2	< 0.2	280	0.17	8.7	20

Notes:
mg/kg milligram per kilogram

Table C-3
Colstrip Plant Site Area, EU2
Borehole Soil Data - Power Road Spill Area
2016

Sample Location	Date	Depth	Remarks	As mg/kg	Ba mg/kg	B mg/kg	Cd mg/kg	Cr mg/kg	Pb mg/kg	Mn mg/kg	Hg mg/kg	Se mg/kg
BH-29	4/15/2016	0-6"	sieved	6.1	261	11.7	0.63	27.6	55.0	380	<0.1	0.6
BH-29 (dup)	4/15/2016	0-6"	sieved	6.4	270	11.6	0.66	33.9	58.1	411	<0.1	0.6
BH-29	4/15/2016	12"-24'	sieved	6.8	182	10.3	0.71	28.4	71.8	366	<0.1	0.5
BH-30	4/15/2016	0-6"	sieved	5.8	197	9.4	0.36	24.3	24.0	380	<0.1	0.4
BH-30	4/15/2016	12"-24'	sieved	5.9	151	11.6	0.44	24.2	73.9	376	<0.1	0.4
BH-30	4/15/2016	5'-6'	sieved	5.7	144	7.8	0.37	31.9	14.6	391	<0.1	0.4
BH-31	4/15/2016	0-6"	sieved	5.4	137	6.6	0.44	24.1	37.6	365	<0.1	0.4
BH-31	4/15/2016	12"-24'	sieved	5.8	140	6.9	0.42	28.2	36.2	376	<0.1	0.4
BH-32	4/15/2016	0-6"	sieved	5.4	138	6.7	0.34	26.0	20.2	385	<0.1	0.4
BH-32	4/15/2016	12"-24'	sieved	5.1	147	7.4	0.36	24.5	20.9	368	<0.1	0.4
BH-32	4/15/2016	12"-24'	bulk-not sieved	5.8	115	8.0	0.31	17.0	21.3	335	<0.1	0.3
BH-32	4/15/2016	6'-7'	sieved	6.3	137	9.1	<0.05	25.3	15.3	359	<0.1	0.6

Notes:

mg/kg milligram per kilogram

Table C-4
Colstrip Plant Site Area, EU3
Borehole Soil Data - Former Sewage Treatment Lagoon Spills Area
2016

Sample Location	Date	Depth	Remarks	As mg/kg	Ba mg/kg	B mg/kg	Cd mg/kg	Cr mg/kg	Pb mg/kg	Mn mg/kg	Hg mg/kg	Se mg/kg
BH-33	4/13/2016	0-6"	sieved	4.7	106	8	<0.05	21.3	14.0	367	<0.1	0.4
BH-33	4/13/2016	12"-24"	sieved	4.9	96	9.9	<0.05	21.2	17.0	378	<0.1	0.4
BH-34	4/13/2016	0-6"	sieved	5.7	203	8.9	<0.05	19.3	13.0	341	<0.1	0.8
BH-34	4/13/2016	12"-24"	sieved	5.3	132	10.1	<0.05	23.3	12.0	309	<0.1	0.6
BH-35	4/13/2016	0-6"	sieved	6.2	135	10.2	0.07	22.2	16.0	412	<0.1	0.5
BH-35	4/13/2016	12"-24"	sieved	6.1	117	10.3	<0.05	21.1	14.0	397	<0.1	0.4
BH-36	4/13/2016	0-6"	sieved	5.9	138	9.6	<0.05	21.5	17.0	400	<0.1	0.4
BH-36	4/13/2016	12"-24"	sieved	5.7	146	14.1	<0.05	19.8	13.0	386	<0.1	0.6
BH-37	4/13/2016	0-6"	sieved	6.1	162	13.9	<0.05	26.8	15.0	402	<0.1	0.5
BH-37	4/13/2016	12"-24"	sieved	5.1	141	14.6	<0.05	19.9	13.0	352	<0.1	0.6
BH-38	4/13/2016	0-6"	sieved	5.2	124	16.2	<0.05	16.8	16.0	383	<0.1	0.7
BH-38	4/13/2016	12"-24"	sieved	5.1	182	15.6	<0.05	15.8	10.0	341	<0.1	0.4
BH-39	4/14/2016	0-6"	sieved	4.8	156	11.1	0.33	21.4	13.9	271	<0.1	0.5
BH-39	4/14/2016	12"-24"	sieved	6.4	129	9.3	0.38	31.4	14.5	401	<0.1	0.7
BH-40	4/14/2016	0-6"	sieved	7.5	141	8.8	0.30	25.1	14.2	449	<0.1	0.6
BH-40	4/14/2016	12"-24"	sieved	6.0	237	7.6	0.28	21.8	10.7	320	<0.1	0.7
BH-41	4/13/2016	0-6"	sieved	6.1	146	9.3	0.34	21.8	16.0	369	<0.1	0.5
BH-41	4/13/2016	12"-24"	sieved	6.1	111	8.8	0.27	22.1	11.4	312	<0.1	0.7
BH-42	4/13/2016	0-6"	sieved	6.6	210	7.7	0.27	18.7	12.4	364	<0.1	0.5
BH-42	4/13/2016	12"-24"	sieved	6.3	195	9.7	0.29	21.6	11.9	376	<0.1	0.5
BH-43	4/13/2016	0-6"	sieved	6.0	175	13.9	0.32	18.0	13.6	377	<0.1	0.5
BH-43 (dup)	4/13/2016	0-6"	sieved	6.2	173	13.7	0.31	19.3	13.6	389	<0.1	0.5
BH-43	4/13/2016	12"-24"	sieved	6.2	178	15.9	0.24	16.7	9.5	335	<0.1	0.5
BH-44	4/13/2016	0-6"	sieved	5.7	180	18.9	0.37	17.9	16.4	395	<0.1	0.5
BH-44	4/13/2016	12"-24"	sieved	5.6	170	15.4	0.27	17.2	11.5	364	<0.1	0.5
BH-45	4/13/2016	0-6"	sieved	5.2	148	17.4	<0.05	15.6	13.0	356	<0.1	0.4
BH-45	4/13/2016	12"-24"	sieved	5.8	191	20.6	0.27	19.1	10.9	349	<0.1	0.4
BH-46	4/14/2016	0-6"	sieved	5.4	175	11.6	0.39	26.2	20.7	349	<0.1	0.4
BH-46	4/14/2016	12"-24"	sieved	6.0	165	7.9	0.32	28.0	13.0	354	<0.1	0.5
BH-47	4/14/2016	0-6"	sieved	6.7	189	7.7	0.34	30.0	17.0	400	<0.1	0.5
BH-47	4/14/2016	12"-24"	sieved	6.4	190	10.2	0.33	26.6	12.5	333	<0.1	0.8
BH-48	4/14/2016	0-6"	sieved	6.6	216	9.2	0.30	24.3	13.1	359	<0.1	0.6
BH-48	4/14/2016	12"-24"	sieved	5.6	161	8.4	0.30	24.3	12.6	319	<0.1	0.8
BH-50	4/14/2016	0-6"	sieved	6.8	229	7.1	0.32	22.7	13.1	382	<0.1	0.4
BH-50	4/14/2016	12"-24"	sieved	6.4	140	10.9	0.33	20.2	12.2	403	<0.1	0.7
BH-51	4/14/2016	0-6"	sieved	6.4	149	14	0.44	18.7	24.4	425	<0.1	0.5
BH-51	4/14/2016	12"-24"	sieved	6.5	110	7.8	0.37	25.7	14.8	398	<0.1	0.4

Sample Location	Date	Depth	Remarks	As mg/kg	Ba mg/kg	B mg/kg	Cd mg/kg	Cr mg/kg	Pb mg/kg	Mn mg/kg	Hg mg/kg	Se mg/kg
BH-52	4/14/2016	0-6"	sieved	7.3	352	9.7	0.37	22.4	25.0	326	<0.1	0.5
BH-52	4/14/2016	12"-24"	sieved	5.8	211	8.2	0.31	23.6	12.6	277	<0.1	1.2
BH-53	4/14/2016	0-6"	sieved	6.9	308	15.1	0.45	27.2	22.2	403	<0.1	0.6
BH-53 (dup)	4/14/2016	0-6"	sieved	6.7	297	14.8	0.46	25.2	22.2	391	<0.1	0.6
BH-53	4/13/2016	12"-24"	sieved	5.6	133	8.5	0.34	27.7	14.1	353	<0.1	0.6
BH-54	4/14/2016	0-6"	sieved	6.9	1130	68.5	0.57	31.5	17.4	375	<0.1	1.3
BH-54 (rerun)	4/14/2016	0-6"	sieved	6.3	1050	67.8	0.57	21.9	17.1	347	<0.1	1.2
BH-54	4/14/2016	12"-24"	sieved	6.8	218	19.8	0.43	27.8	16.3	391	<0.1	0.6
BH-55	4/14/2016	0-6"	sieved	6.3	302	36.8	0.40	25.9	16.6	412	<0.1	0.7
BH-55	4/14/2016	12"-24"	sieved	6.0	156	23.0	0.39	19.0	12.0	476	<0.1	0.4
BH-56	4/14/2016	0-6"	sieved	4.8	116	14.4	0.54	11.9	504	324	<0.1	0.4
BH-56 (rerun)	4/14/2016	0-6"	sieved	4.7	163	18.3	0.41	16.8	18.8	406	<0.1	0.7
BH-56	4/14/2016	12"-24"	sieved	5.7	155	18.1	0.31	17.5	10.7	426	<0.1	0.3
BH-57	4/15/2016	0-6"	sieved	6.7	163	7.6	0.37	25.0	124	402	<0.1	0.4
BH-57	4/15/2016	12"-24"	sieved	5.9	201	7.5	0.28	24.4	13.9	296	<0.1	0.8
BH-58	4/15/2016	0-6"	sieved	6.8	165	9.5	0.35	24.6	17.8	389	<0.1	0.5
BH-58	4/15/2016	12"-24"	sieved	5.8	221	8.3	0.28	21.8	11.7	296	<0.1	0.9
BH-59	4/15/2016	0-6"	sieved	6.8	240	13.5	0.35	22.9	19.7	348	<0.1	0.5
BH-59	4/15/2016	12"-24"	sieved	6.5	170	10.8	0.28	24.2	13.2	346	<0.1	0.5
BH-59	4/15/2016	12"-24"	bulk-not sieved	6.3	153	10.0	0.28	18.8	13.9	357	<0.1	0.5
BH-60	4/14/2016	0-6"	sieved	6.6	417	28.3	0.45	19.2	14.4	481	<0.1	0.9
BH-60	4/14/2016	12"-24"	sieved	5.9	161	10.1	0.34	18.9	11.4	440	<0.1	0.6
BH-61	4/14/2016	0-6"	sieved	5.8	168	8.7	0.31	16.8	11.5	414	<0.1	0.4
BH-61	4/14/2016	12"-24"	sieved	5.7	149	9.4	0.26	15.5	9.5	404	<0.1	0.4
BH-62	4/15/2016	0-6"	sieved	7.9	230	8.0	0.35	27.5	17.7	440	<0.1	0.5
BH-62	4/15/2016	12"-24"	sieved	6.0	198	11.6	0.32	28.9	14.4	349	<0.1	0.8
BH-62	4/15/2016	12"-24"	bulk-not sieved	6.3	174	11.3	0.34	23.3	15.5	349	<0.1	0.6
BH-62	4/15/2016	5.5'-6.5'	sieved	5.9	168	8.3	0.32	26.4	12.4	401	<0.1	0.4
BH-63	4/15/2016	0-6"	sieved	5.9	262	5.9	0.26	24.2	11.8	370	<0.1	0.4
BH-63	4/15/2016	12"-24"	sieved	5.6	182	9.6	0.33	32.3	13.3	357	<0.1	0.7
BH-63	4/15/2016	6'-7'	sieved	5.9	160	8.2	0.32	23.7	12.8	383	<0.1	0.5
BH-64	4/15/2016	0-6"	sieved	6.6	161	8.2	0.38	29.6	21.0	451	<0.1	0.6
BH-64	4/15/2016	12"-24"	sieved	5.6	173	10.7	0.31	28.3	12.9	365	<0.1	0.8
BH-64	4/15/2016	6'-7'	sieved	6.1	152	8.6	0.35	31.8	13.2	409	<0.1	0.4
BH-65	4/15/2016	0-6"	sieved	6.3	272	14.5	0.37	28.2	18.8	435	<0.1	0.7
BH-65	4/15/2016	12"-24"	sieved	5.8	169	11.4	0.30	30.0	13.0	362	<0.1	1.0
BH-65	4/15/2016	6'-7'	sieved	6.0	158	8.9	0.34	34.0	14.0	416	<0.1	0.4
BH-65	4/15/2016	6'-7'	bulk-not sieved	6.4	144	8.9	0.31	21.2	14.6	380	<0.1	0.3
BH-66	4/14/2016	0-6"	sieved	6.0	219	10.0	0.31	16.6	11.6	423	<0.1	0.7
BH-66	4/14/2016	12"-24"	sieved	6.6	158	11.2	0.33	18.7	11.2	461	<0.1	0.5
BH-66	4/14/2016	6'-7'	sieved	5.5	173	8.3	0.30	18.4	10.1	469	<0.1	0.3
BH-66	4/14/2016	6'-7'	bulk-not sieved	5.7	164	8.8	0.25	17.8	11.6	390	<0.1	0.3

Sample Location	Date	Depth	Remarks	As mg/kg	Ba mg/kg	B mg/kg	Cd mg/kg	Cr mg/kg	Pb mg/kg	Mn mg/kg	Hg mg/kg	Se mg/kg
BH-67	4/14/2016	0-6"	sieved	5.7	165	10.9	0.25	18.9	11.4	284	<0.1	0.4
BH-67	4/14/2016	12"-24"	sieved	6.0	216	10.9	0.23	17.3	9.9	277	<0.1	0.5
BH-67	4/14/2016	6'-7'	sieved	6.7	193	10.7	0.31	21.1	13.5	403	<0.1	0.8
BH-68	4/14/2016	0-6"	sieved	6.2	227	7.1	0.25	17.7	11.4	282	<0.1	0.4
BH-68	4/14/2016	12"-24"	sieved	6.1	177	9.1	0.23	19.0	10.5	285	<0.1	0.4
BH-68	4/14/2016	4.5'-5.5'	sieved	6.1	190	7.8	0.28	21.9	12.2	331	<0.1	0.3
BH-69	4/15/2016	0-6"	sieved	5.9	165	12.8	0.33	20.1	16.9	351	<0.1	0.5
BH-69 (dup)	4/15/2016	0-6"	sieved	5.8	166	12.5	0.30	20.2	15.7	347	<0.1	0.6
BH-69	4/15/2016	12"-24"	sieved	5.3	176	9.8	0.27	21.3	10.1	325	<0.1	0.5
BH-73	4/15/2016	0-6"	sieved	7.2	429	11.5	0.40	29.2	18.0	407	<0.1	0.5

Notes:

mg/kg milligram per kilogram

Table C-5
Colstrip Plant Site Area, EU4
Borehole Soil Data - Storm Water Ponding Area
2016

Sample Location	Date	Depth	Remarks	As mg/kg	Ba mg/kg	B mg/kg	Cd mg/kg	Cr mg/kg	Pb mg/kg	Mn mg/kg	Hg mg/kg	Se mg/kg
BH-70	4/13/2016	0-6"	sieved	5.9	135	11.3	0.39	23.7	18.0	497	<0.1	0.5
BH-70	4/13/2016	12"-24"	sieved	5.4	137	9.8	<0.05	23.1	16.0	491	<0.1	0.5
BH-71	4/13/2016	0-6"	sieved	6.7	128	14.6	< 0.05	21.7	15.0	388	<0.1	0.5
BH-71	4/13/2016	12"-24"	sieved	5.8	166	21.9	< 0.05	18.7	11.0	295	<0.1	0.5
BH-72	4/13/2016	0-6"	sieved	6.9	122	16.1	< 0.05	25.2	18.0	468	<0.1	0.5
BH-72 (dup)	4/13/2016	0-6"	sieved	6.4	119	14.6	< 0.05	23.2	17.0	448	<0.1	0.5
BH-72	4/13/2016	12"-24"	sieved	5.8	188	35.3	< 0.05	19.0	11.5	300	<0.1	0.6

Notes:

mg/kg milligram per kilogram

Table C-6
Colstrip Plant Site Area, EU5
Groundwater Data Used in the HHRA (Dissolved Metals)
2014 and 2015

Groundwater Wells Located in the Uncontrolled Access Area of the Plant Site within a Suitable Geologic Layer to Support Domestic Wells		Dissolved Boron (mg/L)	Dissolved Selenium (mg/L)
Location	**Date**	**Result**	**Result**
103D	11/18/2014	0.4	<0.005
103D	4/23/2014	0.3	<0.005
103D	5/6/2015	0.3	<0.005
110D	11/17/2014	1.9	<0.005
110D	4/23/2014	1.6	<0.005
110D	5/6/2015	1.7	<0.005
15D	11/17/2014	0.4	<0.005
15D	4/23/2014	0.4	<0.005
15D	5/6/2015	0.4	<0.005
66D	4/9/2014	1	<0.005
66D	4/29/2015	1.1	<0.005
66D	10/22/2014	1.2	<0.005
80D	4/7/2014	0.9	<0.005
80D	10/22/2014	1	<0.005
80D	4/29/2015	0.9	<0.005
95D	11/17/2014	0.4	<0.005
95D	4/22/2014	0.4	<0.005
95D	5/6/2015	0.3	<0.005
99D	11/18/2014	0.4	<0.005
99D	4/23/2014	0.4	<0.005
99D	5/6/2015	0.4	<0.005

NOTES:

mg/L milligrams per liter

Appendix D

Statistical Analysis

NAC-0074_R0

Appendix D: DRAFT Statistical Analysis for the Colstrip Power Plant, Plant Site Area RA

Prepared for Hydrometrics, Inc.

1 August 2016

Prepared by

Neptune & Company, Inc.

NEPTUNE AND COMPANY, INC.
1435 Garrison St, Suite 201, Lakewood, CO 80215

1. Title: DRAFT Appendix D Statistical Analysis for the Plant Site Area RA		
2. Filename: AppDMaster.docx		
3. Description: Statistical Analysis to support the human health and ecological risk assessments for the Colstrip Power Plant Plant Site Area. Prepared for Hydrometrics.		
	Name	Date
4. Originator	Megan Higgs, Ph.D. Statistician Kenny Flagg, M.S. Statistician	04 July 2016
5. Reviewer	Paul Black, Ph.D. Statistician	31 July 2016
6. Remarks		

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	Name	Date
4. Originator	Megan Higgs, Ph.D. Statistician Kenny Flagg, M.S. Statistician	04 July 2016
5. Reviewer	Paul Black, Ph.D. Statistician	31 July 2016
6. Remarks		

Contents

Appendix D Statistical Analysis

D-1 Introduction

Appendix D describes the exploratory data and statistical analysis supporting the development of Exposure Point Concentrations (EPCs) for the human health and ecological risk assessments at the Plant Site Area, Colstrip Stream Electric Station, Colstrip, MT. Risk assessments are performed using four media: surface water, sediment, soil, and groundwater. Specific analysis and conclusions are presented separately for each medium in Sections D-2 (surface water), D-3 (sediment), D-4 (soil), and D-5 (ground water). Recommended upper confidence limits (UCLs) for the mean concentration for each medium by exposure areas are presented at the end of each section. General information about methods used to calculate EPCs for all media is presented here in Section D-1.

D-1.1 Work plan and goals of the analysis

The Cleanup Criteria and Risk Assessment Work Plan (Ford Canty & Associates, Inc., 2015) specifies that upper confidence limits on the mean (UCLs) will be used to calculate reasonable maximum exposure point concentrations (RMEPCs). The term EPC is used in this report, rather than RMEPC, because this covers both the human health and ecological risk assessment terminology. The Work Plan specifically states "the data will undergo more comprehensive statistical evaluation, including the calculation of RMEPCs." Therefore, this report summarizes the work performed to rigorously evaluate and display the data, as well as calculate 95 % UCLs to be used as EPCs in the risk assessments. The quality of data for the intended use is also discussed throughout this report.

Exploratory data and statistical analyses are performed using the R statistical software (R Core Team, 2016) to allow for flexibility in methods and effective plotting capabilities. This includes estimation of EPCs. The estimate EPCs from using R are also compared to those obtained from default recommendations in ProUCL. By not restricting analyses to only those available in ProUCL, methods for addressing violations of independence assumptions, and results from current research performed at Neptune & Company, Inc. (Neptune) regarding choice of UCL estimators for the mean, can be used.

D-1.2 Use of the UCL of the mean as an exposure point concentration (EPC)

The Cleanup Criteria and Risk Assessment Work Plan (Ford Canty & Associates, Inc., 2015) specifies that EPCs should be calculated for each chemical of potential concern (COPC) using "*the upper 95% confidence limit (UCL) on the mean (or possibly a greater percent if recommended by ProUCL)*." Therefore, focus is on calculating a protective (conservative) estimate of the mean concentration over a spatial area defined by a specified exposure unit (EU) and a specified time interval for inclusion of data. Using an estimate of the mean as an EPC is justified under two scenarios: (1) the concentration of the COPC is homogeneous over the EU so that receptors are only exposed to the mean, or (2) the concentration is not homogeneous, but the receptors make a random walk around the EU over time so that their average exposure is the mean concentration over the EU.

The use of a single point estimate as the EPC ignores the inherent uncertainty around the estimate. A confidence interval is typically developed to express uncertainty in the estimation of a mean. However, when the UCL is used as a single number to calculate risk, it is used as a method to build conservatism into the calculation of exposure, not to explicitly deal with uncertainty. A probabilistic risk assessment incorporates uncertainty in exposure based on available data. However, this risk assessment is specified to be deterministic, and therefore a single number must be developed to represent exposure for each scenario. Therefore, uncertainty must be dealt with informally through discussions of data quantity and quality and careful investigation of available data.

Based on its underlying assumption, a 95% UCL is expected to underestimate the mean in 5% of random samples[1] (by the definition of coverage of a confidence interval). Therefore, in 95% of random samples, the UCL estimate is expected to overestimate the mean (i.e. be "protective"). (Note that it is not clear if a single specific set of data will produce an underestimate of the mean, or an overestimate, because only one set of data is collected and reported.) It is actually very difficult to find an estimator with exactly 5 % underestimation rate (95% coverage) across different population distributions, and the difference of the estimated UCL from the overall mean should be taken into account when estimating a UCL, which is something that ProUCL does not accommodate.

D-1.3 Choice of UCL estimator of the mean

There are many methods currently used for calculating UCLs to be used in risk assessment, and it is common to simply choose the suggestion provided by the ProUCL software. The recommendations in ProUCL are based on a combination of hypothesis tests, summary statistics, and a focus on obtaining low underestimation rate (or sufficient coverage). For this risk assessment, we recommend 95% UCLs obtained using two of the methods available in ProUCL, but perform the actual calculations in R statistical software. The main difference between our approach and that used by ProUCL is our decision not to rely on results of goodness-of-fit hypothesis tests for particular distributions. It is unfortunately common practice to interpret a large p-value for a goodness-of-fit test as evidence that the data do come from the stated distribution, and then methods for UCL calculation are chosen assuming the population of concentrations does have that distribution. Such tests provide measures of evidence against the data coming from a particular distribution (null hypothesis), not *for* that null hypothesis. A large p-value indicates the distribution may be a reasonable approximation to that generating the data OR it indicates there simply isn't enough information in the data to detect departures from the distribution. For small samples sizes, it is usually the latter. The use of such hypothesis tests in the process of choosing a UCL estimator also creates an implicit decision framework behind UCL calculations based on an inappropriate interpretation of a statistical hypothesis test. Additionally, goodness-of-fit tests have assumptions of their own that are rarely checked. It is particularly inappropriate in situations with small sample sizes to base decisions about how UCLs will be calculated on goodness-of-fit tests of the distribution of the data.

In June, 2016 Neptune conducted a large simulation study comparing many UCL estimators in terms of their underestimation rate (coverage), as well as their bias (average error) and variability. This approach considers not only looking at the proportion of samples for which the UCL underestimates the mean, but also how close the resulting estimates are on average to the population mean and the spread of the UCLestimates. In general, desirable properties of a UCL estimator include closeness to the mean over many random samples, and closeness to the stated underestimation rate (coverage). There is a natural trade-off between these two components, and both should be taken into account when choosing an estimator (however, ProUCL focuses only on coverage). The Neptune simulation study was performed

[1] Note that the term samples here refers to a statistical sample, rather than a physical sample, and hence addresses multiple data points. This is, essentially, a statistical reference to the data.

over a wide range of population distributions with varying degrees of skewness and kurtosis and at sample sizes of 5, 10, 20, and 30.

Two methods were found to be particularly robust to changes in sample size and changes in the shape of the population distribution: (1) the Student's t method based on the assumption that the sampling distribution of the average is well-approximated by a t distribution on $n - 1$ df, and (2) the bias-corrected and accelerated (BCa) bootstrap method which uses resampling, along with bias and skew adjustments, to approximate the sampling distribution of the average. Neptune's simulation study indicates that choosing the maximum of the t and the BCA estimates, which provides a nice balance of underestimation rate, bias, and variance across population distribution shapes is a reasonable statistical rule for estimating a 95% UCL of the mean. The size of errors associated with this recommended estimator are much smaller than those coming from Chebyshev's method, which is often recommended by ProUCL, and which tends to have high underestimation rates (close to 0 % in many cases), but at the expense of extreme overestimation of the mean (large bias and variability). Use of the maximum of the t and BCa UCLs is also a very simple estimator, avoiding the need for goodness-of-fit tests and implicit decision paths that are difficult to justify. A report of the simulation study is in preparation (Flagg et al., 2016). Use of Neptune's rule also acknowledges an underlying issue that it is not possible to use a specific distribution method to exactly estimate a 95% UCL. Instead, the intent is, and can only be, to simply estimate a reasonable upper bound estimate of the mean concentration that seems reasonable given the data. Neptune's recommended rule achieves that goal, whereas ProUCL does not always.

D-1.4 Use of sample maximum as the EPC

Historically, it is common practice to use the maximum observed value as the EPC, instead of the 95% UCL (or other estimate) when the UCL exceeds the maximum observed value. For relatively large sample sizes, it is uncommon to obtain a sample maximum that is less than the true mean. Therefore, the logic behind the decision to choose the sample maximum as the EPC in such cases is that the sample maximum is expected to be larger than the mean (so it is still "protective") and it is closer to the mean than the 95% UCL. There is a tendency to assume the sample maximum is always greater than the population mean, but this is not true for small sample sizes, particularly if areas with higher concentrations are not captured. Likewise, it is tempting to assume that the sample maximum should be greater than the 95% UCL. However, with small sample sizes (less than 10), the sample maximum will often be less than the true 95 % UCL (theoretically defined as the 95th percentile of the distribution of possible sample means). Therefore, in practice a choice needs to be made between using a 95% UCL or the maximum reported value as the EPC, which might have a greater chance of underestimating the mean, but is also probably closer to the true mean being estimated. The decision of which to use should be context dependent, depending on both the conceptual model for the site and the observed data.

Additionally, when confronted with a UCL estimate of the mean that is greater than the sample maximum, the high uncertainty surrounding the value used for the EPC should be acknowledged. The EPA (2004) states in Section 5.2.2 that "when data are insufficient to estimate the 95% UCL, any value used [as an EPC estimate] (such as the maximum value or arithmetic mean) is likely to contribute significantly to the uncertainty in estimates" of risk. EPA (2002) allows use of the sample maximum as the EPC when the UCL exceeds the max, but only if the sample size is large because the maximum may not be protective if the sample size is small. For this risk assessment, uncertainty in the EPCs should be considered large given the small number of locations informing each UCL. Decisions about whether to use a maximum value instead of the 95% UCL are made on a case-by-case for each medium, EU, and COPC. For sample sizes of 4, as used in some of the calculations in this report, about 6 % of samples are expected to have maxima less than the true mean (assuming a normal population distribution) which is close to the 5% underestimation rate aimed for with a 95% UCL, so choice of the maximum as the EPC is not an unreasonable decision. For larger samples sizes the choice to use the maximum when it is less than the 95% UCL provides even greater coverage under the normality assumption.

D-1.5 Data available for non-detects

EPA guidance (EPA, 2006) suggests using the lowest “detection limit” available for the data. Method detection limits (MDLs) often fill that need. The lowest “detection limits” are suggested because they provide the best information available to estimate mean concentrations. For the Colstrip data, the non-detect values in the original data set were censored and assigned contract required quantitation limits (CRQLs), which are reported as “contract required reporting limits”, or “reporting limits” (RLs). MDLs are available, but there is no information in the data to capture concentrations between the MDL and the RL. Therefore, the MDLs cannot be used for the statistical analysis, and focus instead is turned to the RLs. Fortunately, this has very little impact on the risk assessment because only a few chemicals include non-detects, and the non-detect values for those chemicals are less than levels of concern for the human health and ecological risk assessments. All discussion in the following section uses RLs as “detection limits”. If effective data censored at the MDLs had been available then the UCLs could be greater or smaller depending on the relationship between the RLs and MDLs and the subsequent effect on both mean concentration and the standard deviation

D-1.6 Data usability and scope of inference

The data used to inform this risk assessment were collected as part of the monitoring and investigation of the area around the Colstrip Power Plant. They were not collected specifically for a risk assessment of the Plant Site Area. Therefore, the scope of inferences justified based on the sampling design is limited by data availability over time and space. The scope of inference for the risk assessment refers to the spatial area and/or temporal span considered appropriate for the risk assessment, based on the data available. A particular scope can be justified based on the study design and expert considerations regarding the context of the risk problem.

Data to inform this risk assessment are restricted to 2014 and 2015 under the assumption that these recent data best reflect the current conditions. Extending results to 2016 or further into the future assumes conditions will remain the same. For surface water and sediment, there are four sampling dates within these two years with one sampling event in the Spring and one in the Fall of each year.

The spatial extent of this risk assessment is defined as the Plant Site Area. However, data were not collected with risk assessment for the Plant Site Area as the primary goal. Data that were collected for general monitoring of the Colstrip Power plant and that are within the EUs defined for the Plant Site Area are used for this analysis. In each section, the spatial layout of the sampling locations within the Plant Site Area polygon is presented. Appropriate data analysis and estimation of EPCs are restricted to areas that can be justifiably represented by the available data. For example, soil sampling areas are spatially restricted and do not necessarily support generalization to all soil in the Plant Site Area. Surface water and sediment calculations are based on only four sampling locations on the East Fork Armells Creek flowing through the Plant Site Area. Therefore, use of the data to make statements about the entire creek in the Plant Site Area should be made with caution. For ground water, there are only seven wells at depths that could be used for domestic wells, again limiting the scope of the data available for estimation of EPCs.

It is important to not only consider the total number of measurements, but the larger context in which they are related in space and time. The total number of observations might not seem overly limited when counted out of context, but when taking into account the specific number of locations and/or sampling dates, the amount of information used for the EPC estimates is more appropriately represented. For example, there are 16 total concentrations for sediment, but these only come from the combination of four locations and four sampling occasions.

D-1.7 Organization of the report

This report is organized by medium: Surface Water (Section 0), Sediment (Section D-3), Soil (Section D-4), and Ground Water (Section D-5). Within each section data available are described, exploratory plots and summary tables are provided, and 95% UCLs are presented if there is sufficient data available.

D-2 Surface Water

This section describes data available for surface water and methods used to estimate EPCs for both human health and ecological endpoints.

D-2.1 Chemicals of Potential Concern

For the human health risk assessment (RA), manganese and boron are the identified chemicals of potential concern (COPCs), and an EPC is also calculated for arsenic. For the ecological risk assessment, there are five identified COPCs: boron, manganese, vanadium, magnesium, and calcium.

D-2.2 Exposure Units

Exposure units (EUs) are defined differently for the human health and ecological risk assessments (see following subsections). Separate EPCs are calculated for each exposure unit and each COPC, as long as adequate data are available. The surface water of interest is that from the East Fork Armells Creek. Therefore, the six locations with East Fork Armells Creed surface water data from within the Plant Site Area are evaluated. For EPC calculations, AR-12 is excluded because it has been identified as a "background" location upstream from the plant. Data from the NSTP (North Sewage Treatment Pond) are also excluded because it is not a stream location, and generally has smaller concentrations of the COPCs than the East Fork Armells Creek stream location very near to it (AR-2).

D-2.2.1 Human Health

For human health, a single EU is defined to cover all surface water within the Plant Site Area. Therefore, all available stream locations (AR-5, AR-4, AR-3, and AR-2) are used to estimate a single EPC for each analyte: boron, manganese, and arsenic.

D-2.2.2 Ecological

For the ecological RA, there are two types of exposure scenarios for East Armells Creek surface water: (1) animals using the entire creek area on and adjacent to the Plant Site Area, and (2) plants or animals restricted to smaller areas within the creek on and adjacent to the Plant Site Area. One exposure unit is defined as all East Fork Armells Creek surface water within and adjacent to the Plant Site Area (same as for Human Health), and data are used from AR-5, AR-4, AR-3, and AR-2 to inform this ecological EPC. The smaller exposure units are defined as areas around each of the four creek sampling locations, with data from one location informing one exposure unit. Therefore, an EPC is developed based on data from each of the four creek sampling locations individually.

D-2.3 Temporal span

EPCs are calculated from data collected in 2014 and 2015, with the goal of representing current conditions at the site given available data. For most sites and COPCs, there are two measurements per year, one in the fall and one in the spring. At the time these calculations were made, data from spring 2016 were not yet available for use in EPC calculations. However, a preliminary look at Spring 2016 data for magnesium, calcium, and boron reveals concentrations similar to those from Fall 2015. Calcium and magnesium have an additional data point from sampling in Spring 2014 and Fall 2015.

D-2.4 Spatial information

There are six locations with surface water data in the Plant Site Area. For the risk assessment, AR-12 is treated as a background location and therefore is not used to calculate EPCs. NSTP is considered different from the other locations and not representative of creek surface water. AR-2 has 5 samples, instead of 4, because of the field duplicate taken there on April 8, 2014. Stream locations used for the analysis are the same for the human health and ecological risk assessments. The locations and their site names are shown on the below map of the Plant Site Area.

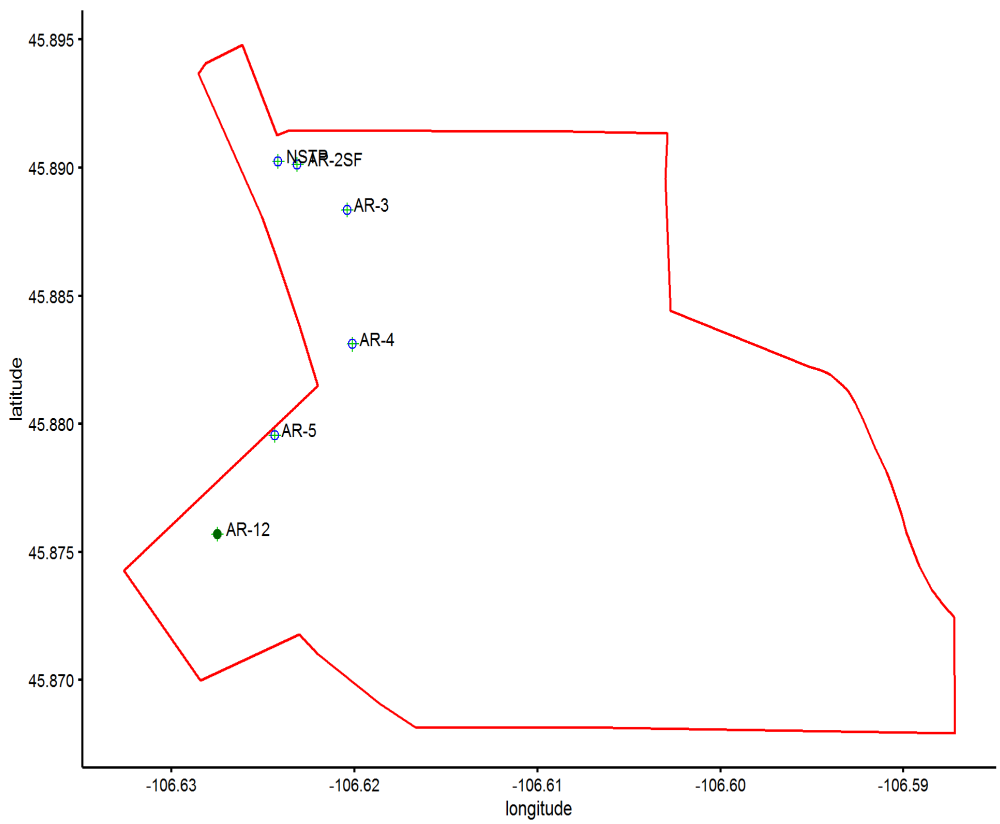

Figure D-2.1. Map of the Plant Site Area showing the locations where surface water samples were taken. The locations used to calculate EPCs are AR-5, AR-4, AR-3, and AR-2.

D-2.5 Available data

For this analysis of surface water data within the Plant Site Area, the data are filtered to include only surface water from locations AR-2, AR-2, AR-3, AR-4, AR-5, NSTP, and AR-12 in 2014 and 2015. For metals, only measurements with "Total" fraction were used. For calcium and magnesium, the only samples available were for "Dissolved" fraction, and, therefore, these were used in the calculations.

Calcium and magnesium have two additional sampling dates at Location AR-2 from non-synoptic run sampling: one in Fall 2014 (September 3 in addition to the October 16 sampling date) and one in Spring 2015 (March 24 in addition to the March 19 sampling date). These data are not used directly in the statistical analysis, although it might be reasonable to use the average of the two March observations because they are close together in time and in concentration.

D-2.6 Time series plots by chemical and location

Concentrations over time are plotted first by chemical and by location (Figures D-2.1 through D-2.3). Figure D-2.2 includes data from all years available for the identified locations and chemicals of interest. Figures D-2.3 and D-2.4 include data from only 2014 and 2015. Initially, all locations are shown on the same plot for each chemical, and then the same information is displayed in separate panels. Both measurements from a field duplicate pair at AR-2 are included as separate points in these plots, and AR-12 and NSTP are included for comparison.

In Figure D-2.3 and Figure D-2.4, location NSTP stands out as usually having lower COPC concentrations, and different trends over time compared to the other locations. This is not surprising given its designation as Sewage Treatment Pond rather than a stream location. This supports the decision to not use NSTP data in the risk assessment.

At all sites except NSTP, the October 2015 measurements for all chemicals are much larger than the other concentrations recorded in 2014 and 2015. Otherwise, the concentrations observed in 2014 and 2015 are generally lower than or similar to values observed in 2007 and earlier. This could be related to lower than usual flow in Fall 2015. A preliminary look at the Spring 2016 data also reveals concentrations similar to Fall 2015, although low flow is not necessarily expected in the spring, Montana did have an unusually dry winter in 2015/16.

The only field duplicate was collected from AR-2 on April 8, 2014. Concentrations were generally very close within the field duplicate pair (Table D-2.1), and therefore are not treated as independent samples from the location. Therefore, before calculating UCLs, the original sample result and the field duplicate are averaged to obtain one measurement to represent that sampling date.

Table D-2.1. Field duplicate results recorded from location AR-2 in April 2014 (mg/L).

Location	Date sampled	Chemical	Result	Detect?
AR-2	2014-04-08	ARSENIC	0.001	N
AR-2FD	2014-04-08	ARSENIC	0.001	N
AR-2	2014-04-08	BORON	1.28	Y
AR-2FD	2014-04-08	BORON	1.17	Y
AR-2	2014-04-08	MAGNESIUM	322	Y
AR-2FD	2014-04-08	MAGNESIUM	333	Y
AR-2	2014-04-08	MANGANESE	0.366	Y
AR-2FD	2014-04-08	MANGANESE	0.351	Y
AR-2	2014-04-08	CALCIUM	281	Y
AR-2FD	2014-04-08	CALCIUM	287	Y
AR-2	2014-04-08	VANADIUM	0.01	N
AR-2FD	2014-04-08	VANADIUM	0.01	N

Summary statistics tables are presented separately for the human health and ecological COPCs. Location AR-12 is excluded from these summaries. Tables D-2.2 excludes the NSTP site, and Table D-2.3 include it for comparison.

Table D-2.2. Summary statistics for COPC's using the average in place of field duplicates and excluding the NSTP* site (mg/L).

			Detects					Non-detects		
Metal	n Locs.	n tot	%	Min	Median	Mean	Max	No.	Min	Max
ARSENIC	4	15	67	0.001	0.002	0.009	0.054	5	0.001	0.001
BORON	4	15	100	0.510	0.99	1.064	2.20	0	NA	NA
CALCIUM	4	17	100	216	284	289	397	0	NA	NA
MAGNESIUM	4	17	100	261	329	342	501	0	NA	NA
MANGANESE	4	15	100	0.59	0.28	1.40	12	0	NA	NA
VANADIUM	4	15	13	0.020	0.035	0.035	0.05	13	0.01	0.01

*NSTP – North Sewage Treatment Pond

Table D-2.2. Summary statistics for COPCs using the average in place of field duplicates, and including the NSTP* site (mg/L).

			Detects					Non-detects		
Metal	n Locs	n tot	%	Min	Median	Avg	Max	No.	Min	Max
ARSENIC	5	18	72.2	0.001	0.002	0.008	0.054	5	0.001	0.001
BORON	5	18	100.00	0.510	0.96	1.02	2.20	0	NA	NA
CALCIUM	5	20	100.00	84.00	276.00	260.55	397.00	0	NA	NA
MAGNESIUM	5	20	100.00	87.00	322.25	306.73	501.00	0	NA	NA
MANGANESE	5	18	100.00	0.059	0.22	1.19	12.00	0	NA	NA
VANADIUM	5	18	11.11	0.020	0.04	0.04	0.05	16	0.01	0.01

*NSTP – North Sewage Treatment Pond

D-2.7 Assessing assumptions and available data for EPC calculations

D-2.7.1 Quantity of data

Surface water EPC calculations are based on a small number of locations and sampling occasions. There are only 4 sampling locations along the stream used in the analysis, with 4 sampling dates for three of those locations and only 3 sampling dates for AR-4 (no data for Fall 2014). For the small exposure units for the ecological risk assessment based on a single location, there are only four observations per location and no variability over space. Therefore, all UCL calculations are based on a small quantity of data informing the mean concentration in time and space, meaning the estimates are highly uncertain, and the EPCs should be used in a way that acknowledges that uncertainty.

D-2.7.2 Assumptions of independence

UCL estimators of the mean are developed under the assumption that independent samples from the population are being used to estimate the mean. In this case, there are violations of the assumption of independence if all the data are to be used together. There are repeat measurements from the same locations (rather than different locations within the EUs), and there are repeat measurements from the same sampling dates. That is, clusters of observations have been collected from the same location (in space) and from the same sampling date (in time). Observations within the same cluster are expected to be more similar than those from different clusters, and in general, this effect is observed in the plots of the data (some locations tend to be greater than average for all dates, and some dates tend to be greater than average for all locations).

Other related sources of dependence are temporal autocorrelation (measurements taken closer in time tend to be more similar), and spatial autocorrelation (measurements taken closer in space tend to be more similar). However, there are too few measurements over time and space to adequately estimate the degree of correlation. For this analysis, this potential correlation is not taken into account. Instead it is assumed that the locations are spaced far enough apart on the stream that this is not a huge concern. An exception is NSTP, which exhibits noticeably different values, but this is because it is a different type of site. Consequently, the NSTP data are not used for the EPC estimates.

The sampling dates are far enough apart that noticeable temporal autocorrelation is not expected. However, seasonal patterns in measurements might be expected, with fall concentrations of chemical constituents expected to be greater than spring measurements because of lower flow in the creek. The risk assessment is being applied over an entire year, and therefore, measurements are used across fall and spring for EPC estimation. Spring and fall measurements could be weighted to better reflect seasonal differences over an entire year, but this is difficult with little data and is not likely to change the conclusions of the risk assessment in this case.

D-2.7.3 Implications of independence violations on calculating UCLs

In the context of producing "protective" estimates of the mean, the potential negative implication of not accounting for sources of dependence in the data is that the variance (or standard deviation) is likely to be under-reported, and the effective sample size is likely to be inflated (because there should be smaller variability among dependent measurements than among independent measurements). This can lead to a UCL estimate that is smaller than what would have been obtained from independent samples. However, in practice, there is a delicate balance between degrees of freedom (from the sample size) and variance, making it difficult to predict whether accounting for sources of dependence in an analysis will affect the UCL. Different methods of accounting for the dependence using the actual data were explored to investigate possible effects, including simulation with artificial data, and found that for this setting results are so close it will not impact the risk assessment. Therefore, for this analysis, the usual approach of calculating UCLs based on all observations available was used.

D-2.7.4 Choice of UCL estimator for the mean

Section D-1.3 provides a justification for the choice of UCL estimator of the mean as the maximum of the UCLs obtained from the t and BCa methods. Note that these results were also compared to the recommendations of ProUCL with no *a priori* assumption about the distribution of the population.

In most cases, ProUCL suggests using the t UCL; therefore the ProUCL suggestion either agrees with the recommendations made or is slightly smaller, when the BCa-based UCL is larger. The only exception occurred for *Manganese* when data from all four locations were combined. In this case ProUCL recommends the 99% Chebyshev UCL; this is not surprising because one very large Manganese measurement gives a large calculated sample skewness and ProUCL considers sample skewness in its decision algorithm. However, the recommendation made is to use the BCa bootstrap estimate in this case.

In the simulation study conducted by Neptune (Flagg et al., 2016), the 95% Chebyshev UCL greatly overestimates the mean (and even the true UCL) for most combinations of input distributions and sample sizes. It also has large variance when the population is skewed. Therefore, use of the 99% Chebyshev is not considered justifiable in this case because it often greatly overestimates the mean.

ProUCL does not take into account that for small sample sizes even random draws from a normal distribution often appear skewed. With so few samples no distribution tests are likely to fail (any distribution test will probably show the assumed distribution cannot be "rejected"). Consequently, and based on Neptune's experience and simulation study, the maximum of the *t* UCL and the BCa bootstrap UCL (both of which are include in the ProUCL software) is preferred for EPC estimation.

D-2.8 Non-detects

Summary information for non-detects is available in Table D-2.3. For surface water data, the analytes with non-detects are arsenic and vanadium each having a single detection limit. Therefore, methods developed to handle multiple detection limits, such as the Kaplan-Meier (KM) estimation method and Gehan ranking, are not needed. These metals with non-detects are also not expected to be critical for the risk assessment because the concentrations are less than threshold risk concentrations.

D-2.8.1 Human health RA

For the human health COPCs, there are no non-detects for boron or manganese. However, for arsenic, the sampling on April 8, 2014 resulted in all non-detects for AR-3, AR-4, AR-5, and AR-2 (which had a pair field duplicates). There was an additional non-detect at AR-2 on March 19, 2015. The reporting detection limit (DL) for arsenic was 0.001 for all these samples. There are an additional 6 detects with the same value of 0.001. Different methods were explored to address the non-detects. These include the robust Regression on Order Statistics (rROS) and simpler substitution methods using DL/2 or DL. UCL Results using the most appropriate ROS method match those using half the detection limit to two decimal places. Additionally, the UCLs do not change by any practically meaningful amount. Consequently, the simplest DL/2 substitution approach is used. In other situations DL/2 might not be a good option, but because of the specific data, it is a reasonable method to use here.

D-2.8.2 Ecological RA

For the ecological COPCs, there are no non-detects for boron, manganese, calcium, or magnesium. However, 20 of the 23 measurements recorded for Vanadium are non-detects. The only detects for Vanadium are from the October 15, 2015 sampling occasion from locations AR-3 and AR-5, as well as the location considered background (AR-12). The reporting detection limit for Vanadium was 0.01 for all samples. Because of the high percentage of non-detects, use of a UCL for the EPCs is not recommended, however, values at the detection limit are used for plots and summaries.

D-2.9 95% UCL calculations

In this section, calculations for the different exposure units defined for surface water are presented. As described above, there are two cases depending on the endpoint of interest: (1) use of all the data for the human health RA and for some ecological receptors, (2) use of data from one location, for other more localized ecological receptors.

D-2.9.1 Single exposure unit (all surface water in the Plant Site Area)

All available concentrations are assumed to be independent pieces data to be used to estimate the mean concentration in surface water in the Plant Site Area during 2014 and 2015. As described in Section D-1.3, the EPCs are calculated as the maximum of the t UCL and the BCA UCL. However, there are only 4 locations along the stream, and the 15 concentrations used in the UCL calculation are from repeat measurements over time at the same locations. Therefore, the data are very limited in time and space and there is large uncertainty in the UCLs. Also, the measurements from the fall sampling in 2015 (the most recent data available) are greater than from previous time points for nearly all chemicals and all locations. The UCLs are calculated by combining the three sampling occasions with relatively low values and the one with higher values. The data for the UCLs are presented in histograms in Figure D-2.5. It is helpful to compare the UCLs to the data to confirm that they appear to be reasonable representations of a conservative estimate of the mean. The UCLs for the human health RA are presented in Table D-2.4, and those for the ecological RA are presented in Table D-2.5.

Note that UCL estimates that are highlighted are suggested for use in the risk assessments. UCL estimates that are not highlighted (e.g., for vanadium in Table D-2.5) are based on data that include a high proportion of non-detects, in which case the UCL is potentially unreliable and it should be used with caution. It might be better in these case to use the maximum reported value instead.

Table D-2.4. 95% UCLs (mg/kg) for the human health risk assessment using all data from sites AR-2, AR-3, AR-4, and AR-5.

	ARSENIC	BORON	MANGANESE
Sample Avg	0.0060	1.064	1.404
Sample Max	0.0540	2.200	12.000
t UCL	0.0125	1.269	2.803
BCa UCL	0.0165	1.282	3.74
Max(t, BCa)	0.0165	1.282	3.74

Table D-2.5. 95% UCLs (mg/kg) for the ecological risk assessment using all data from sites AR-2, AR-3, AR-4, and AR-5.

	BORON	CALCIUM	MAGNESIUM	MANGANESE	VANADIUM[a]
Sample avg	1.064	288.77	341.91	1.40	0.009
Sample max	2.200	397.00	501.00	12.00	0.050
t UCL	1.269	311.93	372.23	2.80	0.014
BCa UCL	1.284[b]	311.12	372.98	3.74	0.016
Max(t, BCa)	1.284	311.93	372.98	3.74	0.016

a - Note that the detect values for vanadium are only from one sampling location, and are greater in the upstream location, AR-12, than at the other locations. Hence, use of the reported UCL for vanadium is not recommended.

B – Note the difference in results for boron for the human health and ecological RAs – this is because the BCa method is a bootstrap method, and the analysis was run separately for the human health and ecological RAs.

D-2.9.2 Smaller location-specific EUs for the ecological RA

There are 4 locations that can be used to define smaller exposure units along East Fork Armells Creek in the Plant Site Area. UCL calculations are performed for each location separately. Consequently, there are only 3 or 4 observations used for each UCL calculation. All variability associated with these UCLs is from variability over time for that location, and does not included variability over space within a smaller EU. Therefore, these UCLs should be treated with caution if used as EPCs in the ecological RA. Calculations are not performed for vanadium because of the few number of detected values.

Note that results for AR-12 and NSTP are included in Tables D-2.6 through D-2.9 only for comparison, and should not be used as EPCs in the risk assessment. These locations have 3 samples, whereas the other locations have 4 samples. As noted earlier, the NSTP is a pond holding treated sewage water, whereas the AR locations are stream sites.

Table D-2.6. 95% UCLs (mg/L) for boron based on concentrations collected over 2014 and 2015.

	AR-12	AR-2	AR-3	AR-4	AR-5	NSTP
Sample Avg	0.690	1.249	1.068	0.760	1.105	0.767
Sample Max	1.000	1.620	1.240	0.990	2.200	0.960
t UCL	0.977	1.670	1.390	1.166	1.991	1.061
BCa UCL	0.852	1.440	1.208	0.850	1.778	0.880
Max(t, BCa)	0.977	1.670	1.390	1.166	1.991	1.061

Table D-2.7. 95% UCLs (mg/L) for manganese, based on four concentrations collected over 2014 and 2015.

	AR-12	AR-2	AR-3	AR-4	AR-5	NSTP
Sample Avg	1.318	0.988	1.006	0.201	3.120	0.100
Sample Max	4.830	2.030	3.390	0.426	12.000	0.151
t UCL	4.074	1.993	2.878	0.531	10.087	0.179
BCa UCL	3.664	1.578	2.598	0.319	9.037	0.131
Max(t, BCa)	4.074	1.993	2.878	0.531	10.087	0.179

Table D-2.8. 95% UCLs (mg/L) for calcium, based on four concentrations collected in 2014 and 2015.

	AR-12	AR-2	AR-3	AR-4	AR-5	NSTP
Sample Avg	290.00	297.00	275.00	272.00	302.75	100.67
Sample Max	371.00	361.00	333.00	326.00	397.00	122.00
t UCL	368.24	342.97	331.86	360.62	391.19	133.41
BCa UCL	329.75	329.33	306.25	307.00	348.00	113.33
Max(t, BCa)	368.24	342.97	331.86	360.62	391.19	133.41

Table D-2.9. 95% UCLs (mg/L) for magnesium, based on four concentrations collected in 2014 and 2015.

	AR-12	AR-2	AR-3	AR-4	AR-5	NSTP
Sample Avg	375.00	322.42	329.50	347.00	379.75	107.33
Sample Max	507.00	375.00	432.00	441.00	501.00	140.00
t UCL	498.00	355.38	421.04	492.69	501.68	155.50
BCa UCL	446.25	346.67	389.50	403.67	442.00	125.00
Max(t, BCa)	498.00	355.38	421.04	492.69	501.68	155.50

D-3 Sediment

This section describes data available for sediment and methods used to estimate EPCs for both human health and ecological endpoints.

D-3.1 Chemicals of Potential Concern

For the human health risk assessment, manganese is the only identified COPC. For the ecological risk assessment, there are three COPCs: boron, manganese, and arsenic. The total concentration is used (rather than dissolved) for both the human health and ecological risk assessment for all metals.

D-3.2 Exposure Units

Separate EPCs are calculated for each EU and COPC defined in the human health and ecological risk assessments, as long as there is adequate data to do so.

D-3.2.1 Human Health

For human health, a single EU is defined to address all sediment in the East Fork Armells Creek within the Plant Site Area. There are 5 surface water and sediment sampling locations along the creek. As with surface water, 4 of those locations are used to develop EPCs. Location AR-12 has been identified as a "background" location, and is not used.

D-3.2.2 Ecological

For ecological health, there are two types of exposure scenarios: (1) animals using the entire Plant Site Area, and (2) plants or animals restricted to smaller areas within the Plant Site Area. One EU is defined as all sediment within the Plant Site Area (same as for Human Health), and smaller EUs are defined around each sampling location, with data from one location informing one EU. With four sampling locations (excluding AR-12), an EPC is developed based on data from each of the four sampling locations individually.

D-3.3 Temporal span

EPCs are calculated from data collected in 2014 and 2015, with the goal of representing current conditions at the site given available data. There are two measurements per year, one in the fall and one in the spring, for each location. At the time of this report, data for all chemicals were not yet available from Spring 2016 sampling.

D-3.4 Spatial information

There are five sediment sampling locations in the Plant Site Area, and the Table D-3.1 presents the number of samples per location and per chemical during 2014 and 2015. AR-12 has 5 samples, instead of 4, because of the field duplicate taken there on October 16, 2014. These are the same locations and dates used for the Surface Water analysis (Appendix Section 0 and Figure D-2.1).

Table D-3.1. Number of sediment samples of taken during 2014 and 2015 by location.

	ARSENIC (AS)	BORON (B)	MANGANESE (MN)
AR-12	5	5	5
AR-2	4	4	4
AR-3	4	4	4
AR-4	4	4	4
AR-5	4	4	4

D-3.5 Available data

For this analysis of sediment data within the Plant Site Area, the data are filtered to include only sediment from locations AR-2, AR-2, AR-3, AR-4, AR-5, and AR-12 in 2014 and 2015. Total fraction was used (rather than dissolved) for all metals. There is only one human health COPC (manganese) and it also an ecological COPC. Consequently, al tables, plots and results are presented for both human health and ecological RAs together.

D-3.6 Time series plots by chemical and location

Time plots are presented in the same order as those for surface water. Concentrations over time are plotted first by chemical and by location (Figures D-3.1 through D-3.3). Figure D-3.1 includes data from all years available for the identified locations and chemicals of interest. Figures D-3.2 and D-3.3 include data from only 2014 and 2015. Initially, all locations are shown on the same plot for each chemical, and then the same information is displayed in separate panels. The field duplicate measurements from AR-12 are both included as points in these plots.

The concentrations of all COPCs recorded at AR-5 in October 2014 are unusually large. At all sites, the arsenic and boron concentrations observed in 2014 and 2015 are less than the concentrations observed in 2007, and the manganese concentrations at AR-2 observed in 2014–2015 are less than the values recorded in 2007.

D-3.7 Field Duplicates

A pair of field duplicates was collected from AR-12 on October 16, 2014. The measurements from the field duplicates are close enough together that it is reasonable to average them (see Table D-3.2). This will not affect EPCs because AR-12 is considered the background location.

Table D-3.2. Field duplicate measurements from AR-12 on October 16, 2014 (mg/kg).

Chemical	Result (mg/kg)
ARSENIC	2.8
ARSENIC	2.7
BORON	15.8
BORON	18.8
MANGANESE	534.0
MANGANESE	564.0

D-3.8 Summary statistics

Summary statistics tables are presented in Table D-3.3. Location AR-12 is excluded from these summaries.

Table D-3.3. Summary of concentration data (mg/kg) from the 4 sampling locations (excluding AR-12) across years 2014 and 2015.

			Detects					Non-detects		
Metal	n Locs.	n tot	%	Min	Median	Mean	Max	n	Min	Max
ARSENIC	4	16	100	1.0	3.00	3.82	12.6	0	NA	NA
BORON	4	16	100	4.4	13.1	13.6	19.9	0	NA	NA
MANGANESE	4	16	100	412	1805	1940	5910	0	NA	NA

D-3.9 Assessing assumptions and available data for EPC calculations

D-3.9.1 Limitations of the data

EPC calculations obtained for sediment are based on only 4 different sampling locations along the creek, and only 4 sampling dates for each location. For the small EUs for the ecological RA that are based on single locations, only four observations are available and, therefore, there the UCLs are highly uncertain and they should be used with caution.

A few other observations from the data deserve mention and should be considered when considering use of these UCLs as EPCs in the risk assessment. The AR-5 site has relatively high values for arsenic and manganese for the fall 2014 sampling, but the AR-5 data appear very similar to the other sites for the other sampling events. The UCLs are pulled higher because of these large values, but they are still less than the maximum values in most cases.

D-3.9.2 Assumptions of independence for calculating UCLs

Potential violations of independence apply to the sediment data in the same way that they apply to the surface water data (see Sections D-2.9.2 and D-2.9.3).

D-3.10 Non-detects

There are no non-detects for any of the metals included and all detects are above the reported detection limits.

D-3.11 95% UCL calculations

In this section, calculations for the different exposure units defined for sediment are presented. As described above, there are two cases depending on the endpoint of interest: (1) use of all the data for the human health RA and for some ecological receptors, (2) use of data from one location, for other more localized ecological receptors.

D-3.11.1 Single exposure unit (all sediment in the Plant Site Area)

UCLs calculated in this section are obtained by treating all available samples within an EU as independent. They are the maximum of the t-based UCL and the BCA, as described in Section D-1.3. The results for the single sediment EU are presented in Table D-3.4.

Again, UCLs that are highlighted are considered reasonable for use in the risk assessments, whereas UCLs that are not highlighted are calculated based on data with a high proportion of non-detects. In the latter cases, the maximum concentration might be preferred for the risk assessment.

Table D-3.4. 95% UCLs (mg/kg) using all observations from the four locations.

	ARSENIC (AS)	BORON (B)	MANGANESE (MN)
Sample Avg	3.83	13.61	1940
Sample Max	12.6	19.9	5910
t UCL	5.00	15.60	2555
BCa UCL	5.58	15.29	2667
Max(t, BCa)	5.58	15.60	2667

D-3.11.2 Smaller location-specific exposure units for ecological RA

There are 4 locations informing the smaller exposure units along the East Fork Armells Creek in the Plant Site Area. UCL calculations are performed for each location separately. Consequently, there are only 3 or 4 observations used for each UCL calculation. All variability associated with these UCLs is from variability over time for that location, and dose not included variability over space within a smaller EU. Therefore, these UCLs should be treated with caution if used as EPCs in the ecological RA. Calculations are not performed for vanadium because of the few number of detected values. The UCLs are presented in Tables D-3.5 (arsenic), D-3.6 (boron), and D-3.7 (manganese). Results for AR-12 are included in these tables for comparison purposes, and are not intended to be used as an EPC.

Table D-3.5. 95% UCLs (mg/kg) for arsenic, based on four concentrations collected in 2014 and 2015.

	AR-12	AR-2	AR-3	AR-4	AR-5
Sample Avg	2.31	2.00	4.45	3.53	5.33
Sample Max	2.9	3.3	5.6	5.1	12.6
t UCL	3.11	3.17	5.88	5.16	11.03
BCa UCL	2.65	2.75	5.10	4.33	10.15
Max(t, BCA)	3.11	3.17	5.88	5.16	11.03

Table D-3.6. 95% UCLs (mg/kg) for boron, based on four concentrations collected in 2014 and 2015.

	AR-12	AR-2	AR-3	AR-4	AR-5
Sample Avg	14.18	11.98	15.65	10.28	16.53
Sample Max	17.8	16.4	19.9	15.4	19.4
t UCL	19.45	16.85	21.01	15.62	20.14
BCa UCL	16.48	14.43	17.88	13.03	17.95
Max(t, BCA)	19.45	16.85	21.01	15.62	20.14

Table D-3.7. 95% UCLs (mg/kg) for manganese, based on four concentrations collected in 2014 and 2015.

	AR-12	AR-2	AR-3	AR-4	AR-5
Sample Avg	538.500	2217.50	2365.00	630.75	2545.00
Sample Max	700.000	3910.00	2970.00	986.00	5910.00
t UCL	762.858	3586.01	2875.79	924.51	5214.29
BCa UCL	630.750	3250.00	2737.50	842.50	4775.00
Max(t, BCA)	762.858	3586.01	2875.79	924.51	5214.29

D-4 Soil

Soil sampling was performed by Hydrometrics following an Interim Response Action Work Plan (Hydrometrics, Inc., 2016). The soil samples are limited in spatial scale relative to the Plant Site Area and represent three small areas with known history of spills or ponding of stormwater that had not been contained on the site.

D-4.1 Soil sampling areas

There are three distinct sampling areas that are shown in a series of figures in the main text (Figures 6, 8, 9, and 10). Area 1 is the middle area with most locations (corresponding to EU 3); Area 2 is the northern cluster of locations (corresponding to EU 2); and, Area 3 is the cluster of locations just to the south of the middle area (corresponding to EU 4). Figure D-4.1 expands the northwest corner of the Plant site, and more clearly shows the sampling locations. Area 1 soil samples were collected based on an approved DEQ grid and spacing. Variations in sample locations from the work plan are the result of slight inconsistencies related to the use of handheld Global Positions System (GPS) and site conditions, which included marshy areas, roads, and physical obstacles. The small collection of locations to the north comprise Area 2, and the three locations in the south comprise Area 3.

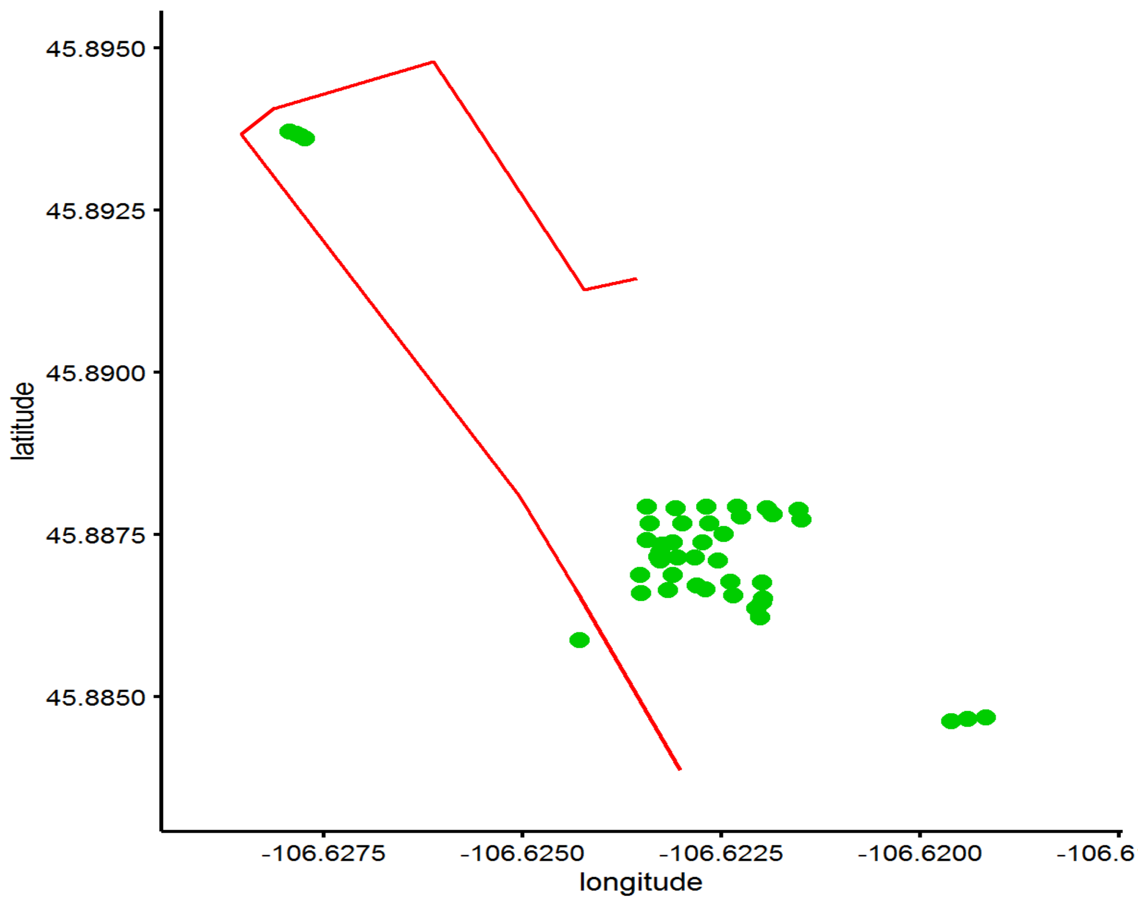

Figure D-4.1. Spatial location of soil sampling points within the northwest part of the Plant Site Area.

Area 1 contains 37 sampling locations, mostly on a grid with 100 ft centers, over a site where two spills are known to have occurred at approximately the same location, one in 1998 and one 2000. Area 1 has four deep soil samples taken from a smaller area used to stage excavated materials during the spill clean-up in 1998, and three additional deep samples taken from the site of a temporary retention pond used to hold water from the 2000 spill. Figure D-4.2 provides the locations and site names for the Area 1 sample locations. Note the data include one location immediately outside the plant site area (BH-73). This sample was collected off the sampling grid for Area 1, to the southwest of Area 1 upstream of the spill area and upstream of a culvert that passes beneath the railroad tracks, and, hence, unaffected by the spills. This location is included because it is close enough to the border of the Plant Site Area, was collected at the same time as the other samples, and is potentially useful for informing the RA.

Area 2 has four sampling locations chosen to be centrally located along the long axis of a spill that occurred in March, 2000, and deep samples were taken from two of those locations. Area 3 has three sampling locations, with no deep samples, and was chosen because stormwater overflows have been historically documented there.

The spills associated with Area 1 and Area 2 were remediated. Area 3 has not been remediated from possible overflows. Therefore, based on this information, it might be expected that Area 1 and Area 2 appear similar in terms of concentrations of chemicals, and possibly different from Area 3. The lack of data from Area 2 and Area 3 makes formal statistical comparisons difficult.

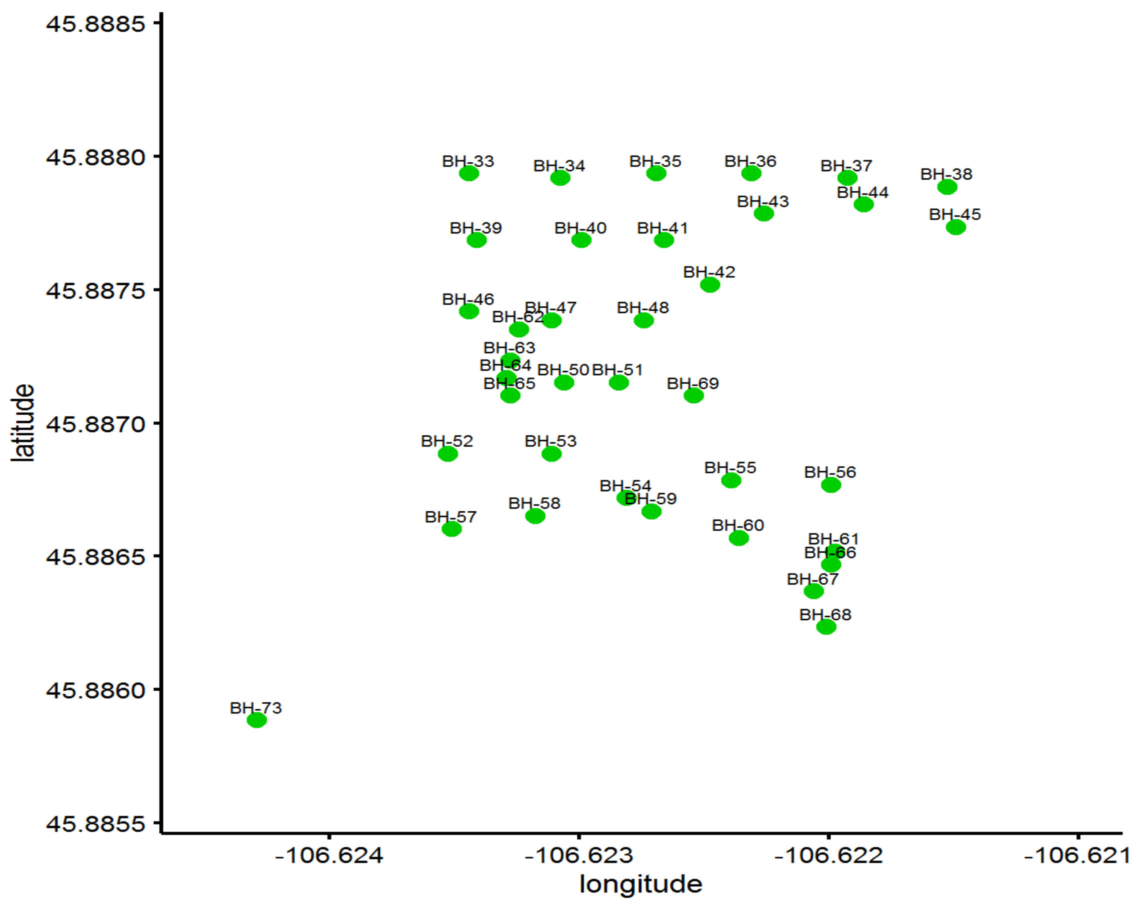

Figure D-4.2. Locations and site names for Area 1.

D-4.2 Soil sampling depths

According to the Soil Sampling plan for the Interim Response Action Work Plan, shallow soil samples were collected from two depth intervals 0-6 inches below the ground cover and 12-24 inches at every location (plus the 5 field duplicates). The shallow samples are recorded as 0-6 inches in the data set, and mid depth samples are 12-24 inches,. Deep soil samples were planned from 6-7 feet from a subset of proposed locations. However, for deep samples, end depths do vary from 7 feet, with end depths of 5.5 (1 sample), 6.0 (1 sample), and 6.5 (1 sample) in the data set due to the presence of shallow groundwater. In the plots and summaries the following distinctions are made: shallow depths (0-6 inches), mid depths (12-24 inches), and deep depths (> 5 ft).

Figure D-4.3 provides some information on the depth of samples taken at each location. Shallow (0-6 inch) samples have a solid gray circle symbol, mid depth samples (12-14 inches) have a hollow purple circle, and locations with deep depth have larger green circles around the other two circles.

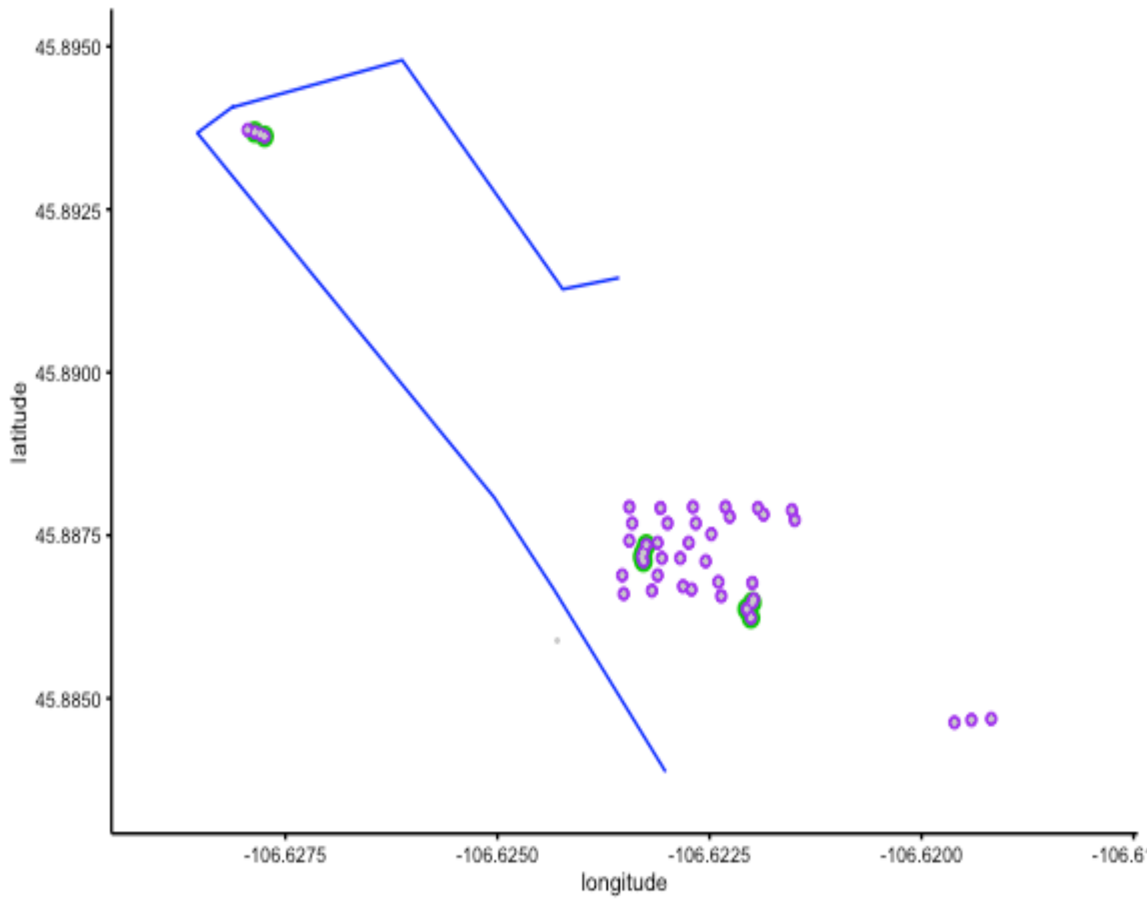

Figure D-4.3. Spatial locations in Area 1 with indicators for depths of samples taken at each location

D-4.3 Exposure unit and COPC definitions

As described above, the soil sampling covers a small proportion of the total spatial area of the Plant Site Area. Data only exist from areas where spills are known to have occurred, and two of the areas have been remediated. There is no information on background soil concentrations in the Plant Site Area. Therefore, the EPC's estimated in this report apply only to the sampled areas. Use of the EPCs to represent a larger EU, or area, requires additional assumptions that cannot be assessed with available data. Also, Area 1 and Area 2 are remediated spills and Area 3 is an unremediated area thought to have had overflows of storm water from Plant Site containment canals.

D-4.3.1 Ecological RA

All nine metals available in the data are considered to be COPCs for the ecological risk assessment: arsenic, barium, boron, cadmium, chromium, lead, manganese, mercury, and selenium. EUs are defined by spatial extent and also by depth, and include all three soil sampling areas. For plant and burrowing animal exposure scenarios, samples at depths up to 24 inches are used (both shallow and mid depth samples). Three sets of UCLs are calculated: (1) shallow depths, (3) mid depths, and (3) shallow and mid depths combined. UCLs are used for EPCs for only shallow depths and shallow and mid combined.

D-4.3.2 Human health

Barium and lead are identified as possible COPCs for human health in the shallowest sampling depth only. For the human health RA, separate EUs are defined for each soil sampling area, although an EPC calculation is only needed to support the human health RA in Area 1. Therefore, 95% UCLs are calculated for barium and lead in the shallowest depth in Area 1.

D-4.4 Data considerations

There are several data issues that require some attention and explanation, which will lead to recommendations on how to use the data to support the RAs. Samples are either bulk or sieved. Also some samples were re-run in the laboratory, and there are some field duplicates. The following subsections describe each data issue in turn.

D-4.4.1 Bulk and sieved samples

Five locations (BH-32, BH-59, BH-62, BH-65, BH-66) have both sieved and bulk results for one depth. BH-32 and BH-59 have bulk samples at an end depth of 14 inches, and sieved samples at end depths of 6 inches and 24 inches. Therefore, these bulk samples come from a depth between the other sieved samples. BH-62 bulk samples were taken from the mid depth category (12-24 inches), where there was also a sieved sample from the same depth. Bulk samples BH-65 and BH-66 were taken in the deep layer (6-7 ft), along with sieved samples.

A comparison of sieved to bulk concentration data within pairs reveals a mix of results. Concentrations of sieved samples have greater concentrations for some metals, as expected, although this is not true for all pairs or metals (Figure D-4.4). For example, there is a mid-depth cadmium sample and a shallow sample for manganese that each have a greater concentration for the bulk sample, and all of the arsenic and lead concentrations are greater for the bulk sample.

It is not clear what the difference is between sieved and bulk samples, and the data do not show that one routinely has greater concentrations than the other. However, only the sieved data are used for the remaining exploratory analysis and EPC calculations because there are comparatively few bulk samples.

D-4.4.2 Laboratory re-runs

The samples from BH-54 and BH-56 were re-run for metals in June 2016 because the lead concentration in the shallow sample in location BH-56 was much greater than all other samples, and the barium sample in location BH-54 was much greater than all other samples. Re-run samples were conducted by preparing completely new aliquots from the original soil and not as a re-run of the original aliquot. The re-run lead concentration(BH-56) was 18.8 mg/kg compared to 504.0 mg/kg, and the re-run barium concentration for BH-54 was 1130 mg/Kg compared to the original 1050 mg/kg. Depending on the source, lead concentrations are sometimes affected by small lead particles or fragments.

All metals were re-run and there is no clear reason to suggest that the first laboratory analysis was not correct. Consequently, the re-run results are treated as laboratory duplicates and the two concentrations are averaged (Table D-4.1) in the following statistical analyses and EPC calculations.

Table D-4.1. Results for the laboratory re-run for samples at locations BH-54 and BH-56, along with average of the two laboratory runs.

Well	chemical	units	Run1	Run2	Average
BH-54	ARSENIC	mg/kg	6.90	6.30	6.60
BH-54	BARIUM	mg/kg	1130	1050	1090
BH-54	BORON	mg/kg	68.5	67.8	68.15
BH-54	CADMIUM	mg/kg	0.57	0.57	0.57
BH-54	CHROMIUM	mg/kg	31.5	21.9	26.7
BH-54	LEAD	mg/kg	17.40	17.10	17.25
BH-54	MANGANESE	mg/kg	375	347	361
BH-54	MERCURY	mg/kg	0.10	0.10	0.10
BH-54	SELENIUM	mg/kg	1.30	1.20	1.25
BH-56	ARSENIC	mg/kg	4.80	4.70	4.75
BH-56	BARIUM	mg/kg	116.0	163.0	139.5
BH-56	BORON	mg/kg	14.40	18.30	16.35
BH-56	CADMIUM	mg/kg	0.54	0.41	0.48
BH-56	CHROMIUM	mg/kg	11.90	16.80	14.35
BH-56	LEAD	mg/kg	504.0	18.8	261.4
BH-56	MANGANESE	mg/kg	324	406	365
BH-56	MERCURY	mg/kg	0.10	0.10	0.10
BH-56	SELENIUM	mg/kg	0.40	0.70	0.55

D-4.4.1 Field duplicates

There are 5 pairs of field duplicates taken at 5 different locations (BH-29, BH-43, BH-53, BH-69, and BH-72). All are taken at the shallowest depth (0-6 inches). BH-29 is in Soil Area 2, BH-72 is in Soil Area 3, and the remaining three are in Soil Area 1.

The pairs of field duplicates generally have very similar concentrations (Figure D-4.5), especially in comparison to variability among observations that are not duplicates (Figure D-4.6). Figure D-4.6 can be compared to Figure D-4.7, in which all field duplicates and laboratory re-run pairs are replaced by their average.

The results from the duplicates are all close together relative to the variability among different locations. Therefore, treating them as independent observations is not appropriate. Due to the similarities of the measurements, the two measurements are averaged to support data analysis and EPC estimation. Under these circumstances, the goal is to estimate UCLs across the spatial area and the sample size used in the estimation should be the number of locations available. Averaging the field duplicates provides a simple way to avoid reporting a UCL that is smaller than it should be simply from a lack of independence among the observations. This decision also avoids ignoring available data in the calculation of EPCs, and avoids putting more weight on sampling occasions and locations with field duplicates or laboratory re-runs. Figure D-4.7 displays the data used for subsequent analysis after averaging.

D-4.5 Summary tables

Summary statistics tables are presented for each depth and area that corresponds to both the human health and ecological EUs (Tables D-4.2 through D-4.7). Consequently, six different summary statistics tables are presented that represent data as follows: all three soil sampling areas split by sampling depths (shallow, mid, deep); data from all three areas combining shallow and mid depths (separately and averaged across depths); and, using only Area 1 at shallow depths. Field duplicate and laboratory re-run pairs are all replaced by their averages.

All of the data represent detected values for most of the metals. The exceptions are some results for cadmium, and all results for mercury, which was not detected in any samples. Consequently, UCLs are not calculated for mercury.

The summaries indicate that the concentrations are not very different by depth interval. For a few metals the average concentration in the shallow depth interval is greater than in the 6-12 and 12-24 in intervals (e.g., barium and lead). It is, perhaps, reasonable to expect that the concentrations should represent background levels, however, there are no background data that can be used directly for comparison. However, the concentrations are mostly within range of the regional Montana state background data that are generally available.

Table D-4.2. Summary of metals concentration data (mg/kg) from all three soil sampling areas for the shallow depth (0-6 inches) interval

			Detects					Non-detects		
Metal	n Locs.	n tot	%	Min	Median	Mean	Max	n	Min	Max
ARSENIC	44	44	100	4.70	6.20	6.18	7.90	0	NA	NA
BARIUM	44	44	100	106.00	171.00	217.53	1090.00	0	NA	NA
BORON	44	44	100	5.90	10.55	13.21	68.15	0	NA	NA
CADMIUM	44	44	82	0.07	0.35	0.36	0.64	8	0.05	0.05
CHROMIUM	44	44	100	14.35	22.80	22.72	30.75	0	NA	NA
LEAD	44	44	100	11.40	16.50	25.81	261.40	0	NA	NA
MANGANESE	44	44	100	271.00	386.50	386.62	497.00	0	NA	NA
MERCURY	44	44	0	NA	NA	NA	NA	44	0.10	0.10
SELENIUM	44	44	100	0.40	0.50	0.54	1.25	0	NA	NA

Table D-4.3. Summary of metals concentration data (mg/kg) from all three soil sampling areas for the middle depth (12-24 inches) interval

			Detects					Non-detects		
Metal	n Locs.	n tot	%	Min	Median	Mean	Max	n	Min	Max
ARSENIC	43	43	100.0	4.90	5.80	5.88	6.80	0	NA	NA
BARIUM	43	43	100.0	96.30	166.00	165.73	237.00	0	NA	NA
BORON	43	43	100.0	6.90	10.20	12.05	35.30	0	NA	NA
CADMIUM	43	43	79.1	0.23	0.31	0.33	0.71	9	0.05	0.05
CHROMIUM	43	43	100.0	15.50	21.80	22.75	32.30	0	NA	NA
LEAD	43	43	100.0	9.47	12.60	15.97	73.90	0	NA	NA
MANGANESE	43	43	100.0	277.00	357.00	360.12	491.00	0	NA	NA
MERCURY	43	43	0.0	NA	NA	NA	NA	43	0.10	0.10
SELENIUM	43	43	100.0	0.30	0.50	0.58	1.20	0	NA	NA

Table D-4.4. Summary of metals concentration data (mg/kg) from all three soil sampling areas for the deep depth (5-7 ft) interval

			Detects					Non-detects		
Metal	n Locs.	n tot	%	Min	Median	Mean	Max	n	Min	Max
ARSENIC	9	9	100.0	5.50	6.00	6.02	6.70	0	NA	NA
BARIUM	9	9	100.0	137.00	160.00	163.89	193.00	0	NA	NA
BORON	9	9	100.0	7.80	8.30	8.63	10.70	0	NA	NA
CADMIUM	9	9	88.9	0.28	0.32	0.32	0.37	1	0.05	0.05
CHROMIUM	9	9	100.0	18.40	25.30	26.06	34.00	0	NA	NA
LEAD	9	9	100.0	10.10	13.20	13.12	15.30	0	NA	NA
MANGANESE	9	9	100.0	331.00	401.00	395.78	469.00	0	NA	NA
MERCURY	9	9	0.0	NA	NA	NA	NA	9	0.10	0.10
SELENIUM	9	9	100.0	0.30	0.40	0.46	0.80	0	NA	NA

Table D-4.5. Summary of metals concentration data (mg/kg) from all three soil sampling areas for the shallow and mid depths combined

			Detects					Non-detects		
Metal	n Locs.	n tot	%	Min	Median	Mean	Max	n	Min	Max
ARSENIC	44	87	100.0	4.70	6.00	6.03	7.90	0	NA	NA
BARIUM	44	87	100.0	96.30	168.00	191.93	1090.00	0	NA	NA
BORON	44	87	100.0	5.90	10.20	12.64	68.15	0	NA	NA
CADMIUM	44	87	80.5	0.07	0.33	0.34	0.71	17	0.05	0.05
CHROMIUM	44	87	100.0	14.35	22.40	22.73	32.30	0	NA	NA
LEAD	44	87	100.0	9.47	14.00	20.94	261.40	0	NA	NA
MANGANESE	44	87	100.0	271.00	370.00	373.52	497.00	0	NA	NA
MERCURY	44	87	0.0	NA	NA	NA	NA	87	0.10	0.10
SELENIUM	44	87	100.0	0.30	0.50	0.56	1.25	0	NA	NA

Table D-4.6. Summary of metals concentration data (mg/kg) from all three soil sampling areas using the average of the shallow and mid depths for each location

			Detects					Non-detects		
Metal	n Locs.	n tot	%	Min	Median	Mean	Max	n	Min	Max
ARSENIC	44	44	100.0	4.70	6.20	6.18	7.90	0	NA	NA
BARIUM	44	44	100.0	106.00	171.00	217.53	1090.00	0	NA	NA
BORON	44	44	100.0	5.90	10.55	13.21	68.15	0	NA	NA
CADMIUM	44	44	81.8	0.07	0.35	0.36	0.64	8	0.05	0.05
CHROMIUM	44	44	100.0	14.35	22.80	22.72	30.75	0	NA	NA
LEAD	44	44	100.0	11.40	16.50	25.81	261.40	0	NA	NA
MANGANESE	44	44	100.0	271.00	386.50	386.62	497.00	0	NA	NA
MERCURY	44	44	0.0	NA	NA	NA	NA	44	0.10	0.10
SELENIUM	44	44	100.0	0.40	0.50	0.54	1.25	0	NA	NA

Table D-4.7. Summary of metals concentration data (mg/kg) from the shallow depth for soil sampling Area 1 only

			Detects					Non-detects		
Metal	n Locs.	n tot	%	Min	Median	Mean	Max	n	Min	Max
ARSENIC	37	37	100.0	4.70	6.20	6.21	7.90	0	NA	NA
BARIUM	37	37	100.0	106.00	175.00	228.39	1090.00	0	NA	NA
BORON	37	37	100.0	5.90	10.20	13.67	68.15	0	NA	NA
CADMIUM	37	37	83.8	0.07	0.35	0.35	0.57	6	0.05	0.05
CHROMIUM	37	37	100.0	14.35	22.20	22.30	30.00	0	NA	NA
LEAD	37	37	100.0	11.40	16.00	25.59	261.40	0	NA	NA
MANGANESE	37	37	100.0	271.00	383.00	382.24	481.00	0	NA	NA
MERCURY	37	37	0.0	NA	NA	NA	NA	37	0.10	0.10
SELENIUM	37	37	100.0	0.40	0.50	0.55	1.25	0	NA	NA

D-4.6 Exploratory data analysis

Further exploratory data analysis is performed to help better visualize and understand the data that support the risk assessment. Field duplicates and laboratory re-runs are replaced by their averages and non-detects are represented with a different symbol.

D-4.6.1 General data observations

The mercury data are all non-detects and therefore are not be used in the UCL calculations. The cadmium data include some non-detects and the technical approach for addressing these is discussed in the next section.

Barium and lead both contain one large concentration (after averaging the field and laboratory re-run duplicates), and these are found at different locations. The largest lead concentrations for the shallow depth are found in Area 1, but there are also two higher values in Area 2 around 50 mg/kg. For barium, the greatest values are all from Area 1, though there is one value from Area 2 near 300 mg/kg. Other metals with only a few noticeably larger concentrations are boron, cadmium, and selenium. Interpretation of spatial plots of these data is presented below.

D-4.6.2 General observations from the spatial plots

The spatial plots include Figures D-4.8 through D-4.10 for all the locations, and Figures D-4.11 through D-4.13 for Area 1 locations only. These plots show how measurements from shallow and mid depths at the same location tend to relate to each other. Whereas many locations appear to exhibit similar concentrations for different depths at the same location, the data occasionally indicate a large value in the shallow interval and a small value in the mid-level interval, or vice-versa (Figures D-4.8 and D-4.9).

One sampling location stands out has having large values for multiple metals: BH-54. This is one of the locations chosen for the laboratory re-run because of the unusually large concentration for barium, but it also has high values for boron, cadmium, and selenium for the shallow depth samples relative to other locations. All values remained higher in the laboratory re-run. The one location with very high lead is BH-56, which was also chosen for the laboratory re-run.

In general, cadmium, chromium, and arsenic show similar spatial patterns, and manganese tends to have higher concentrations in the northern part of Area 1 than most other locations. Patterns are similar between the shallow and mid depths for Area 1.

As suggested in the exploratory data analysis, the data indicate evidence of positive autocorrelation, which appears to taper off within about 200 meters for most metals. However, the 95% UCLs needed to support the RAs do not account for the spatial autocorrelation. Preliminary investigations in the context of t-UCLs indicates that the UCLs can be slightly greater when accounting for the spatial autocorrelation, but not by enough to impact the outcome of the RA.

D-4.6.3 Non-detects

Cadmium and mercury are the only metals with non-detects, and each has a single reported detection limit. All measurements for mercury are non-detects with a detection limit of 0.1. Consequently, it is not possible to calculate UCLs of the mean for mercury.

For cadmium in shallow depths, 9 of the 49 measurements are non-detects (18.4 %), with two of those coming from a field duplicate pair at BH-72 in Area 3; there are 8 unique locations with non-detects at the shallow depth, with 6 in Area 1 (BH-33, BH-34, BH-36, BH-37, BH-38, and BH-45) and 2 in Area 3 (BH-71 and BH-72). After averaging the field duplicates, 8 out of 44 locations (18.2%) have non-detects for cadmium.

For middle depths, 9 of 43 samples were non-detects (26 %); 3 of the 9 locations are the Area 3 locations (BH-70, BH-71, and BH-72), and 5 are locations close together within Area 1 (BH-33, BH-34, BH-35, BH-36, BH-37,and BH-38). Most of these locations are the same as those with non-detects at the shallow depth. For deep depths, 1 of the 9 samples was a non-detect (11.1 %), at location BH-32, which did not have non-detects at the shallow and mid depths.

D-4.7 Non-detect strategy for Cadmium (CD)

For cadmium, several statistical methods were investigated for addressing the censored observations that have a single censoring limit. All the Cadmium non-detects are examples of Type I censored observations with a single censoring limit. The EnvStats R package is used because it provides more options for estimation (or imputation) related to non-detects and methods for calculating the 95% UCL.

Data from the shallow and mid depths were combined to compare statistical methods. The distribution of detects for cadmium is fairly symmetric, leading to reasonable use of the normal distribution and robust regression on order statistics (rROS) for imputation, with all imputed values being greater than zero. The method of maximum likelihood, rROS method, and substituting half the detection limit all result in BCa-method 95% UCLs of 0.30 (rounded to the nearest 100th). The rROS used with the t-UCL method gives a slightly higher 95% UCL at 0.32. The linear relationship with the quantiles appears reasonable for use of the rROS and therefore this method is recommended over maximum likelihood. For the different depths, both the t-UCL and BCa-UCL are computed after using rROS for the non-detects, and the larger of the two is recommended for use as the EPC; the result is slightly greater than that obtained when directly substituting the detection limit.

Note that ProUCL recommends implementation of Kaplan-Meier. The ProUCL implementation of Kaplan-Meier gives the same results as substituting the DL when there is only one DL.

D-4.8 Calculation of 95% UCLs

The general approach to estimating UCLs is described on Section D-1.3, and involves choosing the maximum of the *t*-UCL or the BCa-UCL. These two UCLs are estimated using data from all three soil sampling areas for 4 different subsets of depth: (1) shallow depth only, (2) Mid depth only, (3) shallow and mid depths combined (87 total measurements), and (4) the average of shallow and mid depths for each location (44 total measurements).

For the human health RA, 95% UCLs are also estimated using data only from Area 1 at shallow depths. All metals are included for comparison, but only lead and barium are used in the HHRA.

The results are presented in Tables D-4.8–D-4.12, and the data used for each are summarized in Tables D-4.2, D-4.3, D-4.5, D-4.6, and D-4.7, along with plots. Histograms of the data used in the calculations are also included in Figures D-4-14 through D-4.17 (the cadmium histogram has non-detects simply plotted at the DL.).

Highlighted values in the tables are UCL estimates that are considered sufficiently reliable that they can be used to support the human health and ecological risk assessments. Other UCL estimates are based on data that contain a large proportion of non-detects. In these cases it might be preferable to use the maximum reported concentration.

Table D-4.8. 95% UCLs (mg/kg) for the shallow depth and all three soil sampling areas

	Avg	Max	t-UCL	BCa-UCL	max(t, BCa)
ARSENIC	6.18	7.90	6.36	6.35	6.36
BARIUM	217.53	1090.00	256.46	278.99	278.99
BORON	13.21	68.15	15.79	17.07	17.07
CADMIUM	0.303	0.645	0.341	0.338	0.341
CHROMIUM	22.723	30.750	23.78	23.73	23.78
LEAD	25.81	261.40	36.05	43.76	43.76
MANGANESE	386.63	497.00	398.57	398.01	398.57
SELENIUM	0.535	1.250	0.576	0.584	0.584
CADMIUM_cens	0.303	0.645	0.355	0.346	0.355

Table D-4.9. 95% UCLs (mg/kg) for the mid depth (12-24 inches) and all three soil sampling areas

	Avg	Max	t-UCL	BCa-UCL	max(t, BCa)
ARSENIC	5.88	6.80	5.995	5.99	5.995
BARIUM	165.73	237.00	173.91	173.73	173.91
BORON	12.05	35.30	13.447	13.751	13.75
CADMIUM	0.269	0.71	0.304	0.303	0.304
CHROMIUM	22.75	32.30	23.88	23.89	23.89
LEAD	15.97	73.90	19.40	21.10	21.10
MANGANESE	360.12	491.00	373.24	373.65	373.65
SELENIUM	0.581	1.20	0.630	0.630	0.630
CADMIUM_cens	0.269	0.71	0.321	0.307	0.321

Table D-4.10. 95% UCLs (mg/kg) for shallow and mid depth combined for all three soil sampling areas

	Avg	Max	t-UCL	BCa-UCL	max(t, BCa)
ARSENIC	6.03	7.90	6.14	6.14	6.14
BARIUM	191.93	1090.00	212.23	223.772	223.77
BORON	12.64	68.15	14.09	14.649	14.65
CADMIUM	0.286	0.71	0.312	0.311	0.312
CHROMIUM	22.73	32.30	23.50	23.50	23.50
LEAD	20.94	261.40	26.38	29.97	29.97
MANGANESE	373.52	497.00	382.55	382.45	382.55
SELENIUM	0.558	1.25	0.589	0.592	0.592
CADMIUM_cens	0.286	0.71	0.328	0.321	0.328

Table D-4.11. 95% UCLs (mg/kg) for the average of the shallow and mid depth observations for all three soil sampling areas

	Avg	Max	t-UCL	BCa-UCL	max(t, BCa)
ARSENIC	6.04	7.20	6.17	6.17	6.17
BARIUM	194.62	654.00	217.15	227.13	227.13
BORON	12.63	43.98	14.34	14.91	14.91
CADMIUM	0.288	0.678	0.322	0.320	0.322
CHROMIUM	22.81	29.58	23.82	23.79	23.82
LEAD	20.91	136.05	26.42	29.16	29.16
MANGANESE	373.90	494.00	384.44	384.38	384.44
SELENIUM	0.557	0.925	0.590	0.591	0.591
CADMIUM_cens	0.288	0.678	0.355	0.346	0.355

Table D-4.12. 95% UCLs (mg/kg) for shallow samples from Area 1 only

	Avg	Max	t-UCL	BCa-UCL	max(t, BCa)
ARSENIC	6.21	7.90	6.42	6.41	6.42
BARIUM	228.39	1090.00	273.96	301.76	301.76
BORON	13.67	68.15	16.71	18.22	18.22
CADMIUM	0.299	0.57	0.337	0.333	0.337
CHROMIUM	22.30	30.00	23.48	23.45	23.48
LEAD	25.59	261.40	37.73	47.83	47.83
MANGANESE	382.24	481.00	395.08	393.97	395.08
SELENIUM	0.55	1.25	0.594	0.604	0.604
CADMIUM_cens	0.299	0.57	0.355	0.346	0.355

D-5 Ground Water

D-5.1 Exposure Units and COPCs

An area in the Plant Site Area was delineated for use in the groundwater human health RA (see red polygon in Figure D-5.1) to represent the area in which domestic wells could potentially be located in the future. Domestic wells would be drilled into the SubMcKay geologic unit, and therefore only wells at approximately this depth are included. Boron and manganese are of interest for the human health RA based on comparison to risk thresholds, but data are only available for boron at these locations, depths, and times.

These restrictions result in data for boron from 7 wells: 15D, 66D, 95D, 99D, 103D, 80D, and 110D (see Figure D-5.2). There are 9 unique sampling dates corresponding to sampling of all the wells in April 2014, all wells in October or November 2014, and all wells in April or May of 2015. Accordingly, the data are categorized into three sampling periods (Spring 2014, Fall 2014, and Spring 2015), and are summarized in Table D-5.1.

Table D-5.1. Boron concentrations (mg/L) for groundwater by well and sampling period.

	Spring 2014	Fall 2014	Spring 2015
103D	0.3	0.4	0.3
110D	1.6	1.9	1.7
15D	0.4	0.4	0.4
66D	1.0	1.2	1.1
80D	0.9	1.0	0.9
95D	0.4	0.4	0.3

D-5.2 Exploratory plots

D-5.2.1 Time series plots

Time plots of the boron data are provided in Figure D-5.3 for each of the wells. These plots show consistent and small concentrations for the three sampling events.

D-5.2.2 Spatial plots

The spatial plot (Figure D-5.4) also show very small concentrations. There is some indication that the concentration in well 110D are greater than those in other wells, but there are no other obvious effects.

Figure D-5.5 shows the relative magnitude of the data by sampling events and by location. Again, location 110D shows greater concentrations, followed by wells 66D and 80D. Note that both of these wells are the northern most wells of the group. There are not other obvious effects, but this does imply the need to address the repeated sampling from these wells in the statistical analysis and EPC calculations.

D-5.3 Field duplicates

Location 110-D has a field duplicate observation in April, 2014. The duplicate pair both report a concentration of 1.6, which is the value used in the statistical analysis.

D-5.4 Check for non-detects

There are no non-detects for the data selected for the risk assessment, and all detected values are greater than the single detection limit of 0.1.

D-5.5 Summary tables

Tables D-5.2 through D-5.4 summarize Boron concentrations from the seven wells identified with depths that could be consistent with domestic water use and within the Plant Site Area and with data from 2014 and 2015.

Table D-5.2. Boron data

Well	Sample Date	Result (mg/L)
103D	2015-05-06	0.3
103D	2014-11-18	0.4
103D	2014-04-23	0.3
110D	2015-05-06	1.7
110D	2014-11-17	1.9
110D	2014-04-23	1.6
15D	2015-05-06	0.4
15D	2014-11-17	0.4
15D	2014-04-23	0.4
66D	2015-04-29	1.1
66D	2014-04-09	1.0
66D	2014-10-22	1.2
80D	2015-04-29	0.9
80D	2014-04-07	0.9
80D	2014-10-22	1.0
95D	2015-05-06	0.3
95D	2014-11-17	0.4
95D	2014-04-22	0.4
99D	2015-05-06	0.4
99D	2014-11-18	0.4
99D	2014-04-23	0.4

Table D-5.4. Summary statistics by sampling period for the seven locations (mg/L).

		Detects					Non-detects		
Well	n tot	%	Min	Median	Mean	Max	n	Min	Max
Spring 2014	7	100	0.3	0.4	0.71	1.6	0	NA	NA
Fall 2014	7	100	0.4	0.4	0.81	1.9	0	NA	NA
Spring 2015	7	100	0.3	0.4	0.73	1.7	0	NA	NA

Table D-5.3. Summary statistics by location for the three sampling occasions (mg/L).

		Detects					Non-detects		
Well	n tot	%	Min	Median	Mean	Max	n	Min	Max
103D	3	100	0.3	0.3	0.33	0.4	0	NA	NA
110D	3	100	1.6	1.7	1.73	1.9	0	NA	NA
15D	3	100	0.4	0.4	0.40	0.4	0	NA	NA
66D	3	100	1.0	1.1	1.10	1.2	0	NA	NA
80D	3	100	0.9	0.9	0.93	1.0	0	NA	NA
95D	3	100	0.3	0.4	0.37	0.4	0	NA	NA
99D	3	100	0.4	0.4	0.40	0.4	0	NA	NA

D-5.6 Calculation of the 95% UCLs

Details regarding choice of UCL estimator of the mean are provided in Section D-1.3 and are the same as for the other media.

Calculation of UCLs assumes independence among observations. As for surface water, the available data are from repeat measurements on the same wells over time, and on different wells within the same time. Therefore, there are multiple clusters of samples (wells and sampling period) associated with clear sources of dependence. There might also be temporal and spatial dependence beyond the clusters, though the data are too limited to assess this, and it is unlikely that the results would be affected noticeably.

UCLs are first calculated by treating all measurements as independent and are then compares to UCLs obtained from fitting a model that properly accounts for the clusters in time and space. There are different statistical methods available to account for the dependence from the repeat measurements in the same sampling periods and same locations. A common method is to use a random effects model fit, with a constant mean and both time period and location as random effects. This method relies on assessing approximate normality, and estimating variances. Assumption checks and results appear reasonable in this case, and the resulting UCL for the overall mean is 1.086, which is slightly greater than the UCL estimated assuming independence, as expected. The estimate that accounts for the cluster effects is more appropriate, and is recommended for use in the human health RA. The results are presented in Table D-5.5 below. The highlighted UCL is recommended.

Table D-5.3. 95% UCLs for boron in mg/L

	Sample Avg	Sample Max	t-UCL	BCa-UCL	max(t, BCa)	t-cluster
BORON (B)	0.752	1.90	0.943	0.952	0.952	1.086

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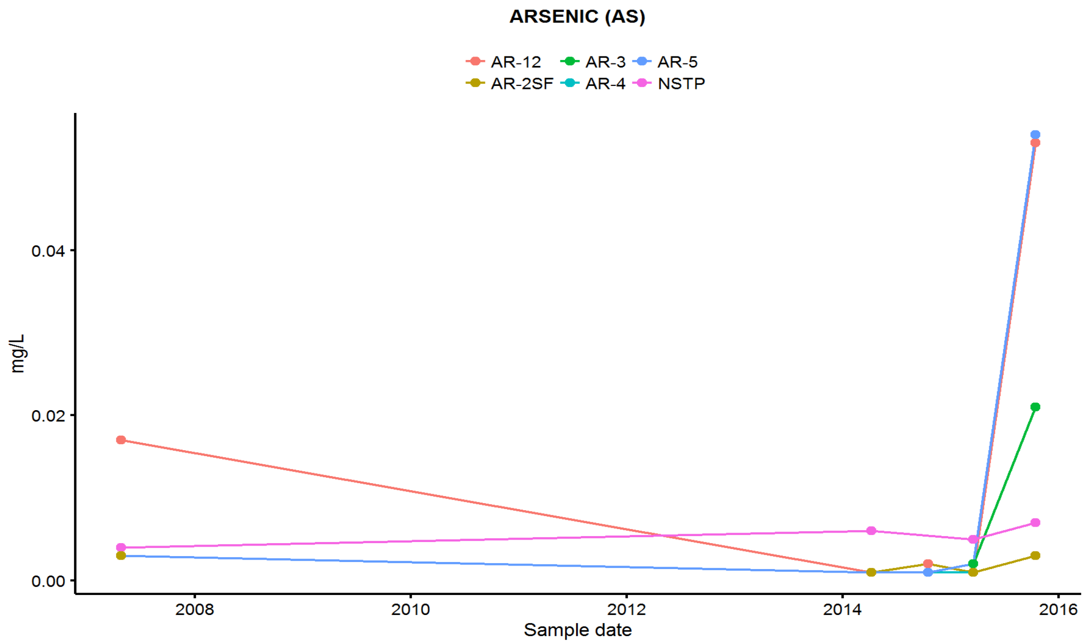
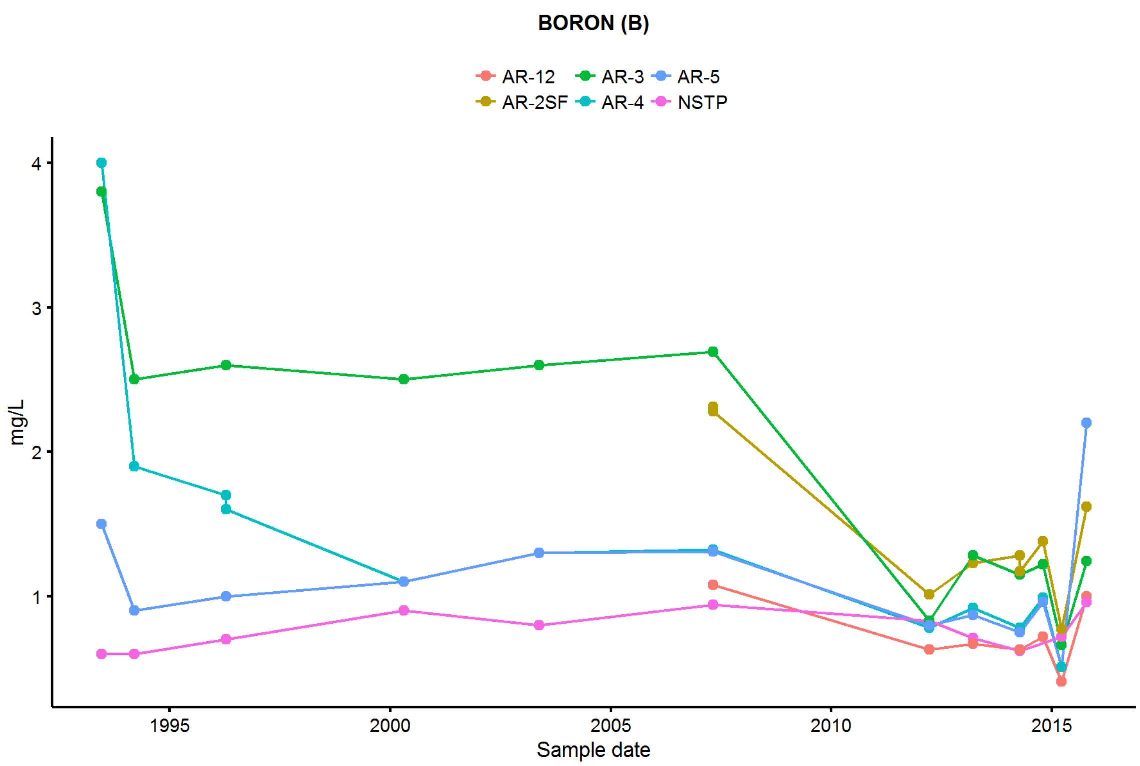
FIGURES

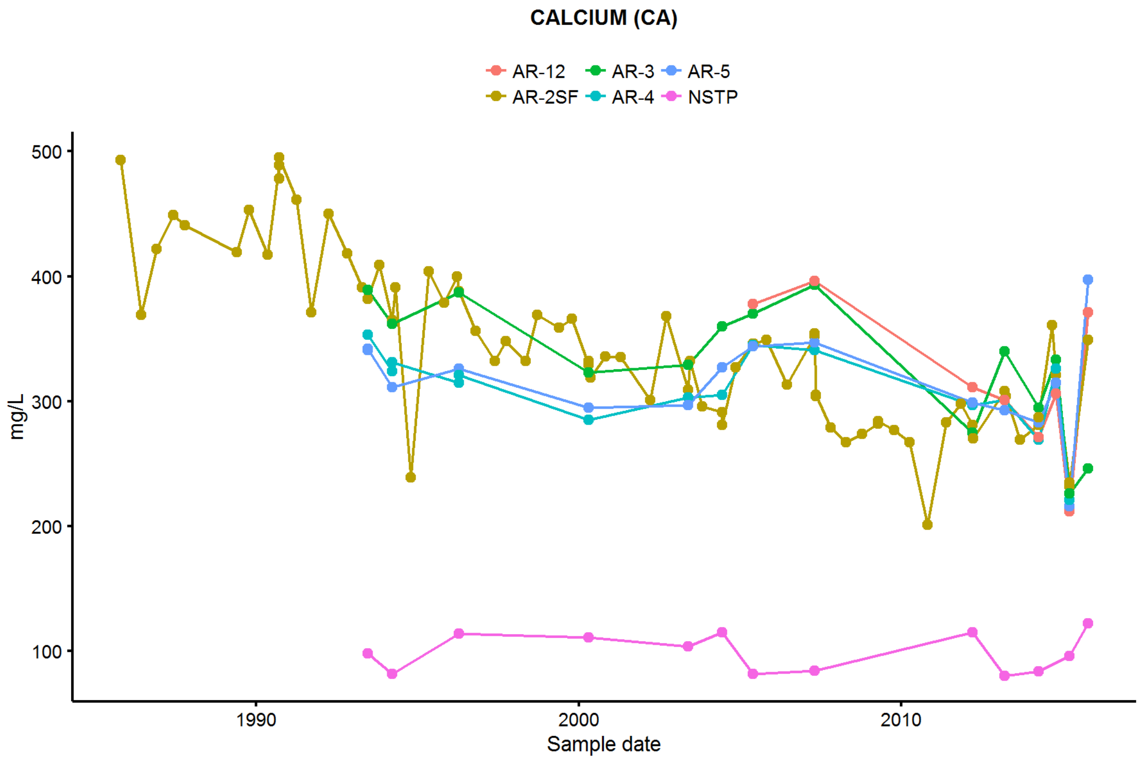
Appendix D Figures

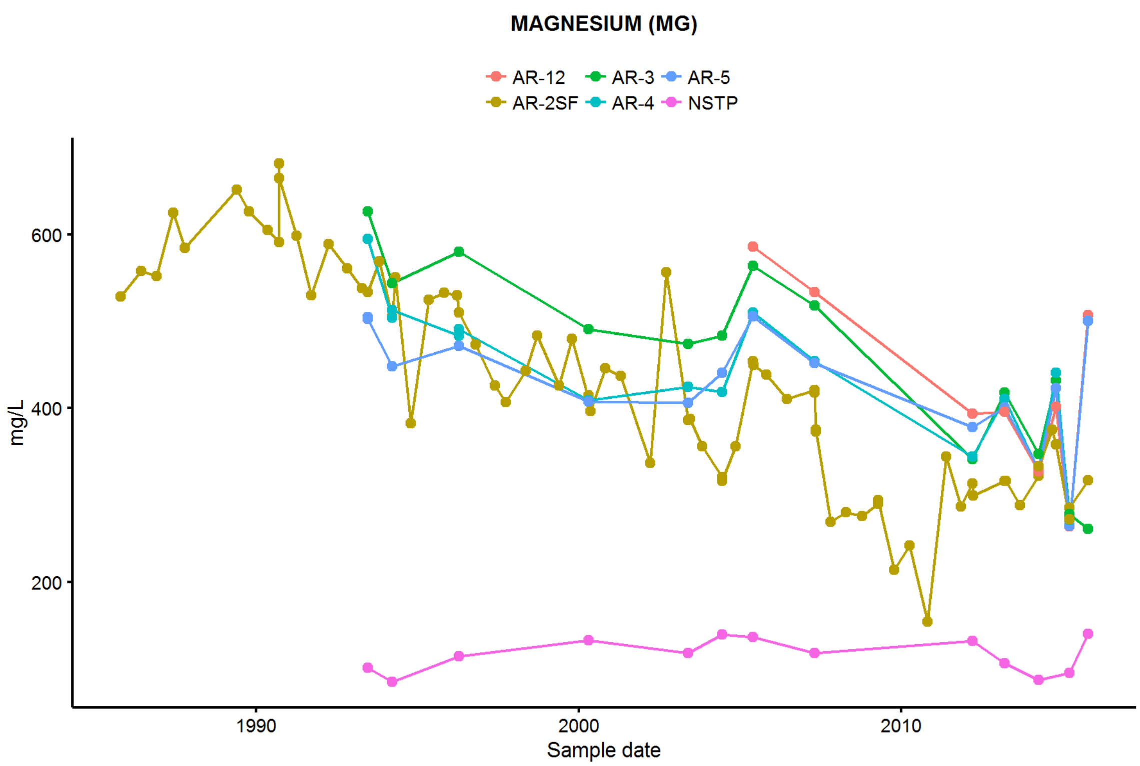
Section D-2 Figures: Surface Water Data

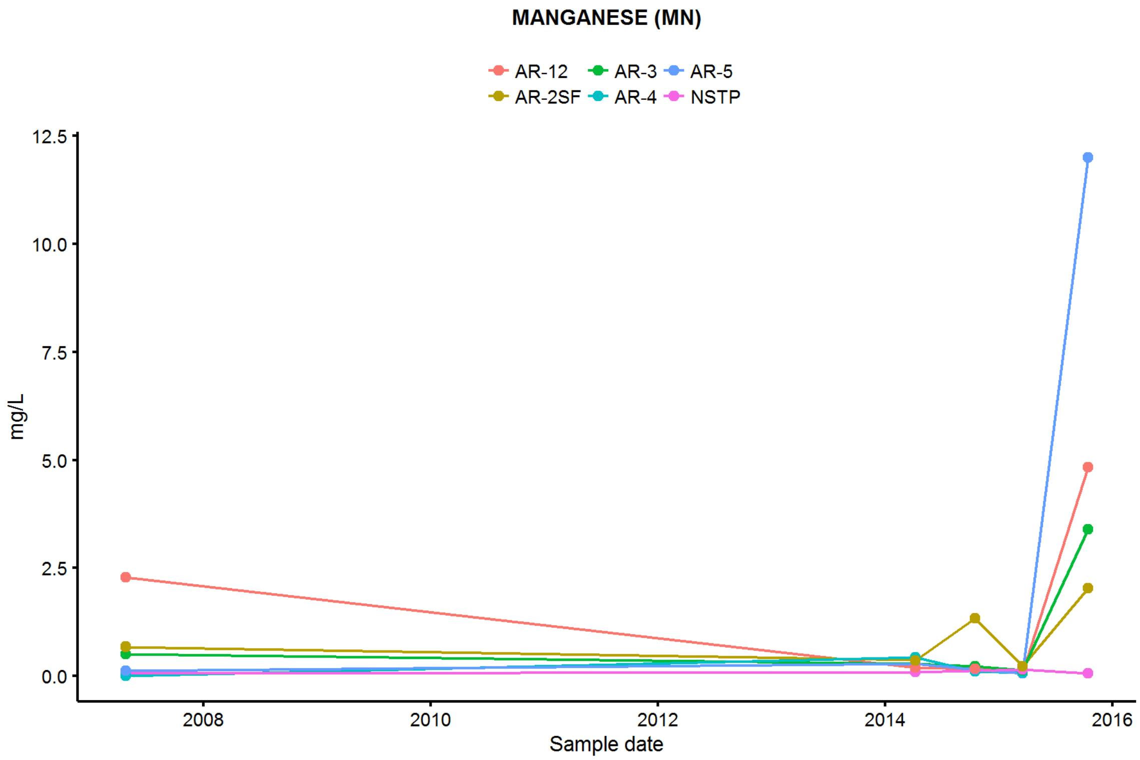
Figure D-2.1. Concentrations (mg/L) over time for all data available (not restricted to 2014 and 2015).



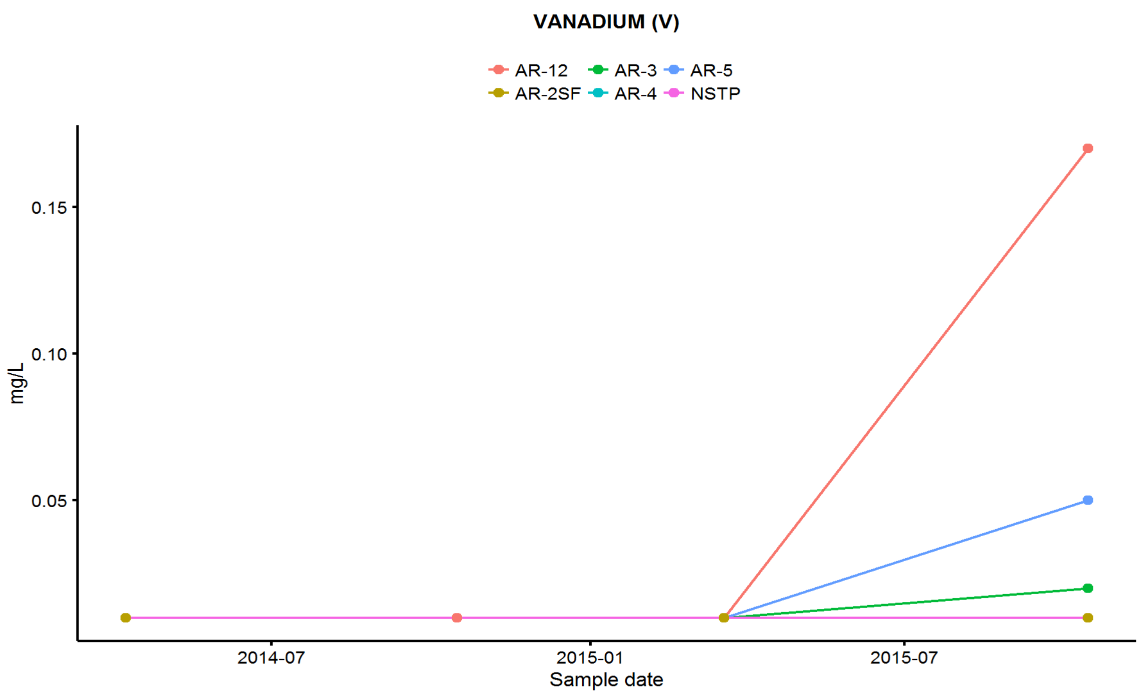



CALCIUM (CA)
AR-12
AR-3
AR-5
AR-2SF
AR-4
NSTP
500
400
300
200
100
mg/L
1990
2000
2010
Sample date


MAGNESIUM (MG)
AR-12
AR-3
AR-5
AR-2SF
AR-4
NSTP
600
400
200
mg/L
1990
2000
2010
Sample date

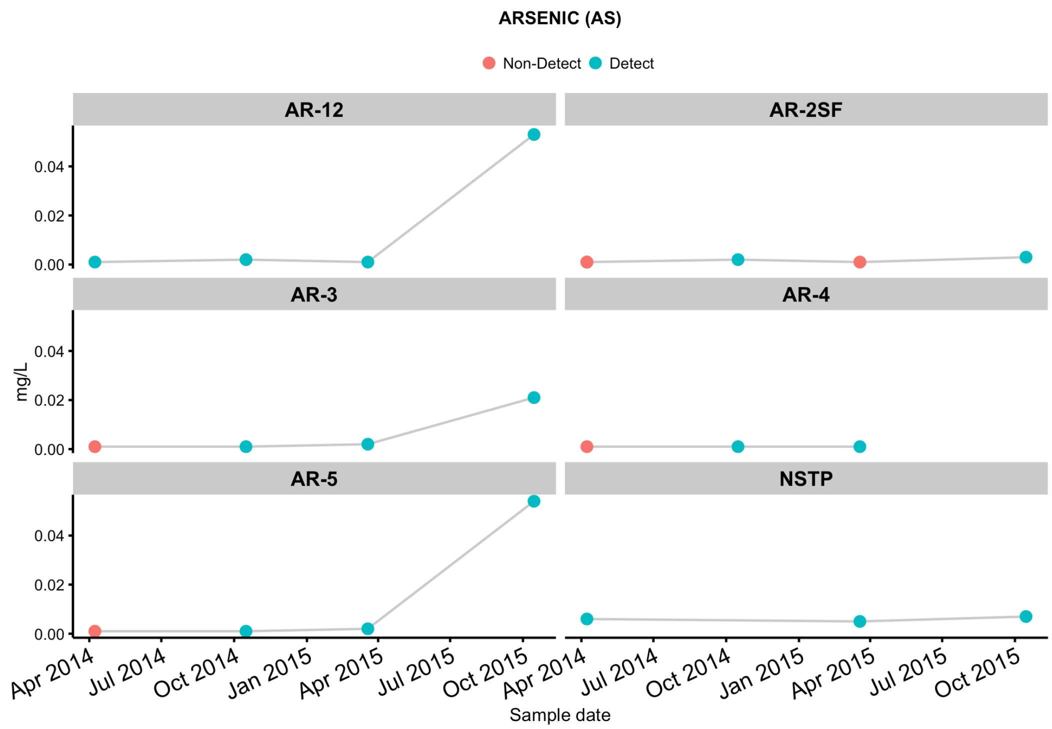


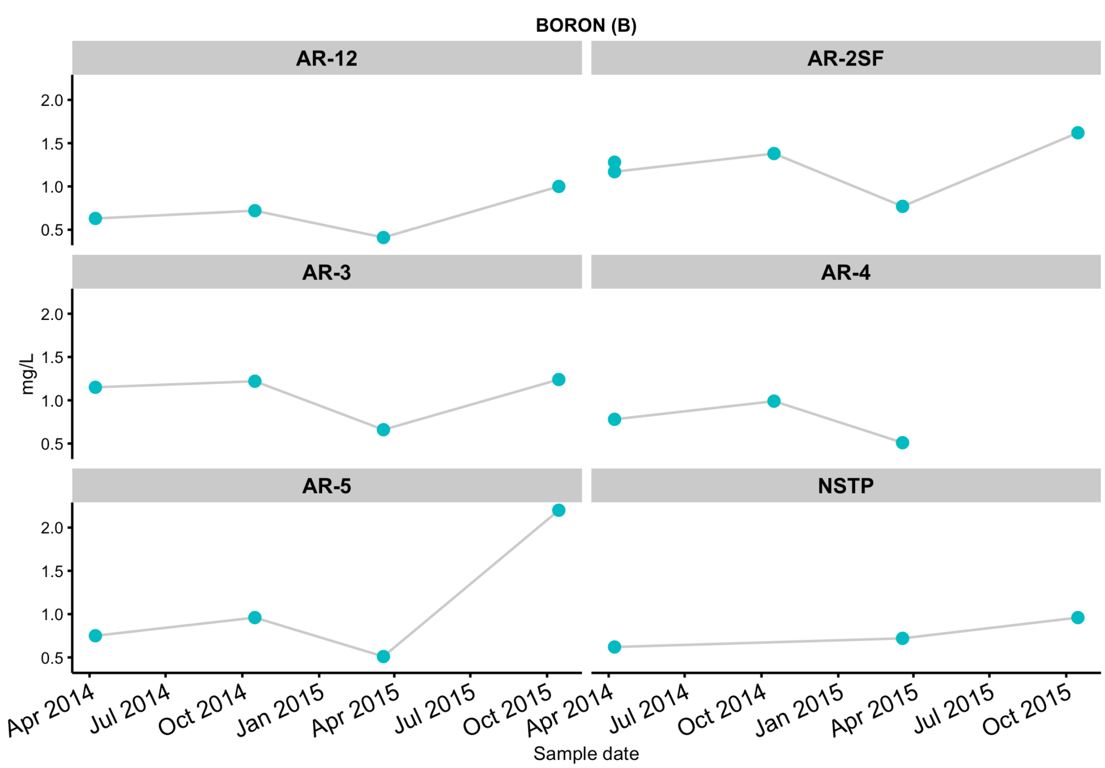
MANGANESE (MN)
AR-12
AR-3
AR-5
AR-2SF
AR-4
NSTP
12.5
10.0
7.5
5.0
2.5
0.0
mg/L
2008
2010
2012
2014
2016
Sample date

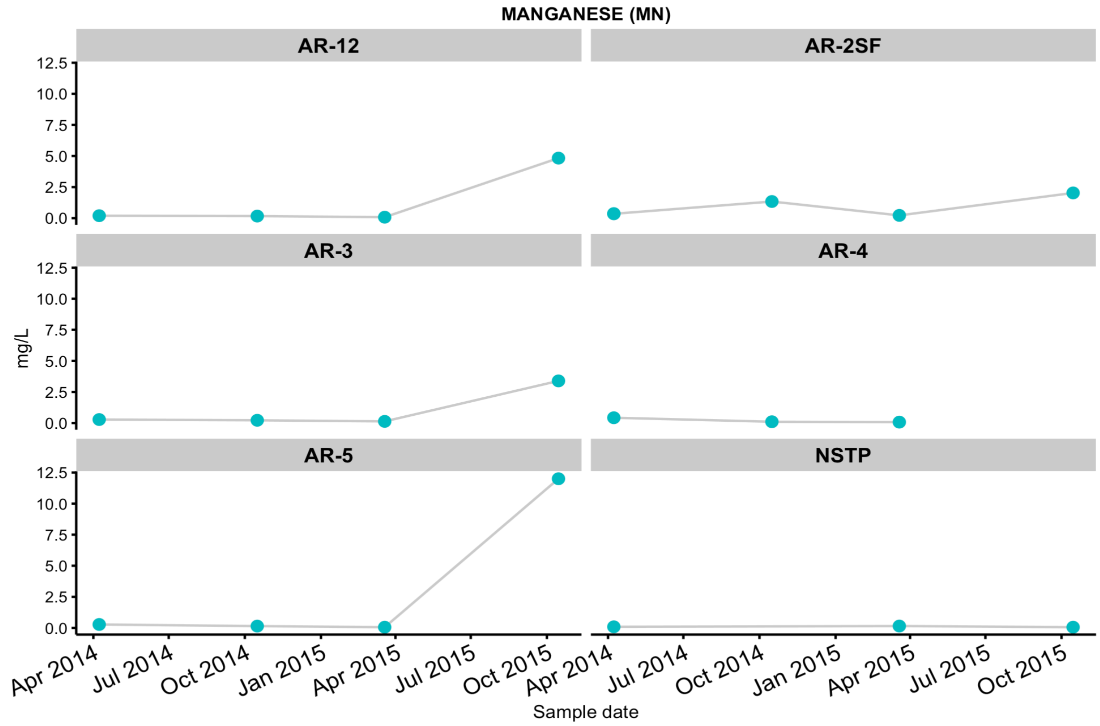


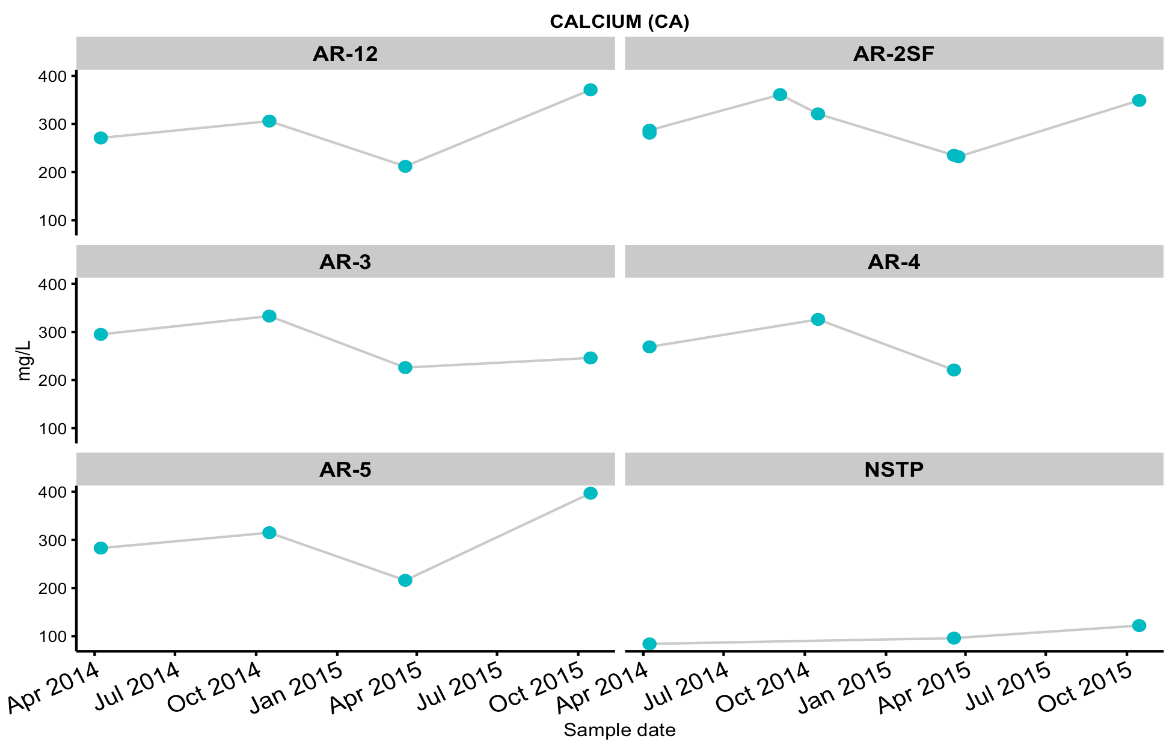
VANADIUM (V)
AR-12
AR-3
AR-5
AR-2SF
AR-4
NSTP
0.15
0.10
0.05
mg/L
2014-07
2015-01
2015-07
Sample date

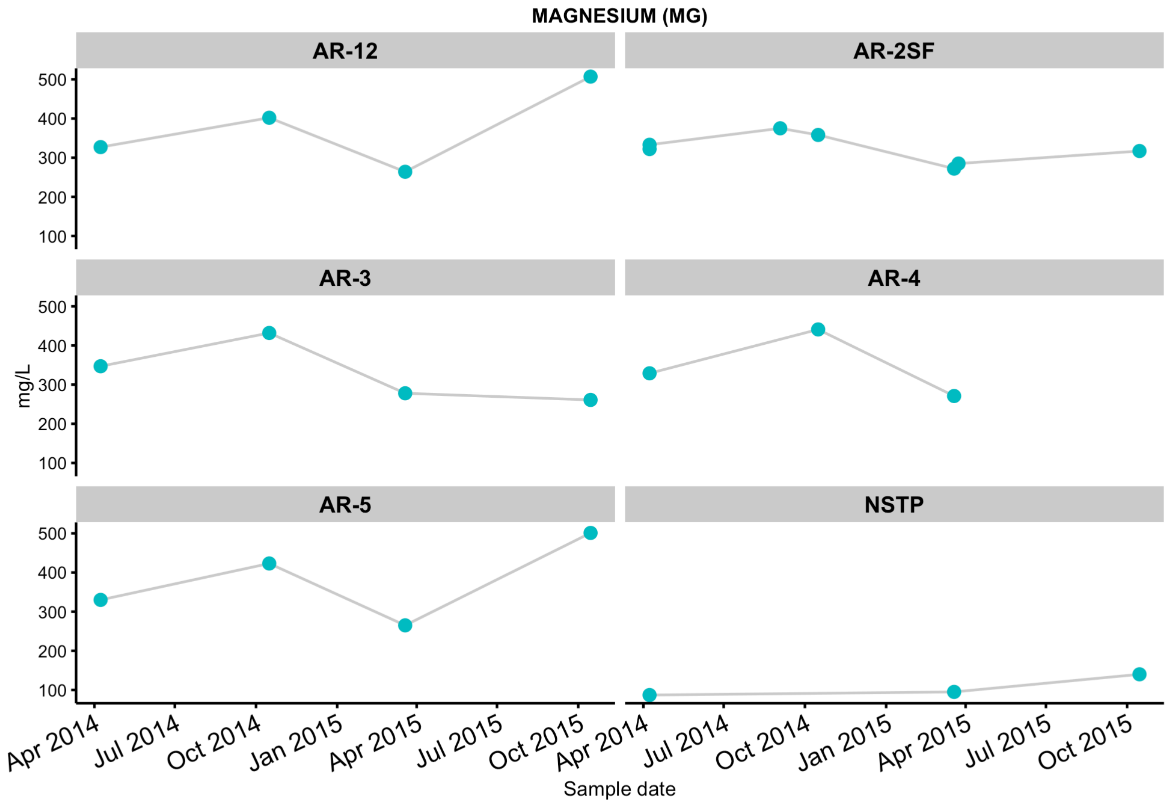
Figure D-2.2. Plots of concentrations (mg/L) over sampling occasions in 2014 and 2015






MANGANESE (MN)
AR-12
AR-2SF
AR-3
AR-4
AR-5
NSTP
mg/L
12.5
10.0
7.5
5.0
2.5
0.0
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015
Sample date


CALCIUM (CA)
AR-12
AR-2SF
AR-3
AR-4
AR-5
NSTP
mg/L
400
300
200
100
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015
Sample date


MAGNESIUM (MG)
AR-12
AR-2SF
AR-3
AR-4
AR-5
NSTP
mg/L
500
400
300
200
100
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015
Sample date

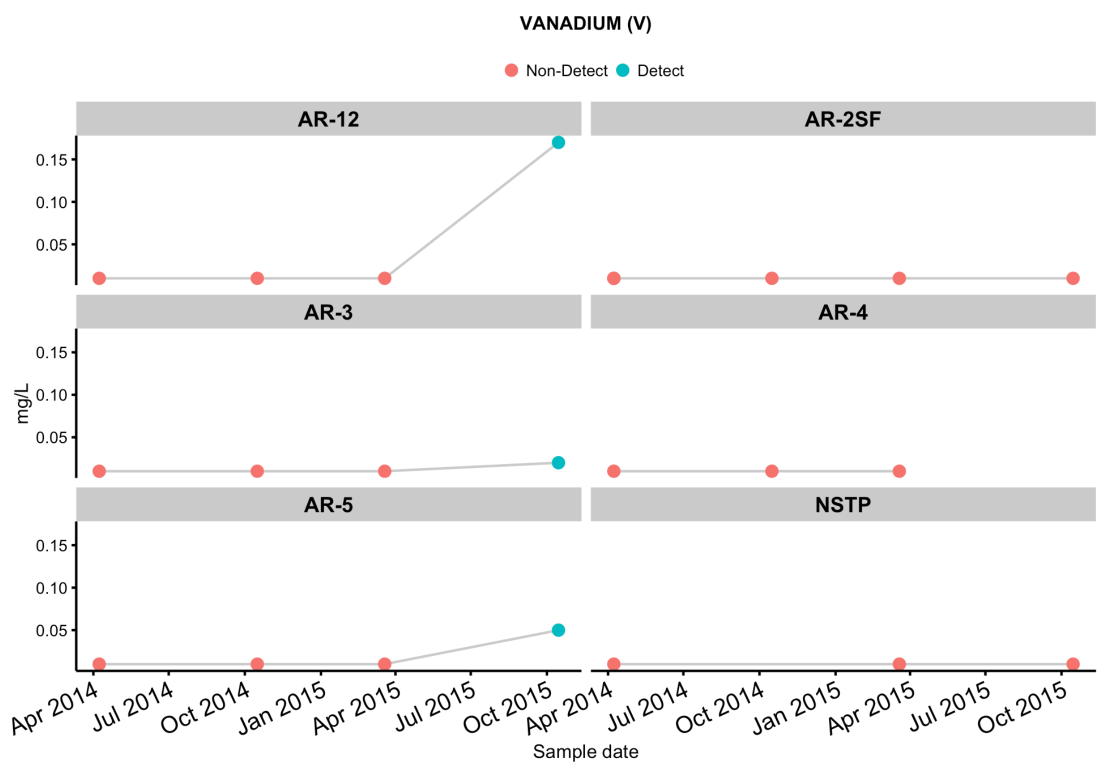

VANADIUM (V)
Non-Detect
Detect
AR-12
AR-2SF
AR-3
AR-4
AR-5
NSTP
mg/L
0.15
0.10
0.05
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015
Sample date

Figure D-2 Error! No text of specified style in document.**.3. Concentrations (mg/L) across locations for each metal and each sampling date for the human health risk assessment. The placement of sampling locations along the horizontal axis corresponds to the distance from AR-2 (moving upstream).**

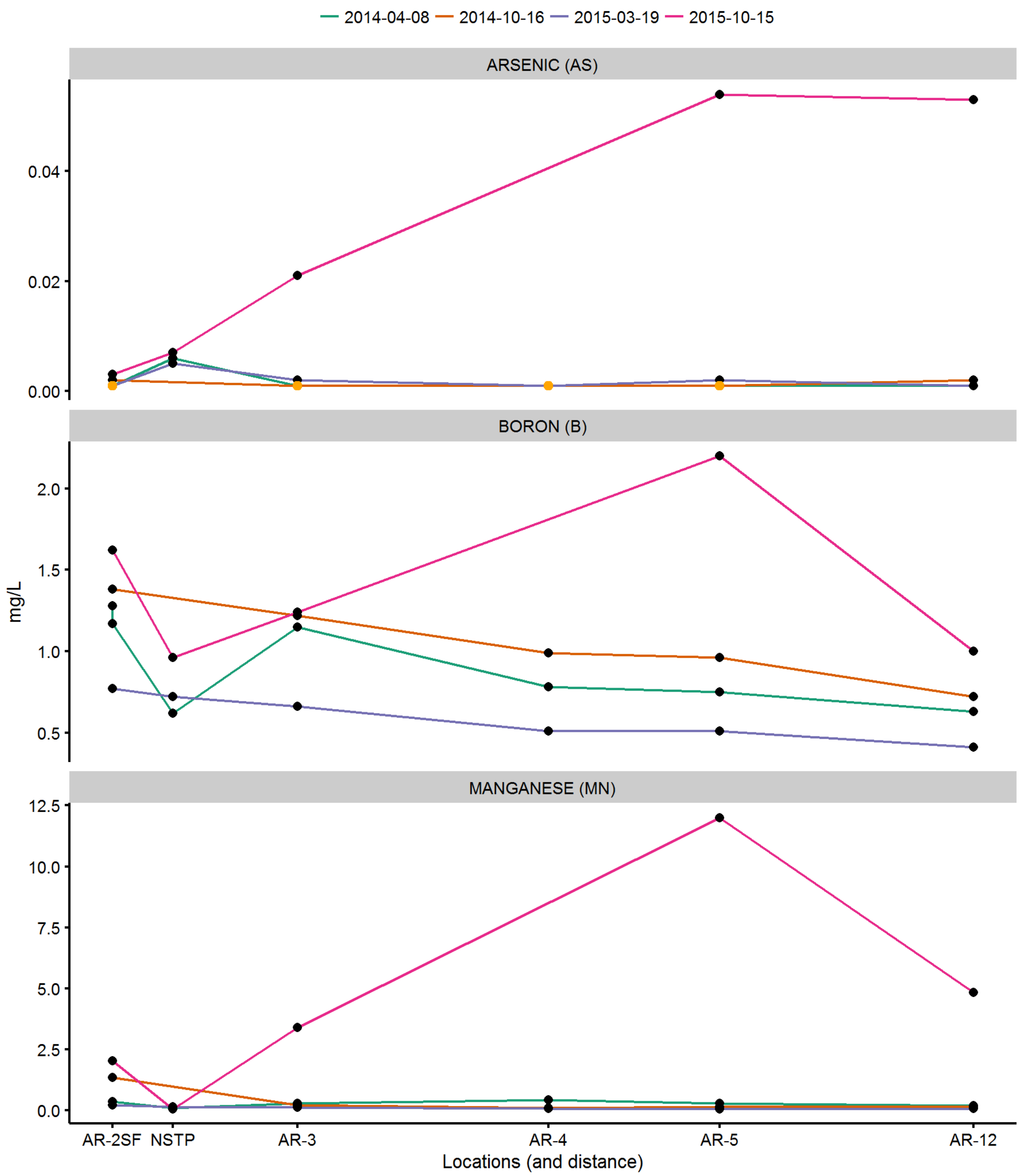


Figure D-2.4. Concentrations across locations for each metal and each sampling date for the ecological risk assessment. The placement of sampling locations along the horizontal axis corresponds to the distance from AR-2 (moving upstream).

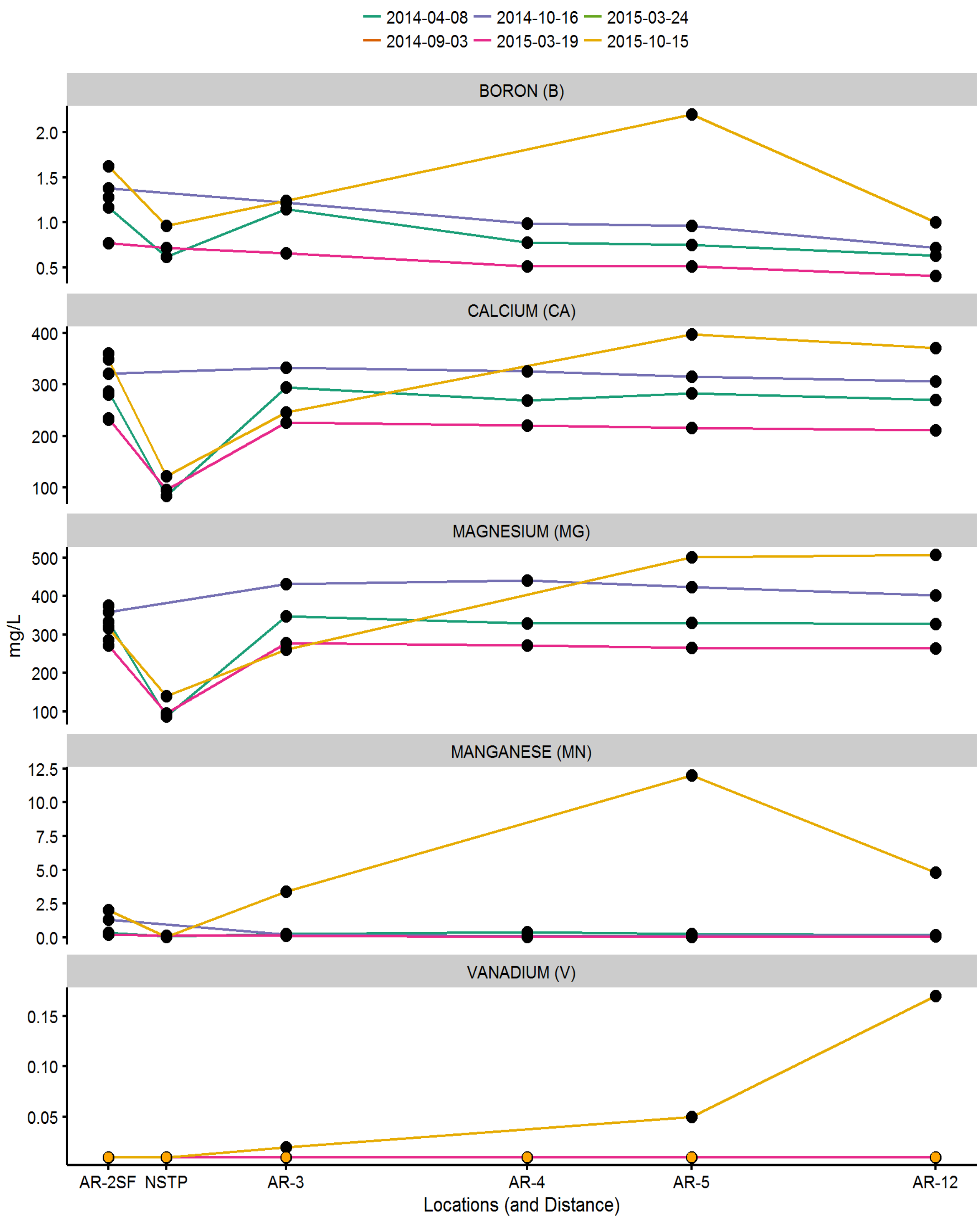
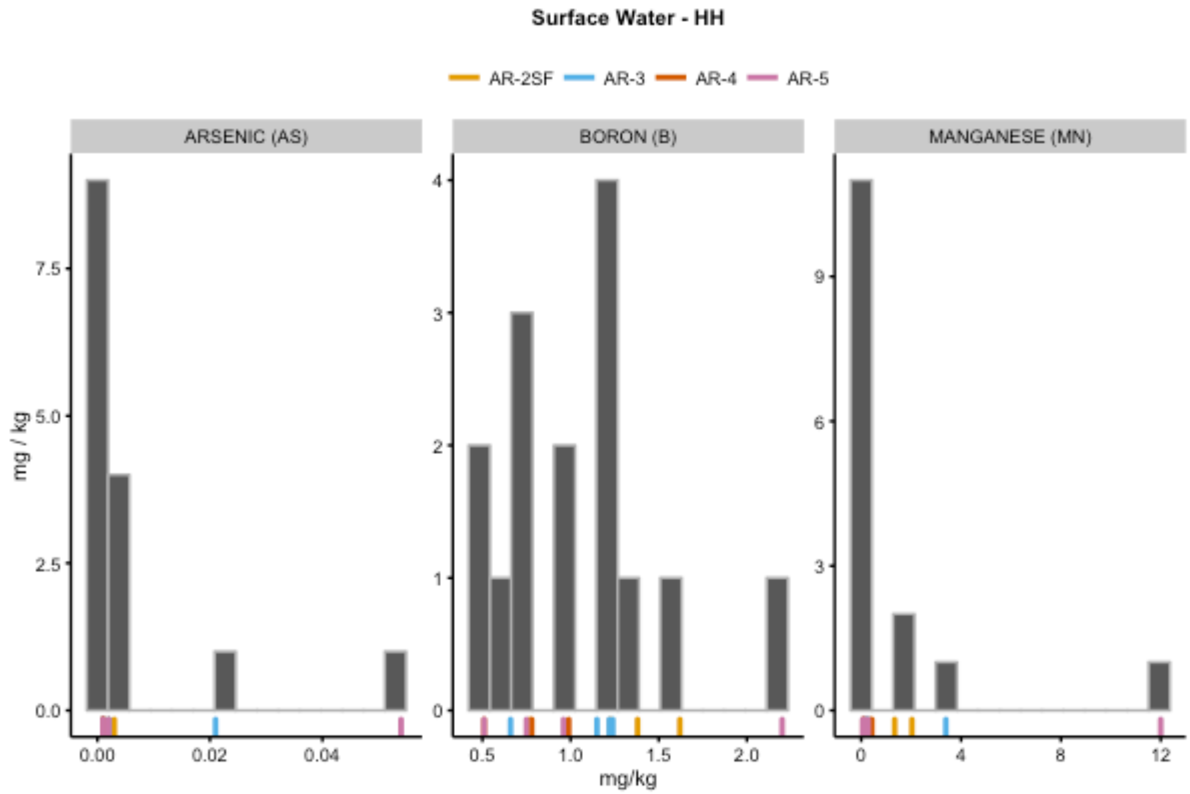
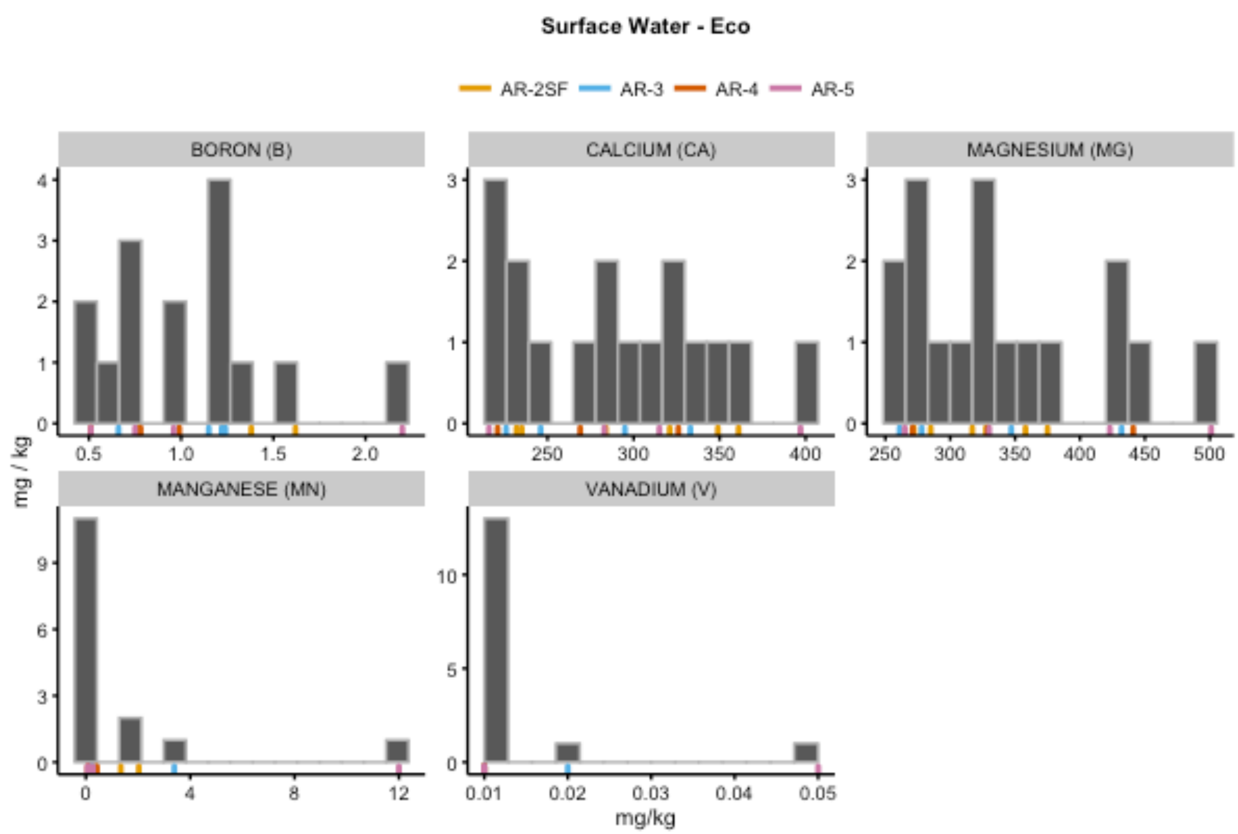


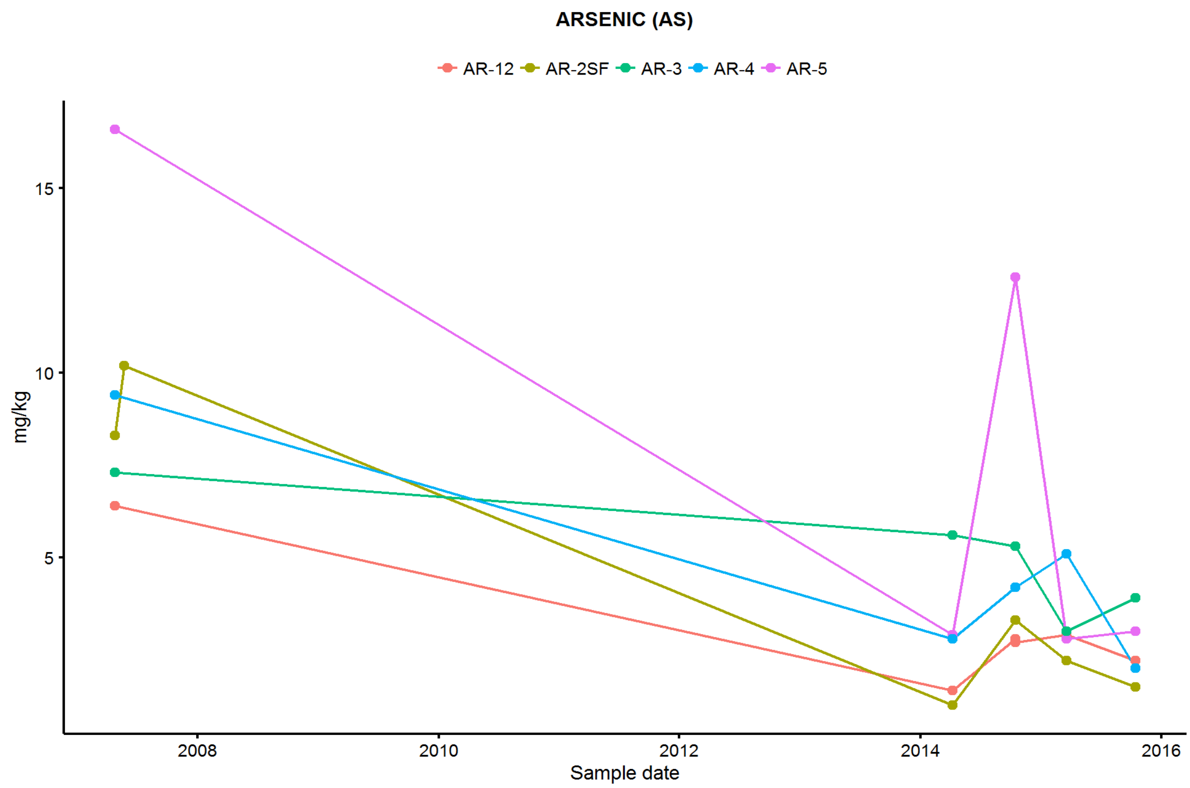
Figure D-2.5. Histograms of data (in mg/L) used for UCL calculations

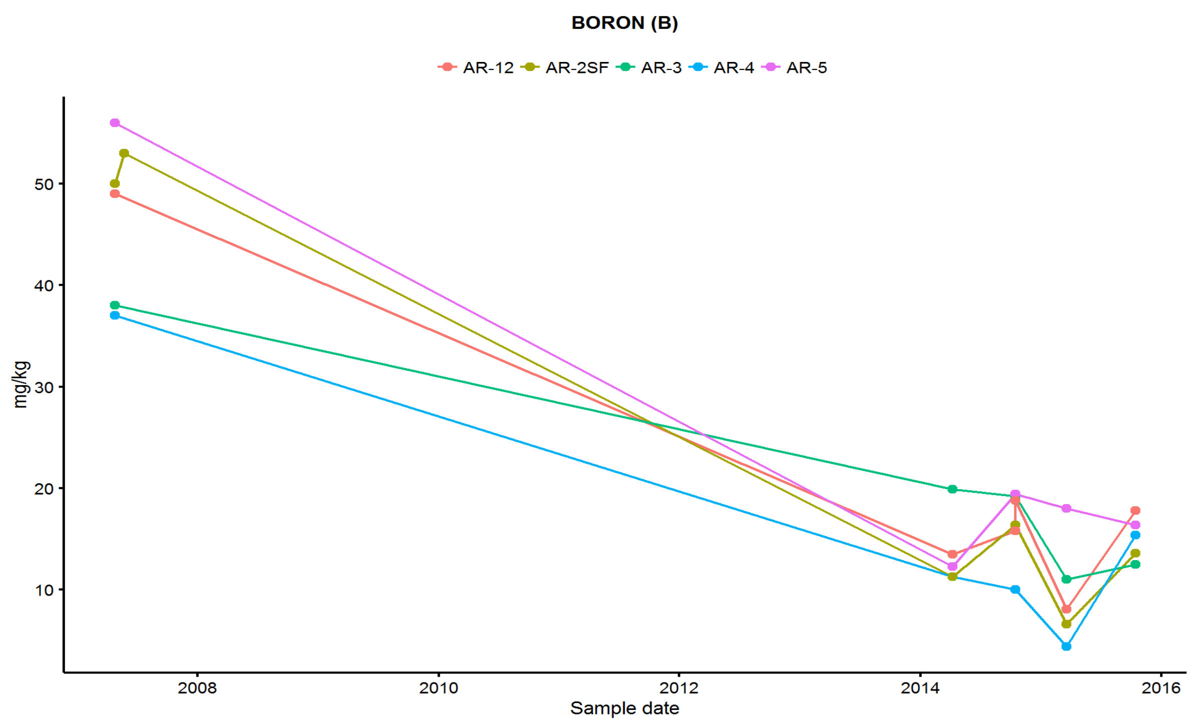




Figures: Section D-3 Sediment

Figure D-3.1. Concentrations (mg/kg over time for all data available (not restricted to 2014 and 2015).





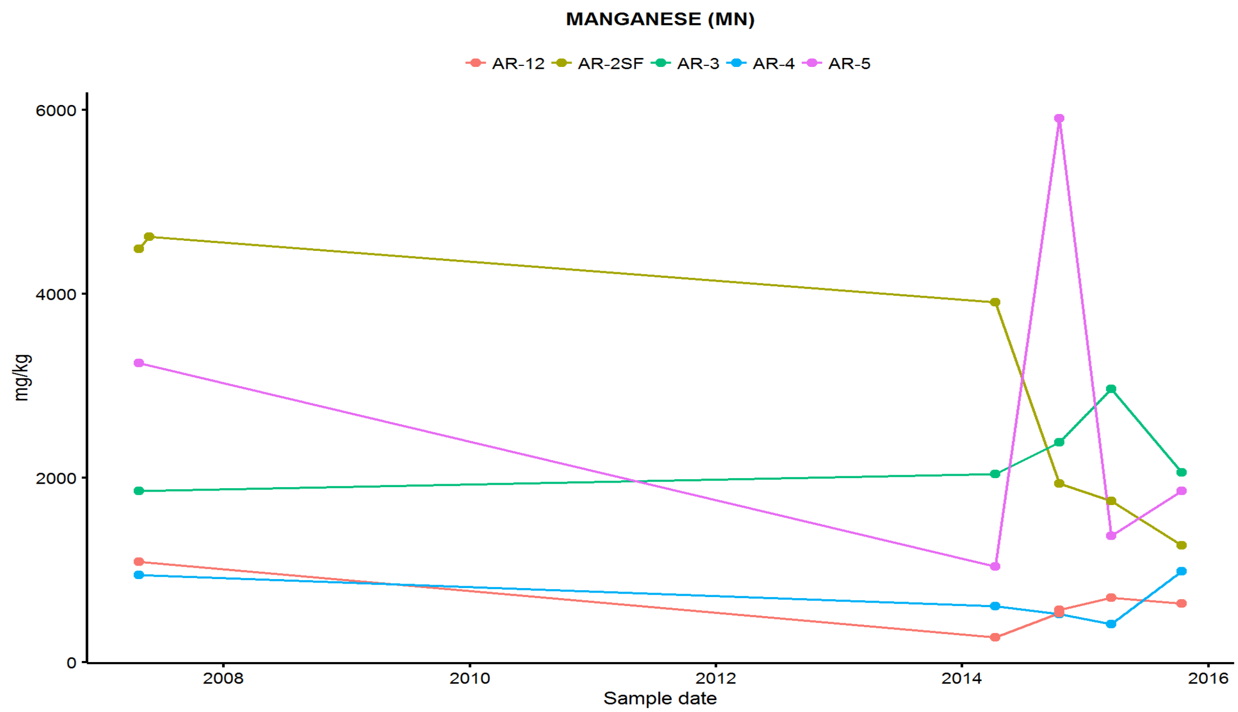
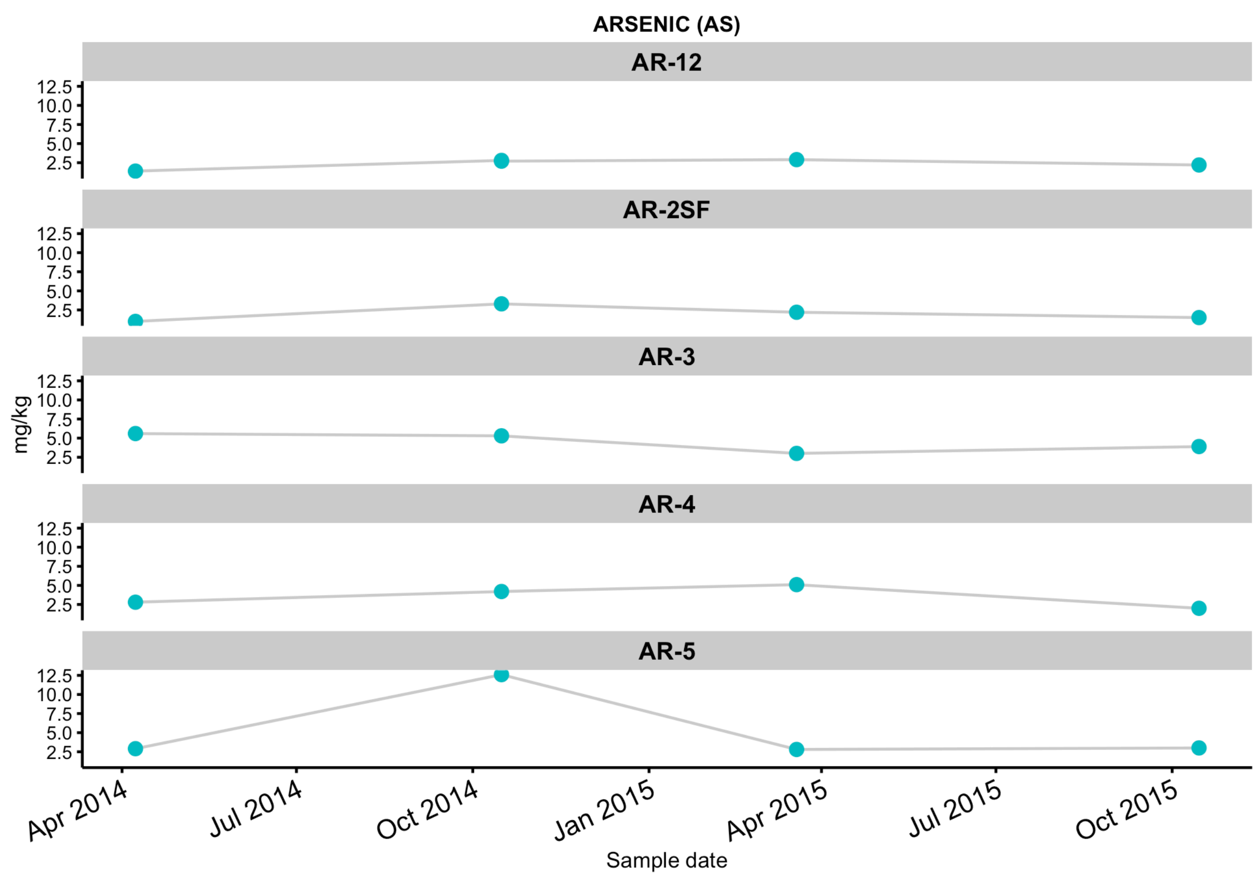
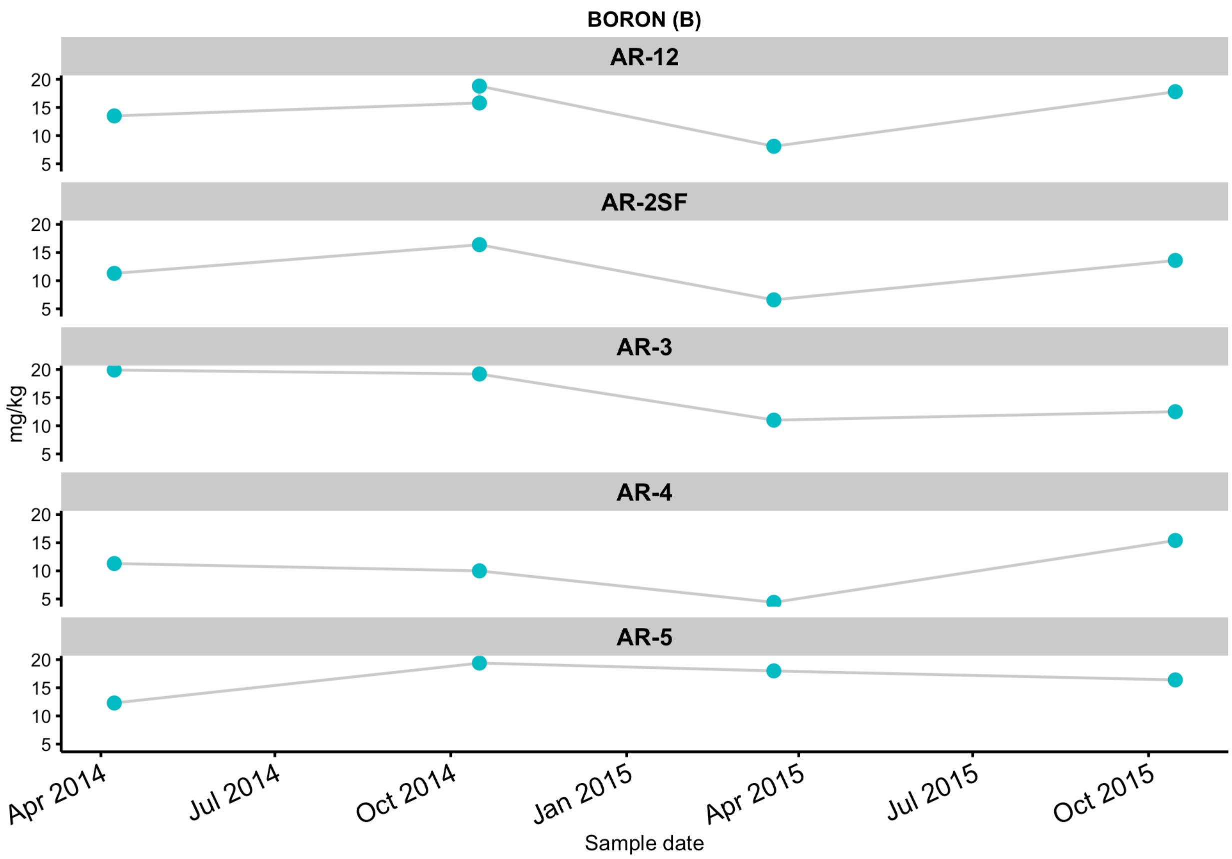
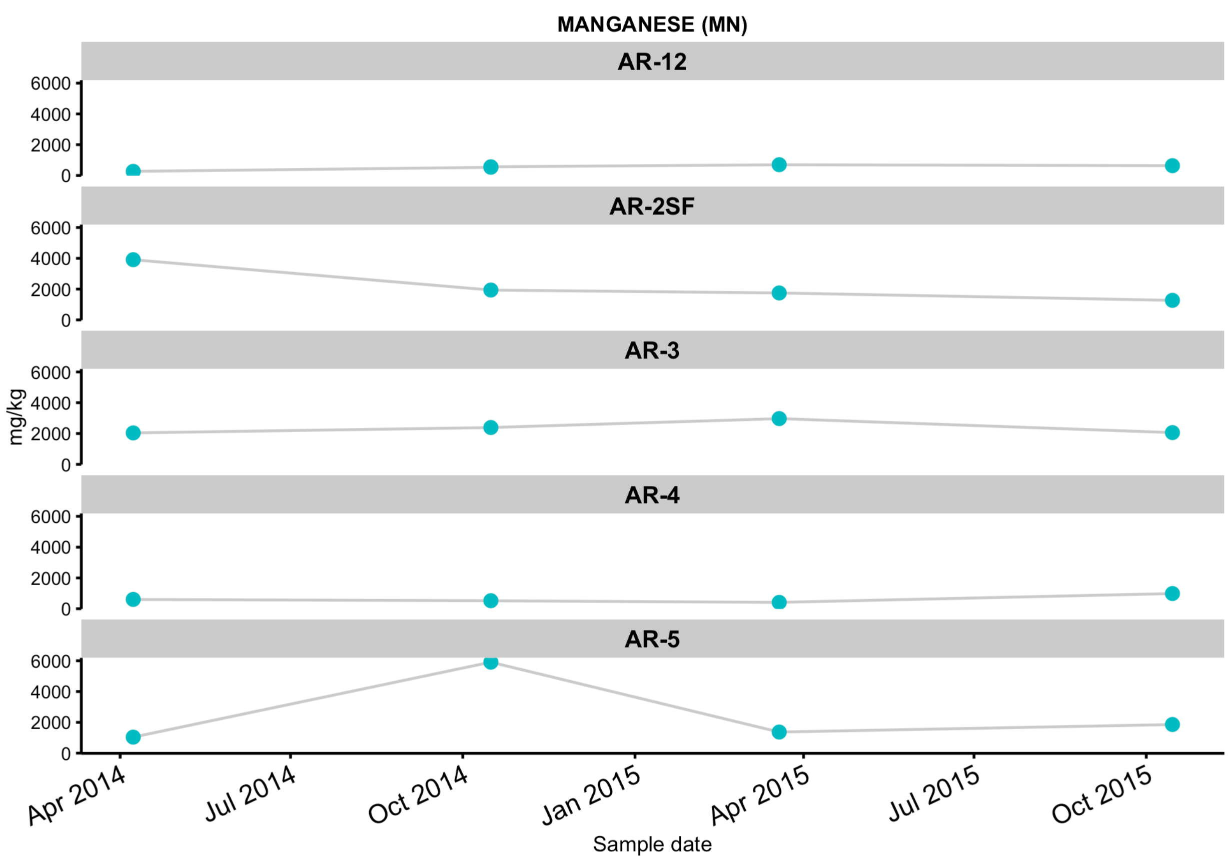


Figure D-3.2.6. Concentrations (mg/kg) over time for 2014 and 2015, paneled by location and metal.





BORON (B)
AR-12
AR-2SF
AR-3
AR-4
AR-5
mg/kg
20
15
10
5
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015
Sample date



MANGANESE (MN)
AR-12
AR-2SF
AR-3
AR-4
AR-5
mg/kg
6000
4000
2000
0
Apr 2014
Jul 2014
Oct 2014
Jan 2015
Apr 2015
Jul 2015
Oct 2015
Sample date

Figure D-3.3. Concentrations (mg/kg) across locations for each metal and each sampling date. The placement of sampling locations along the horizontal axis corresponds to the distance from AR-2 (moving upstream).

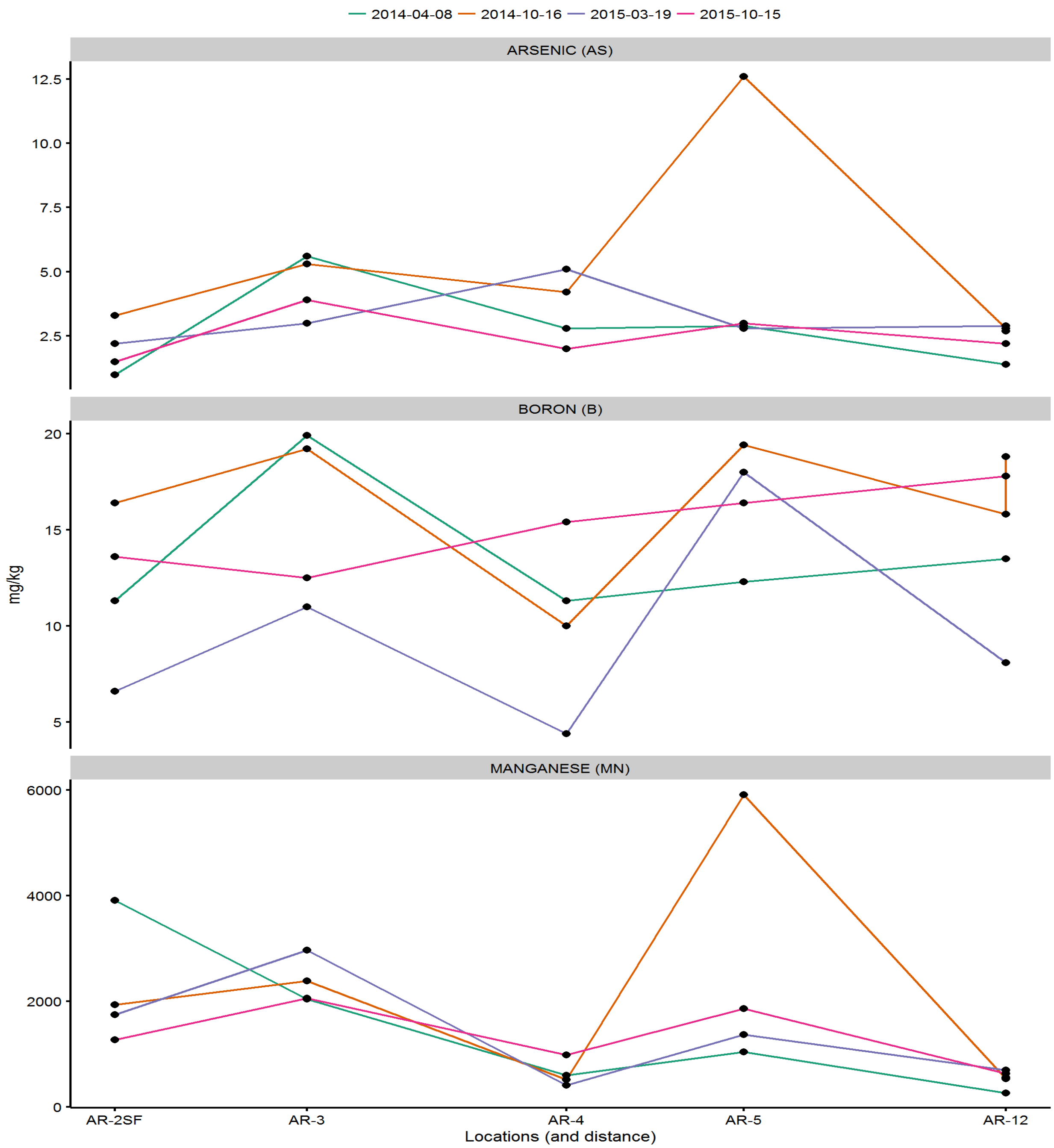
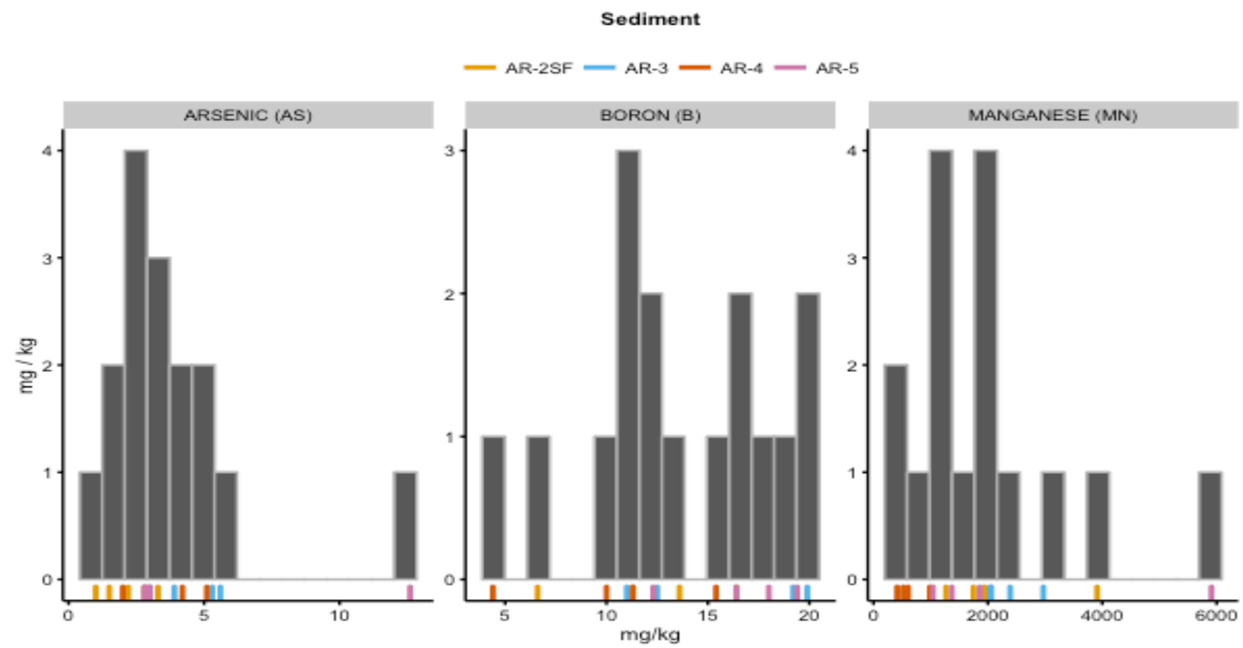


Figure D-3.4.7. Histograms of concentrations (mg/kg) used in the UCL calculations in Table D-3.4.



Figures: Section D-4 Soil

Figure D-4.4. Comparison of bulk and sieved samples occurring in pairs at the same depths for locations BH-62, BH-65, BH-66. For BH-32 and BH-59

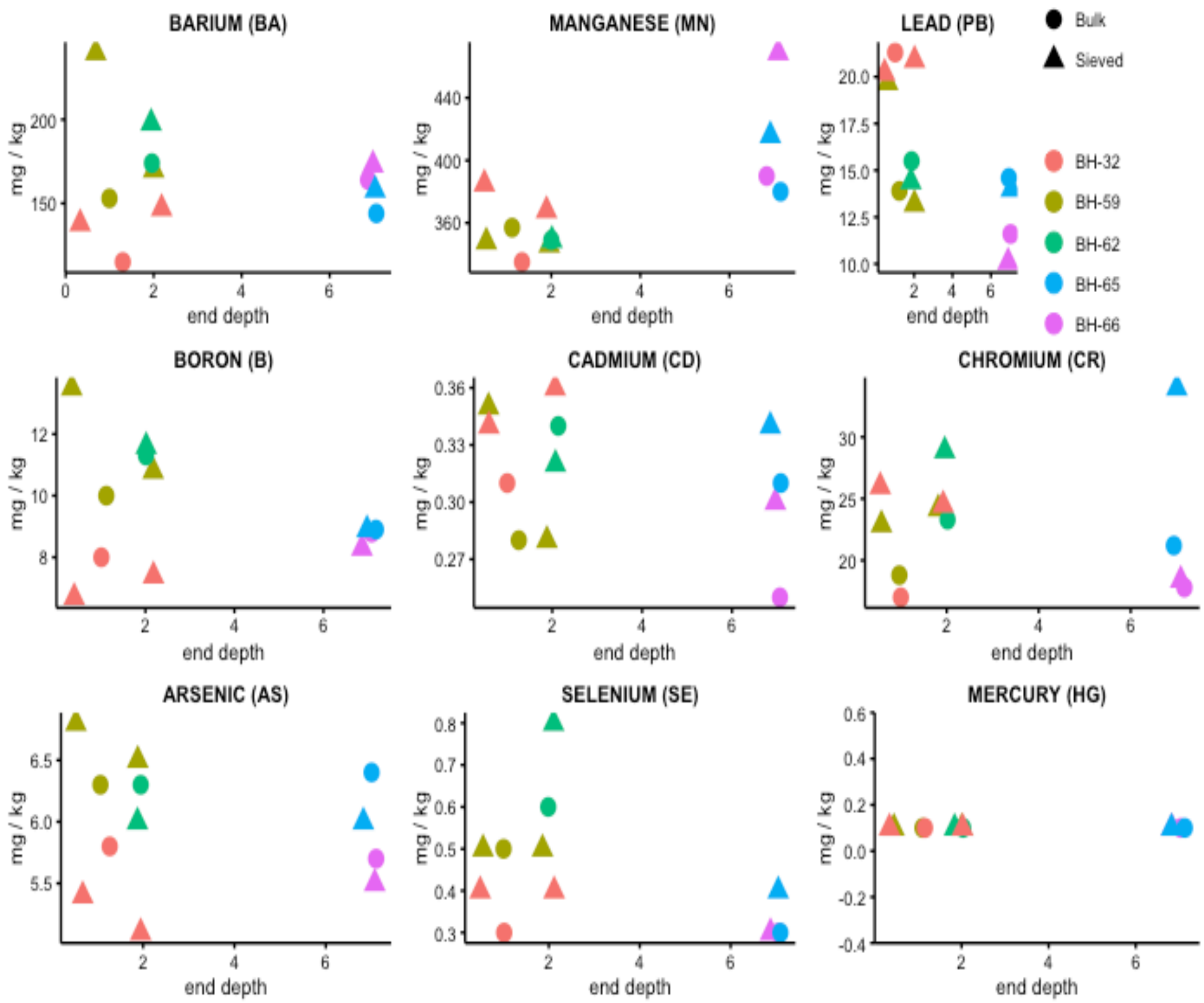


Figure D-4.5. Plots comparing concentrations (mg/kg) of field duplicate pairs for each metal by location. Pink and light blue symbols are the original measurements and open triangles are the averages of the two measurements within each pair.

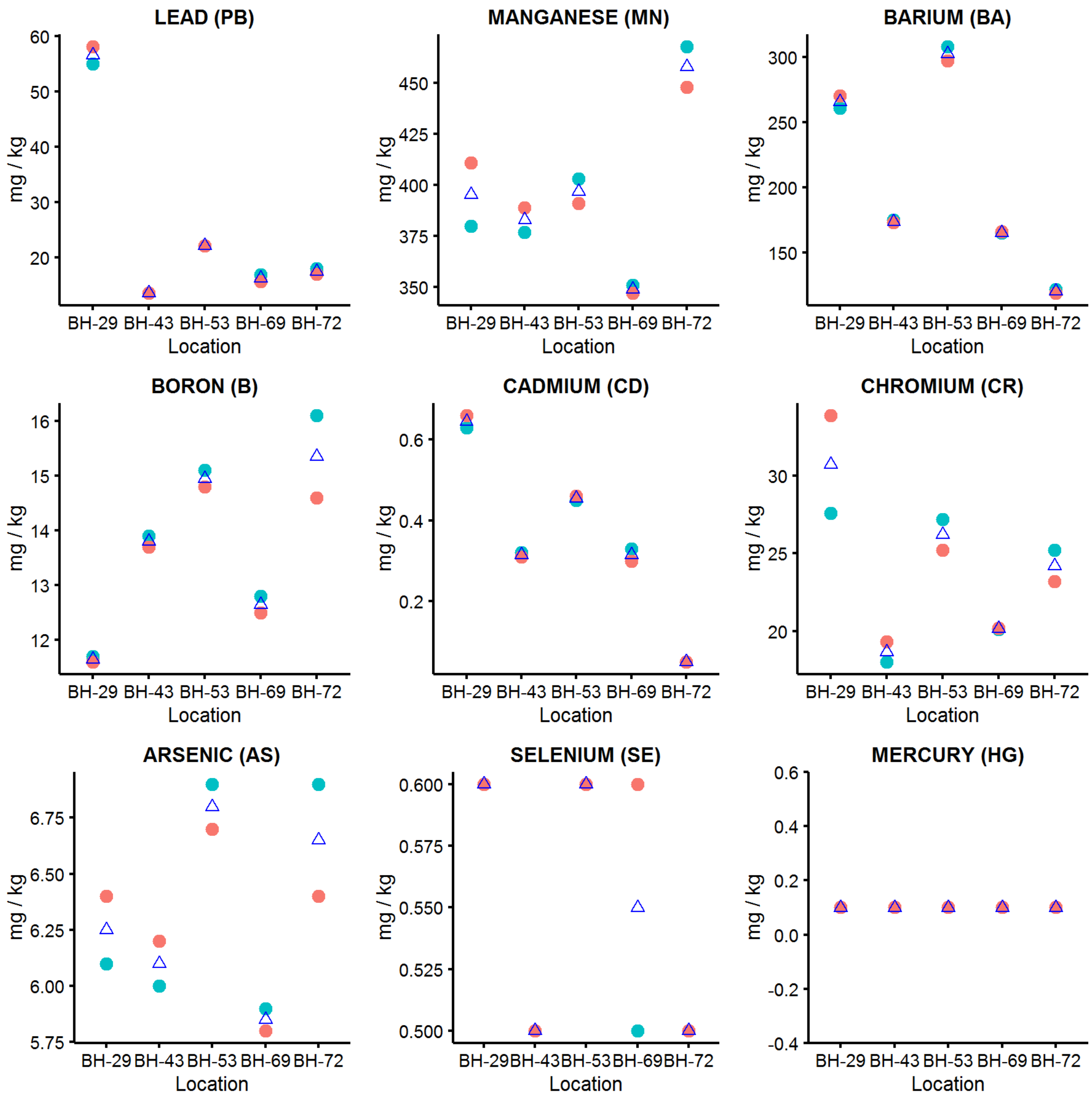


Figure D-4.6. Concentrations (mg/kg) by soil sampling area and depth. Field duplicates and laboratory re-runs are in blue. Points are jittered within each soil sampling area.

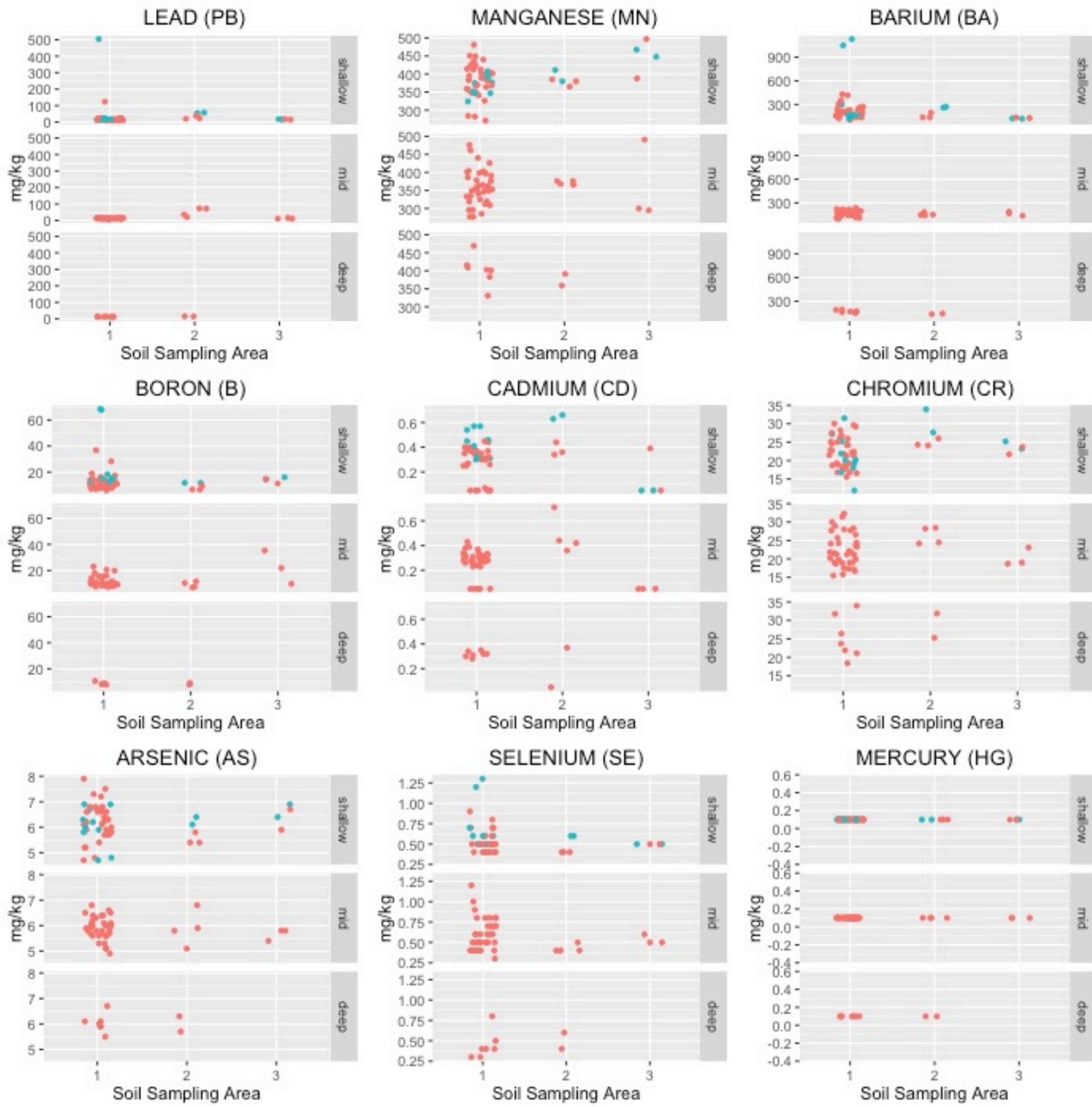


Figure D-4.7. Concentrations in mg/kg by soil sampling area and depth. Field and lab duplicates are replaced by the average of the pairs, and points are jittered within each sampling area. Scale for lead is different than in Figure D-4.6.

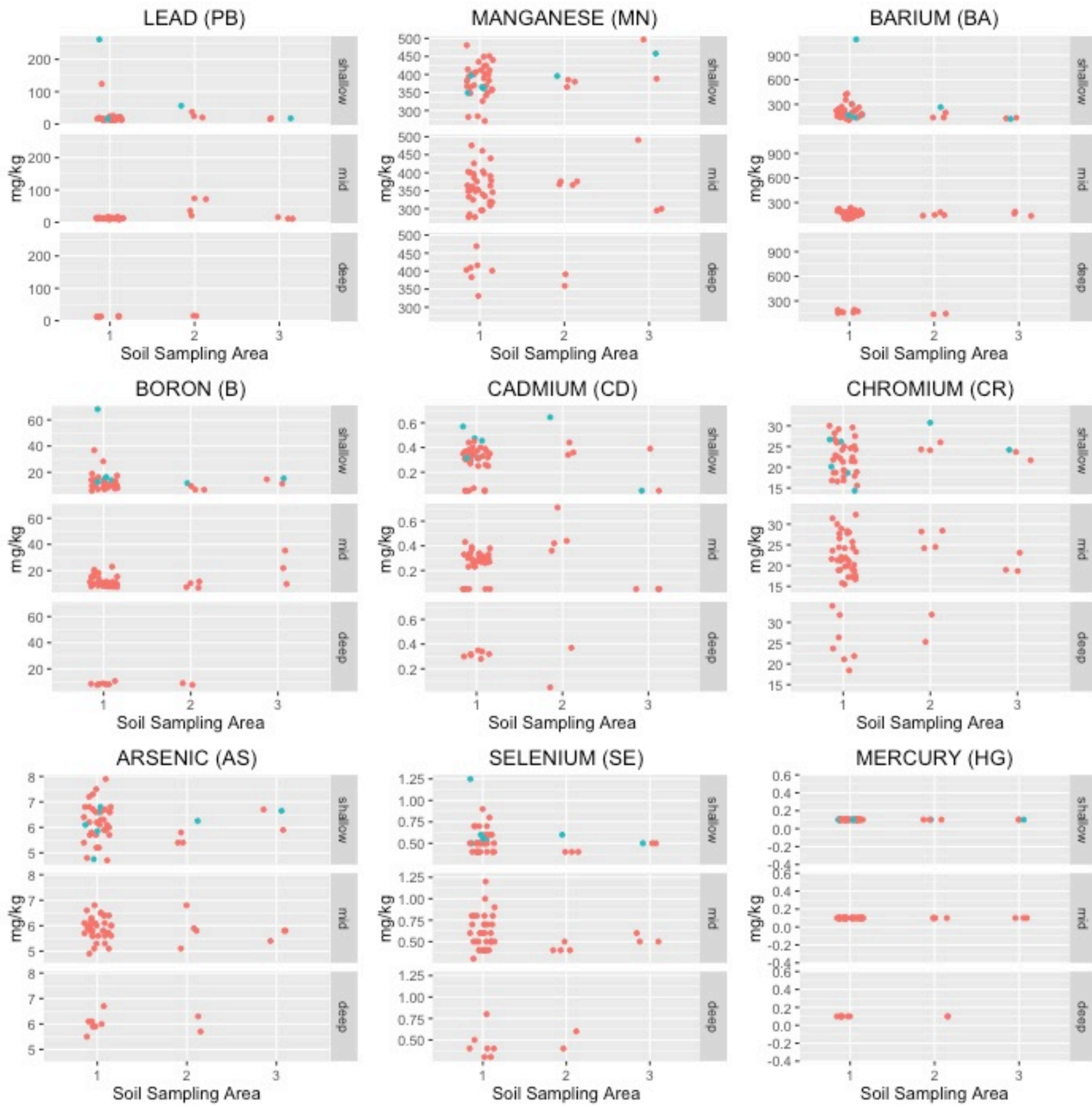


Figure D-4.8. Shallow depth measurements, with magnitude of concentrations (mg/kg) indicated by the color gradient. Scales are different for the different metals.

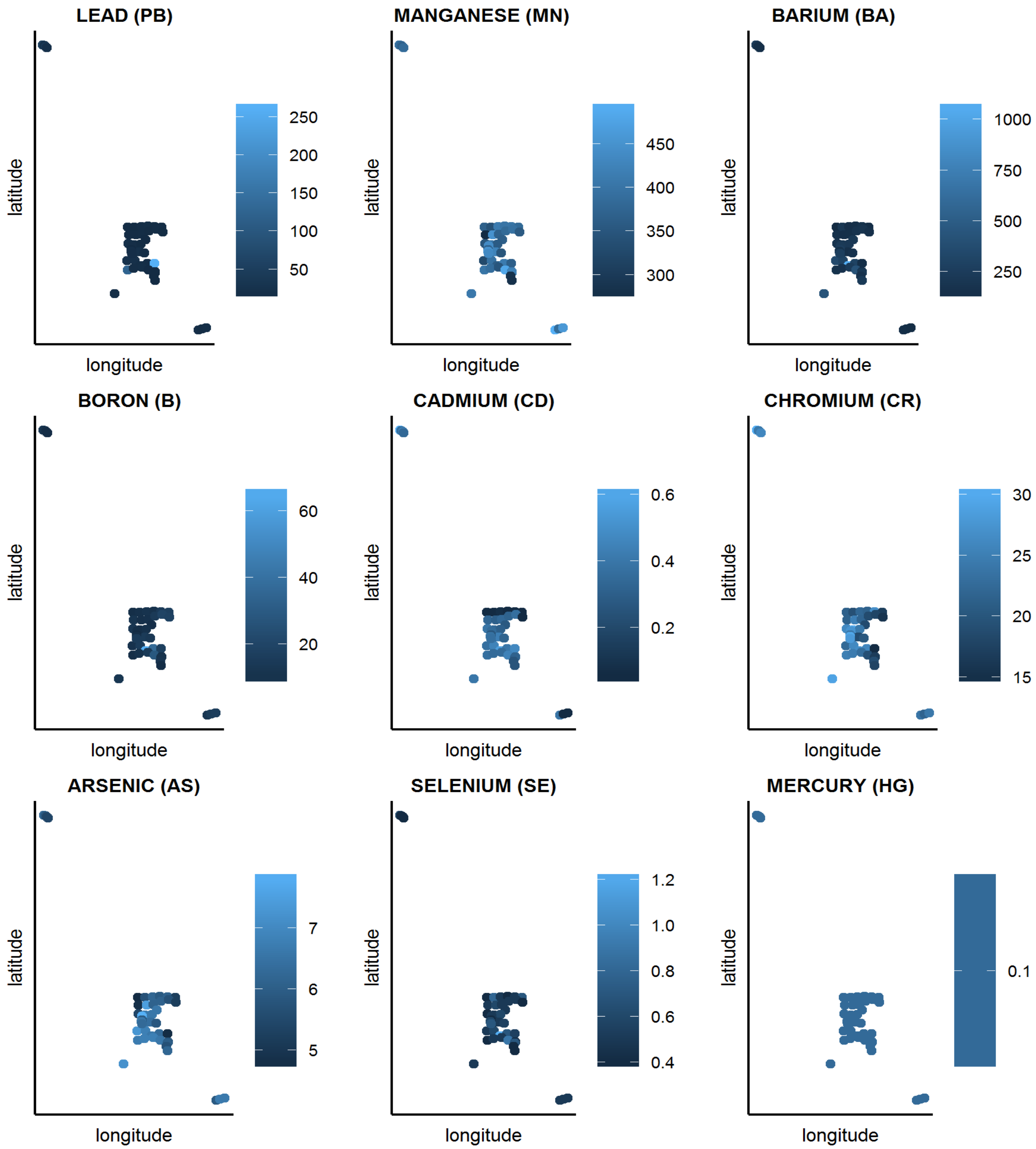


Figure D-4.9. Mid depth measurements, with magnitude of concentrations (mg/kg) indicated by the color gradient. Scales are different for the different metals.

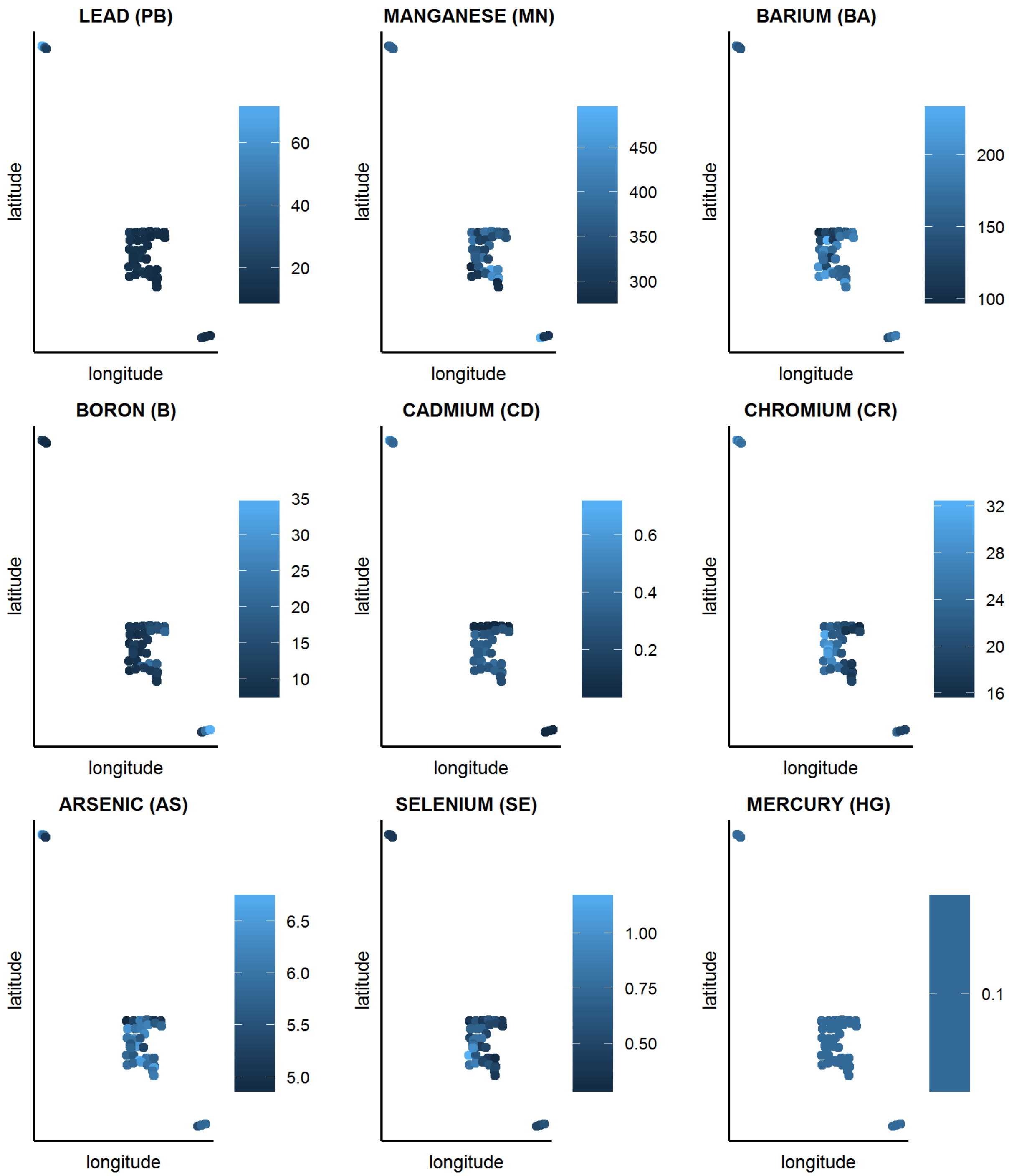


Figure D-4.10. Deep depth measurements, with magnitude of concentrations (mg/kg) indicated by the color gradient. Scales are different for the different metals.

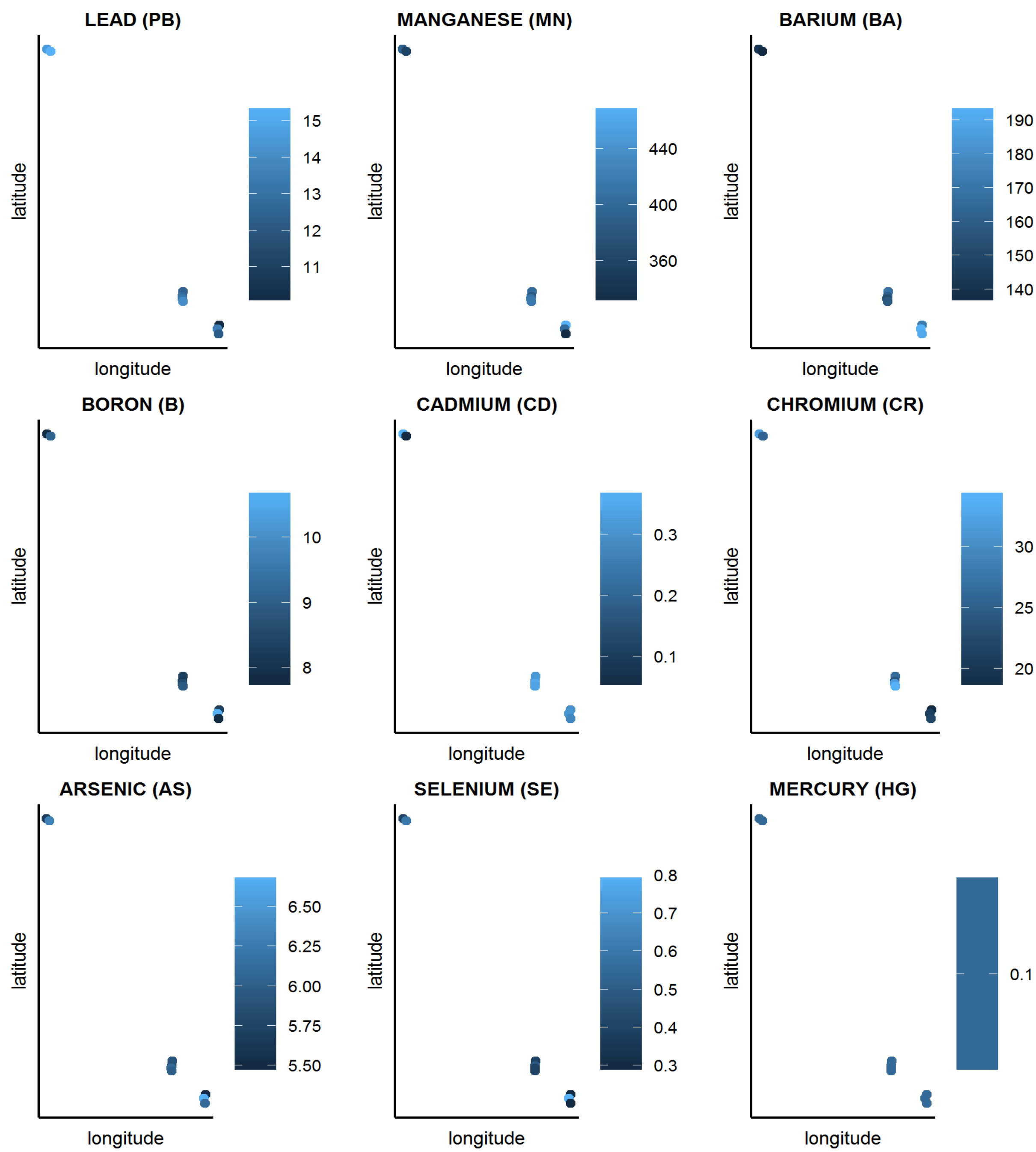


Figure D-4-11. Shallow depth measurements, with magnitude of concentrations (mg/kg) indicated by the color gradient. Scales are different for the different metals.

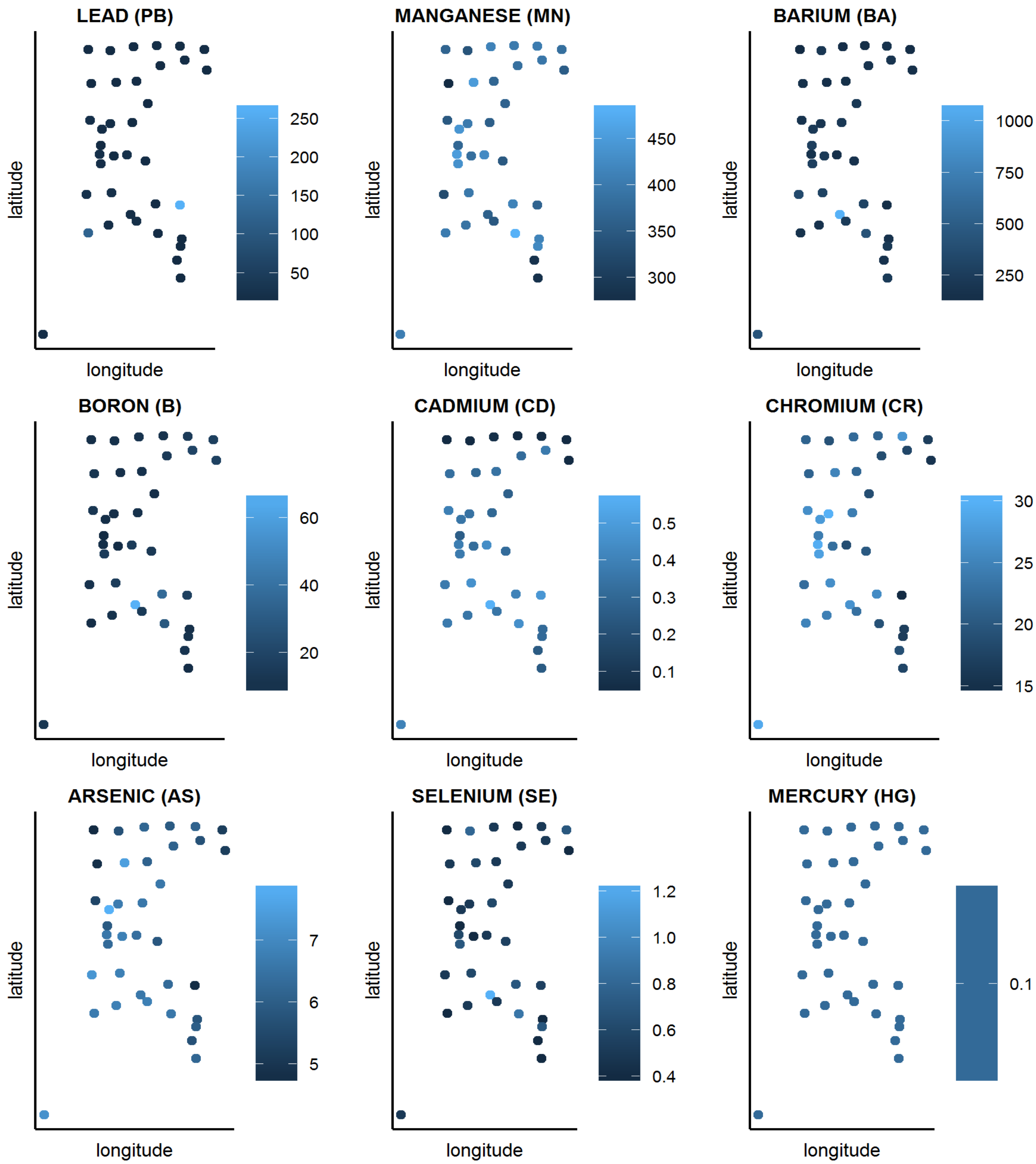


Figure D-4-12. Mid depth measurements, with magnitude of concentrations (mg/kg) indicated by the color gradient. Scales are different for the different metals.

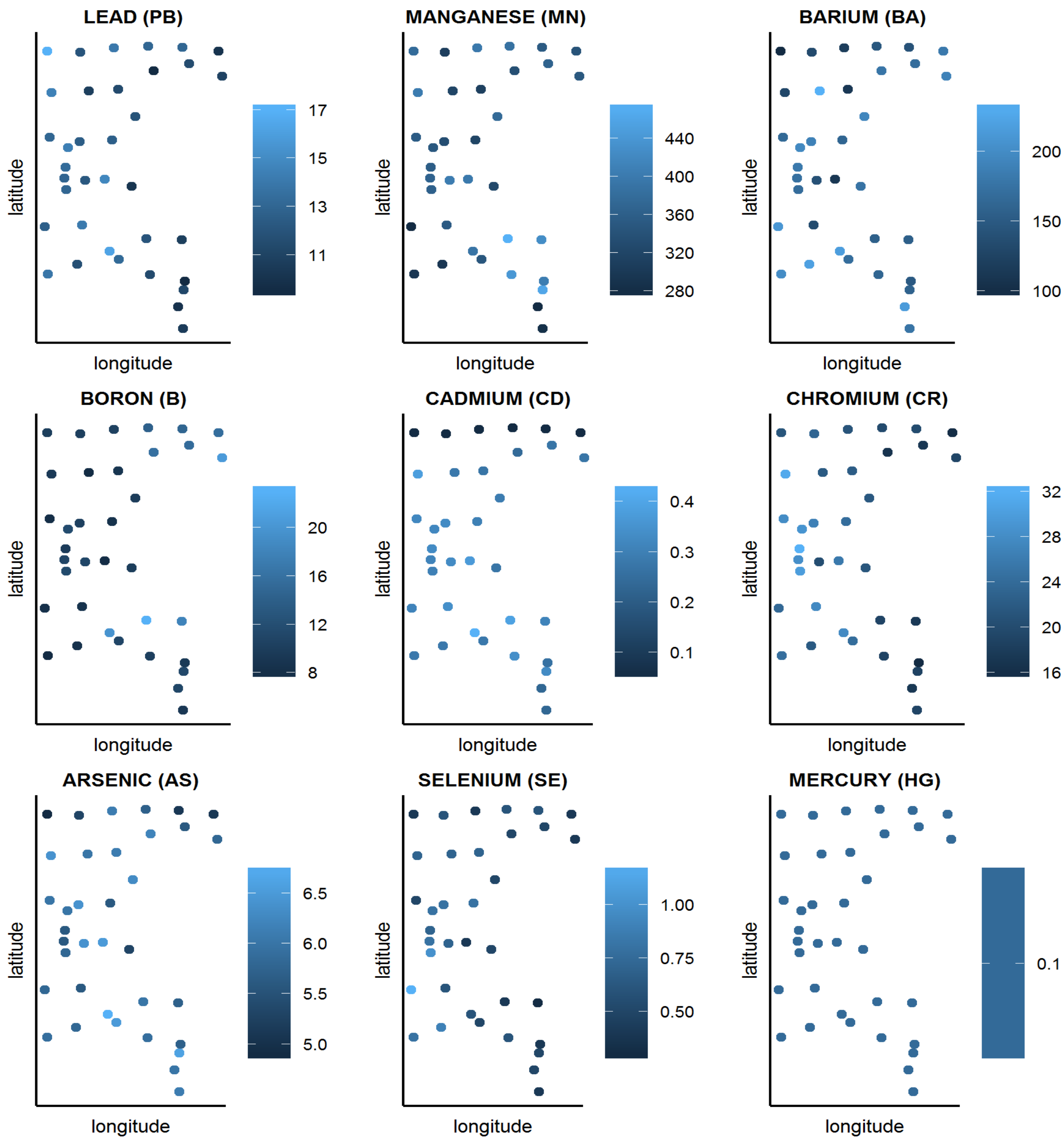


Figure D-4-13. The average of shallow and mid depth measurements, with magnitude of concentrations (mg/kg) indicated by the color gradient. Scales are different for the different metals.

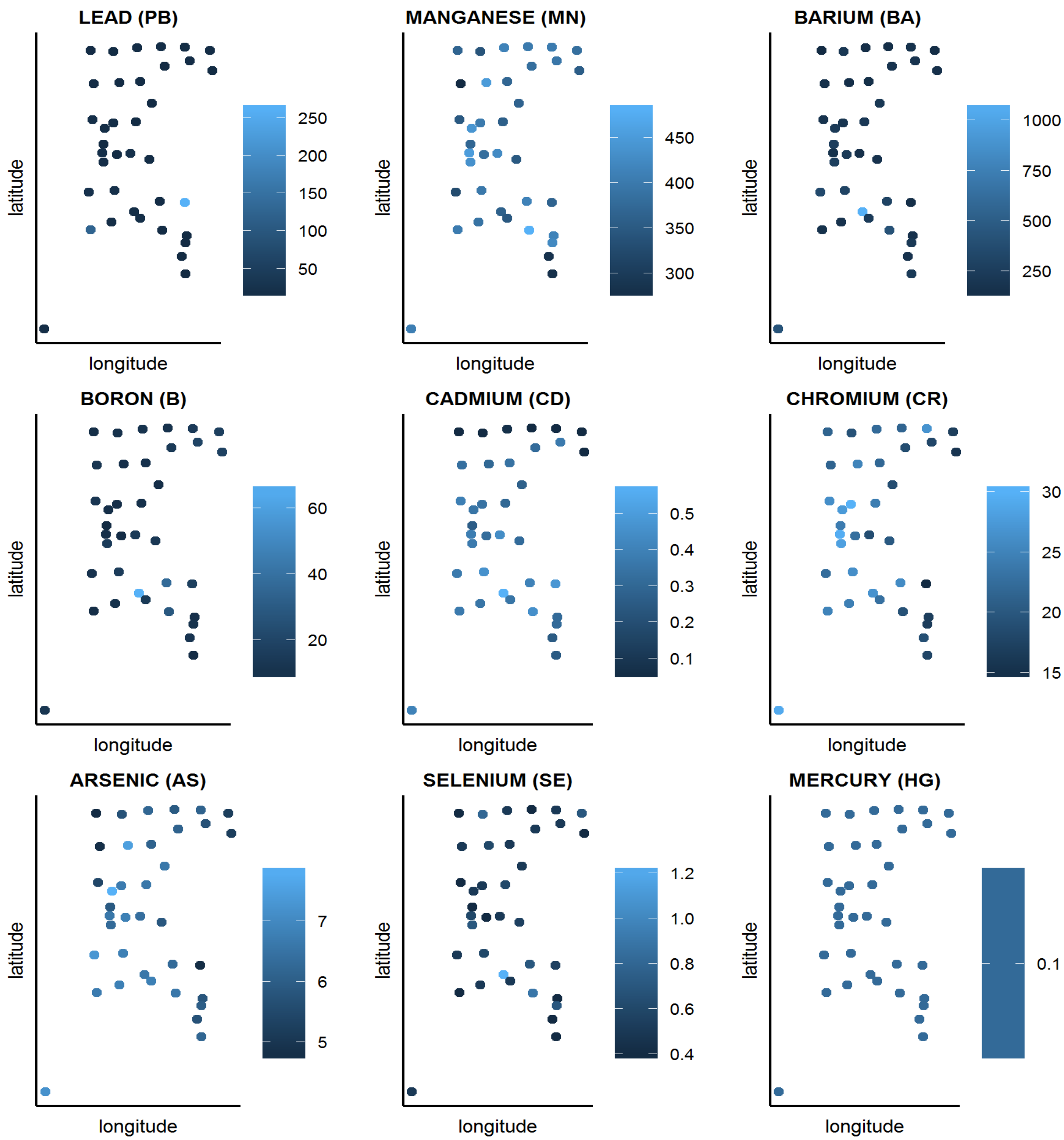


Figure D-4.14. Data (mg/kg) used in UCL calculations for shallow depth and all soil sample areas.

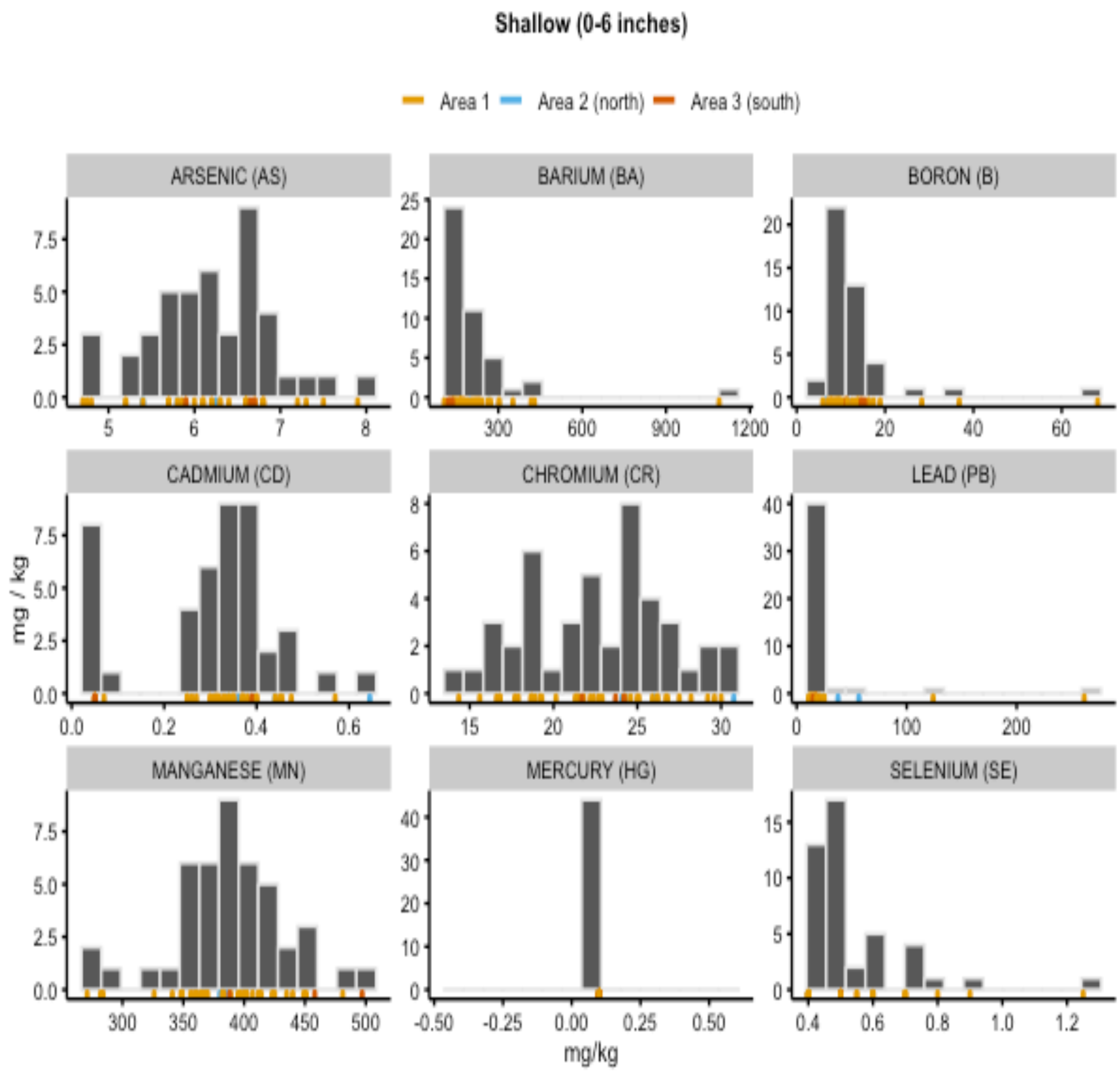


Figure D-4.15. Data (mg/kg) used in UCL calculations for middle depth and all soil sample areas.

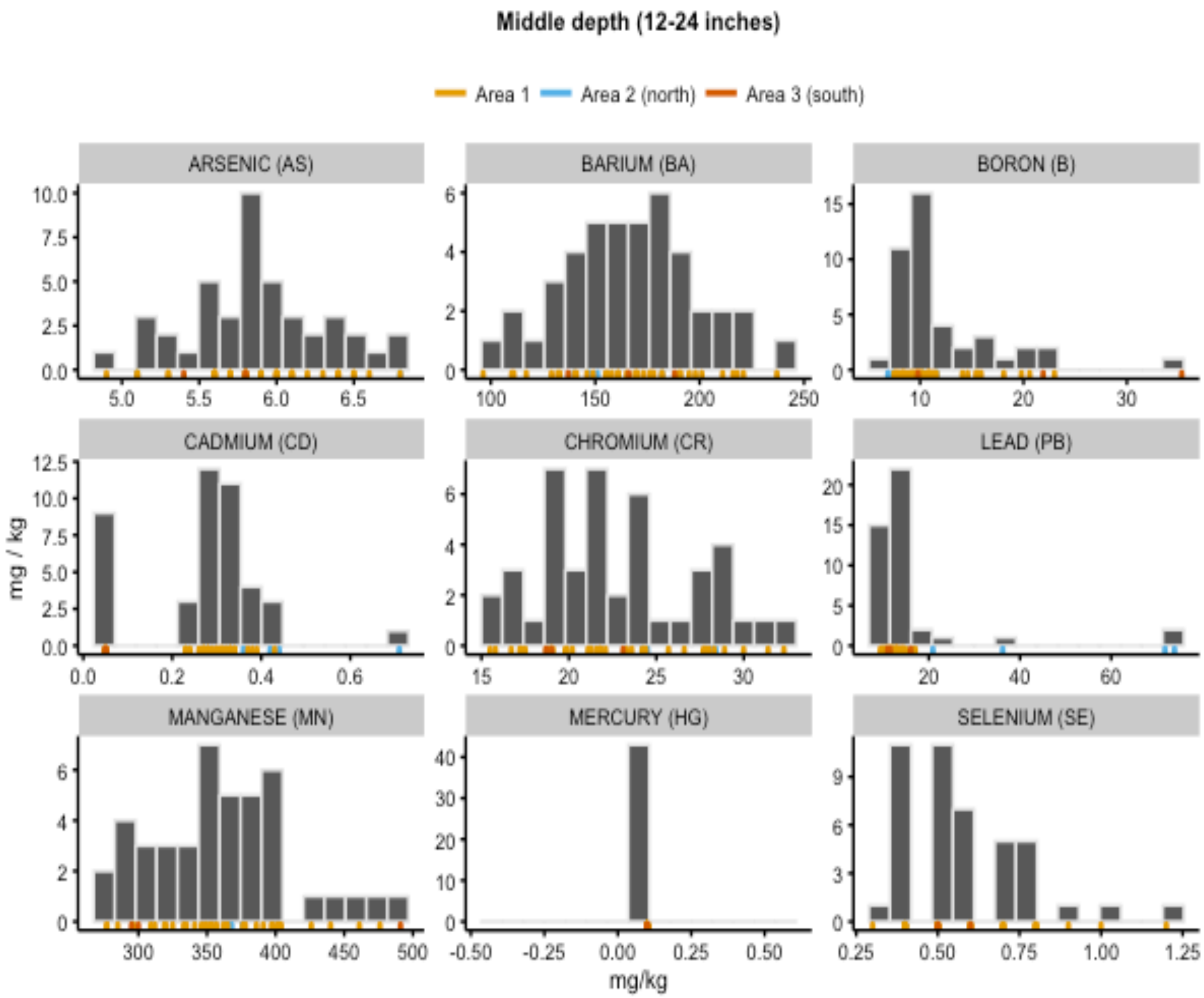


Figure D-4.16. Data (mg/kg) used in UCL calculations when averaging the shallow and middle concentrations for a location.

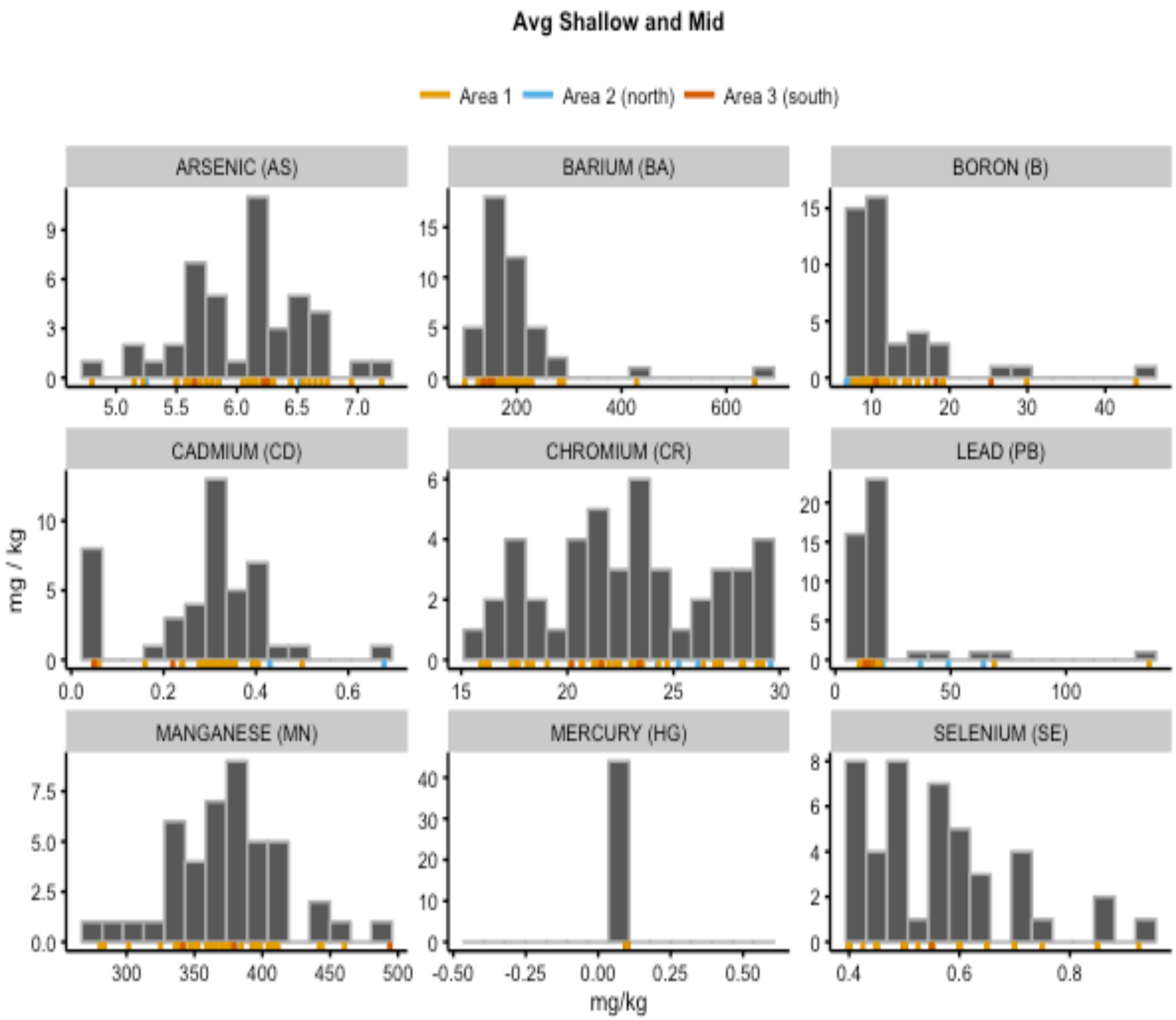
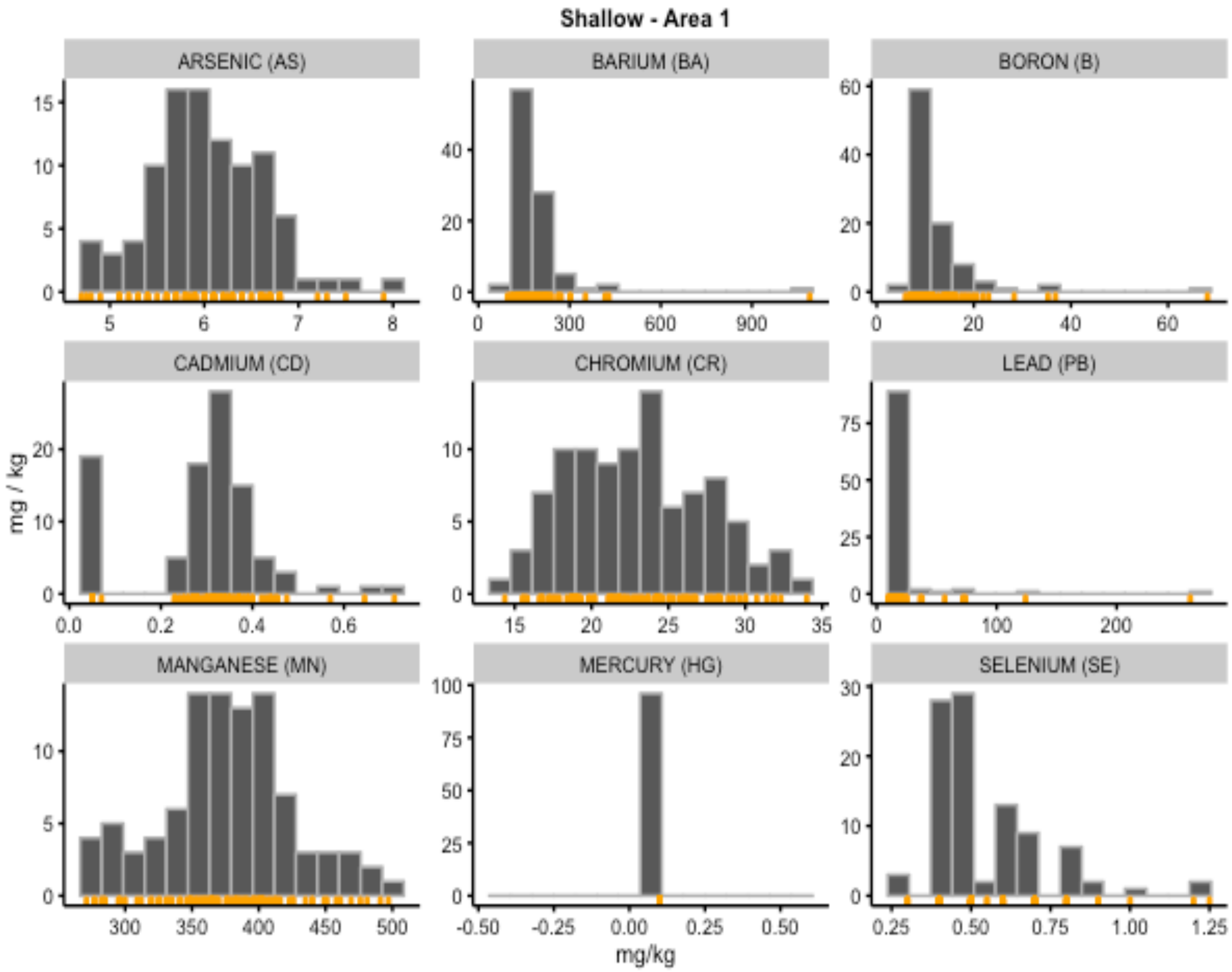


Figure D-4.17. Data (mg/kg) used in UCL calculations for human health including only shallow depth concentrations from Soil Sampling Area 1



Figures: Section D-5 Groundwater

Figure D-5.1. Area for groundwater well inclusion in the HHRA is depicted by the red polygon.

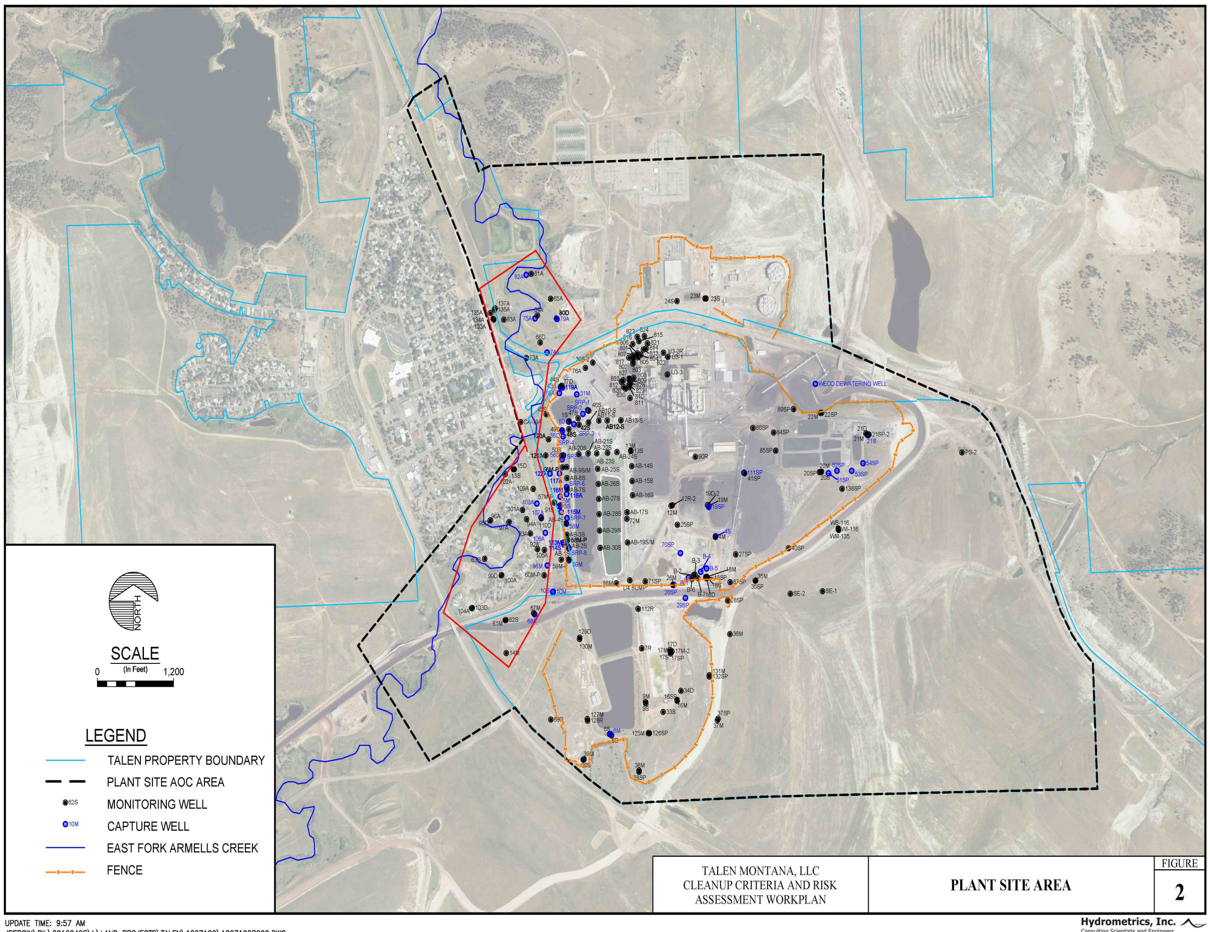


Figure D-5.2. Locations of the 7 wells used for the human health risk assessment for groundwater. The Plant Site Area boundary is shown in blue

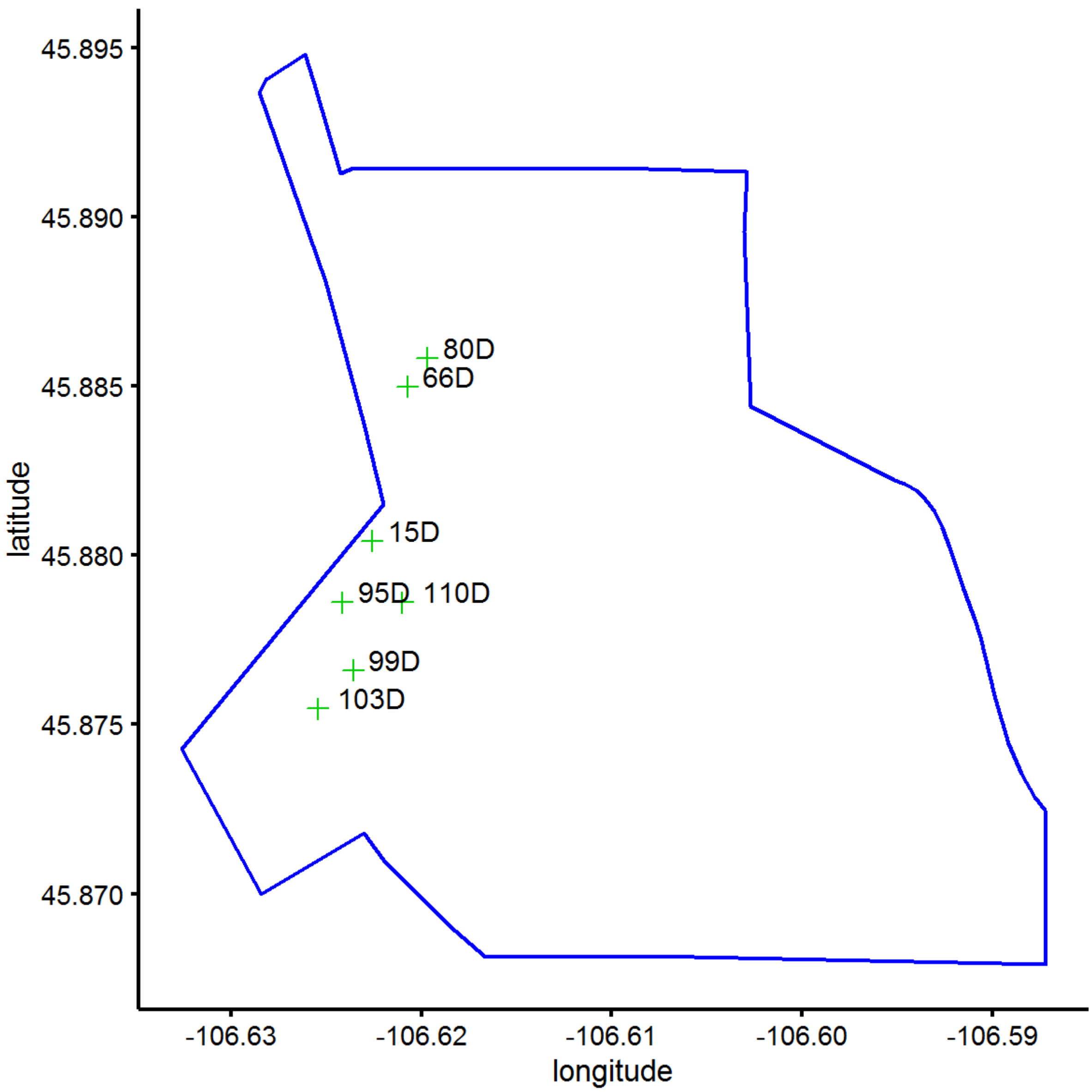


Figure D-5.3. Plots of Boron concentration (mg/L) over time for each sampling location

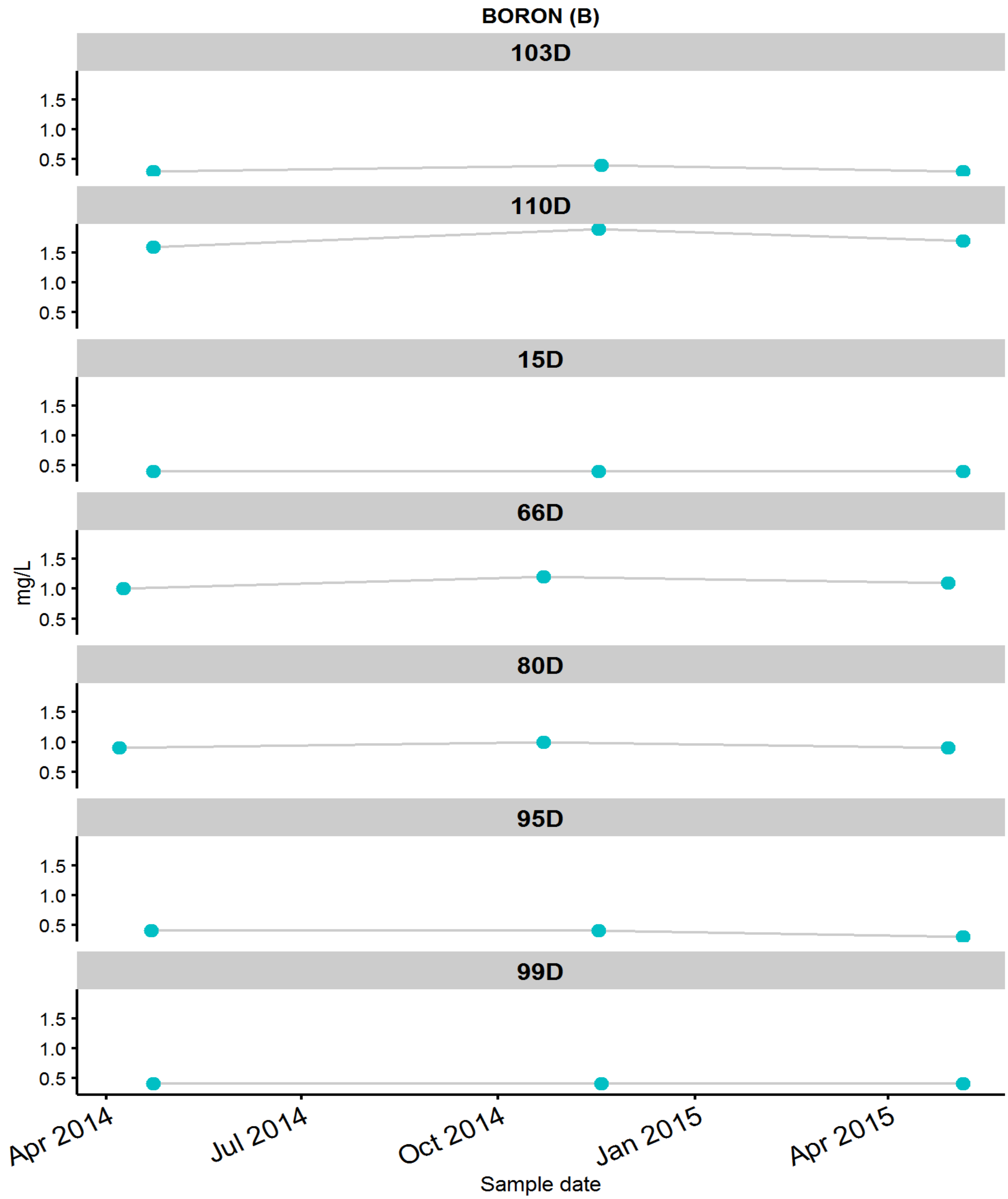


Figure D-5.4. Boron concentrations (mg/L) over space, split up by sampling period

Figure D-5.5. Plots of all observed Boron concentrations, in mg/L, colored by sampling date (left) and sample location (right)