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October 17, 2018

Mr. Garin Schrieve, P.E.
Washington State Dept. of Ecology
PO Box 47600
Olympia, WA 98504-7600

Subject: Kaiser Mead NPL – Submittal of Final Supplemental Feasibility Study Report

Dear Mr. Schrieve:

On behalf of the Mead Custodial Trust, enclosed please find two paper copies and two electronic copies of the Final Supplemental Feasibility Study Report (SFS) for the Kaiser Mead Site. The SFS represents our current understanding of the Site and identifies and evaluates eight remedial alternatives to address groundwater. Included as appendices to the report are technical reports on groundwater ex situ treatability, in situ groundwater treatment, groundwater numeric flow model, sediment:groundwater partitioning model, pilot scale grout wall evaluation, lab scale wetland-EC treatment evaluation, summary of site characterization data collected for the SFS, an updated conceptual site model, and scoring tables for disproportionate cost analysis under MTCA.

Please call me at 406-257-4204 if you have any questions.

Sincerely,

Scott Mason

Scott Mason, LHG.
Senior Geochemist

c: Dan Silver, Mead Custodial Trust (electronic copy only)
Bob Pender, AIG (electronic copy only)

Enclosure: Final Supplemental Feasibility Study Report for the Kaiser Mead NPL Site

SUPPLEMENTAL FEASIBILITY STUDY REPORT FOR KAISER MEAD NPL SITE

-FINAL-

Prepared for:

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October 2018

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

SUPPLEMENTAL FEASIBILITY STUDY REPORT
FOR KAISER MEAD NPL SITE

-FINAL-

1.0 INTRODUCTION

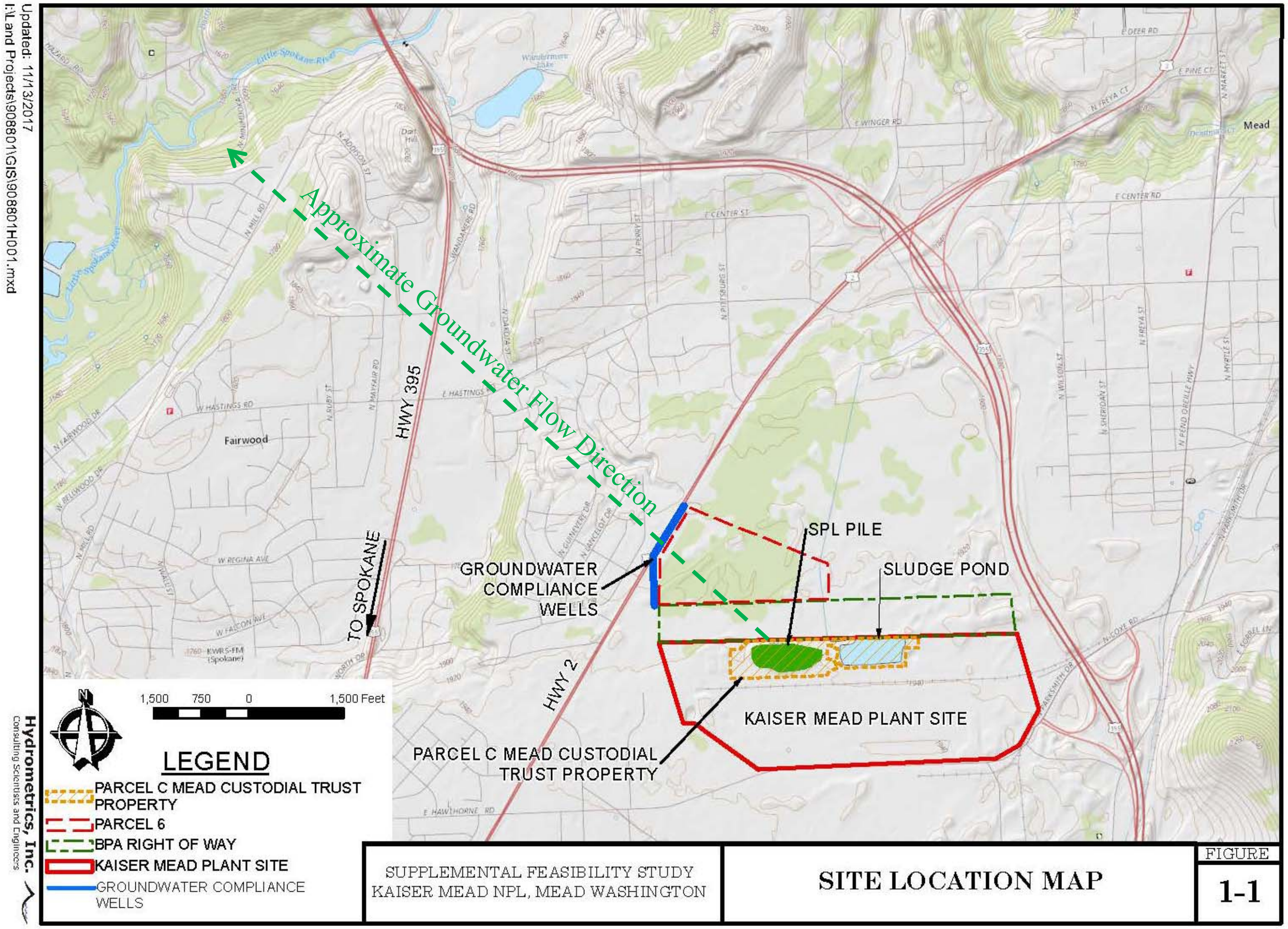
1.1 OBJECTIVE

This report has been prepared to comply with the directive by the Washington Department of Ecology (Ecology) to Mead Custodial Trust (MCT) dated November 9, 2012, to proceed with preparation of a Supplemental Feasibility Study (SFS) for the Kaiser Mead NPL Site (Kaiser Mead). The purpose of the SFS is to develop and evaluate groundwater remedial action alternatives for the Kaiser Mead Site.

1.2 BACKGROUND

The directive to proceed with this SFS is the outcome of the findings of a Groundwater MTCA/CERCLA Performance Evaluation conducted in 2012 (Hydrometrics, 2012). The Performance Evaluation was conducted pursuant to Task 4 of the Remedial Action Plan (RAP) for the Kaiser Mead Site. The RAP is attached to the Consent Decree Relating to Mead Aluminum Reduction Works entered in *In re Kaiser Aluminum Corporation*, Case No. 02-10429 (JKF) (US Bankr. Ct. Del.) (2004). Task 4 of the RAP requires one or more Performance Evaluations to determine whether cyanide and fluoride concentrations in groundwater have attained MTCA and CERCLA requirements in wells located at the downgradient southwestern edge of the parcel located north of the former Kaiser facility that is currently owned by Kaiser Aluminum Properties, Inc., including the area that borders State Highway 2 (Compliance Wells) (Figure 1-1). The Performance Evaluation concluded that after the requisite five-year groundwater monitoring period following completion of certain remedial actions at the Kaiser Mead facility the groundwater cleanup requirements at the

FIGURE 1-1. KAISER MEAD NPL SITE LOCATION



Compliance Wells had not yet been attained. Under Task 5 of the RAP, the Mead Custodial Trust (MCT or Trust) is to prepare an SFS if the Performance Evaluation indicates that cyanide or fluoride concentrations in groundwater do not meet MTCA and CERCLA requirements at the Compliance Wells. Ecology directed the Trust to perform the SFS to evaluate additional groundwater remedial actions at the Site. Additional Site characterization, including continued groundwater compliance monitoring, aquifer sediment and groundwater testing, and groundwater modeling conducted as part of this SFS, indicate that absent additional groundwater remedial actions, groundwater cleanup requirements likely will not be achieved for several decades.

2.0 IDENTIFICATION OF CLEANUP STANDARDS

2.1 ARARS AND PREVIOUS CLEANUP ACTION PLAN

Applicable or relevant and appropriate requirements (ARARs) for the Site based on federal and State laws were identified in the 1993 FS (RETEC, 1993) and the 2002 Cleanup Action Plan (CAP; Ecology, 2002). Ecology determined in the CAP that the groundwater cleanup levels for the Site were based on the drinking water maximum contaminant level (MCL). These levels were adopted by Ecology and are listed in the 2002 CAP as 4 mg/L fluoride and 0.2 mg/L cyanide (free)[1].

2.2 REVIEW OF CLEANUP STANDARDS IN PERFORMANCE EVALUATION

A component of the MTCA/CERCLA Performance Evaluation (Hydrometrics, 2012) was to determine MTCA/CERCLA requirements (cleanup standards) for the Site applicable at the time. The Performance Evaluation review of MTCA/CERCLA requirements revealed that requirements had not changed and that the 2002 groundwater cleanup levels were still appropriate for the Site as MCL values for fluoride and cyanide have not changed.

The cleanup levels for groundwater at the Compliance Wells are:

- 4 mg/L fluoride; and
- 0.2 mg/L cyanide (free).

As per the Consent Decree governing this cleanup action (Task 5 of the RAP), this SFS is focused on addressing groundwater contamination at the Compliance Wells (see Figure 1-1) at the downgradient western border of Parcel 6, currently owned by Kaiser Aluminum Properties, Inc. (area that borders State Highway 2).

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[1] Note that the cyanide standard refers to “free” cyanide. Free cyanide refers to the sum of HCN and CN ions in a sample and is the most toxic form of cyanide. Weak to moderately strong metal-cyanide complexes are compounds that dissociate and release HCN under mildly acidic conditions. The WAD (weak acid dissociable) method was developed to quantify available cyanide, which measures the weak and moderately strong metal cyanide complexes plus free cyanide (Lipps). The Remedial Action Plan attached to the Consent Decree (Task 2) between Ecology and MCT specifies that WAD CN be analyzed in the groundwater monitoring program. Ecology elected to use the WAD CN method as they determined the analytical method for WAD CN provided more consistent results at low levels than free CN methods and its use is consistent with the state clean water act for surface water (WAC 173-201A-240). Since that time newer methods for analysis of free CN that are more reliable than current WAD CN methods have been approved by US EPA. Therefore, Ecology has directed MCT to adopt free CN analysis in lieu of WAD CN at Kaiser Mead (Ecology, 2016).

3.0 SITE CONDITIONS

3.1 FACILITY HISTORY AND BACKGROUND

The Kaiser Mead facility is a former a prebake aluminum smelter that was constructed during WWII in 1942. The smelter facility covered approximately 270 acres, of which approximately 50 acres are owned by the Trust (Figure 1-1). The Trust property consists of an approximately twenty-five (25) acre pile (SPL Pile) of spent potlining (SPL), solid waste rubble and butt tailings that Kaiser Aluminum and Chemical Corporation consolidated and covered with a low permeability capping system during interim actions in 2001 (Ecology Order DE 01 TCPIS-2075) and an approximately twenty-five (25) acre existing wet scrubber sludge bed to the east of the SPL Pile.

During operation of the smelter, waste materials including spent potlining, a listed RCRA hazardous waste (designated K088) and dangerous waste under WAC 173-303-9904 that contains high concentrations of fluoride and cyanide, was disposed in the northwest corner of the smelter facility in the vicinity of the current SPL pile. Process water from smelter operations, including fluoride- and cyanide-rich water used to soak and remove spent potlining from the smelting pots, and stormwater, was disposed in the waste material disposal area. Process water, stormwater, and water from leaking water pipelines area leached fluoride and cyanide from the waste materials and carried the contaminants to the underlying groundwater. The groundwater contaminant plume from the Site historically and currently extends from the area of the SPL pile to the northwest to the Compliance Wells and beyond toward the Little Spokane River.

3.2 SITE CHARACTERIZATION

Site conditions were characterized in detail by Hart Crowser in 1988 and their work (and work by others previously) was the basis for selection of the source control (waste capping and pipe repairs) and groundwater pump and treat as the remedial alternatives of choice by RETEC in their 1993 Feasibility Study. Site characterization identified the waste material in the northwest plant Site area, primarily SPL, as the primary source of fluoride and cyanide to groundwater. Leaching of fluoride and cyanide from the waste material to groundwater was exacerbated by exposure of the waste material to rainfall, stormwater, and leaking water lines. Remedial alternatives in the 1993 Feasibility Study included technologies to control the leaching of the fluoride and cyanide source materials (waste consolidation and capping and pipeline repair, monitoring, and maintenance) and groundwater pumping and treatment.

The cleanup alternative selected by Ecology in the 2002 Cleanup Action Plan (Ecology, 2002) included waste capping, pipe repairs, groundwater pump and treat, institutional controls, and long-term monitoring and cap maintenance. Additional work by MFG, Inc. concluded that completion of source control remedial actions without groundwater pump and treat would result in attainment of cleanup levels at the Compliance Wells in a five-year time frame (MFG, 2004). The 2004 Consent Decree did not require groundwater pump and treat, but retained the option for supplemental groundwater remedial action if MTCA/CERCLA requirements were not met (Task 5 of the RAP). The failure of the cleanup model to accurately predict a cleanup time frame revealed the need to assess the present condition of the Site and update the conceptual Site model as part of this SFS. Additional Site characterization activities and an updated conceptual Site model are described in Sections 3.4 and 3.5 below.

3.3 PAST REMEDIAL ACTIONS

Since the discovery of groundwater contamination associated with spent potliner (SPL) management practices in 1978, a number of actions have been taken to address the issues contributing to the migration of identified contaminants. Table 3-1 below lists the actions taken to date.

As a result of these actions, transport of contaminants by process waters has been eliminated and leaching of waste materials within the SPL pile by rainfall/snowmelt and stormwater is believed to be greatly reduced, if not eliminated, by the engineered, low permeability SPL pile cap. The plant water pipe systems have been replaced and/or lined and pressure and gravity-line transported waters are assumed to be contained within the vicinity of waste storage and impacted sediments.

TABLE 3-1. REMEDIAL ACTIONS COMPLETED AT KAISER MEAD

Date	Action
1978	Use of sludge bed, pot soaking operations, discharge of sewage effluent to sludge bed ceased.
1979	SPL material covered with asphalt cap.
1979	Pot cleaning activities conducted on asphalt pad.
1981	SPL handling and storage activities moved into SPL building.
1981	Tharp Lake unlined settling basin abandoned.
1983	Pipe leak repaired.
1986	Pot cleaning activities moved to building.
1986	Area 2 capped with asphalt.
2001	Interim Action Agreed Order DE 01 TCPIS-2075 resulted in waste materials (butt pile, rubble pile, asphalt covered SPL pile) consolidated into the current SPL pile and capped with synthetic liner.
2002	Cured-in-place liners installed in stormwater and sanitary sewer lines.
2005	Semi-annual inspections of SPL and asphalt cap areas and surface water drainage features.
2005	Compliance monitoring well network installed.
2006	Pressure main water supply pipelines replaced and sanitary sewer line break repaired above shallow aquitard.
2005 - Present	Ongoing groundwater and surface water monitoring and inspection and maintenance of source controls.

Also as a result of these actions, the current contaminant migration pathways differ from the historic (pre-actions) pathways as 1) there is no longer any process water being infiltrated to the groundwater system; 2) waste material has been substantially isolated from precipitation infiltration by the SPL pile cap; and 3) there is less water from plant water and piping systems being infiltrated to the groundwater system from the SPL pile area. The current primary migration pathway is leaching of contaminated aquifer sediments (beneath the SPL pile and extending to the Compliance Wells and likely beyond) by groundwater. The leaching of contaminated aquifer sediments constitutes a secondary contaminant source (i.e., a contaminant source separated in space or location from the area where the contaminant was initially released) was identified by supplemental Site characterization activities described in Section 3.4, below.

The CAP (Ecology, 2002) selected institutional controls consisting of a covenant to ensure that no groundwater is removed for domestic purposes from the contaminant plume, prevent

Kaiser from taking actions that interfere with the integrity of the SPL pile cap and control exposure of future site workers to the Site contaminants. This covenant was specified in the Task 6 of 2004 Consent Decree Scope of Work and subsequently executed as an Easement Agreement between Kaiser Aluminum Properties, Inc. and MCT for the property upgradient (southeast) of the Highway 2 and the Compliance Wells. No institutional controls for properties downgradient of the Compliance Wells were included in the CAP or Consent Decree. Ecology (2016) reviewed the status of off-Site institutional controls and identified State and Spokane County restrictions on groundwater use and concluded that sufficient protective measures are in place to protect human health and the environment from exposure to contaminated groundwater from the Kaiser Mead facility. These identified measures include State Department of Health regulation of public water supply systems and Spokane County final plat dedications regarding provision of public water supply systems and prohibition of use of private wells.

3.4 SUPPLEMENTAL SITE CHARACTERIZATION ACTIVITIES, PILOT TESTS, AND TREATABILITY STUDIES

A review of Site data compiled in the 1980s and 1990s revealed information gaps in the characterization of Site geochemistry and hydrology and Site-specific testing of remedial technologies. From 2013 through 2016, a series of field and laboratory activities were undertaken to supplement the data that was collected and evaluated 20 to 30 years ago, including aquifer testing; ex situ treatability testing; in situ treatability testing; Site borings and testing of aquifer sediment and groundwater; a grout wall pilot test; development of a numeric groundwater flow model and a sediment:groundwater partitioning and mass balance model. These activities are described further below.

3.4.1 Aquifer Testing

The hydrogeology of the Site consists of a mixed glacial outwash package of fine to coarse sands with minor gravel, and thin intervening layers of silt and clay. The glacial outwash sequence is approximately 285 feet thick in the vicinity of the Site and underlain by a regional aquitard. Previous investigators have divided the aquifer stratigraphy into three zones for purposes of defining contaminant transport at the Site. The uppermost zone, A

Zone, is composed of fine to coarse and/or medium to coarse sand with discrete zones of silt and very fine sand. The A Zone is approximately 10 to 20 feet thick and underlain by a silt and clay layer that is present beneath the SPL pile but is laterally discontinuous to the west and is not present in the Compliance Wells area. A Zone is the shallowest aquifer in the vicinity of the SPL pile and is the most highly contaminated. The B Zone consists of fine sand, fine to medium sand, and/or medium to coarse sand, sometimes silty or with silt layers and is underlain by a silt/clay layer. The B Zone is reported in boring logs to range from 6 to 20 feet in thickness. B Zone is not contaminated in the area of the SPL pile but is contaminated in the area of the Compliance Wells where the aquitard separating the A and B Zones is absent.

In the 1980s and early 2000s, a limited amount of aquifer testing was conducted by Hart Crowser and MFG, Inc., respectively, to characterize the hydrogeology beneath the Site, primarily the contaminated A Zone aquifer. The failure of prior cleanup actions conducted from 2000 to 2006 to meet the anticipated cleanup time frames predicted by the MFG (2004) groundwater model prompted questions as to the level of understanding of aquifer characteristics of the A Zone aquifer. In order to supplement the information collected by those efforts, Hydrometrics conducted field tests in 2013 to better define aquifer characteristics and support more accurate contaminant transport predictions and groundwater capture analyses to be used in assessing remedial technologies as potential cleanup alternatives. The results of the field tests were previously submitted in the Aquifer Characterization and Groundwater Capture Analysis (Hydrometrics, 2013). This work was supplemented in 2015 and 2016 and the results of the supplemental work are presented in the Groundwater Model Report, which is included as Appendix A to this SFS.

3.4.2 Ex Situ Treatability Testing

In 1993 and 2002, ex situ groundwater cleanup technologies (pump and treat) were evaluated as part of the recommended cleanup alternative for the Site. RETEC (1993) recommended alkaline hydrolysis for destruction of cyanide followed by treatment with calcium chloride to precipitate and remove fluoride. RETEC’s recommendation was based on a literature search and not on actual testing of Site groundwater. MFG (2002) recommended chemical precipitation as the most effective means of treatment for both cyanide and fluoride, using ferrous chloride and calcium chloride respectively for each contaminant. MFG's recommendation was based on testing on Site groundwater, but cleanup levels were not used to gauge the effectiveness of the individual treatment tests.

To expand upon the earlier evaluations, additional laboratory treatment tests on Site groundwater were conducted in 2013 and 2016. Hydrometrics (2013) testing indicated that several treatment methods were effective and capable of reducing WAD cyanide[2] concentrations to below the cleanup level of 0.2 mg/L. Chemical precipitation by ferrous sulfate addition and chemical oxidation by peroxide addition were selected as the most effective and implementable for inclusion in potential water treatment process trains. None of the primary fluoride removal methods were capable of reducing concentrations to the cleanup level of 4 mg/L. However, a polishing treatment by ion exchange (IX) was found to be effective in reducing fluoride concentrations to the cleanup level. Alum/XSORBX, with and without IX polishing, were selected for fluoride removal in the potential treatment process trains. A full report on the Hydrometrics' ex situ treatability study is included as Appendix B in this report.

The chemical precipitation treatment methods tested by Hydrometrics (2013) have potentially significant shortcomings of excessive cost and treatment waste generation. An alternative wetland + electrocoagulation (EC) treatment process train was identified to potentially avoid these shortcomings. In 2016 MCT contracted with Arconic to perform a treatability study using a laboratory-scale wetland for cyanide destruction and EC technology for treatment of fluoride. Site groundwater was used in the tests and results indicate effective treatment to established cleanup levels is possible if initial water quality is within a contaminant concentration range similar to that occurring upgradient of the Compliance

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[2] At the time of these studies, Ecology specified monitoring of WAD cyanide, rather than free cyanide for determination of compliance with groundwater cleanup standards (0.2 mg/L as free cyanide). Thus, the focus of the study was treatment of WAD and total cyanide. Since that time, newer methods for analysis of free CN have been approved by US EPA that are more reliable than current WAD CN methods and Ecology directed MCT to adopt free CN analysis in lieu of WAD CN at Kaiser Mead (Ecology, 2016).

Wells. A full report on the Arconic ex situ treatability study is included as Appendix C in this report.

3.4.3 In Situ Treatability Testing

In the 1993 FS, RETEC excluded in situ groundwater treatment methods during the initial technology screening exercise due to lack of documented experience treating cyanide and the challenges of treating groundwater at the depths required. Advances in situ treatment technologies in the 20 years since the RETEC feasibility study prompted a new evaluation of in situ treatment for Site groundwater. In 2013, Hydrometrics performed laboratory proof of concept treatability testing on Site groundwater using both solid and liquid reagents. Three reagents for cyanide treatment (zero valent iron (ZVI), ferrous sulfate treatment and hydrogen peroxide oxidation (potentially with copper sulfate catalyst)) were retained as potentially viable technologies because they were demonstrated to be effective in lab tests and were likely to be implementable. Two reagents for fluoride treatment (calcium phosphate and bone char) were retained as potentially viable in situ technologies. A full report on the in situ treatability study is included as Appendix D.

As described in Appendix D, further evaluation of the in situ reagents identified prohibitive problems with implementation of in situ treatment and thus no in situ treatment methods are retained for consideration in remedial alternatives. Both identified reagents for treatment of fluoride contain phosphorus compounds which would likely result in the addition of phosphorus to groundwater and the Little Spokane River which conflicts with the established Total Maximum Daily Load (TMDL) for phosphorus in the Spokane River (Ecology, 2010). Although no prohibitive problems were encountered for cyanide treatment, the inability to treat both fluoride and cyanide by in situ methods is considered to preclude in situ treatment alternatives.

3.4.4 Site Borings and Testing of Aquifer Sediment and Groundwater

Previous Site characterization efforts by Hart Crowser (1988) identified potential contaminant sources in unsaturated sediments beneath the SPL pile and determined that a remaining pathway for contaminant migration was facility-introduced water from pipe leaks traveling along an identified shallow aquitard (SAQ) and interacting with contaminated unsaturated sediments beneath the SPL pile area. However, the full extent and distribution of potential subsurface contaminant sources in sediments beneath the SPL pile area and areas outside of the footprint of the SPL pile were not well characterized. In addition, there was a general lack of knowledge regarding the geochemistry of saturated sediments in the A Zone aquifer. In an effort to close these data gaps, during 2013 through 2016 a number of borings were drilled in and around the SPL pile and samples were collected and tested to further characterize saturated and unsaturated sediments and groundwater in and above the SAQ and A Zone aquifer. Methods and results of the groundwater and sediment characterization studies are summarized in the Data Report on Additional Field Characterization for the Kaiser Mead Facility (Hydrometrics, 2017a). Evaluation of the supplemental characterization data is described in an appendix (Supplemental Site Characterization Analysis) to the Conceptual Site Model (Appendix E in this report).

Supplemental Site characterization efforts in 2013 revealed the following:

- Available data appeared to rule out the identified SAQ as either a significant pathway for contaminants or a source of groundwater capable of mobilizing contaminants within an unsaturated sediment secondary source; and
- A potential significant secondary source (i.e., a source that has been transported from its original or primary location) for fluoride was identified in saturated A Zone sediments beneath the SPL pile but the areal extent of the secondary source was not fully identified.

In 2015 and 2016, additional borings/wells were drilled northwest of the SPL pile (along the track of the identified contaminant plume) from the northern border of the Bonneville Power power line right-of-way to the Compliance Wells to characterize groundwater and saturated sediment contamination from the SPL pile to the Compliance Wells. The 2015 and 2016 field and laboratory activities revealed:

- Fluoride-enriched sediments extend from the SPL pile to at least the Compliance Wells, and likely beyond;
- Cyanide-enriched sediments occur in the highest concentration areas of the groundwater plume; and
- The levels of fluoride and cyanide contamination in A Zone saturated sediments and B Zone saturated sediments (near the Compliance Wells) are contributing to groundwater contamination to an extent that generates the observed current groundwater concentrations and without further remedial action will likely sustain levels of fluoride and cyanide in groundwater exceeding cleanup levels for a very long time (30 to 130 years) in the future.

3.4.5 Grout Wall Pilot Test

The identification of ongoing sources to groundwater, including a secondary source in aquifer sediments, led to consideration of hydraulic controls/containment in the form of a grout wall as a potentially viable technology option. However, the approximately 160-foot depth of the A Zone aquifer is near the limit of implementability of grout walls. To determine if hydraulic control in the form of a grout wall could be implemented on Site, a pilot test of a grout wall installation was completed in 2015 as described in Appendix G to this SFS. Following installation of the grout wall, aquifer testing was done to determine the effects of grout wall on groundwater flow and to estimate the hydraulic performance of the grout wall. Overall conclusions of the pilot test were that a wall could be installed and although some defects would be expected, a grout wall is a potentially effective technology for the Site. Information obtained from the grout wall pilot test is used to determine potential costs and performance of a full-scale grout wall for comparison with other technologies and alternatives.

3.4.6 Numeric Groundwater Flow Model

In 2004, MFG prepared a groundwater flow and contaminant transport model to predict effects of remedy implementation. This model proved inaccurate as it predicted attainment of groundwater cleanup levels at the Compliance Wells in a very short time (see discussion in the current CSM report (Appendix E). As part of the SFS, additional groundwater flow models were developed to supplant the earlier model. In 2013, a simple analytical simulation of the flow field in the A Zone aquifer was developed to show the potential effects of the grout curtain on groundwater flow in the SPL area (Hydrometrics, 2013). In 2015 and 2016, Hydrometrics developed a numeric groundwater flow model to predict the effects of implementing remedial alternatives (grout wall and pumping/ ex situ treatment). The model utilized MODFLOW-USG (Panday et al., 2013) to simulate the physical flow system. MODFLOW-USG is an updated version of the U.S. Geological Survey's modular 3D finite difference groundwater flow model, MODFLOW (McDonald and Harbaugh, 1988). A full description of the model is provided in the Groundwater Model Report included as Appendix A of this SFS.

3.4.7 Sediment:Groundwater Partitioning and Mass Balance Model

In 2016 and 2017, a Sediment:Groundwater Partitioning and Mass Balance Model (Partitioning Model) was developed to simulate behavior of fluoride, total cyanide[3] and free cyanide in the aquifer sediment:groundwater system at the Kaiser Mead Site and to predict the effects of remedial alternatives on contaminant concentrations in groundwater. The Partitioning Model is based on the Conceptual Site Model (CSM) for the Kaiser Mead Site and in particular results of laboratory-based sediment:groundwater partitioning experiments (leach and desorption testing of sediments and Site groundwater). The Partitioning Model is a relatively simple spreadsheet-based model (Excel) that performs a series of partitioning and mass-balance calculations to simulate transfer of fluoride and cyanide from groundwater to sediment, and vice versa, with removal of groundwater fluoride and cyanide mass by groundwater flow. The Partitioning Model report describing the conceptual and mathematical basis of the model and results of model simulations forecasting or estimating the effects of

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[3] Total cyanide is a measure of all cyanide dissociable by strong acid and includes WAD cyanide, free cyanide plus strong-cyanide complexes such as iron cyanide compounds.

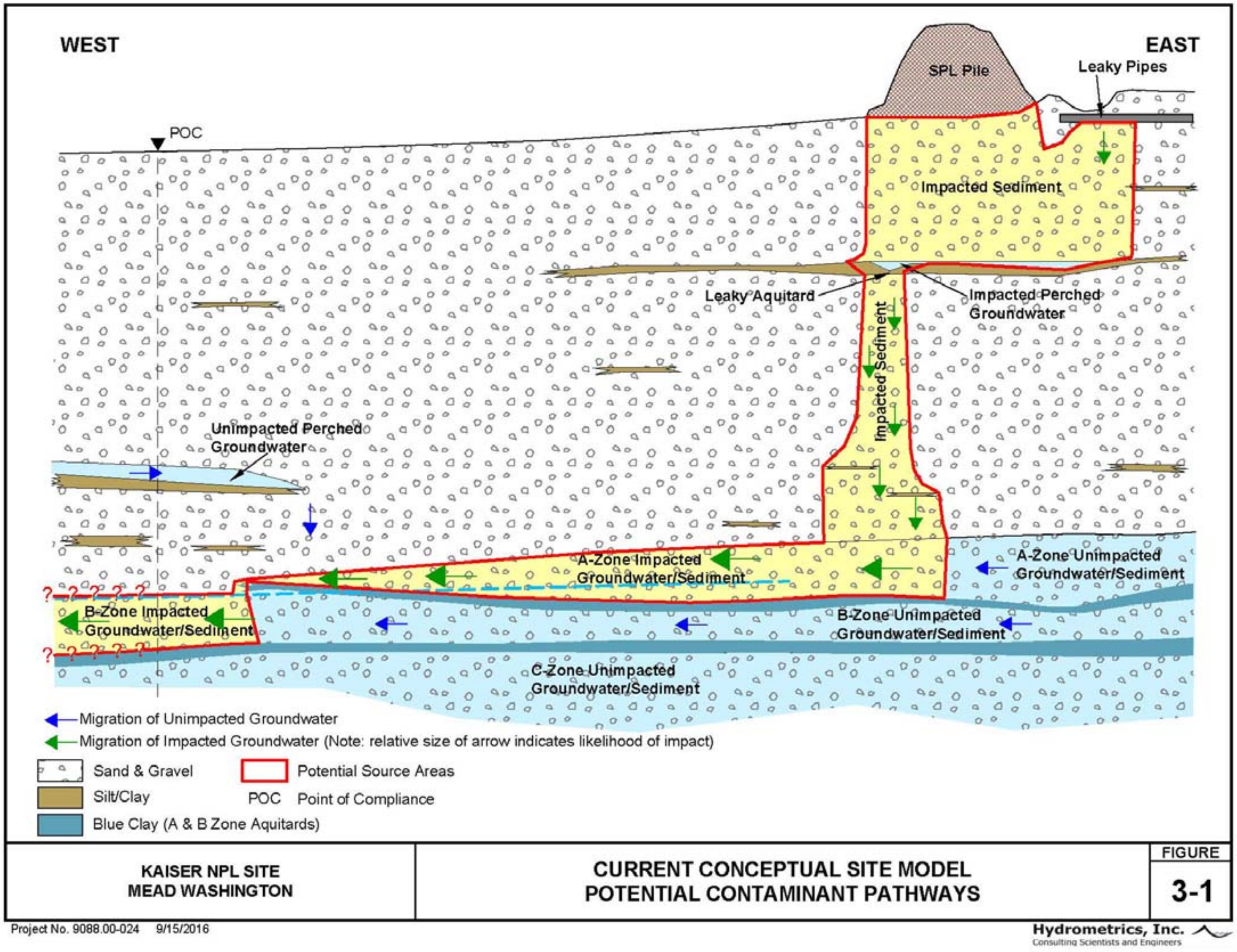
remedial alternatives is included as Appendix F to this SFS. Forecasts of the model regarding the time required to meet cleanup levels under remedial alternatives are presented in Sections 4 through 6 of this SFS as part of alternative evaluation and comparison.

3.5 CONCEPTUAL SITE MODEL

At the conclusion of the supplemental Site characterization work in 2016, the conceptual Site model (CSM, see Appendix E) was updated to reflect changes in the understanding of the Site and the sources and causes of ongoing elevated concentrations of cyanide and fluoride in groundwater. A graphical representation of the current CSM is shown in Figure 3-1. The primary differences between the current CSM and the earlier Hart Crowser (1988) CSM and MFG (2004) CSM and groundwater model are:

1. Prior CSMs assumed that all migration pathways from contaminant sources in the capped SPL pile and underlying sediment were completely eliminated. The current CSM acknowledges that although active water sources have not been identified, it is possible that there are unknown water sources that are still actively leaching contaminated sediment beneath the SPL pile and that have not been entirely controlled by remedial actions. Thus there is the possibility that groundwater contaminant loading from the SPL area may continue at some unknown, likely small rate. The rate of loading from these sources is believed to be insignificant relative to secondary sources in aquifer sediment, and thus the remedial alternatives developed in this SFS do not include additional actions to control these sources, only continued maintenance and monitoring of existing controls.
2. Prior CSMs did not identify any contaminant sources and migration pathways from secondary contaminant sources in aquifer (saturated) sediment. The current CSM identifies extensive secondary contaminant sources within the aquifer sediments in the area of the groundwater contaminant plume (based on test wells and borings completed in 2013, 2015, and 2016) and that these secondary sources are the primary ongoing contributors of cyanide and fluoride to groundwater. Thus, the remedial

FIGURE 3-1. CURRENT CONCEPTUAL SITE MODEL POTENTIAL CONTAMINANT PATHWAYS



alternatives developed in this SFS are focused on providing control actions for these secondary sources.

Currently, cyanide and fluoride can potentially migrate to groundwater by three mechanisms:

1. Leaching of impacted sediments in the unsaturated zone beneath the SPL Pile by an unidentified water source (i.e., leaching of sediments by zones of saturated flow within the otherwise unsaturated zone above the regional water table, such as could occur above a shallow aquitard or adjacent a leaky pipe);
2. Leaching of impacted sediments within the saturated zone of the A Zone aquifer and downgradient B Zone aquifer by groundwater; and
3. Contaminant release to unsaturated flow of soil moisture through the vadose zone.

Of these three potential mechanisms, leaching of impacted aquifer sediments by groundwater (bullet 2) is believed to be dominant. Although plausible, leaching of sediment above the A Zone aquifer as described in bullets 1 and 3 is believed to be minor due to the lack of a significant documented water source.

Once in the groundwater system, cyanide and fluoride migrate through groundwater flow and are transported through the A Zone aquifer to the northwest, toward the Compliance Wells and ultimately toward the Little Spokane River. The A Zone aquitard is discontinuous in the vicinity of monitoring well KM-4, allowing contaminated groundwater within the A Zone to mix with the underlying B Zone aquifer upgradient of the Compliance Wells. The B Zone aquifer transports cyanide and fluoride to the downgradient Compliance Wells and beyond. Within the groundwater system, the transport of cyanide and fluoride is controlled by the aquifer properties. Average linear velocity of groundwater flow is approximately 3 to 5 ft/day and estimated groundwater travel time from the SPL pile to the Compliance Wells (a distance of approximately 2,000 feet) is approximately one to two years.

During groundwater transport, cyanide and fluoride are subject to dilution by mixing and dispersion and react with the aquifer sediments through the chemical processes of mineral dissolution, mineral precipitation, adsorption/desorption, and ion-exchange. These physical and chemical processes cause cyanide and fluoride transport to be retarded (or slowed) relative to groundwater transport velocity. These mechanisms also resulted in the formation of secondary contaminant sources within the aquifer sediment beneath and downgradient of the SPL pile area.

3.6 CURRENT AND FUTURE GROUNDWATER CONDITIONS

Distributions and concentrations of free cyanide and fluoride in groundwater are shown on Figures 3-2 and 3-3, respectively. Groundwater concentrations currently exceed cleanup levels for free cyanide and fluoride at the Compliance Wells and in a contaminant plume that extends from the Compliance Wells upgradient to the SPL pile. Although not documented by groundwater monitoring data, extrapolation of data from the Compliance Well area suggests that concentrations likely exceed cleanup levels downgradient of the Compliance Wells also.

Overall, cyanide and fluoride concentrations within the groundwater contaminant plume appear to have declined slightly since the implementation of the cleanup remedy, particularly near the SPL area and in some downgradient locations near the plume center (e.g., near monitoring wells KM-5 and KM-6). Thus it appears that contaminant loading to groundwater from the SPL area and the mass of contaminants present in groundwater may have been reduced by remedial actions between 2001 and 2006 as the observed reductions in groundwater concentrations may represent a groundwater response to the implemented source control actions. However, aquifer sediments comprise a secondary contaminant source in the form of adsorbed and/or mineral precipitated fluoride and cyanide. The secondary sources of fluoride and cyanide are being slowly leached by groundwater and groundwater concentrations are expected to decline as the secondary source contaminant mass is diminished. The observed reductions in groundwater concentrations in the SPL and plume center areas likely also represent groundwater responses to the ongoing leaching of the secondary aquifer sediment source.

FIGURE 3-2. FREE CN CONCENTRATION IN GROUNDWATER

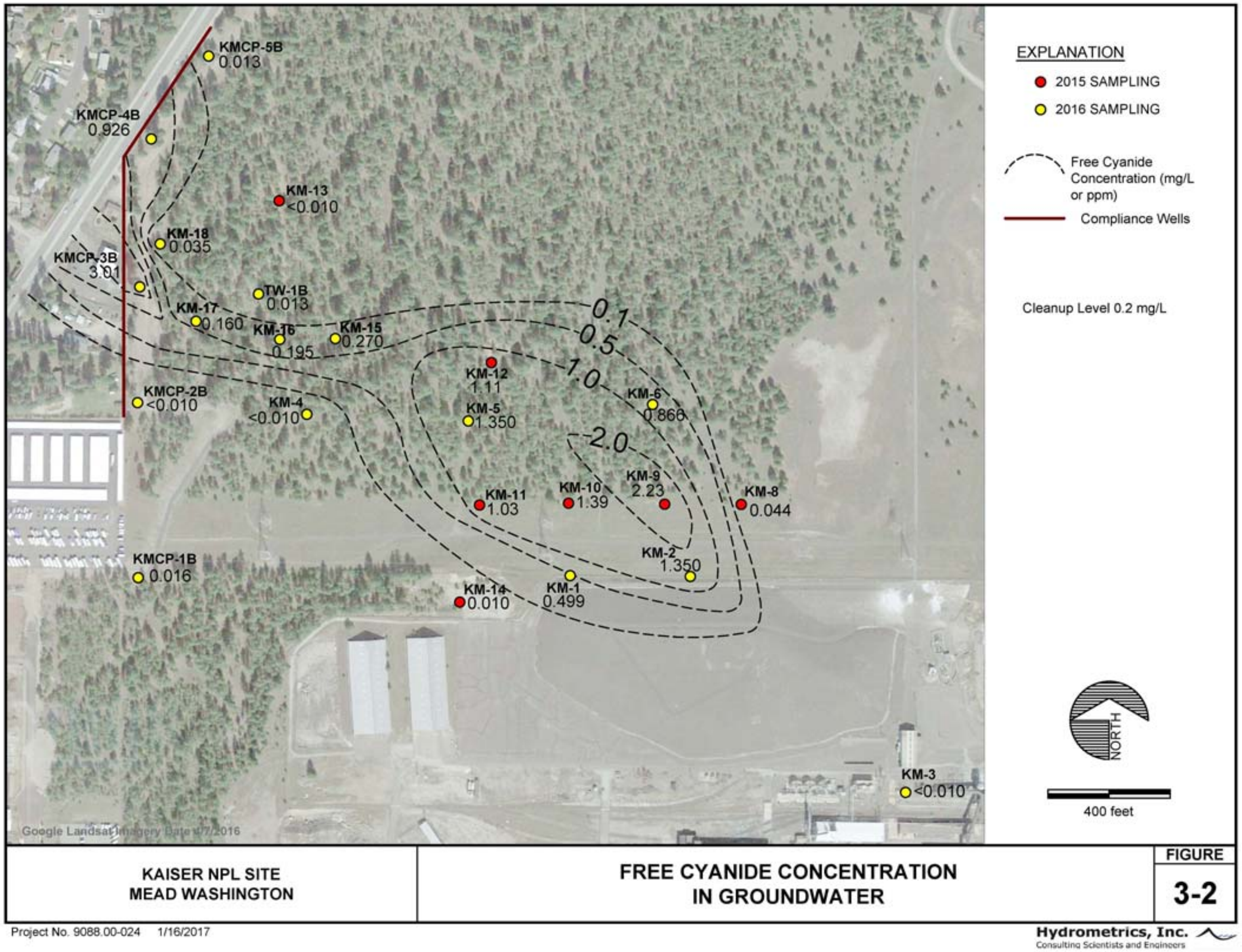
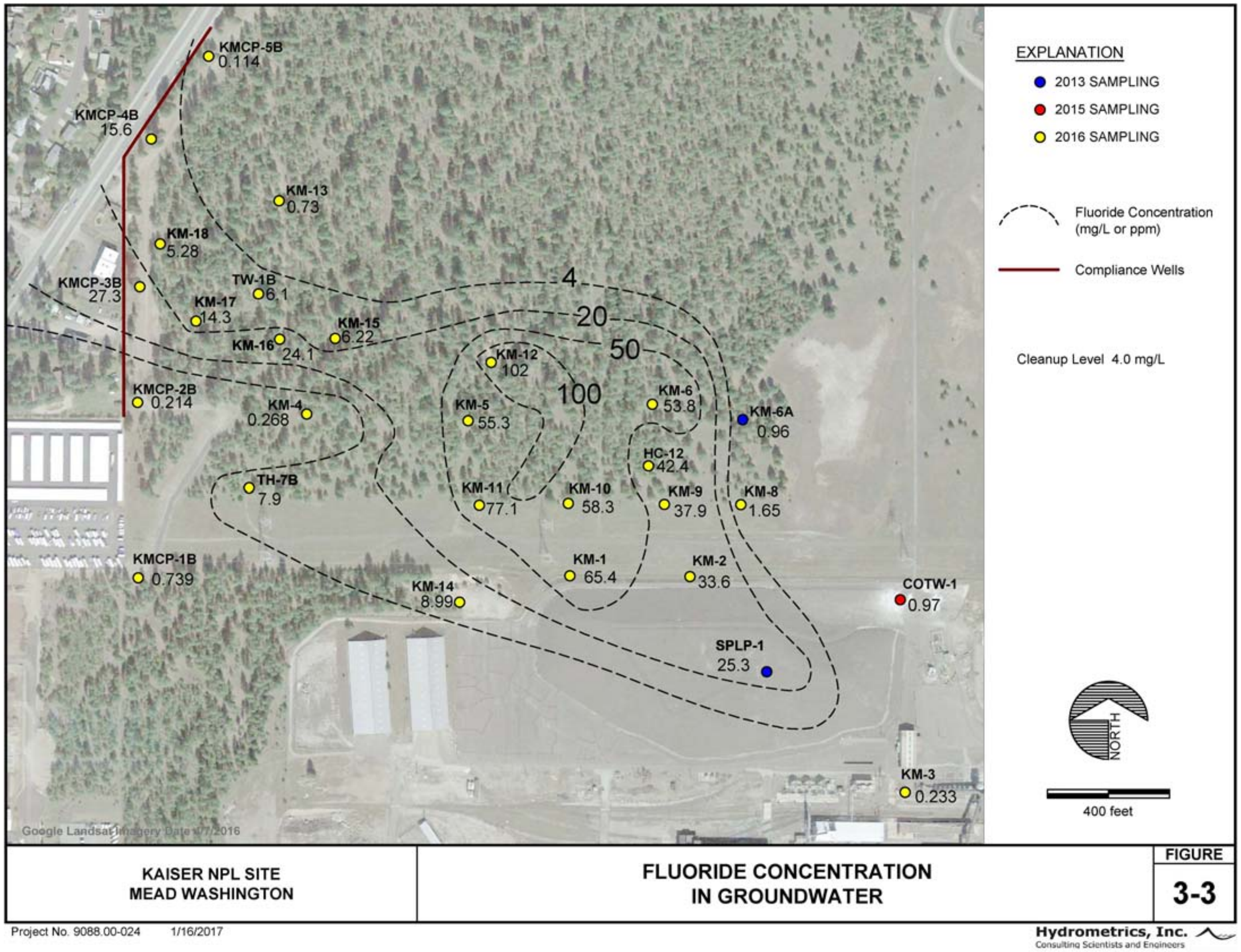


FIGURE 3-3. FLUORIDE CONCENTRATION IN GROUNDWATER



Absent additional remedial actions, groundwater contaminant concentrations are likely to decrease slowly, due to continued leaching and diminishment of the secondary contaminant sources in the aquifer sediments, such that concentrations may be reduced to cleanup levels at the Compliance Wells in approximately 30 to 80 years for cyanide and 50 to 130 years for fluoride. This estimated time to attain cleanup levels is based on the observed rates of decline in cyanide and fluoride concentrations within the groundwater contaminant plume since the implementation of the cleanup remedy and on partition model simulations of cleanup rates using cyanide and fluoride sediment:groundwater partitioning ratios developed through laboratory testing of sediment in 2015 and 2016. Further discussion of changes in groundwater concentrations over time are presented in the CSM (Appendix E) and in the Supplemental Site Characterization Analysis (Appendix A to the CSM).

4.0 IDENTIFICATION AND SCREENING OF CLEANUP TECHNOLOGIES

4.1 INTRODUCTION

This section presents the identification and screening of technologies that were evaluated to supplement the previously implemented remedies for the Kaiser Mead Site. Screening of cleanup technologies was done in steps as follows:

1. As discussed in Section 3.0, a number of remedial technologies were investigated, and in some cases Site-specific testing was conducted, to determine potential applicability to Kaiser Mead Site conditions. These investigative efforts resulted in an initial screening of technologies. The following sections present the technologies (monitored natural attenuation, containment, and ex situ treatment) that were found to be potentially effective in meeting cleanup requirements. In situ remedies were administratively excluded from further consideration for the reasons described in Section 3.4.3 above and Ecology, 2015a.
2. There are multiple options within the containment and ex situ treatment technologies. In the second phase of screening (Section 4.2), technology options are described and evaluated for effectiveness, implementability, and cost.
3. Section 4.3 describes and identifies the most effective and implementable technology options that are retained for inclusion in the remedial action alternatives.
4. Section 4.4 describes the eight remedial action alternatives formed by combining the retained technology options. These alternatives are evaluated in Section 5 for Model Toxics Control Act (MTCA; WAC 173-340-360) requirements and a comparison of alternatives is provided in Section 6.

4.2 SCREENING OF CLEANUP TECHNOLOGIES

The types of cleanup technologies which were retained for further consideration are:

- Monitored Natural Attenuation – includes continued groundwater monitoring, maintenance of previously implemented remedies such as cap maintenance (includes inspection and testing), sewer lines inspection and testing, testing of specific buried water pressure mains, institutional controls, and the ongoing attenuation of contaminants that is naturally occurring;

- Containment/Physical Barriers – includes technologies to isolate potential source areas from groundwater or reduce the effects of groundwater flow through potential source areas;
- Ex Situ Groundwater Treatment – includes extraction (pumping) of groundwater from the contaminant plume area, on-Site treatment with chemicals or constructed wetland for cyanide removal; treatment with chemicals, ion exchange, reverse osmosis or electrocoagulation (EC) for fluoride removal; and discharge of treated water to groundwater or municipal sewer; and
- Excavation, Consolidation, and Disposal.

The initial screening included evaluating the technologies against three criteria: effectiveness, implementability, and cost. MTCA (WAC 173-340-350(8)(b)(i)) allows for elimination of cleanup action alternatives that, based on a preliminary analysis, so clearly do not meet the minimum requirements in WAC 173-340-360 that a more detailed analysis is unnecessary. These include alternatives that are not technically possible at the Site and alternatives for which costs are clearly disproportionate to benefits. The criteria and questions considered during the initial screening include:

- Effectiveness – Does the technology have the demonstrated potential to attain, or significantly contribute to the attainment of, cleanup levels or significant contaminant mass reduction?
- Implementability – Can the technology be reliably constructed, installed, implemented, operated and maintained?
- Cost – What are the capital and operation and maintenance (O&M) cost of the technologies? Estimated costs are intended to provide a relative comparison between alternatives, and are considered to be +/-25 percent of actual costs.

4.2.1 Monitored Natural Attenuation

EPA (1999) and MTCA (WAC 173-340-200) defines natural attenuation as “a variety of physical, chemical, or biological processes that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of hazardous substances [contaminants] in soil or groundwater. These in-situ processes include biodegradation; dispersion; dilution; sorption; volatilization; radioactive decay; and chemical or biological stabilization, transformation, or destruction of hazardous substances [contaminants].” EPA (1999) defines “Monitored natural attenuation” as “the reliance on natural attenuation processes (within the context of a carefully controlled and monitored site cleanup approach) to achieve site-specific remediation objectives within a time frame that is reasonable compared to that offered by other more active methods.”

Monitored natural attenuation (MNA) at the Kaiser Mead Site would rely on the attenuation of contaminants that is naturally occurring; maintenance of the capped SPL pile; and continuation of other previously implemented remedial actions including continued inspection of specific subsurface pipelines to control the introduction of pipeline water to impacted unsaturated sediments; and continuation of the groundwater monitoring program that is now conducted by the MCT. Although MNA alone may not meet minimum requirements for cleanup actions (see further discussion in Section 5.3.8), it is retained as a technology option for the following reasons:

1. Since MNA is already being implemented, it serves as the no additional action alternative for this Site (note that all technology options and alternatives include previously implemented source controls);
2. MNA will continue under all remedial alternatives; and
3. The estimated times to attain cleanup levels by MNA are comparable to other more active technologies.

The estimated time to attain cleanup levels in the Compliance Wells by MNA are 33 to 80 years for cyanide and 52 to 130 years for fluoride based on forecasts by the sediment:groundwater Partitioning Model (Appendix F). Forecasted future groundwater concentrations in the Compliance Wells under MNA (Base Case Model Simulations) are shown in Figures 4-1 and 4-2. As for all forecast or prediction models, the Partitioning Model includes uncertainties in the accuracy and representativeness of the conceptual model, model algorithms, and model parameters that represent aquifer and groundwater properties. The ranges in estimated time to attain cleanup levels and groundwater concentrations in the Compliance Wells reflect the uncertainties in the Partitioning Model.

FIGURE 4-1. ESTIMATED TIME TO CLEANUP (CYANIDE) BY MNA (BASE CASE)

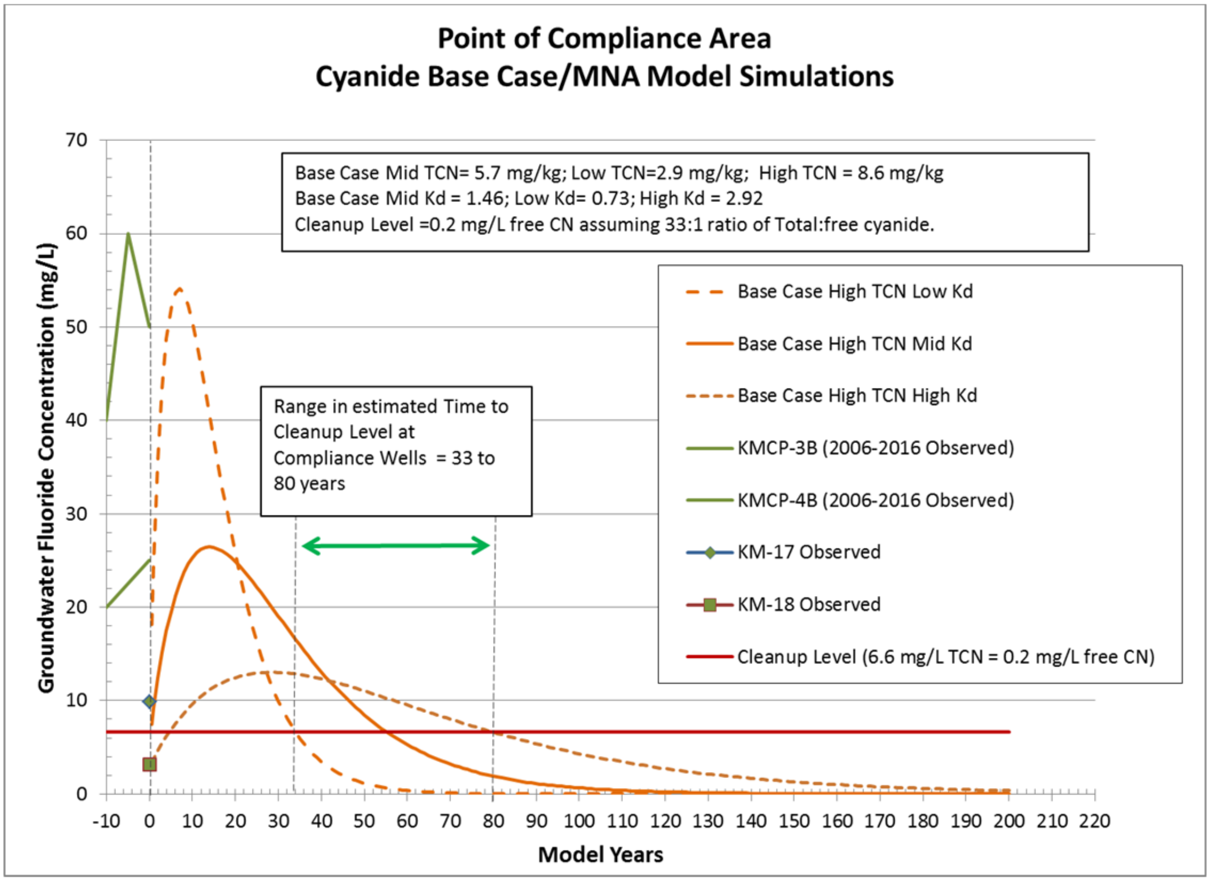
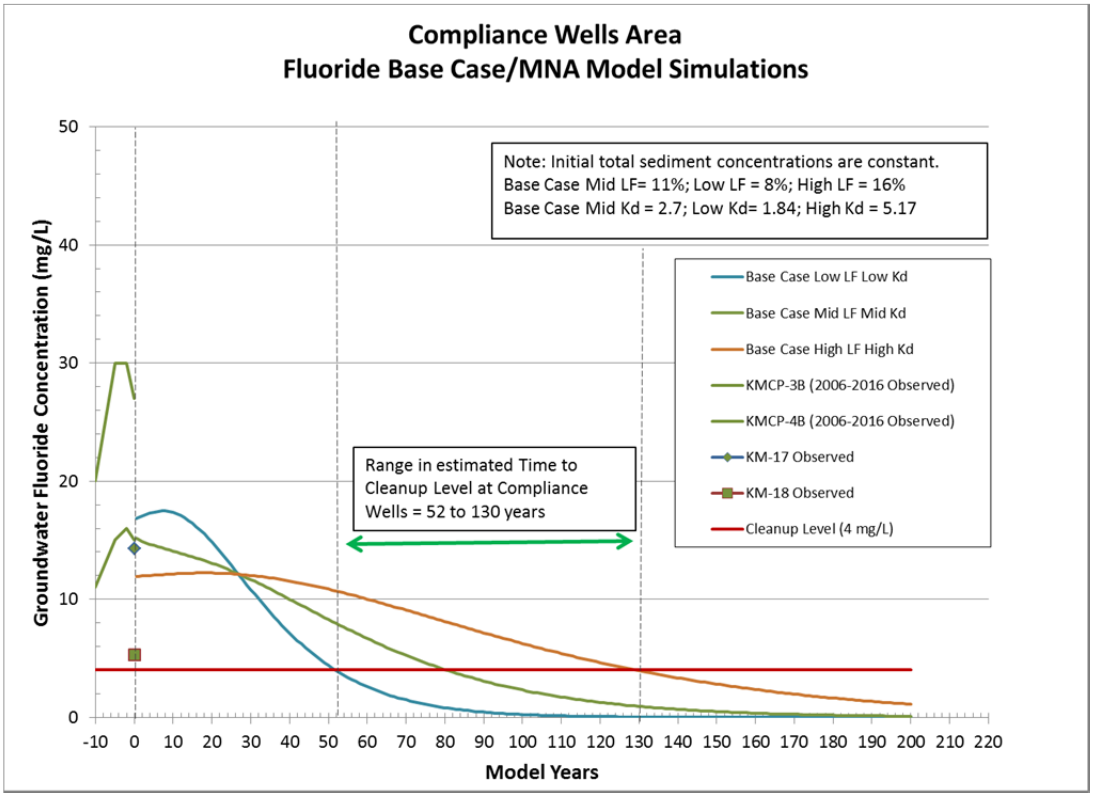


FIGURE 4-2. ESTIMATED TIME TO CLEANUP (FLUORIDE) BY MNA (BASE CASE)



4.2.2 Containment/Physical Barriers

As capping of the significant waste material and source areas by Kaiser Aluminum in 2000 and 2001 was fairly comprehensive, physical containment technologies remaining to be considered are limited to subsurface barrier walls. Results of the screening of containment technologies are summarized in Table 4-1 and are further described as follows:

1. A total of five technology options were considered, including three aquifer/location options (shallow perched aquifer (SAQ) area at SPL pile; A Zone aquifer at SPL Pile only; and A Zone at SPL Pile plus Plume Center) and two construction method options (trenching and injection). The Compliance Wells area was not considered for application of this technology due to physical constraints (e.g., increased depth of aquifers and heterogeneity of Site geology) that reduce the likelihood of constructing an effective grout wall in this area.

TABLE 4-1. GROUNDWATER PHYSICAL CONTAINMENT TECHNOLOGIES SCREENING

Technology Option	Effectiveness	Implementable?	Capital Cost ($ Million)	Estimated Time To Meet Cleanup Levels in Compliance Wells (years)*	Retained?
SAQ Slurry Wall (Trench)	Minimal, due to lack of groundwater flow	Yes, common at depths < 65 feet	$9.4, for 2,000 linear feet	Not estimated	No
A Zone Slurry Wall (Trench)	Unknown	Unlikely, unproven at depths required	Unknown, but high	Not estimated	No
SAQ Grout Wall (Inject)	Minimal, due to lack of saturation and groundwater flow.	Yes	Unknown	Not estimated	No
A Zone Grout Wall (Inject); SPL Pile Area	Pilot test indicates an effective wall is possible.	Yes	$15.5, for 3,400 linear feet	Fluoride – 52 to 115; Cyanide – 41 to 64	No
A Zone Grout Wall (Inject); SPL and Plume Center Area	Pilot test indicates an effective wall is possible.	Yes	$28.1 for 5,900 linear feet	Fluoride – 31 to 51; Cyanide – 0 to 70	Yes

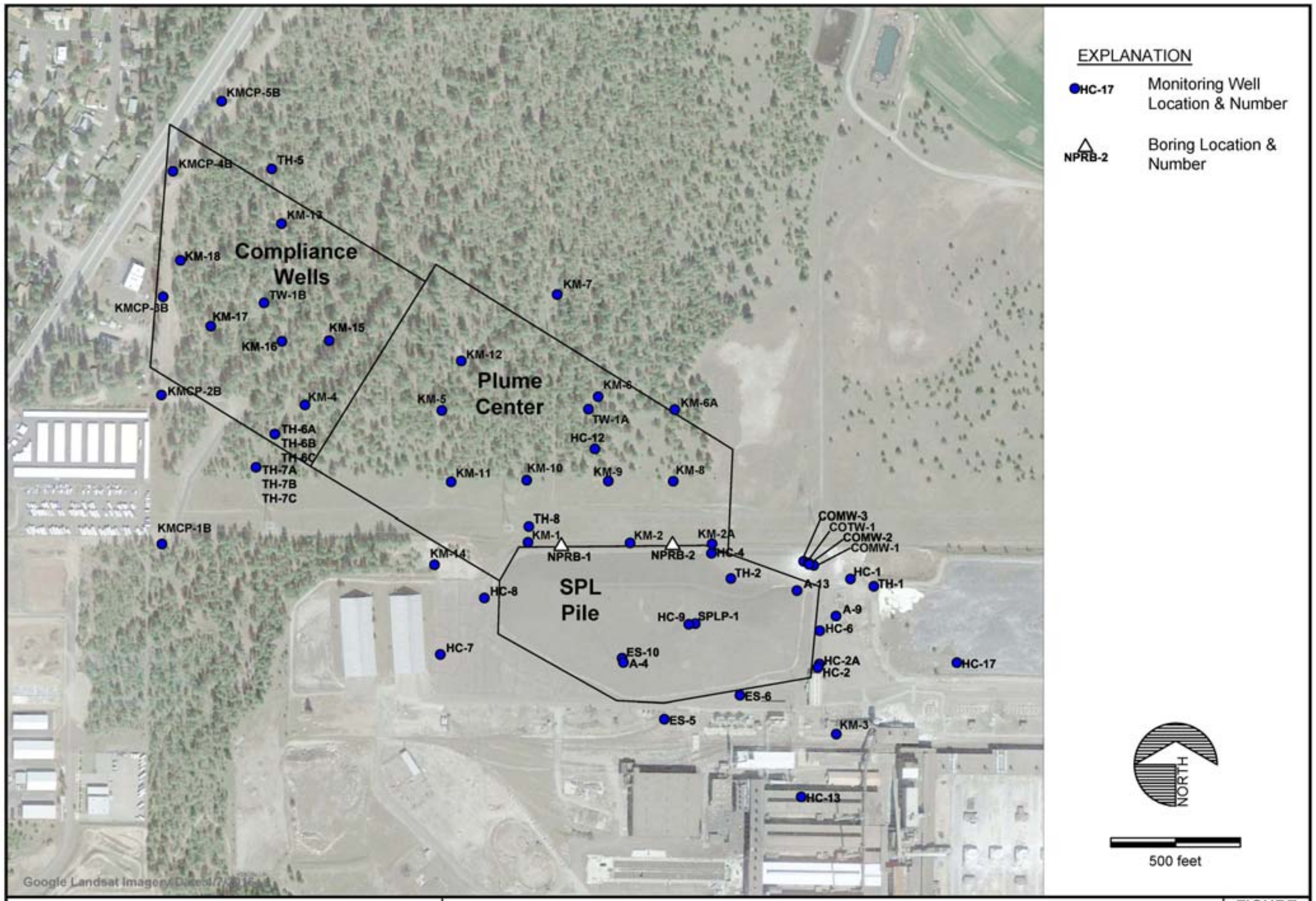
Notes:

*Partitioning Model estimated time to attain 4 mg/L fluoride and 0.2 mg/L free cyanide in Compliance Wells. Range in estimated time is due to uncertainty in model parameters. See Appendix F for model simulation descriptions. Estimated costs are intended to provide a relative comparison between alternatives, and are considered to be +/-25 percent of actual costs.

2. One technology option (A Zone grout wall installed by injection) was retained for implementation at one location/configuration, the A Zone aquifer around the SPL pile and center of the groundwater plume. This option would reduce the flux of groundwater through potential source areas in saturated sediments beneath and downgradient of the consolidated SPL pile and was demonstrated to be effective and implementable based on pilot-scale testing in 2015 as described below and in Appendix G.
3. A smaller A Zone grout wall around only the SPL pile area would have very limited effectiveness in controlling contaminant sources as the majority of the secondary fluoride and cyanide sources in sediment are downgradient of the SPL pile. Although this option is lower cost than the larger grout wall, the cost/benefit of this option is judged to be worse than the larger grout wall and thus this location option is not retained.
4. A trenched slurry wall or injected grout wall to divert flow at the SAQ are expected to have little effect due to lack of saturated flow above the SAQ and therefore are not retained as the costs are deemed excessive for the benefit received.
5. A trenched grout wall in the A Zone is likely not implementable due to depth to the aquifer and is likely excessively expensive.

The two configurations of grout walls in the A Zone aquifer (Figure 4-3) were evaluated for cost, implementation, and potential effectiveness by a field pilot study and by simulations with the groundwater numeric model and Partitioning Model. In 2015, a pilot test using high-pressure grout injection was conducted on the Site as described in Appendix G. Estimated costs and effectiveness of a grout wall are based on results of the pilot test and groundwater flow modeling (Appendix A). Overall conclusions of the pilot test were that a wall could be installed although a defect rate of approximately 0.7 percent would be expected. Defects would consist of spots where the grout wall would be thin or missing.

FIGURE 4-3. GROUNDWATER PLUME CONTAMINATION AND GROUT WALL ZONES



KAISER NPL SITE
MEAD WASHINGTON

MODELED AREAS OF CONTAMINATION

FIGURE
4-3

Project No. 9088.00-024 2/17/2017

Hydrometrics, Inc.
Consulting Scientists and Engineers

Based on the modeled groundwater flux results, the Partitioning Model was used to estimate cleanup time frames for the two A Zone grout wall configurations with closed ends[4]. Model simulation results are summarized in Table 4-2. The smaller SPL-only grout wall is predicted to achieve a relatively high reduction in groundwater flux of approximately 94 percent with a defect rate of 0.6 (slightly lower than observed in the 2015 pilot test). In spite of the high flux reduction, the Partitioning Model predicts that the SPL-only grout wall will have little benefit in terms of estimated time to reach cleanup levels because a large portion of the secondary contaminant source occurs downgradient of the SPL area and therefore would not be controlled or contained within the grout wall. For this reason, the smaller SPL-only grout wall is not retained for further evaluation. Figures 4-4 and 4-5 show the time to cleanup curves of the combined SPL area and Plume Center area grout wall for fluoride and cyanide, respectively.

TABLE 4-2. SIMULATED GROUNDWATER FLUX AND ESTIMATED TIME TO CLEANUP FOR A ZONE GROUT WALL CONFIGURATIONS

Grout Wall Configuration	Ambient Groundwater Flux (gpm)	Flux With Grout Wall (gpm)	Percent Reduction of Flux Through Area with Grout Wall	Estimated Time To Meet Cleanup Levels in Compliance Wells (years)*
None	--	--	--	Fluoride – 52 to 130; Cyanide – 33 to 80
SPL Area	64	4	94	Fluoride – 52 to 115; Cyanide – 41 to 64
SPL + Plume Center Area	110	24	79	Fluoride – 31 to 51; Cyanide – <2 to 70

Note: Assumed grout wall defect of 0.6 and 0.7 percent for SPL and SPL+Plume Center grout walls, respectively. See Appendix A for further details. Range in estimated time to meet cleanup levels is due to uncertainty in model parameters.

---

[4] As described in Appendix A, grout wall configurations with open ends were also modeled and were found to be much less effective than closed configurations. Thus open ended grout walls were eliminated from consideration in the SFS.

FIGURE 4-4. FLUORIDE TIME TO CLEANUP SPL AND PLUME CENTER AREA GROUT WALL

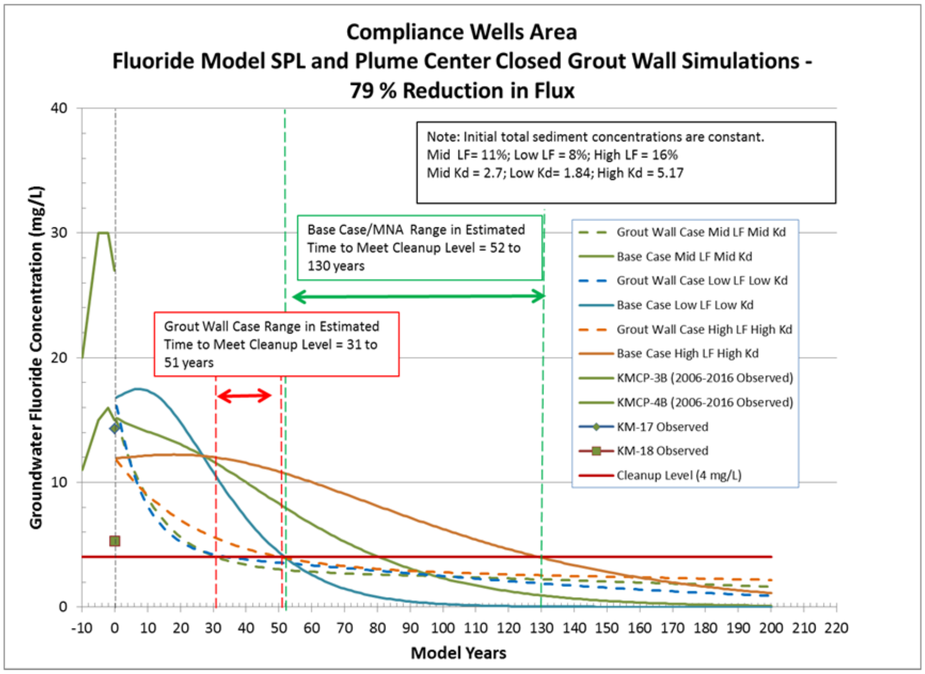
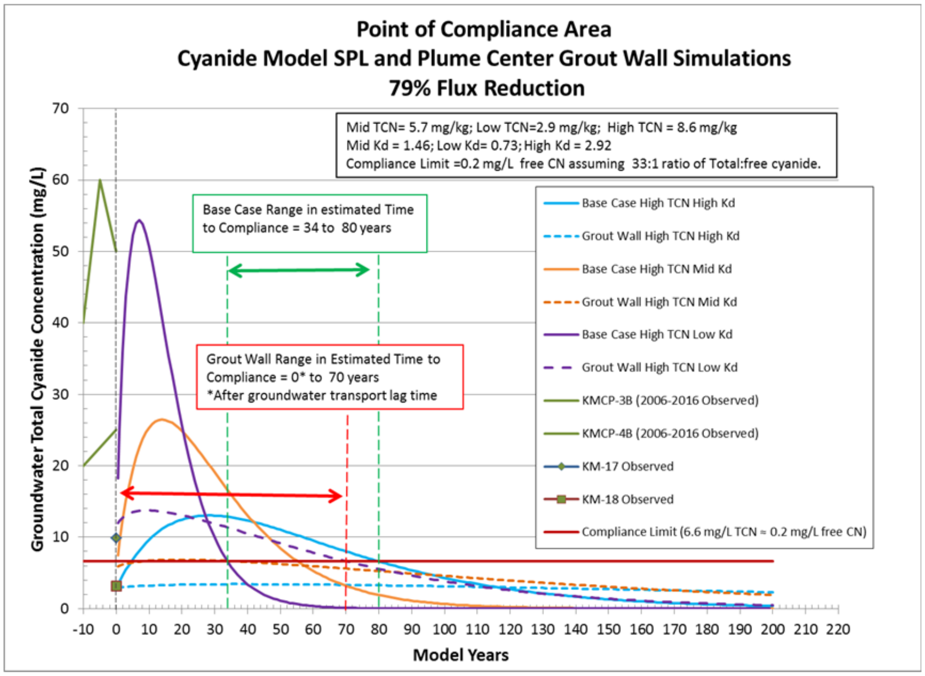


FIGURE 4-5. CYANIDE TIME TO CLEANUP SPL AND PLUME CENTER AREA GROUT WALL



4.2.3 Ex Situ Groundwater Treatment

Ex Situ treatment technologies include:

- Technologies for extraction of water from the contaminated aquifer;
- Technologies for removal of cyanide from groundwater;
- Technologies for removal of fluoride from groundwater, and
- Technologies for discharge or release of treated water.

The evaluation and screening of potential ex situ treatment technologies are summarized in Tables 4-3 through 4-6. One of the key factors determining potential cost and effectiveness of ex situ treatment options is the pumping and treatment rate. For purposes of technology screening and comparison of treatment options, a treatment rate of 100 gpm is assumed as this extraction rate was determined to result in a very high level of groundwater plume capture as described in the groundwater flow model (Appendix A) and would achieve cleanup levels at the compliance wells in a few years as described in the sediment-groundwater partitioning and mass balance model (Appendix F).

Potentially effective and implementable extraction technologies consist of conventional water wells and horizontal wells. Many monitoring wells have been installed at the Site using conventional water well technologies (e.g., air-rotary or rotosonic drilling) and therefore this technology is demonstrated to be implementable. Horizontal wells are technically feasible but have high costs and therefore are not retained (Table 4-3).

TABLE 4-3. EX SITU TREATMENT GROUNDWATER EXTRACTION TECHNOLOGIES

	Effective?	**Implementable**	**Cost**	**Retained for Inclusion in Treatment Process Train?**
Conventional water wells	Yes	Yes	$15,000 per well ($1,000 per foot of screened aquifer)	Yes
Horizontal wells	Yes	Yes	$500,000 per well ($500/foot of screened aquifer)	No

Potential treated water discharge technologies (Table 4-4) include groundwater injection wells, discharge to municipal sewer, and groundwater infiltration pond(s). All of these technologies are technically feasible but infiltration ponds or sewer connections would likely have the lowest costs and would be easiest to implement; thus only infiltration ponds and municipal sewer are retained. Injection wells may be subject to clogging and would be difficult to operate and maintain, potentially requiring very high level of water filtration prior to injection and/or frequent replacement of wells. Infiltration ponds are much less subject to clogging than wells (due to much larger infiltration surface area) and are more easily operated and maintained by excavation and removal of accumulated fine material. Municipal sewer lines are available near (approximately 1,000 feet to the northwest) the MCT property.

Since infiltration ponds and municipal sewer have different potential advantages and limitations, both are retained and it is expected that the final selection of disposal method would be made during engineering design of the final remedial alternative. In particular, discharge to infiltration ponds has the advantage of likely lower capital and O&M costs but may require additional or more restrictive discharge permit requirements. For discharges to groundwater, AKART ("all know and reasonable methods of treatment;" RCW 90.48.010, RCW 90.48.520); defines the effluent limits (WA Ecology, 2015b). Discharge to municipal sewer may have higher costs but simpler discharge permit requirements as Spokane County has an Ecology-approved Pre-treatment Program for industrial dischargers under NPDES Permit WA-0093317. Moreover, the Spokane County treatment plant is considered to be AKART for municipal wastewater (WA Ecology, 2011).

TABLE 4-4. EX SITU TREATMENT GROUNDWATER DISPOSAL TECHNOLOGIES

	Effective?	**Implementable**	**Cost**	**Retained for Inclusion in Treatment Process Train?**
Injection Wells	Yes	Yes, but difficult to maintain	$20,000 per well	No
Infiltration Pond	Yes	Yes	$20,000 capital plus land acquisition cost	Yes
Municipal Sewer	Yes	Yes	$3,000 to $10,000	Yes

A variety of potential water treatment methods for cyanide and fluoride removal were laboratory-tested on Site groundwater using chemical reagents during ex situ treatability testing in 2013. Details of test methods and results and an evaluation of the effectiveness, implementability and estimated cost of the technologies are described in the Ex Situ Treatability Report (Appendix B). In 2016 additional treatability testing was done by Arconic (with EC testing subcontracted to Baker Corporation) (described in Appendix C) with a laboratory scale wetland (8.75 sq. ft wetland area treating 0.002 to 0.006 gpm) for cyanide removal followed by electrocoagulation (EC) for fluoride removal. Tables 4-5 and 4-6 (below) summarize the effectiveness of the treatment methods tested in 2013 and 2016. For purposes of this assessment, effectiveness of treatment is defined as the ability to meet cleanup levels for cyanide and/or fluoride; or to contribute to removal of cyanide and/or fluoride such that cleanup levels can be met when combined with other treatment methods in a multi-step process. Treatment methods that were effective were then combined into several potential water treatment process trains for removal of both cyanide and fluoride. Evaluation and screening of the water treatment process trains is described in Table 4-7 (below).

Several treatment methods including iron (ferrous sulfate) precipitation, hydrogen peroxide oxidation, and wetland treatment were found in treatability tests to be effective and capable of reducing WAD and free cyanide concentrations to below the cleanup level of 0.2 mg/L (Table 4-5). Of the effective cyanide treatment methods using chemicals, chemical precipitation by ferrous sulfate addition and chemical oxidation by peroxide addition were selected as the most effective and implementable for inclusion in potential water treatment process trains. The wetland pilot study demonstrated that wetland treatment is effective when cyanide concentrations in the influent are similar to groundwater concentrations in the Compliance Wells. Although some minor toxicity to plants (mild browning of shoots from fluorosis) was observed with high strength water from the plume center area (see discussion page 4-20, Appendix C), this high strength water is not proposed to be treated, rather lower strength water from the Compliance Wells is proposed. In addition to removing WAD and free cyanide, ferrous sulfate precipitation and wetland methods also removed the majority of the total cyanide, which upon exposure to sunlight, may convert to free cyanide.

TABLE 4-5.   EX SITU CYANIDE TREATMENT TECHNOLOGIES

	Effective?	Retained for Inclusion in Treatment Process Train?
Ferrous sulfate precipitation	Yes[1]	Yes
Ferric chloride precipitation	No	No
Ferrous sulfate + ferric chloride precipitation	No	No
Hydrogen peroxide oxidation	Yes[1]	Yes
Activated alumina adsorption	No	No
Sorbster adsorption	No	No
Wetland	Yes	Yes

Notes:

1) Effective in reducing WAD cyanide concentrations to less than 0.2 mg/L. Free cyanide was not measured in the testing as cleanup level was interpreted to be based on WAD at time of testing. Since free cyanide is a fraction of WAD cyanide, free cyanide concentrations would be expected to also meet cleanup levels.

None of the primary fluoride removal methods using chemical reagents (Table 4-6) were capable of reducing concentrations to the cleanup level of 4 mg/L; however, Alum and several adsorption media (XSORBX, activated alumina, sorbster) achieved significant fluoride reduction. Two polishing treatments (reverse osmosis (RO) and ion exchange (IX)) were also evaluated and IX was found to be effective in reducing concentrations to the cleanup level while RO was found to be ineffective/not implementable due to fouling of the RO membrane. Alum/XSORBX with IX polishing was selected for inclusion in the potential treatment process trains.

The EC system (treating effluent from the wetland) was capable of reducing fluoride concentrations to the cleanup level of 4 mg/L, although effectiveness was dependent upon fluoride concentration in the wetland effluent. Similar to wetland treatment, EC is effective when treating groundwater with fluoride contaminant concentrations similar to the Compliance Wells levels (less than 20 mg/L). EC was paired with both wetland treatment and ferrous sulfate treatment for cyanide removal for inclusion in the potential treatment process trains.

TABLE 4-6. EX SITU FLUORIDE TREATMENT TECHNOLOGIES

Primary Treatment	Effective?[1]	Retained for Inclusion in Treatment Process Train?
Calcium chloride precipitation	No	No
Lime	No	No
Alum	Yes	Yes
Alum/XSORBX	Yes	Yes
Activated Alumina	No	No
Sorbster	No	No
Aluminum chlorohydrate	No	No
Electrocoagulation	Yes	Yes
Polishing Treatment	**Effective?**	**Retained for Inclusion in Treatment Process Train?**
Reverse osmosis	No	No
Ion exchange	Yes	Yes
Electrocoagulation	Yes	Yes

Notes:

1) Only electrocoagulation reduced fluoride concentration to the cleanup level. Primary methods deemed effective achieved >80 percent concentration reduction.

A discharge of treated waters to ground must meet the requirements of Chapters 90.48 RCW and 173-216 WAC, including the need to apply AKART. To date, there have been several engineering evaluations (Retec, 1993; MF&G, 2004; Hydrometrics, 2013; Arconic, 2017) of treatment methods for cyanide and fluoride. Three of these evaluations included bench-scale tests (MF&G, 2004; Hydrometrics, 2013; Arconic, 2017). Thus, it is assumed that the evaluations and data collected to date constitute proof that these treatment methods meet AKART for cyanide and fluoride. Additional AKART demonstration may be necessary for other parameters during engineering design. In particular, concentrations of nitrate exceed the WA groundwater quality standard (10 mg/L) throughout the plume, ranging from approximately 100 mg/L in the plume center to 20 to 40 mg/L at the compliance wells. An advantage of the wetland treatment system is the potential for nitrogen compounds such as nitrate to be treated and removed during cyanide treatment. Although the laboratory testing of the wetland system did not consider nitrate removal, treatment of nitrate in wetland systems is well documented (EPA, 2000; Kadlec and Wallace, 2009) and it is expected that some degree of nitrate removal would occur in the cyanide treatment system.

The degree of ammonia and nitrate removal in a cyanide treatment wetland is difficult to predict without actual testing, but extrapolation of results from other wetlands suggests that treated concentrations could range from <10 to 30 mg/L, equivalent to 25 to >50 percent removal efficiency. As preliminary designed and described in Appendix C, the cyanide treatment wetland would have a hydraulic retention time of 7 days and volume of approximately 0.88 acres/10 gpm of inflow. Assuming an influent concentration equivalent to water in KMCP-3B (36 mg/L nitrate as N; 0.5 mg/L ammonia as N, 44 mg/L cyanide or 17 mg/L cyanide as N) this inflow equates to a total nitrogen mass loading of approximately 300 g N/m2/yr or 7.3 lb N/acre/day. This preliminary nitrogen loading rate is within the range of typical nitrogen loading rates of 2 to 9 lb N/acre/day reported by EPA (2000) for nitrogen removal wetlands. EPA (2000) reports typical wetland systems to remove about 50 percent of the nitrogen and yield effluent concentrations of 1 to 10 mg/L nitrate and total nitrogen. Kadlec and Wallace (2009) compiled performance characteristics from 116 free water surface wetlands and found a fairly good correlation between total nitrogen and nitrate loading and total nitrogen and nitrate effluent concentrations. Based on these correlations and the preliminary design nitrogen loading rate of 300 g N/m2/yr, an effluent concentration of 5 to 30 mg/L total nitrogen is estimated.

A comparison and screening of ex situ treatment process trains are presented in Table 4-7. Capital costs range from $4.6 million (Peroxide-Alum-IX) to $7.5 million (Wetland-EC) for 100 gpm treatment capacity. All treatment processes have high annual O&M costs that yield estimated 30-year total costs (capital plus 30 years of O&M) ranging from $65.6 million (Wetland-EC) to $102.2 million (Ferrous sulfate-EC).

TABLE 4-7. EX SITU WATER TREATMENT PROCESS TRAINS

Process Train	Effective?	Implementable?	Capital Cost[1]	30-Year Cost[2]	80-Year Cost[6]	Technology Process Train Retained?
Ferrous sulfate-Alum-IX	Yes	Yes	$5.8 million	$102.7 million[4]	$264.0 million[4]	No, excessive O&M cost
Peroxide-Alum-IX	Yes, for free cyanide	Yes	$4.6 million	$93.3 million[4]	$241.1 million[4]	No, excessive O&M cost
Iron Precipitation (Ferrous sulfate) - EC	Yes	Yes	$6.8 million	$77.5 million	$195.4 million	Yes, very high O&M, but lowest non-wetland cost
Wetland – EC[3]	Yes	Yes	$7.5 million	$65.6 million	$162.8 million	Yes, very high O&M; but lowest 30 & 80 year cost

Notes:

1) Capital cost includes equipment cost as outlined in Ex Situ Treatability Study (Appendices B and C) plus WA sales tax (8%), legal and administration (5%), engineering (20%), mobilization and bonding (7%), contingency (20%). Costs do not include groundwater pumping or discharge.
2) Cost assumes treatment of 100 gpm for 30 years (capital cost plus O&M). Cost does not include monitoring. Cost assumes disposal of treatment waste as hazardous waste at $195/ton (solid) and $609/ton (semi-solid).
3) Wetland-EC capital cost includes 10 gpm pilot scale test cost of $1 million.
4) The Ex Situ Treatability Report assumed treatment residual/sludge would be disposed as non-hazardous waste at a cost of $67/ton. Costs shown are adjusted to reflect disposal cost of $195/ton.
5) Estimated costs are intended to provide a relative comparison between alternatives, and are considered to be +/-25 percent of actual costs.
6) Cost assumes treatment of 100 gpm for 80 years (capital cost plus O&M). Cost does not include monitoring. Cost assumes disposal of treatment waste as hazardous waste at $195/ton (solid) and $609/ton (semi-solid).

As was done for MNA and grout wall technologies, the sediment:groundwater Partitioning Model was used to estimate the amount of time required to attain compliance for ex situ treatment. Figures 4-6 and 4-7 show the time to cleanup curves for fluoride and cyanide, respectively, assuming groundwater pumping from a location approximately 300 feet upgradient of the Compliance Wells and treatment at a rate of 100 gpm. For both fluoride and cyanide, pumping and treatment of 100 gpm is predicted to result in attainment of cleanup levels at the Compliance Wells within a few years. Base case Partitioning Model

FIGURE 4-6. FLUORIDE TIME TO CLEANUP FOR EX SITU TREATMENT OF 100 GPM

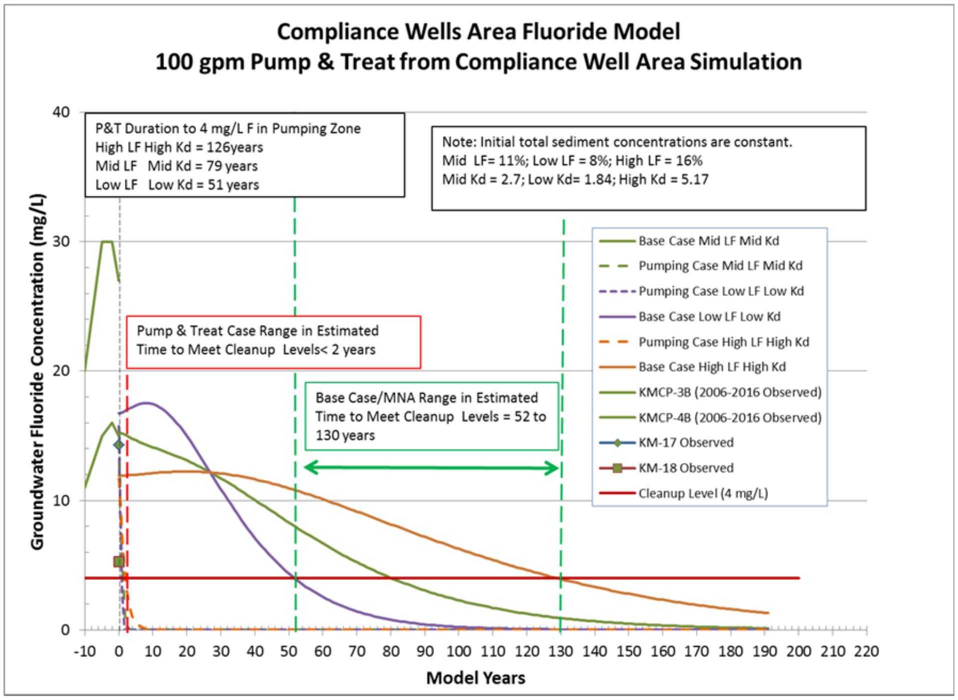
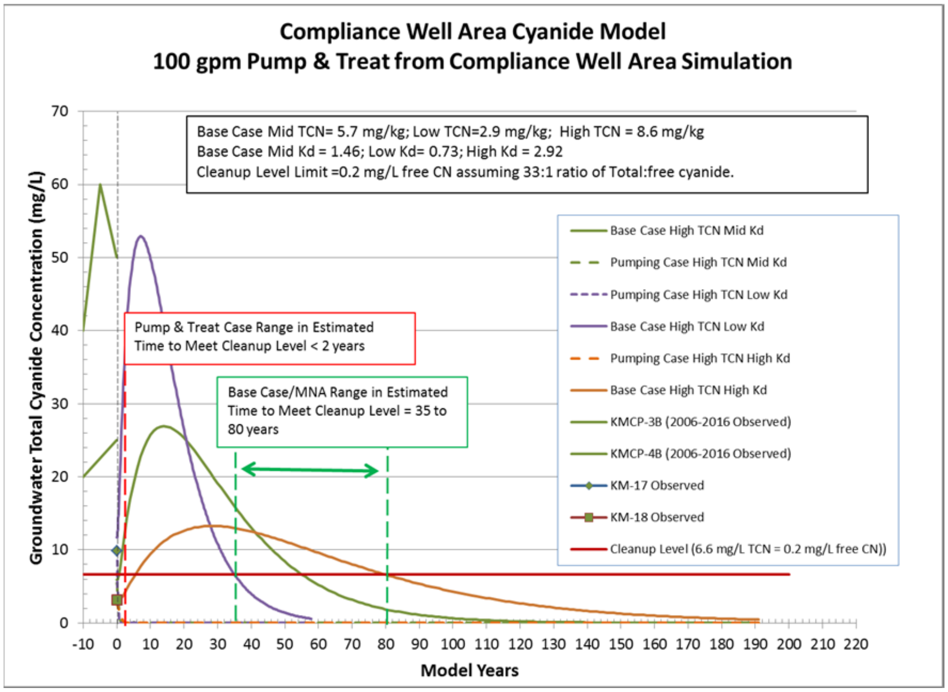


FIGURE 4-7. CYANIDE TIME TO CLEANUP FOR EX SITU TREATMENT OF 100 GPM



simulations (representing conditions if ex situ treatment or other remedial actions were not conducted; shown by solid curves in Figures 4-6 and 4-7) indicate that fluoride and cyanide concentrations in groundwater at the Compliance Wells will continue to exceed cleanup levels for approximately 52 to 130 years (fluoride) and 33 to 80 years (cyanide); thus it is estimated that pumping and treatment would need to be continued for greater than 30 years in order to maintain compliance with cleanup levels at the Compliance Wells. For comparison and screening purposes, Table 4-7 presents costs for assuming 30 years and 80 years of ex situ treatment, representing best case (30) and worst case (80) estimate durations for cyanide treatment and shorter than best case to intermediate case conditions for fluoride treatment. Because of the potentially long period that ex situ treatment would have to be conducted to meet cleanup levels, the primary factor determining long-term cost of treatment is operation and maintenance cost. Although the capital cost of the wetland-EC option is not the lowest of the options, it has the lowest 30-year and 80-year costs and thus is retained for inclusion in remedial alternatives. Iron Precipitation (Ferrous sulfate) – EC is also retained as it has the lowest 30-year and 80-year cost of the non-wetland treatment options.

4.2.4 Excavation, Consolidation, and Disposal

Excavation, consolidation, and disposal was identified during initial screening as a technology that could possibly meet requirements of a permanent cleanup action as defined by WAC 173-340-200 that is capable of achieving cleanup levels at the standard point of compliance, which is throughout the Site from the uppermost level of the saturated zone extending vertically to the lowest depth that could potentially be affected by the Site (WAC 173-360-720(8)(b)). Because the secondary source in the aquifer sediments constitutes an ongoing source, the only method to achieve cleanup at the standard point of compliance would be to excavate and remove the secondary source. This technology is deemed to be impractical and is not retained. Conceptually, this technology would at a minimum require the following:

1. Re-location and disposal of the SPL pile to allow access to the underlying sediments;
2. Excavation and disposal of unsaturated and saturated sediments beneath the SPL pile to depth of approximately 150 feet; and

3. Excavation and disposal of saturated sediments within the groundwater contaminant plume to a depth of approximately 150 feet.

This technology is impractical due to the excessively large amount of material that would need to be excavated and disposed. Preliminary estimates are that an area of approximately 80 acres would have to be excavated to a depth of approximately 150 feet; generating a sediment volume of approximately 20 million cubic yards of material, of which approximately 8 million cubic yards would be considered to be hazardous waste. Disposal cost alone for hazardous material alone is estimated to exceed $1 billion, if disposed off-Site. This technology clearly has disproportionate cost under WAC 173-340-360(3)(e) and although permanent, is not retained, as allowed under WAC 173-340-350(8)(b)(i).

4.3 DESCRIPTION OF RETAINED CLEANUP TECHNOLOGIES

The technologies that will be retained and combined to form remedial alternatives include:

- MNA with continued maintenance and monitoring of previously implemented and existing remedial actions;
- Grout wall;
- Ex situ treatment (aka pump and treat) with water treatment by Wetland-EC; and
- Ex situ treatment with water treatment by Iron Precipitation-EC.

4.3.1 Monitored Natural Attenuation (MNA)

The technologies in this category include the currently occurring natural attenuation of cyanide and fluoride, continued operation and maintenance of the remedies implemented under the 2002 Cleanup Action Plan and 2004 Consent Decree, and continued groundwater monitoring. The groundwater monitoring program includes wells strategically positioned to monitor groundwater cleanup (Ecology, 2002).

4.3.2 Grout Wall

The technology retained in this category is the injection of a grout wall in the A Zone. The bottom of the grout wall would be keyed into the aquitard that separates the A Zone from the underlying B Zone aquifer and the wall will extend vertically up to a height of approximately 10 feet above the recorded A Zone high water table elevation. The anticipated effects of the grout wall are to significantly reduce the groundwater flux through the saturated A Zone beneath the footprint of the SPL pile and downgradient in the Plume Center area. This would effectively divert a significant portion of groundwater flow around contaminated sediments beneath the SPL pile and in the most highly contaminated portion of the groundwater contaminant plume; thereby reducing interaction with contaminated aquifer sediments in the potential source areas and lowering the rate of contaminant migration from this impacted area. The location of the grout wall configuration is shown in Figure 4-7. Monitoring wells positioned between the grout wall and Compliance Wells should provide an early indication of the effectiveness of this technology. Implementability, potential cost, and effectiveness of this technology were evaluated in a pilot scale test conducted in 2015 (described in Appendix G). Full-scale effectiveness of a grout wall was simulated and evaluated with the groundwater model (Appendix A) and sediment:groundwater Partitioning Model (described in Appendix F).

4.3.3 Ex Situ Groundwater Treatment

The ex situ groundwater treatment option consists of the combination of technologies:

- Groundwater extraction by conventional water wells;
- Water treatment in a constructed wetland for cyanide removal;
- Water treatment by iron precipitation (ferrous sulfate) for cyanide removal;
- Water treatment by electrocoagulation (EC) for fluoride removal; and
- Discharge/release of treated water either to groundwater via an infiltration pond, or to the Spokane municipal water reclamation facility for further treatment and subsequent discharge to the Spokane River.

The groundwater extraction component would consist of approximately four water wells (with associated pumps, piping, and controls) constructed in a line perpendicular to groundwater flow direction across the groundwater contaminant plume approximately 200 to

300 feet upgradient of the Compliance Wells (Figure 4-8). Wells would be completed in the B Zone aquifer. Location of wells in this area rather than in the plume center area has the advantages of shorter time to meet cleanup levels at the Compliance Wells, greater saturated thickness of the aquifer to sustain pumping, and minimizing the contaminant mass transported past the Compliance Wells. Additionally, the selected pumping location has lower groundwater cyanide and fluoride concentrations to allow treatment by the wetland system.

A groundwater capture analysis of the aquifer system (Groundwater Model Report, Appendix A) predicts that pumping rates of 100 gpm could be achieved with one or more extraction wells at the proposed location. As described in Section 4.2.3 and Appendix F, pumping and treatment of 100 gpm from a location upgradient of the Compliance Wells is estimated to attain cleanup levels for fluoride and cyanide within a few years. Pumping/treatment of lower flow rates could be selected or implemented for several reasons including:

1. If it is found that adequate control is achieved with a lower pumping/treatment rate;
2. If 100 gpm treatment cost is determined to be disproportionate to benefit; and
3. If pilot-scale testing indicates a significantly larger wetland area is required to attain the desired level of treatment and land costs or access issues preclude expansion of the wetland.

For these reasons, a range of pumping rates (25, 50, and 100 gpm) is considered for ex situ treatment options. The principal uncertainties in the pumping rate that would be needed to meet compliance levels in a short time arise from a) uncertainty and variations in groundwater concentrations in the proposed extraction well locations; and b) uncertainty about how Compliance Well concentrations will respond to groundwater extraction. It is anticipated that these two uncertainties would be addressed during engineering design. As illustrated by Figure 4-9, fluoride concentrations (and similarly cyanide concentration) are quite variable near the Compliance Wells and the exact contaminant concentrations in the specific extraction well locations are not fully known and fluoride concentrations in existing wells are variable. This uncertainty in extraction well contaminant concentrations could be

FIGURE 4-8. GROUT WALL CONFIGURATION

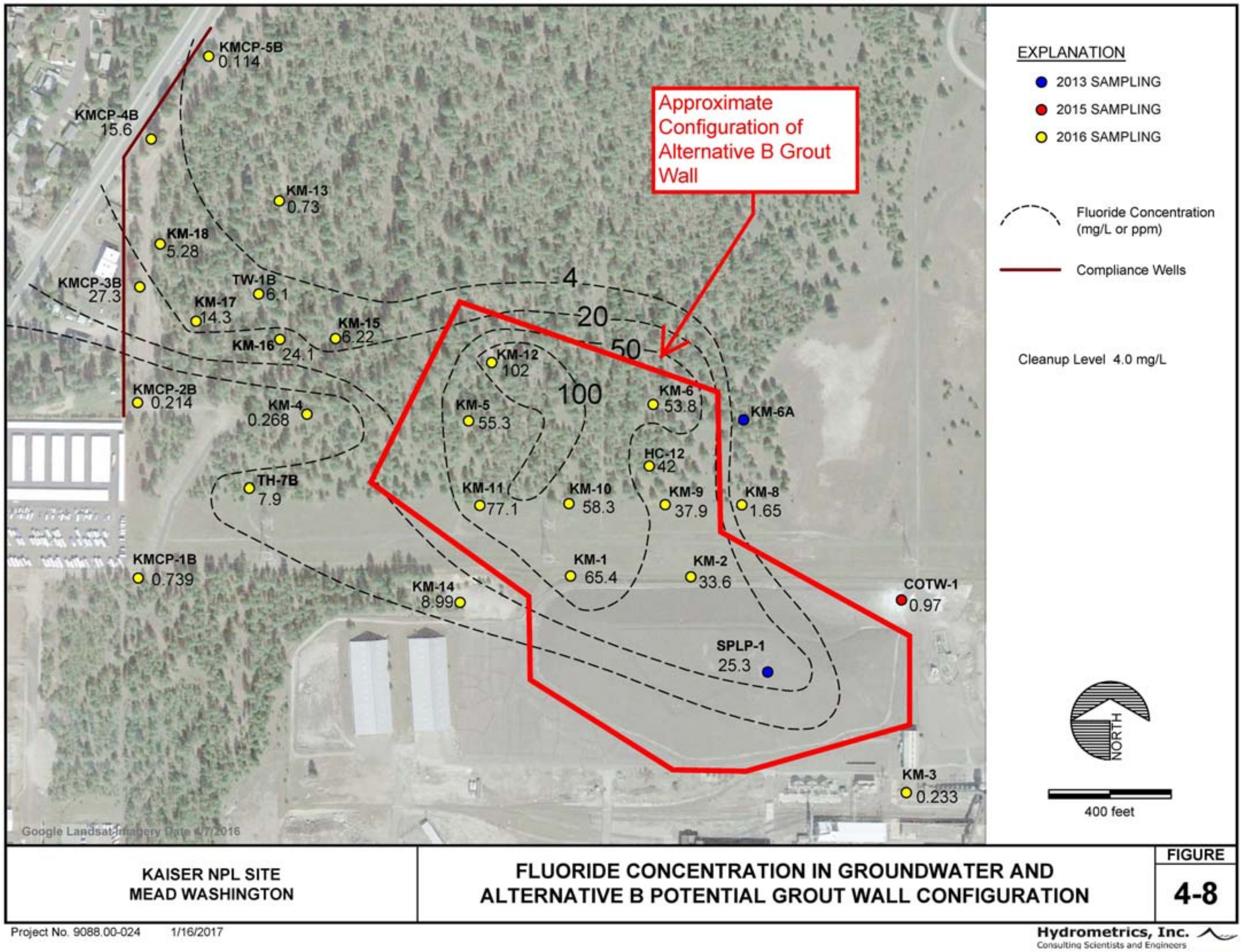
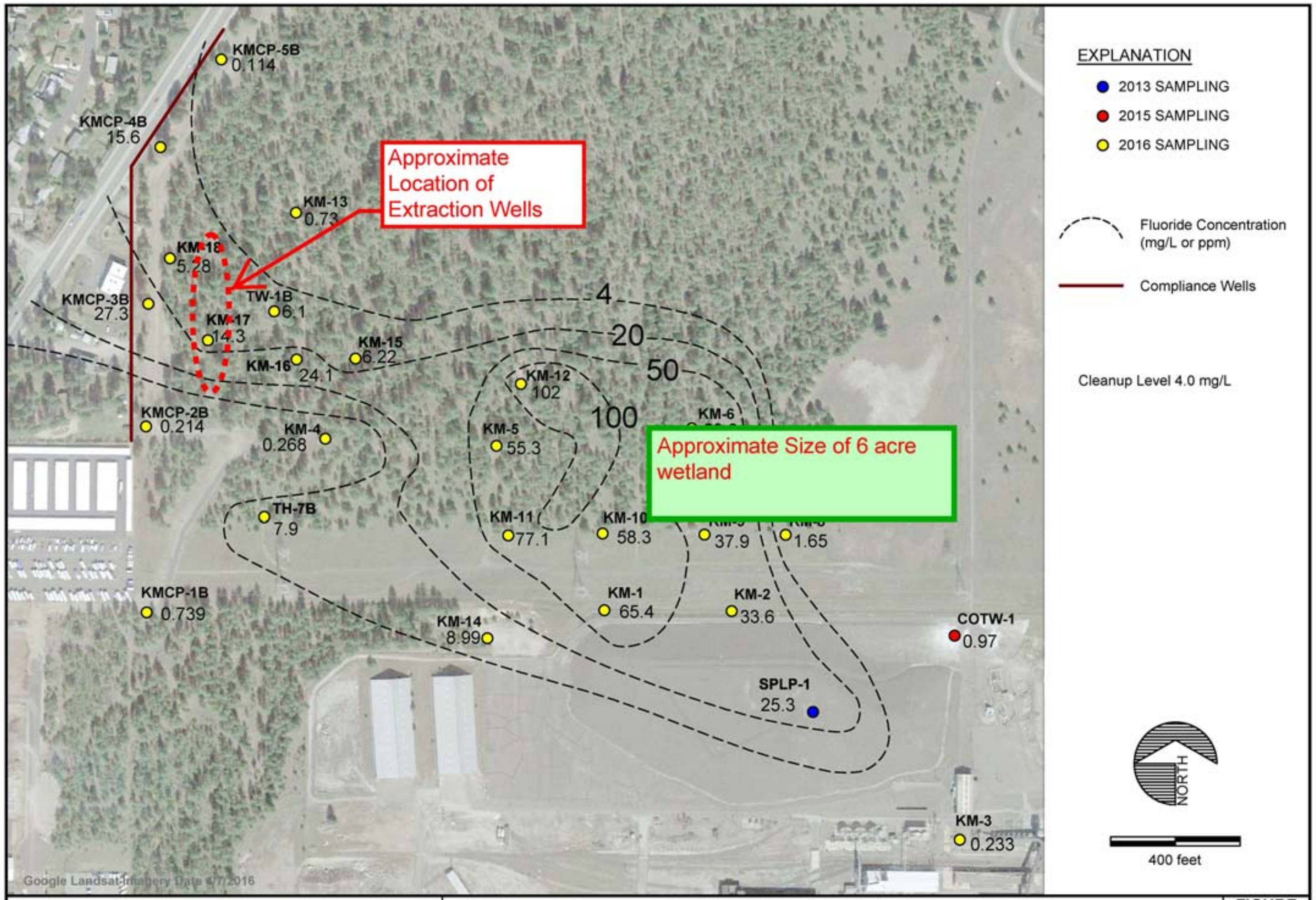


FIGURE 4-9. POTENTIAL EXTRACTION WELL AND WETLAND LOCATIONS



KAISER NPL SITE
MEAD WASHINGTON

FLUORIDE CONCENTRATION IN GROUNDWATER AND ALTERNATIVE C POTENTIAL EXTRACTION WELL AND WETLAND LOCATIONS

FIGURE
4-9

Project No. 9088.00-024 1/16/2017

Hydrometrics, Inc.
Consulting Scientists and Engineers

addressed by installing and testing extraction wells early in ED so that this uncertainty is eliminated prior to final design and construction.

The uncertainty regarding the effect of pump and treat on Compliance Well concentrations is difficult or impossible to eliminate at this Feasibility Study phase without long term operation of the pump and treat system, that can only be done after the full scale pump and treat system is fully built. Long term pumping tests could largely eliminate this uncertainty, but all water pumped must be disposed as dangerous waste unless treated, which makes this approach impractical. A practical approach is to use the data obtained from the extraction wells completed during early phases of engineering design (based on short-term tests) to refine the understanding of the relationship between Compliance Well concentrations and upgradient concentrations and refine estimates of the effects of pumping and contaminant mass removal. Refinements could include updates to the conceptual model, hydrogeologic cross-sections, partitioning and mass balance model, and numeric groundwater model. Additionally, the potential need to operate the pump and treat systems at higher or lower rates than the nominal design rate could be considered in engineering design and incorporated to the extent that it is practical (i.e., flexibility in rates could be designed and built into the system where it is possible to do so without incurring excessive cost).

Ex situ water treatment would consist of either a constructed wetland or iron precipitation (ferrous sulfate) water treatment system for cyanide (total, WAD, and free) removal and an electrocoagulation (EC) system for removal of fluoride.

The wetland treatment system would consist of one or more constructed wetland cells. The cell(s) would be lined with a low permeability liner (e.g., geocompoSite liner) and would have a water depth of approximately six to eight inches with planted and volunteer emergent and submergent plant species. Final sizing of the wetland pond would be based on field pilot-scale testing (Alternative C(100) only) or initial start-up testing (Alternatives C(50) and C(25)) to determine optimal hydraulic retention time for the Site groundwater chemistry and environmental factors. Based on the results of the laboratory scale pilot test (Appendix C), it is estimated that approximately six acres of wetland would be required to treat 100 gpm of groundwater at the Mead Site.

Final location of the wetland treatment system for cyanide removal would be selected based on the size of the treatment area required and land ownership considerations. Within the MCT property, the candidate area is the paved area west of the SPL pile. This area is advantageous from a land ownership perspective and would make use of previously unutilized area. However, the paved area is limited in size. Other possible locations for the constructed wetland include areas to the north of the sludge pond (Kaiser Aluminum Properties, Inc. property), land within the BPA transmission corridor easement, and land west or south of MCT property that is owned by Spokane Recycling. Figure 4-9 shows the relative size of a six-acre wetland compared to the surrounding area. An additional consideration for location is the presence of contaminated sediments in the vicinity of the SPL pile. Location of the wetland above uncontaminated sediments and over areas not underlain by the shallow aquitard is preferred to avoid the potential for leaching of contaminants by leakage from the wetland.

The iron precipitation (ferrous sulfate) treatment system for cyanide removal would use a ferrous iron reagent to form an iron cyanide solid precipitate. The iron cyanide precipitates would then be separated from the water by aeration and flocculation in a clarifier. The iron cyanide particles would then be dewatered to form a sludge that could be handled as a solid. The system would require a building to house the system as well as piping, pumps, reaction tanks, and storage tanks that would be co-located with the EC treatment system.

The fluoride removal system would consist of electrocoagulation (EC). The system would require a building to house the system as well as piping, pumps, reaction tanks, and storage tanks. The treated water discharge system would consist of an unlined infiltration pond excavated into the native sandy soil materials in the area. Because of the relatively high infiltration rate of the native sand, a relatively small infiltration pond system (approximately 2,500 square feet) would be required for an infiltration capacity of 100 gpm. Final size of the pond would depend on the rate of groundwater extraction and treatment. The infiltration pond could be located in a variety of areas. Potential options include adjacent to the water treatment system to reduce piping costs and disturbance; or upgradient of, or within, the footprint of the groundwater contaminant plume to minimize potential deleterious effects of treated water to un-impacted groundwater (treatment processes target only cyanide and fluoride, untreated and treated water is anticipated to have high total dissolved solids and nitrate concentrations that could reduce the suitability of groundwater for drinking water use). Potential impacts to plume capture would be an important consideration in location of the infiltration pond.

Remaining uncertainties regarding ex situ treatment technologies that would need to be addressed during final design of a remedial alternative include:

1. Optimal location and required number of extraction wells;
2. Required groundwater extraction rate;
3. Efficiency and effectiveness of the wetland and EC treatment systems under Site conditions;
4. Size and location of the wetland system;
5. Efficiency and effectiveness of the iron precipitation and EC treatment systems when employed in a combined process train; and
6. Size and location of the water disposal infiltration pond system.

4.4 IDENTIFICATION OF CLEANUP ALTERNATIVES

Eight remedial alternatives (MNA, Grout Wall, Ex Situ Treatment by Wetland-EC (at rates of 25, 50, and 100 gpm), and Ex Situ Treatment by Iron Precipitation-EC (at rates of 25, 50, and 100 gpm)) have been preliminarily identified as potentially feasible for cleanup of groundwater at Kaiser Mead. These identified cleanup alternatives were developed from technologies that were screened in Section 4.2 and detailed in Section 4.3. The remedial alternatives are summarized in Table 4-8 and the remainder of this subsection and are evaluated in detail for compliance with MTCA requirements in Section 5 of this SFS.

TABLE 4-8. SUMMARY OF REMEDIAL ALTERNATIVES

Alternative	Description of Cleanup Technologies	Capacity/Size	Estimated Cost ($ Million, 30 years, NPV)[1]	Estimated Cost ($ Million, 80 years, NPV)[1]	Estimated Time to Attain Cleanup Levels at Compliance Wells After Full Implementation (years)
A	Monitored Natural Attenuation (MNA)	-	$0.674	$1.528	F: 52 to 130 CN: 33 to 80
B	Grout Wall + MNA	5,900 feet wall length encompassing SPL and Plume Center area	$28.9	$30.1	F: 31 to 51 CN: 0 to 70
C(100)	Pump & Treat (w/Wetland-EC) + MNA	100 gpm; 7 acre wetland	$55.8	$123.4	F: <2 CN: <2
C(50)	Pump & Treat (w/Wetland-EC) + MNA	50 gpm; 3.5 acre wetland	$29.4	$61.7	F: 38 to 80 CN: 28 to 40
C(25)	Pump & Treat (w/Wetland-EC) + MNA	25 gpm; 1.75 acre wetland	$15.9	$31.6	F: 46 to 110 CN: 32 to 66
D(100)	Pump & Treat (w/Iron-EC) + MNA	100 gpm	$71.3	$152.9	F: <2 CN: <2
D(50)	Pump & Treat (w/Iron-EC) + MNA	50 gpm	$39.1	$83.1	F: 38 to 80 CN: 28 to 40
D(25)	Pump & Treat (w/Iron-EC) + MNA	25 gpm	$22.5	$47.3	F: 46 to 110 CN: 32 to 66

Notes:

1) Net Present Value (NPV) assuming discount rate of 0.7 percent. Estimated costs are intended to provide a relative comparison between alternatives, and are considered to be +/-25 percent of actual costs. The 30-year and 80-year costs represent approximate durations of remedial actions under approximate best case (30) and worst case (80) conditions for cyanide and intermediate case (80) conditions for fluoride treatment. For ex situ treatment alternatives, cost estimates assume treatment for both cyanide and fluoride for the duration of the estimate period (30 or 80 years).

The MTCA cleanup regulation, WAC 173-340-350(8)(c), requires that a reasonable number and type of remedial alternatives be evaluated, including at least one permanent alternative and at least one alternative with a standard point of compliance. For groundwater, MTCA (WAC 173-340-360(2)(c)) requires that a permanent cleanup action be used to achieve cleanup levels at the standard point of compliance where a permanent cleanup action is practicable or determined by Ecology to be in the public interest. Ecology also recommends that a no action alternative be considered. The selected alternatives are judged to satisfy Ecology requirements for the following reasons:

- None of the alternatives are permanent groundwater cleanup actions because they will not achieve cleanup levels at the standard point of compliance, which is throughout the site from the uppermost level of the saturated zone extending vertically to the lowest depth that could potentially be affected by the site (WAC 173-360-720(8)(b)). A permanent technology (excavation, consolidation, and disposal) was screened as described in Section 4.2.4 and cost was determined to be clearly disproportionate to benefits. WAC 173-340-350(8)(c)(ii)(B)(III) allows that a feasibility study does not have to include a permanent cleanup action alternative where the cost is clearly disproportionate.
- The eight alternatives vary in the extent of permanence as defined by WAC 173-340-360(3). Evaluation of the alternatives for the permanence and disproportionate cost analysis criteria is detailed in the following Section 5.
- All alternatives can achieve cleanup levels at the Compliance Wells; however, restoration time frames (i.e., time to attain cleanup levels at the Compliance Wells) vary between alternatives.
- A "no action" alternative is not included as all alternatives include continued monitoring and maintenance of previous remedial action components (i.e., maintenance of existing SPL cap, etc.). Alternative A (MNA) may be considered a "no additional action" alternative as it includes no additional groundwater controls beyond those previously implemented.

Inclusion of technologies and alternatives in the alternatives evaluation does not necessarily mean that the technologies/alternatives meet MTCA requirements or pass DCA.

Alternative A – MNA

The MNA alternative allows for continued monitoring of the groundwater plume, continued inspection and maintenance of the previously completed remedial actions (waste consolidation under the cap and pipe repairs/replacements), and routine monitoring of pipe leaks and repair as needed. An Easement Agreement between Kaiser Aluminum Properties, Inc. and MCT precludes groundwater use from the groundwater contaminant plume except for testing or monitoring. In addition, under the MNA alternative, deed restrictions will be recorded on the MCT property if not presently in place. This alternative relies on continuation of the presently occurring natural attenuation of cyanide and fluoride in the groundwater contaminant plume.

Two configurations are evaluated for the groundwater monitoring program as part of the remedy selection. The first configuration would be implemented should MNA (with remedy operations and maintenance) be selected. The modified groundwater monitoring program would focus on the two Compliance Wells that continue to exceed established cleanup levels and the program would be reduced to monitoring of background well KM-3 and Compliance Wells KMCP-3B and KMCP-4B. The current monitoring program operates on a quarterly schedule. The modified program under this first configuration would be reduced to a one-time sampling per year (annual) schedule.

Under the second configuration, the groundwater monitoring program would continue under its present scope and schedule (11 wells monitored quarterly). This second configuration would be used to monitor remedy effects if another alternative is selected.

Alternative B – Grout Wall Plus Alt A

This alternative installs a grout wall around the SPL pile source area and the Plume Center area in the A Zone aquifer. The grouting would install a low permeability "wall" from the A

Zone aquitard to a specified distance above the water table of the A Zone. Alternative A (MNA) will also be a component of this alternative.

Alternative C(100) – Ex Situ Treatment (with Wetland-EC) at Rate of 100 gpm Plus Alt A

This alternative effects plume treatment by extracting groundwater in the contaminant plume near the Compliance Wells via extraction wells, treatment (destruction) of the cyanide component of the contamination through photolytic and biologic degradation in a wetland system and treatment of the fluoride component through electrocoagulation. Fluoride removed by EC treatment would form treatment residuals (sludge) that would be disposed as waste at a licensed and approved off-Site hazardous waste facility. A pumping rate of 100 gpm is estimated to capture all or most of the plume such that attainment of cleanup levels at the Compliance Wells would occur within a few years. Treated water would be released to a shallow subsurface infiltration pond for return to the groundwater system. This alternative requires field pilot testing to verify wetland design elements. Alternative A (MNA) will also be a component of this alternative.

Alternative C(50) – Ex Situ Treatment (with Wetland-EC) at Rate of 50 gpm Plus Alt A

Alternative C(50) is identical to Alternative C(100) with the exception that water would be pumped and treated at a rate of 50 gpm, which would capture approximately half of the contaminant plume. Because the plume would not be fully captured, compliance with cleanup levels at the Compliance Wells would not be attained in a short time, however, contaminant mass would be removed from the aquifer. Due to relatively similar size of the proposed 10 gpm pilot test to the full scale 50 gpm wetland, a pilot test is not included with this alternative. Instead, it is expected that wetland optimization would occur during the start-up period. Alternative A (MNA) will also be a component of this alternative.

Alternative C(25) – Ex Situ Treatment (with Wetland-EC) at Rate of 25 gpm Plus Alt A

Alternative C(25) is identical to Alternative C(100) with the exception that water would be pumped and treated at a rate of 25 gpm which would capture approximately one quarter of the contaminant plume. Because the plume would not be fully captured, compliance with cleanup levels at the Compliance Wells would not be attained in a short time, however, contaminant mass would be removed from the aquifer. Due to relatively similar size of the proposed 10 gpm pilot test to the full scale 50 gpm wetland, a pilot test is not included with this alternative. Instead, it is expected that wetland optimization would occur during the start-up period. Alternative A (MNA) will also be a component of this alternative.

Alternative D(100) – Ex Situ Treatment (with Iron-EC) at Rate of 100 gpm Plus Alt A

Alternative D(100) is identical to Alternative C(100) except iron precipitation would be used instead of a constructed wetland for cyanide removal. The cyanide removed from the water would be stabilized as iron cyanide solids. Identical to Alternative C(100), this alternative would remove fluoride by EC. Cyanide and fluoride removed by water treatment would form treatment residuals (sludge) that would be disposed as waste at a licensed and approved off-Site hazardous waste facility. A pumping rate of 100 gpm is estimated to capture all or most of the plume such that attainment of cleanup levels at the Compliance Wells would occur within a few years. Treated water would be released to a shallow subsurface infiltration pond for return to the groundwater system. Alternative A (MNA) will also be a component of this alternative.

Alternative D(50) – Ex Situ Treatment (with Iron-EC) at Rate of 50 gpm Plus Alt A

Alternative D(50) is identical to Alternative D(100) with the exception that water would be pumped and treated at a rate of 50 gpm which would capture approximately half of the contaminant plume. Because the plume would not be fully captured, compliance with cleanup levels at the Compliance Wells would not be attained in a short time, however, contaminant mass would be removed from the aquifer. Alternative A (MNA) will also be a component of this alternative.

Alternative D(25) – Ex Situ Treatment (with Iron-EC) at Rate of 25 gpm Plus Alt A

Alternative D(25) is identical to Alternative D(100) with the exception that water would be pumped and treated at a rate of 25 gpm which would capture approximately one quarter of the contaminant plume. Because the plume would not be fully captured, compliance with cleanup levels at the Compliance Wells would not be attained in a short time, however, contaminant mass would be removed from the aquifer. Alternative A (MNA) will also be a component of this alternative.

5.0 EVALUATION OF CLEANUP ALTERNATIVES

In Section 4, eight cleanup alternatives were identified which include combinations of potentially feasible technologies for remediation of groundwater at Kaiser Mead. The alternatives are evaluated in this section according to the requirements identified in WAC 173-340-360 (Selection of Cleanup Actions). MTCA identifies specific criteria against which alternatives are to be evaluated and categorizes them as either “threshold” or “other” requirements. All cleanup actions must at a minimum meet the threshold requirements. The other MTCA requirements are considered when selecting from among the alternatives that fulfill the threshold requirements. Additionally, MTCA requires that a cleanup action use permanent solutions to the maximum extent practicable as determined based on a disproportionate cost analysis (DCA; WAC 173-340-360(3)). The eight remedial alternatives are evaluated against the MTCA threshold criteria in Section 5.1, a description of other MTCA criteria and DCA criteria is provided in Section 5.2, and alternatives are evaluated for the other MTCA criteria and DCA evaluation criteria in Sections 5.3 through 5.5. Alternatives are compared with respect to DCA criteria, costs, and benefits in Section 6.

5.1 MTCA MINIMUM REQUIREMENTS FOR CLEANUP ACTIONS

WAC 173-340-360 (2) describes the MTCA minimum requirements as:

> *All cleanup actions shall meet the following requirements. Because cleanup actions will often involve the use of several cleanup action components at a single Site, the overall cleanup action shall meet the requirements of this section. The department recognizes that some of the requirements contain flexibility and will require the use of professional judgment in determining how to apply them at particular Sites.*
>
> *(a) Threshold requirements. The cleanup action shall:*
>
> - *(i) Protect human health and the environment;*
> - *(ii) Comply with cleanup standards (see WAC 173-340-700 through 173-340-760);*
> - *(iii) Comply with applicable state and federal laws (see WAC 173-340-710); and*
> - *(iv) Provide for compliance monitoring (see WAC 173-340-410 and 173-340-720 through 173-340-760).*

The overall protectiveness that the cleanup alternatives provide depends on their ability to meet cleanup standards for cyanide and fluoride. Cleanup standards include a cleanup level (4 mg/L fluoride and 0.2 mg/L free cyanide) and a location (i.e., Compliance Wells) where compliance with the cleanup level must be demonstrated. All of the eight alternatives except possibly Alternative A MNA are expected to meet threshold criteria, although the estimated time required to achieve compliance with cleanup levels at the Compliance Wells varies among the alternatives. Alternative A MNA relies primarily on monitored natural attenuation, institutional controls and monitoring. WAC 173-340-370 (*Expectations for Cleanup Action Alternatives*) describes specific conditions where natural attenuation may be appropriate. Alternative A is judged to meet some of these conditions as detailed in Section 5.3, but the determination of whether Alternative A meets the Expectations is dependent on the DCA which is not final, pending Ecology review as described in Section 6.

5.2 MTCA CRITERIA FOR EVALUATION AND COMPARISON OF CLEANUP ALTERNATIVES

MTCA requirements for evaluation and selection of alternatives that meet the minimum threshold requirements include:

- “Other requirements” for permanent solutions to the maximum extent practicable and reasonable restoration time frames;
- Permanent groundwater actions where practicable; and
- Permanence determined by a disproportionate cost analysis (DCA).

5.2.1 Other MTCA Requirements

The other MTCA requirements are considered when selecting from among the alternatives that fulfill the threshold requirements.

> *(b) Other requirements. When selecting from cleanup action alternatives that fulfill the threshold requirements, the selected action shall:*
>
> *(i) Use permanent solutions to the maximum extent practicable (see subsection (3) of this section);*

(ii) Provide for a reasonable restoration time frames (see subsection (4) of this section); and

(iii)Consider public concerns (see WAC 173-340-600).

The maximum extent practicable criteria for permanent solutions are detailed in Section 5.2.3. Disproportionate Cost Analysis, ranking, and scoring of alternatives for DCA criteria are described in Section 6 and detailed in Appendix H.

Several factors are to be considered in determining whether a cleanup action provides for a reasonable restoration time frame (see WAC 173-340-360(4)). Moreover, the reasonableness determination is closely tied to the determination of permanence and disproportionate cost. Restoration time frames, permanence, and cost are further discussed in Section 6 Comparison of Alternatives, but a final judgment based on these criteria will be made by Ecology.

Consideration of public concerns is beyond the scope of this SFS and is anticipated to be addressed during the public comment period for this SFS or any future cleanup action plans.

5.2.2 Permanent Groundwater Actions

For groundwater cleanup actions, there is an additional requirement for permanent actions: *"A permanent cleanup action shall be used to achieve the cleanup levels for ground water in WAC 173-340-720 at the standard point(s) of compliance (see WAC 173-340-720(8)) where a permanent cleanup action is practicable or determined by the department to be in the public interest."* WAC 173-340-360(2)(c)(i).

A permanent cleanup action is a "*cleanup action in which cleanup standards of WAC 173-340-700 through 173-340-760 can be met without further action being required at the Site being cleaned up or any other Site involved with the cleanup action, other than the approved disposal of any residue from the treatment of hazardous substances*." WAC 173-340-200.

5.2.3 Disproportionate Cost Analysis

MTCA specifies in WAC 173-340-360(3)(e) that the disproportionate cost analysis must be used in order to determine whether a cleanup action uses permanent solutions to the maximum extent practicable. The disproportionate cost analysis compares the costs and benefits of the cleanup alternatives evaluated in the feasibility study. Costs are disproportionate to benefits if the incremental costs of the alternative over that of a lower cost alternative exceed the incremental degree of benefits achieved by the alternative over that of the other lower cost alternative (WAC 173-340-360(3)(e)(i)). The costs and benefits to be compared are the evaluation criteria identified in WAC 173-340-360(3)(f):

- Protectiveness: overall protectiveness of human health and the environment, including the degree to which existing risks are reduced, time required to reduce risk at the facility and attain cleanup standards, on-Site and off-Site risks resulting from implementing the alternative, and improvement of the overall environmental quality.
- Permanence: the degree to which the alternative permanently reduces the toxicity, mobility, or volume of hazardous substances, including the adequacy of the alternative in destroying the hazardous substances, the reduction or elimination of hazardous substance releases and sources of releases, the degree of irreversibility of waste treatment process, and the characteristics and quantity of treatment residuals generated.
- Cost: the cost to implement the alternative, including the cost of construction, the net present value of any long-term costs, and agency oversight costs that are recoverable. Long-term costs include operation and maintenance costs, monitoring costs, equipment replacement costs, and the cost of maintaining institutional controls. Cost estimates for treatment technologies shall describe pretreatment, analytical, labor, and waste management costs. The design life of the cleanup action shall be estimated and the cost of replacement or repair of major elements shall be included in the cost estimate.
- Effectiveness over the long term: the degree of certainty that the alternatives will be successful, the reliability of the alternative during the period of time hazardous substances are expected to remain on-Site at concentrations that exceed cleanup

levels, the magnitude of residual risk with the alternative in place, and the effectiveness of controls required to manage treatment residues or remaining wastes. The following types of cleanup action components may be used as a guide, in descending order, when assessing the relative degree of long-term effectiveness: Reuse or recycling; destruction or detoxification; immobilization or solidification; on-Site or off-Site disposal in an engineered, lined and monitored facility; on-Site isolation or containment with attendant engineering controls; and institutional controls and monitoring.

- Management of short-term risks: the risk to human health and the environment associated with the alternative during construction and implementation, and the effectiveness of measures that will be taken to manage such risks.
- Technical and administrative implementability: consideration of whether the alternative is technically possible, availability of necessary off-Site facilities, services and materials, administrative and regulatory requirements, scheduling, size, complexity, monitoring requirements, access for construction operations and monitoring, and integration with existing facility operations and other current or potential remedial actions.
- Consideration of public concerns: whether the community has concerns regarding the alternative and, if so, the extent to which the alternative addresses those concerns. This process includes concerns from individuals, community groups, local governments, tribes, federal and state agencies, or any other organization that may have an interest in or knowledge of the Site.

5.2.4 Use of Evaluation Criteria

The use of the first six criteria listed in Section 5.2.3 to evaluate the eight cleanup alternatives for the Kaiser Mead Site is described below. The seventh criterion, consideration of public concern, will be addressed through a public comment period.

Protectiveness

Alternatives will be evaluated under this criterion by focusing on the relative reduction in risk by implementation of the alternatives. Risk factors include estimated time to attain cleanup levels at the Compliance Wells, mass of contaminants removed from the groundwater system, and reduction in the mass flux of contaminants across the Compliance Wells.

Permanence

This criterion judges the alternative's ability to permanently remove the contaminants from the environment. Alternatives that reduce the mass of contaminants, by removal or destruction, will be ranked higher than alternatives that leave the contaminants in the environment.

Cost

Costs estimated for this criterion include capital costs (costs to design/engineer and construct/implement the alternatives) and operating costs (operating labor, power, reagents, waste disposal, and analytical).

Operating costs are carried out to life of remedy operation, estimated to range from 30 to 80 years for all alternatives for cost comparison. The 30-year remedial action duration corresponds to a "best case" situation where fluoride and cyanide concentrations are reduced by MNA at rates equal or better than Partitioning Model simulations that yield the shortest estimated time to meet cleanup levels at Compliance Wells. The 30-year remedial action duration also corresponds to the estimated shortest duration that pumping and treatment would be required under ex situ treatment alternatives. The 80-year remedial action duration corresponds to a "worst case" situation for cyanide treatment and an "average case" situation for fluoride. For cyanide, the 80-year duration assumes that concentrations are reduced by MNA at rates equal to Partitioning Model simulations that yield the longest estimated time to meet cleanup levels at Compliance Wells. For fluoride, the 80-year duration assumes that concentrations are reduced by MNA at rates equal to Partitioning Model simulations that yield the mid-range estimated time to meet cleanup levels at Compliance Wells. The 80-year remedial action duration corresponds to the estimated longest duration that pumping and cyanide treatment would be required under ex situ treatment alternatives and the average duration that pumping and fluoride treatment would be required under ex situ treatment alternatives.

Net present value costs are based on a discount rate of 0.7 percent per the most recent federal recommended discount rates (USOMB, 2016). Estimated costs are intended to provide a relative comparison between alternatives, and are considered to be +/-25 percent of actual costs. No agency oversight costs are included.

The estimated costs are considered to be reasonably accurate as they are based on lab scale and field pilot scale testing of technologies: lab scale testing of iron precipitation water treatment for cyanide in 2013 (Appendix B), field pilot scale test of grout wall in 2015 (Appendix G), and lab scale testing of wetland cyanide treatment and electrocoagulation fluoride treatment in 2016 (Appendix C). Estimated costs for the technologies were then combined to form estimated costs for the alternatives described in this Section 5 and Section 6. In some cases, costs for the technologies were adjusted so that the basis for the alternatives would be comparable (e.g., similar electricity cost, waste disposal cost, treatment rate, etc.).

Estimated costs assume that water treatment residuals (i.e., sludge) would require handling and disposal as hazardous waste as the waste is derived from spent potliner which is a listed hazardous waste (K088), even though sludge does not appear to be a characteristic hazardous waste based on testing that was conducted during the lab-scale treatability tests (Appendices B and C). Under the contained-in policy, Ecology could determine that environmental media (soil and groundwater) containing K088 waste need not be managed as hazardous waste, as long as concentrations of cyanide or fluoride in the media do not exceed the applicable cleanup level. If Ecology made a contained-in determination for the Mead Site, then any environmental media with concentrations of cyanide and fluoride below their respective cleanup levels removed during the remedial action could be managed as solid waste, not hazardous waste. If treatment residuals were determined to be non-hazardous, estimated operation and maintenance costs for pump and treat alternatives C(100), C(50), C(25), D(100), D(50), and D(25) would be approximately 20 to 30 percent less than currently estimated.

Long-Term Effectiveness

This criterion judges the degree of certainty that the alternatives will be able to achieve required cleanup levels at the Compliance Wells and the residual risk from groundwater that exceeds cleanup levels upgradient and downgradient of the Compliance Wells. The alternatives will also be assessed according to how they compare with Ecology preference for types of cleanup action, in descending order;

1. Reuse or recycling;
2. Destruction or detoxification;
3. Immobilization or solidification;
4. On-Site or off-Site disposal in an engineered, lined and monitored facility; and
5. Institutional controls and monitoring.

Management of Short Term Risks

Under this criterion, the alternatives will be judged on the relative risks to human health and the environment during construction and implementation of the alternatives. Measures taken to manage the identified risks will be discussed.

Technical and Administrative Implementability

Alternatives will be judged according to the relative certainty that they can be effectively implemented. Alternatives that can be implemented without additional pilot testing will ranked higher than alternatives that require additional pilot testing. A second assessment will be conducted as the alternatives are evaluated against administrative implementability. This second assessment identifies non-technical requirements such as permitting and access to lands for purposes of monitoring or remedy implementation.

5.3 ALTERNATIVE A: MONITORED NATURAL ATTENUATION (MNA)

5.3.1 Process Description

This alternative maintains the remedies (waste containment and isolation measures) performed from 2001 to 2006 and continues monitoring of groundwater at the well network installed by MCT. Maintenance includes periodic inspection of cap areas, pressure water mains, and sewer lines (storm water and sanitary), and performance of repairs as necessary. As a stand-alone alternative, the scope of groundwater monitoring will be reduced to annual monitoring of one background well, one plume center well and the two Compliance Wells that continue to exceed the cleanup levels. An Easement Agreement between Kaiser Aluminum Properties, Inc. and MCT precludes groundwater use from the groundwater contaminant plume except for testing or monitoring controls[5]. In addition, under the MNA alternative, deed restrictions will be recorded on the MCT property if not presently in place.

This alternative relies on continued natural attenuation to clean up the groundwater such that contaminant concentrations will be reduced over time and cleanup levels are ultimately attained at the Compliance Wells. Consolidation of spent potliner waste beneath an engineered cap has already occurred and other former waste areas have been covered with an asphalt cap thereby eliminating any direct contact exposure pathways.

5.3.2 Protectiveness

Estimated time to meet cleanup levels at Compliance Wells

Based on current knowledge of contaminant loading rates from aquifer sediment, cleanup of groundwater at the Compliance Wells by Alternative A is expected to take 33 to 80 years for cyanide and 52 to 130 years for fluoride.

Mass of contaminants removed from groundwater system

No contaminants would be removed from groundwater.

Reduction in mass flux beyond the Compliance Wells

The mass flux of contaminants across the Compliance Wells would not be reduced beyond the natural decrease that would occur from groundwater leaching and flushing of the sediments.

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[5] Article 3 of the October 7, 2004 Easement Agreement between Kaiser Aluminum Properties and MCT prevents extraction or use of groundwater from within the plume on Parcel 6, the property immediately downgradient of the MTCA property, except for testing, monitoring or other purposes such as treatment required by laws, regulations, or orders.

5.3.3 Permanence

Destruction of hazardous substances

This alternative does not destroy any hazardous substances.

Reduction or elimination of hazardous substance releases and sources of releases

This alternative does not permanently or actively remove contaminants from the environment. Natural attenuation mechanisms including sorption and/or mineralization of fluoride and cyanide on aquifer sediments would continue to limit the mobility of cyanide and fluoride in groundwater.

Degree of irreversibility of waste treatment process

This alternative does not treat source materials or contaminated groundwater.

Characteristics and quantity of treatment residuals generated

This alternative does not generate treatment residuals.

5.3.4 Cost

Costs estimated for this alternative include annual inspection and monitoring costs and periodic maintenance costs for asphalt repairs and weed control on the SPL pile for the next 30 to 80 years.

The estimated future costs for this alternative are based on current costs as shown in Table 5-1.[6]

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[6] The costs of this alternative are already being incurred, and will continue to be incurred, in accordance with the requirements of the Consent Decree.

TABLE 5-1. ALTERNATIVE A (MNA) COST ESTIMATE

Activity	Annual Cost
Groundwater Monitoring (3 wells)	$1,600
Surface water Monitoring	$830
Cap Inspections	$1,465
Pressure Mains Leak Survey	$1,120
Cap Maintenance	$10,000
Sub Total	$15,015
30-year Cost Estimate (NPV[1])	$674,771
80-year Cost Estimate (NPV[1])	$1,528,329

Notes:

1) Net Present Value (NPV) assuming discount rate of 0.7 percent. Estimated costs are intended to provide a relative comparison between alternatives, and are considered to be +/-25 percent of actual costs. The 30-year and 80-year costs represent approximate durations of remedial actions under approximate best case (30) and worst case (80) conditions for cyanide and intermediate case (80) conditions for fluoride.

5.3.5 Long-Term Effectiveness

Under this alternative, the time to achieve cleanup at the Compliance Wells is expected to be long, 33 to 80 years for cyanide and 52 to 130 years for fluoride. According to Ecology order of preference, this alternative will score lowest of the preferred cleanup methods.

Degree of certainty that alternative will be successful

Groundwater monitoring data, laboratory testing of aquifer sediment, and the Partitioning Model simulations demonstrate with a high level of certainty that groundwater concentrations will continue to decrease over time such that cleanup levels are ultimately attained at the Compliance Wells.

Reliability

The actions of monitoring and maintenance required in this Alternative are currently ongoing and will reliably be continued in the future.

Residual risk

Groundwater concentrations within the contaminant plume area, upgradient of the Compliance Wells (southeast of Hwy 2) on properties owned by MCT and Kaiser Aluminum

Properties, are predicted by the Partitioning Model to exceed cleanup levels for 33 to 80 years for cyanide and 52 to 130 years for fluoride. Over time, the areal extent of the groundwater contaminant plume would shrink and the concentrations of fluoride and cyanide would decline. The residual risk from groundwater concentrations exceeding cleanup levels is estimated to be low as institutional controls will restrict access to groundwater upgradient of the Compliance Wells.

Groundwater concentrations downgradient of the Compliance Wells is not monitored by MCT and was not simulated with the Partitioning Model. However, groundwater conditions downgradient of the Compliance Wells can be qualitatively estimated by extrapolation of observed and model-simulated upgradient groundwater concentrations and trends. By extrapolation, groundwater concentrations for some distance downgradient of the Compliance Wells is expected to exceed cleanup levels for a roughly a similar amount of time as for upgradient areas, from a few to several decades. The residual risk from groundwater concentrations exceeding cleanup levels is estimated to be low as State and Spokane County restrictions on groundwater use will restrict access to groundwater downgradient of the Compliance Wells.

<u>Management of treatment residuals</u>

This alternative generates no treatment residuals.

5.3.6 Management of Short-Term Risks

This alternative does not require construction or handling of potential waste, except for purge water from the groundwater monitoring activity. Purge water exceeding cleanup levels is classified as hazardous and is sent off-Site for proper disposal at a hazardous waste facility. Institutional controls will restrict access to groundwater upgradient of the Compliance Wells. State and Spokane County restrictions on groundwater use will restrict access to groundwater downgradient of the Compliance Wells.

5.3.7 Technical and Administrative Implementability

As this alternative is already in place and is being implemented, there are no concerns with technical and administrative implementability. This alternative will score highest under this criterion.

5.3.8 MTCA Expectation for MNA

WAC 173-340-370 Expectations for Cleanup Action Alternatives describes specific conditions where natural attenuation may be appropriate:

> *(7) The department expects that natural attenuation of hazardous substances may be appropriate at Sites where:*
>
> > *(a) Source control (including removal and/or treatment of hazardous substances) has been conducted to the maximum extent practicable;*
> >
> > *(b) Leaving contaminants on-Site during the restoration time frame does not pose an unacceptable threat to human health or the environment;*
> >
> > *(c) There is evidence that natural biodegradation or chemical degradation is occurring and will continue to occur at a reasonable rate at the Site; and*
> >
> > *(d) Appropriate monitoring requirements are conducted to ensure that the natural attenuation process is taking place and that human health and the environment are protected.*

An assessment of Alternative A for these criteria is:

a) Alternative A partially meets the source control criterion (a) as the primary sources continue to be controlled by the previous remedial alternatives (capped SPL pile, asphalt pavement, and water controls). Alternative A addresses the secondary sources in aquifer sediment through natural attenuation, but perhaps not to the “maximum extent practicable” as defined by MTCA and determined based on a disproportionate cost analysis (DCA) as described in Section 6. Because the DCA is preliminary, the extent to which Alternative A meets the source control criterion cannot be judged at this time.

b) Alternative A includes institutional controls that preclude the use of groundwater and thus human exposure to Site groundwater contaminants and thus meets criterion (b).

c) The natural attenuation processes that affect fluoride and cyanide are believed to be largely adsorption and retention of the contaminants on aquifer sediment which retards the release and transport of the contaminants. Sorption of contaminants is considered to be chemical degradation, thus Alternative A does comply with criterion (c).

d) Alternative A fully complies with criterion (d) as effective monitoring is provided.

5.4 ALTERNATIVE B: GROUT WALL PLUS ALTERNATIVE A

5.4.1 Process Description

This alternative diverts a substantial portion of the groundwater flow of the A Zone aquifer around the secondary source of impacted A Zone sediments that lie beneath the SPL pile and within the center of the contaminant plume. The groundwater diversion will be achieved by placement of a grout wall (approximately 5,900 feet in length) encircling the SPL pile and central portion of the groundwater contaminant plume (an area of approximately 40 acres) and extending from the bottom of the A Zone aquitard to a level approximately ten feet above the recorded high water table elevation. This groundwater diversion will decrease groundwater flow through the zone of most-highly impacted sediments resulting in a reduction in the leaching and transport of contaminants from the secondary source area, and thereby increasing the effects from mixing and attenuation of contaminants in the groundwater system downgradient of the containment area. The reduction in the flow of contaminants will allow cleanup levels to be attained at the Compliance Wells in a somewhat shorter time than Alternative A. However, because the flow of groundwater flushing the contaminated sediments will be reduced, contaminant concentrations in groundwater within the containment area will be elevated for a longer period of time than under Alternative A and the six ex situ treatment alternatives (see Figures 4-4 and 4-5). Since the natural flushing of contaminant load is reduced, the overall time that contaminant remobilization to groundwater occurs also will be increased. The net effect of Alternative B is to reduce groundwater concentrations at the Compliance Wells and beyond in the short- and long-term while maintaining high contaminant concentrations within the containment area on Kaiser Aluminum Properties, Inc. and MCT properties in the long-term.

This alternative employs grout wall treatment technologies proven to be effective and implementable based on the success of a field pilot-scale test (approximately 100 lineal feet of grout wall, emplaced from 160 to 135 feet below the surface) in 2015 (described in Appendix G). Overall conclusions of the pilot test were that a wall could be installed although a defect rate of approximately 0.7 percent would be expected. Defects would consist of spots where the grout wall would be thin or missing. Although the pilot test grout wall was small relative to the proposed Alternative B wall, the small size required abrupt corners which proved to be difficult to install. For this reason and in this respect, the pilot test results likely overestimate full-scale defect rate. Conversely, since the pilot test was small the pilot installation was likely done in an area with fairly uniform geologic conditions. In this respect, the pilot test may underestimate the effect of geologic heterogeneity on defect rates. In spite of these limitations, the pilot scale test results provide the best available estimate of likely full-scale wall performance and potential defect rate. Full-scale effectiveness of a grout wall was simulated and evaluated with the groundwater model (Appendix A) and sediment:groundwater Partitioning Model (described in Appendix F). A grout wall with 0.7 percent defect rate would reduce groundwater flux within the containment area by approximately 79 percent. If the defect rate were higher or lower than expected, groundwater flux reduction and wall effectiveness would be increased or decreased accordingly.

5.4.2 Protectiveness

Under Alternative B, groundwater contaminant concentrations outside the grout wall and at the Compliance Wells would improve (decrease) at a faster rate than under Alternative A MNA, while groundwater quality inside the grout wall would improve at a slower rate than Alternative A. Thus, implementation of this alternative has the effect of reducing the risk in groundwater beyond the containment area as the concentrations of contaminants in groundwater water downgradient of grout wall are expected to be reduced. Additionally, the mass flux of contaminants beyond the Compliance Wells would be reduced.

Estimated time to meet cleanup levels at Compliance Wells

The time needed to meet cleanup levels at the Compliance Wells is estimated to be approximately 31 to 51 years for fluoride and <2 to 70 years for cyanide, after implementation. This alternative would require approximately one year to complete full-scale implementation after final design.

Mass of contaminants removed from groundwater system

The same as under Alternative A MNA, this alternative would not remove any contaminants from the groundwater system.

Reduction in mass flux beyond the Compliance Wells

Compared to Alternative A MNA, the grout wall is estimated to reduce the mass of fluoride and cyanide (all forms) transported in groundwater past the Compliance Wells by 44 percent and 70 percent, respectively over 30 years; and 48 and 52 percent over 80 years.

5.4.3 Permanence

Destruction of hazardous substances

Alternative B does not permanently or actively remove contaminants from the environment. Thus, Alternative B is ranked similar to Alternative A and lower than Alternatives C(100), C(50), C(25), D(100), D(50), and D(25).

Reduction or elimination of hazardous substance releases and sources of releases

This alternative will not provide further control of contaminant releases to Site groundwater above that currently provided by Alternative A. Alternative B will reduce the rate of transport of contaminants to groundwater beyond the containment area to the Compliance Wells and beyond, relative to Alternative A.

Degree of irreversibility of waste treatment process

This alternative does not treat source materials or contaminated groundwater.

Characteristics and quantity of treatment residuals generated

This alternative will generate spoils or cuttings (removed sediments) from the injection process. Approximately 53,000 tons of waste will require management and disposal, of which approximately 27,000 tons is expected to be considered hazardous.

5.4.4 Cost

Costs estimated for this alternative include costs associated with the Alternative A component; i.e., annual inspection and monitoring costs and periodic maintenance costs for asphalt repairs and weed control on the SPL pile for the next 30 years. Costs for the implementation of the grout wall are based on a proposal by Hayward Baker, the contractor that installed the pilot-scale test wall in 2015. Once installed, there are no operating or maintenance costs for the grout wall (other than Alternative A) and thus NPV cost for grout wall implementation is same as capital/construction cost. Estimated costs for Alternative B are shown in Table 5-2.

TABLE 5-2. ALTERNATIVE B COST ESTIMATE

Activity	Cost[1]
Grout Wall Implementation Cost	$28,090,000
Alternative A (MNA) 30-year Cost (NPV)	$904,000[2]
Alternative A (MNA) 80-year Cost (NPV)	$2,047,000[2]
Total Alternative B 30-year Cost (NPV)	$28,994,000
Total Alternative B 80-year Cost (NPV)	$30,137,000

Notes:

1) Net Present Value (NPV) assuming discount rate of 0.7 percent. Estimated costs are intended to provide a relative comparison between alternatives, and are considered to be +/-25 percent of actual costs.
2) Cost reflects monitoring of 11 wells.

5.4.5 Long-Term Effectiveness

This alternative relies on a combination of natural attenuation and reduced flux through secondary source areas in aquifer sediment to reduce the time required to attain cleanup levels at the Compliance Wells. Relative to Ecology preferences for types of cleanup action described in WAC 173-340-360(3)(f)(iv), this alternative ranks better than Alternative A as Alternative B provides some immobilization and retention of contaminants within the grout wall, but lower than the six ex situ treatment alternatives which would remove some contaminants from the environment.

Degree of Certainty that Alternative will be Successful

The use of grout walls to lower the groundwater flux around an area of contamination is a common method of controlling the flow of contaminated groundwater. What separates this Site from the more common application of grout walls is the substantial depth of the aquitard (approximately 160 feet) in which the grout wall will be keyed. Experience gained through the pilot-scale grout wall installation in 2015 demonstrates that the grout wall can be installed effectively, although some defects in the wall would likely occur. Groundwater model simulations of the pilot test grout wall suggest a wall defect rate of 0.7 percent of the wall area exposed to the aquifer. Numeric groundwater flow model simulations (Appendix G and summarized in Table 4-2) indicated that a wall with this expected defect rate would still reduce groundwater flux by approximately 79 percent. Partition model simulations of the full-scale grout wall with this same defect rate of 0.7 percent indicate that the wall will be effective at reducing the chemical mass flux of cyanide and fluoride in spite of these defects. Achieving this low level of defects can be achieved through an effective construction quality assurance/quality control program. The estimates of time to meet cleanup levels for alternative B (approximately 31 to 51 years for fluoride and <2 to 70 years for cyanide) derived with the Partitioning Model assumed a defect rate of 0.7 percent. However, if the grout wall were to have a higher defect rate than observed in the pilot test then the grout wall effectiveness would be more limited, and time to meet cleanup levels at the Compliance Wells would be longer than estimated.

Reliability

Assuming that the grout wall is properly installed with a low level of defects, the reliability of the grout wall is high as no further operation or maintenance would be required.

Residual Risk

Within the containment area, inside the grout wall, groundwater concentrations would exceed cleanup levels for a very long time, greater than the 200-year simulation period of the Partitioning Model. Outside of the grout wall, groundwater concentrations would clean up more quickly. Groundwater concentrations within the portion of the contaminant plume, upgradient of the Compliance Wells and downgradient of the grout wall containment area on property owned by Kaiser Aluminum Properties, are predicted by the Partitioning Model to exceed cleanup levels for <2 to 70 years for cyanide and 31 to 51 years for fluoride. Over time, the areal extent of the portion of the groundwater contaminant plume outside the grout wall would shrink and concentrations of fluoride and cyanide would decline. The residual risk from groundwater concentrations exceeding cleanup levels is estimated to be low as institutional controls will restrict access to groundwater.

Groundwater concentrations downgradient of the Compliance Wells is not monitored by MCT and was not simulated with the Partitioning Model. However, groundwater conditions downgradient of the Compliance Wells can be qualitatively estimated by extrapolation of observed and model-simulated upgradient groundwater concentrations and trends. By extrapolation, groundwater concentrations for some distance downgradient of the Compliance Wells is expected to exceed cleanup levels for a roughly a similar amount of time as for upgradient areas, perhaps a few to several decades. The residual risk from groundwater concentrations exceeding cleanup levels is estimated to be low as State and Spokane County restrictions on groundwater use will restrict access to groundwater.

Management of Treatment Residuals

This alternative reduces the generation and migration of contaminated groundwater rather than treatment or removal of source materials. Therefore, treatment residuals are not generated but the areas of potential source materials and the grout wall that surrounds them should be protected by maintaining existing controls. Alternative B will generate spoils or cuttings (removed sediments) from the injection process. Approximately 53,000 tons of waste will require management and disposal, of which approximately 27,000 tons is expected to be considered hazardous.

5.4.6 Management of Short-Term Risks

This alternative requires handling of waste generated from the injection of cement grout into the geologic materials comprising the A Zone aquifer and underlying aquitard. The grout injection process returns spoils to the surface which is a mix of cement grout and native geologic materials. If the spoils are considered hazardous because they have come in contact with K088 hazardous waste, they will require disposal at a permitted hazardous waste disposal facility unless Ecology makes a contained-in determination allowing spoils with cyanide or fluoride concentrations below the applicable cleanup level to be managed as solid waste. Approximately 53,000 tons of waste will require management and disposal, of which approximately 27,000 tons is expected to have come in contact with K088 hazardous waste.

5.4.7 Technical and Administrative Implementability

Construction of a grout wall to depths of greater than 150 feet over a continuous length of approximately 5,900 feet will present challenges to ensure the integrity of the wall. A portion of the grout wall north of the SPL pile will be installed beneath high voltage power transmission lines and implementation may require alternative methods to avoid safety issues with the power lines. Administratively, there are no permits required, but the grout wall extends beyond Trust-controlled property across land used by Bonneville Power Administration for overhead high-voltage transmission and onto undeveloped land owned by Kaiser Aluminum Properties, Inc. Other than institutional controls on groundwater use, there should be no restrictions on land use above the grout wall by property owners.

5.5 ALTERNATIVE C(100) – EX SITU TREATMENT (WETLAND-EC) AT RATE OF 100 GPM PLUS ALTERNATIVE A

5.5.1 Process Description

Ex situ groundwater treatment by wetland-EC would consist of extraction of contaminated groundwater by conventional water wells at a rate of approximately 100 gpm, water treatment by a constructed wetland-electrocoagulation (EC) system, and treated water disposal either by discharge to the Spokane municipal sewer system or by infiltration pond to return water to the groundwater system. This alternative employs water treatment technologies proven to be effective and implementable based on the success of a laboratory pilot-scale test (8.75 sq. ft wetland area treating 0.002 to 0.006 gpm) conducted with Site groundwater in 2016 (described in Appendix C) and a full-scale system (200 gpm flow) currently operating at ALCOA's Tennessee Site (Dzombak et al, 2006 and Ghosh, pers. Comm.). Field pilot-scale testing of Site waters and Site conditions (principally climate) would be required to confirm design parameters for a full-scale system. Full-scale implementation of Alternative C(100) would require approximately four years (two years to complete the field pilot test, one year for final design and regulatory approval and one year for construction and maturation of the wetland vegetation).

Table 5-3 compares the size, estimated costs, estimated time to meet cleanup levels in Compliance Wells, and contaminant mass removal for the pump and treat Alternatives C(100), C(50), and C(25) that employ wetland-EC. For the six ex situ treatment alternatives, once cleanup levels are met, continued operation of the pumping and treatment systems is required to maintain cleanup levels at the Compliance Wells. The duration of continued ex situ treatment is estimated based on the Partitioning Model to range from approximately 30 to 80 years for cyanide and 50 to 130 years for fluoride.

The groundwater extraction component would consist of approximately four water wells (with associated pumps, piping, and controls) constructed in a line perpendicular to groundwater flow direction across the groundwater contaminant plume, approximately 200 to 300 feet upgradient of the Compliance Wells, completed in the B-Zone aquifer (see Figure 4-9 in Section 4.3.3 for approximate well locations).

Ex situ water treatment would consist of a wetland water treatment system for cyanide removal and an electrocoagulation (EC) system for removal of fluoride. The wetland treatment system would consist of a constructed wetland where cyanide would be removed, first by photodegradation of iron cyanide complexes, followed by phytoremediation/ biological degradation of WAD and free cyanide. The majority of the cyanide compounds (approximately 76 percent based on laboratory pilot testing) will be permanently and

TABLE 5-3. ALTERNATIVE C(100), C(50) AND C(25) SIZING COMPARISON

Alternative	Treatment Capacity (gpm)	Size of Wetland[2]	Estimated Cost ($ Million, 30 years, NPV)[1]	Estimated Time to Cleanup at Compliance Wells Following Implementation (years)		Estimated Mass (kg) of Contaminants Removed from Groundwater in 30 years	
				F	CN	F	CN
C(100)	100 gpm	6 acres	$55.8	<2	<2	82,068	134,345
C(50)	50 gpm	3 acres	$28.4	38 to 80	28 to 40	41,034	67,189
C(25)	25 gpm	1.5 acres	$14.8	46 to 110	32 to 66	20,517	33,595

Alternative	Treatment Capacity (gpm)	Size of Wetland[2]	Estimated Cost ($ Million, 80 years, NPV)[1]	Estimated Time to Cleanup at Compliance Wells Following Implementation (years)	Estimated Mass (kg) of Contaminants Removed from Groundwater in 80 years	
					F	CN
C(100)	100 gpm	As above	$123.4	As above	148,881	212,173
C(50)	50 gpm		$60.7		73,578	106,086
C(25)	25 gpm		$30.5		34,968	53,043

Notes:

1) Net Present Value (NPV) assuming discount rate of 0.7 percent. Estimated costs are intended to provide a relative comparison between alternatives, and are considered to be +/-25 percent of actual costs. The 30-year and 80-year costs represent approximate durations of remedial actions (pumping, treatment and disposal) under approximate best case (30) and worst case (80) conditions for cyanide and intermediate case (80) conditions for fluoride.

2) Estimated size of wetland treatment cell based on results of laboratory scale testing as described in Appendix C. Assumes disposal of EC sludge as hazardous waste.

irreversibly destroyed. The wetland system would be lined with a low permeability liner (e.g., geocomposite liner) and would have a water depth of approximately 1 foot with planted and volunteer emergent and submergent plant species.

Field pilot-scale testing would be required to verify effectiveness, implementability, proper sizing, and final estimated cost of the 100 gpm system. Final sizing of the full-scale wetland pond would be based on field pilot testing to determine optimal hydraulic retention time for the Site groundwater chemistry and environmental factors. There are several options for sizing, scheduling and implementing the pilot scale test. The wetland-EC treatability study (Appendix C) recommended a pilot-scale size of 0.58 acres to treat 10 gpm and the estimated cost in this SFS are based on that size. However, it may be desirable to conduct a larger pilot scale test (e.g., 25 or 50 gpm) so that the pilot scale wetland cell could function as part or all of a full-scale system if high treatment effectiveness is achieved.

The fluoride removal system will consist of EC after treatment of cyanide. In the EC defluoridation system, the contaminated groundwater will flow through an electrolytic cell containing aluminum anodes. As electrical current is applied to the cell, the aluminum electrodes release aluminum ions (Al^{3+}) that react with hydroxide and fluoride to form solid aluminum-fluoride-hydroxide flocs (aggregation of suspended particles) that are separated from water by coagulation and settling. The EC process will generate fluoride-bearing aluminum hydroxide sludge (treatment residual) that will be classified as hazardous. The EC system would require a building to house the system as well as piping, pumps, reaction tanks, and storage tanks.

The treated water discharge system would consist of either an unlined infiltration pond excavated into the native sandy soil materials in the area or discharge to the Spokane municipal sewer system. Because of the relatively high infiltration rate of the native sand, a relatively small infiltration pond system (approximately 0.5 acres) would be required to accommodate 100 gpm. Final size of the pond would depend on the rate of groundwater extraction and treatment. The infiltration pond could be located in a variety of areas. Potential options include adjacent to the water treatment system to reduce piping costs and disturbance; or upgradient of, or within, the footprint of the groundwater contaminant plume to minimize potential deleterious effects of the release of treated water to un-impacted groundwater (treatment processes target only cyanide and fluoride, treated water is anticipated to have high total dissolved solids and nitrate concentrations that could reduce the suitability of groundwater for drinking water use). The wetland treatment system has the potential to ameliorate impacts from nitrate as nitrogen compounds could be removed through biologic uptake within the wetland cell, however, the likelihood and extent of nitrogen removal has not been determined based on testing but is estimated to range from 25 to >50 percent removal (see discussion in Section 4.2.3) and would be evaluated during pilot testing.

5.5.2 Protectiveness

Estimated Time to Meet Cleanup Levels at Compliance Wells

Alternative C(100) would attain cleanup levels in groundwater for both fluoride and cyanide at the Compliance Wells in approximately two years following full implementation. Once cleanup levels are met, continued operation of the pumping and treatment systems is required to maintain cleanup levels at the Compliance Wells. The duration of continued ex situ treatment is estimated based on the Partitioning Model to range from approximately 30 to 80 years for cyanide and 50 to 130 years for fluoride.

Reduction in Mass Flux Beyond the Compliance Wells

This alternative will remove contaminant mass from the groundwater system and reduce the mass flux of contaminants to groundwater downgradient of the extraction wells, and to and beyond the Compliance Wells. Relative to Alternative A MNA, Alternative C(100) would reduce the mass flux of fluoride and cyanide by approximately 99 percent over 30 years of operation; and 98 to 99 percent over 80 years of operation.

Mass of Contaminants Removed from Groundwater System

Alternative C(100) would remove approximately 82,000 kg of fluoride and 134,000 kg of cyanide from the groundwater system over 30 years of operation; and 149,000 kg of fluoride and 212,000 kg of cyanide over 80 years of operation.

5.5.3 Permanence

Destruction of Hazardous Substances

Fluoride is an element and thus cannot be destroyed by this or any other alternative. This alternative removes fluoride from groundwater and produces fluoride-bearing sludge that will be disposed in an off-Site hazardous waste landfill. This alternative will destroy free, WAD and total cyanide in a stepwise fashion, first by photo-degradation of iron cyanide complexes, followed by phytoremediation/biological degradation of WAD and free cyanide.

Reduction or Elimination of Hazardous Substance Releases and Sources of Releases

Release of contaminants from wastes on the MCT property to groundwater is currently controlled by previously completed and maintained remedial actions (e.g., containment of waste in the capped SPL pile, monitoring and maintenance of water lines, etc.). This alternative will not provide further control of contaminant releases to groundwater above that currently provided by Alternative A-MNA.

Degree of Irreversibility of Waste Treatment Process

This alternative treats contaminated groundwater rather than source materials. The majority of the cyanide compounds (approximately 76 percent based on laboratory pilot testing) will be permanently and irreversibly destroyed. As noted above, fluoride is an element and cannot be destroyed.

Characteristics and Quantity of Treatment Residuals Generated

Table 5-4 summarizes the quantities of treatment residuals generated by the three wetland-EC alternatives C(100), C(50), and C(25). Ex situ treatment will create treatment residuals consisting of fluoride-bearing sludge that will be disposed off-Site in a hazardous waste landfill. Following the wetland’s operational life, wetland media will need to be reclaimed in placed or disposed.

TABLE 5-4. ALTERNATIVES C(100), C(50), AND C(25) TREATMENT RESIDUAL GENERATION

Alternative	Treatment Capacity (gpm)	Size of Wetland[2]	EC Sludge Generated in 30 Years (tons)[1]	EC Sludge Generated in 80 Years (tons)[1]	Wetland Media To Be Disposed at End of Treatment Period (tons)
C(100)	100 gpm	7 acres	62,000	165,000	6,000
C(50)	50 gpm	3.5 acres	31,000	82,000	3,000
C(25)	25 gpm	1.75 acres	15,500	41,000	1,500

Notes:

1) Sludge mass at 91.4 percent moisture.
2) Includes treatment cell(s) plus adjacent area sufficient for construction and operation.

5.5.4 Cost

Costs estimated for this alternative include:

- Costs associated with the Alternative A component (i.e., annual inspection and monitoring costs and periodic maintenance costs for asphalt repairs and weed control on the SPL pile for the next 30 to 80 years);
- Costs for a 2-year field pilot test of the wetland and EC technologies (assumes leasing of equipment and personnel);
- Final design and engineering of the full-scale wetland-EC treatment system; and
- Construction and operation of the pumping system and wetland-EC treatment technologies for an estimated 30 to 80 years.

Costs for this alternative are derived from estimated full-scale implementation costs based on results of the wetland laboratory pilot test and quotes from Baker Corporation for a full-scale EC operation (Appendix C). Table 5-5 shows capital and operating expenses for the wetland-EC alternatives at pumping and treatment rates of 25, 50, and 100 gpm systems. Table 5-6 shows estimated NPVs for construction and 30 to 80 years of operation for the wetland-EC alternatives at pumping and treatment rates of 25, 50, and 100 gpm systems.

TABLE 5-5. ASSUMPTIONS FOR ALTERNATIVES C(100), C(50) AND C(25) ESTIMATED COSTS

	Alternative C(100) Treatment Rate of 100 gpm	Alternative C(50) Treatment Rate of 50 gpm	Alternative C(25) Treatment Rate of 25 gpm
Capital Costs			
Wetland Construction	$1,248,000	$624,000	$312,000
EC Process Equipment	$3,000,000	$1,800,000	$1,000,000
Land Acquisition	$350,000	$175,000[1]	$87,500[1]
Extraction Wells and Pumps	$107,000	$89,000	$71,000
Infiltration Pond Construction or Pipeline to Municipal Sewer	$3,300	$3,300	$3,300
Pilot Test	$1,025,000	None	None
Tax, fees, engineering, etc.[2]	$2,825,000		
Total[2]	$7,533,000	$4,306,000	$2,358,000
Operation and Monitoring Costs (annual)			
Estimated by Alcoa/Arconic based on operating full-scale system	$1,944,000	$972,000	$486,000

Notes:

1) Smaller treatment systems could potentially be located on MCT property such that land acquisition is not required. Land cost assumes $50,000/acre.
2) Capital costs include WA sales tax, legal and administrative fees, engineering, mobilization, and bonding and contingencies. Costs rounded to nearest $1,000.
3) Pilot test not proposed for 50 and 25 gpm systems as optimization would be done during start up.

TABLE 5-6. ALTERNATIVES C(100), C(50) AND C(25) ESTIMATED COSTS (30 AND 80 YEAR LIFE)

	Alternative C(100) Treatment Rate of 100 gpm	Alternative C(50) Treatment Rate of 50 gpm	Alternative C(25) Treatment Rate of 25 gpm
Pilot Test cost	$1,025,000	None	None
Capital cost	$7,533,280	$4,306,080	$2,358,080
O&M cost /year	$1,944,088	$972,000	$486,000
Alternative A Cost	$903,786	$903,786	$903,786
Total cost for 30 years (NPV)	$55,822,344	$28,366,527	$14,831,240
Total cost for 80 years (NPV)	$123,351,819	$60,659,458	$30,527,182

Notes:

Estimated costs are intended to provide a relative comparison between alternatives, and are considered to be +/-25 percent of actual costs. The 30-year and 80-year costs represent approximate durations of remedial actions under approximate best case (30) and worst case (80) conditions for cyanide and intermediate case (80) conditions for fluoride.

5.5.5 Long-Term Effectiveness

Alternative C(100) ranks highest of the alternatives relative to Ecology’s order of preference for types of cleanup action as it results in destruction of the majority of cyanide forms and immobilization of the remainder of the cyanide and the fluoride contaminants by removing them from the environment/groundwater system at rates that are estimated to capture all or most of the groundwater contaminant plume.

Degree of Certainty that Alternative will be Successful

The methods of treatment provided in Alternative C(100) (pumping of conventional wells for groundwater extraction; removal of cyanide by wetland treatment; removal of fluoride by EC) are well established and commonly employed for water treatment. The level of effectiveness of the wetland system under the specific climatic conditions of the Site was simulated in the laboratory pilot test (including cold weather conditions) but has not been verified under actual field conditions. Additional verification of the effectiveness of these treatments will be determined during field pilot-scale testing. The likelihood that the field pilot test will indicate that the wetland will not function under Site conditions is believed to be very low. If the wetland were found to be significantly less effective than observed in the laboratory, this could be mitigated by increasing the hydraulic residence time of the wetland system which would result in either an areal expansion of the wetland (with higher costs) or a reduction in the flow rate that could be treated (with lower than currently estimated effectiveness of the alternative in terms of meeting cleanup levels at the Compliance Wells and removing contaminant mass from the environment).

Reliability

The reliability of this alternative is good and will depend on providing adequate hydraulic retention time within the wetland system to allow photolytic and biological degradation of cyanide to occur and on proper operation and maintenance of the EC system. Wetland biological treatment of cyanide is successfully employed in the mining industry (Mudder and Smith, 1991; Dzombak et al, 2006) and is demonstrated to be reliable by ALCOA at a full-scale treatment system. EC treatment of fluoride is also a commonly employed method of fluoride removal that has been used by ALCOA on aluminum plant wastewater.

Identification of optimal wetland retention time and proper EC operational parameters will be determined during field pilot testing prior to implementation. This alternative assumes employment of 1.5 full-time operators for operation and maintenance of the system.

Residual Risk

Implementation of this alternative would reduce risk by reducing concentrations of cyanide and fluoride in groundwater downgradient of the extraction wells.

Residual risk would vary with location and would be similar to Alternative A MNA upgradient of the extraction wells and lower than Alternative A downgradient of the extraction wells and Compliance Wells. This alternative does not provide any additional controls than Alternative A upgradient of the extraction wells. Identical to Alternative A, upgradient of the extraction wells, groundwater concentrations within the contaminant plume area (approximately 30 acres) are predicted by the Partitioning Model to exceed cleanup levels for 33 to 80 years for cyanide and 52 to 130 years for fluoride. Over time, the areal extent of the groundwater contaminant plume would shrink and the concentrations of fluoride and cyanide would decline. The residual risk from groundwater concentrations exceeding cleanup levels is estimated to be low as institutional controls will restrict access to groundwater.

Within the contaminant plume from the extraction wells to the Compliance Wells, an area of approximately 3 acres, groundwater concentrations would be cleaned up to cleanup levels for fluoride and cyanide within approximately two years following full implementation of ex situ treatment. The residual risk from groundwater in this area is low as groundwater concentrations would be better than cleanup levels and MCLs and institutional controls will restrict access to groundwater.

Groundwater concentrations downgradient of the Compliance Wells is not monitored by MCT and was not simulated with the Partitioning Model. However, groundwater conditions downgradient of the Compliance Wells can be qualitatively estimated by extrapolation of observed and Partitioning Model-simulated upgradient groundwater concentrations and trends. By extrapolation, groundwater concentrations for some distance downgradient of the Compliance Wells is expected to meet cleanup levels in roughly a similar amount of time as for upgradient areas, perhaps two to five years. The residual risk is estimated to be low as groundwater concentrations would be better than cleanup levels and MCLs and State and Spokane County restrictions on groundwater use will restrict access to groundwater.

Pumping of groundwater to the surface for treatment would increase potential human and wildlife exposure to the contaminated water, most notably in the wetland where the water will necessarily be open and exposed to sunlight and the atmosphere. This risk would be mitigated through institutional controls (e.g., fencing, signage, bird netting etc.) to prohibit human contact and limit wildlife contact with water in the wetland; however, it is not practical to prevent all wildlife contact.

Management of Treatment Residuals

Ex situ treatment will create treatment residuals (quantified in Table 5-4 above) consisting of cyanide and fluoride-bearing sludge during operation and wetland media at the cessation of treatment. These residuals will be disposed off-Site in permitted hazardous waste landfills and will not pose further risk. Media within the wetland system (soil and vegetation) at the end of treatment would be reclaimed in place at the end of its operational life.

5.5.6 Management of Short-Term Risks

This alternative will require installation of approximately four groundwater extraction wells which will expose workers to sediment and water containing cyanide and fluoride. Workers would also be exposed to purge water from well monitoring activities. During these activities, worker exposure would be limited by the use of proper personal protective equipment (PPE). Purge water with concentrations exceeding cleanup levels has been classified as hazardous and will be sent off-Site for proper disposal at a permitted facility.

Certain reagents (e.g., sodium hydroxide) that might be employed may be harmful if mishandled or spilled. Proper engineering controls, PPE and standard operating procedures will be developed for storage, handling and use of potentially harmful chemicals.

The wetland will provide potential habitat for aquatic species, waterfowl, and other wildlife. Field pilot testing will be required to confirm that cyanide and fluoride concentrations in the wetland do not cause risk to ecological receptors. Waterfowl could be excluded through the use of bird netting as is commonly employed for industrial and waste water treatment ponds. The need for bird netting would be further evaluated during engineering design based on the actual concentrations of contaminants in the wetland and available toxicity data. The wetland will also potentially attract human visitors and therefore will be fenced and signed to prevent non-authorized access.

5.5.7 Technical and Administrative Implementability

This alternative is technically possible although there are uncertainties regarding optimal operating conditions of the wetland-EC system that would be addressed during field pilot testing. This alternative requires access to land outside MCT property for groundwater extraction well installation and maintenance and monitoring. This alternative requires approximately 7.5 acres of land for the wetland treatment system and groundwater infiltration pond if that disposal option is selected during engineering design. Agreements for land access for the wetland system and infiltration pond will be needed unless the system is located on Mead Custodial Trust property. Possible locations for the wetland ponds include areas to the north of the sludge pond (Kaiser Aluminum Properties, Inc. property), west and south of the SPL pile (Spokane Recycling property) and land within the BPA power line easement. This alternative may require an easement for pipeline access to the municipal sewer system if that disposal option is selected during engineering design. The Trust currently has an easement across Parcel 6 that would provide access to the municipal waste line. There is potentially a cheaper access to the waste line that would require a new easement.

This alternative would require a permit, or meeting the substantive requirements of a permit, for discharge to either groundwater through an infiltration pond or to the Spokane County Riverside Park Water Reclamation Facility and subsequently to the Spokane River. A summary of the potential permit requirements for these two treated water disposal options is as follows:

- Discharge to Groundwater
    - A *State Waste Discharge Permit* is required for discharge of wastewater to groundwater. Revised Code of Washington (RCW) 70.105D.090(1) exempts parties conducting MTCA cleanups under order or decree from obtaining certain permits including state waste discharge permits. However, the substantive requirements of the permit, including requirements to meet groundwater quality standards and apply AKART would still apply.
    - An *NPDES (National Pollutant Discharge Elimination System) Permit* may be required if it is determined that there is “hydraulic continuity” such that discharge to groundwater also results in a discharge to surface water. The determination of hydraulic continuity is based on “whether pollutants discharged to the ground(water) can be traced to surface water” (WA Ecology, 2015b). Since cyanide and fluoride from the Site are documented to discharge from springs to the Little Spokane River, it is likely that hydraulic continuity is established and an NPDES Permit would be required. Discharges under MTCA are not exempt from NPDES permits.
- Discharge to Spokane County Riverside Park Water Reclamation Facility
    - Spokane County has an NPDES Permit (WA0093317) for discharge of treated municipal water to the Spokane River. As part of the Permit, Spokane County administers a Pre-Treatment Program whereby dischargers of industrial wastewater to the municipal system are not required to obtain individual NPDES Permits, instead dischargers must meet Pre-Treatment Discharge Permit from Spokane County and meet Local Limits.

A comparison of expected treated water quality for this alternative and groundwater quality standards and Spokane County Local Limits is provided in Table 5-7. With the possible exception of nitrate in discharge to groundwater, the quality of treated water is not expected to pose any impediments to discharge permitting.

TABLE 5-7. COMPARISON OF EXPECTED TREATED WATER QUALITY WITH POTENTIAL DISCHARGE LIMITS

Parameter	Potential Groundwater Discharge Limit (MTCA Method B or SCL) (2)	Spokane Municipal Treatment System Pre-treatment Program Local Limits (mg/L)	Expected Treated Water Quality (mg/L)	Basis for Estimate of Expected Effluent Quality
Total Cyanide	None	1.9	<0.5	A
Free Cyanide	0.2	None	<0.2	A
Fluoride	4	None	<4	A
pH std. units	(6.5 to 8.5)	5 to 11	6 to 8	A
Temperature	None	130 F	35 to 80 F	A
Nitrate	10	None	<10 to 30	F
Ammonia	None	None	<0.5	C
TDS	(500)	None	2,000	C
Spec. Conductivity (umhos/cm)	None	None	3,500	C
Sulfate	(250)	None	<300	C
Chloride	(250)	None	<40	C
TPH	(3)	100	Believed absent	D, E
BTEX (sum)	(3)	1.4	Believed absent	D, E
Arsenic	0.01	0.41	<0.02	A
Barium	1.0	None	<0.02	A
Cadmium	0.008	0.11	<0.01	A
Chromium	0.1	5	<0.02	A
Copper	0.64	1.9	0.3	A
Iron	(0.3)	None	<0.2	A
Lead	0.015	0.32	<0.02	A
Manganese	(0.05)	None	<0.05	A
Mercury	0.002	0.05	<0.0002	B
Molybdenum	0.08	1.5	<0.02	A
Nickel	0.32	3.98	<0.02	A
Selenium	0.05	1.0	<0.02	A
Silver	0.08	1.7	<0.01	A
Zinc	0.48	5.6	<0.05	A
Bis(2-ethylhexyl)phthalate	6	6	<0.5 to 1.2	E

Notes:

1 – No limit except general prohibition of interference with the municipal treatment plant.
2 – CLARC Data Table – July 2015 https://fortress.wa.gov/ecy/clarc/CLARCDataTables.aspx. If not MTCA B value exists, value in parentheses are secondary contaminant limits in Table 1 WAC 173-200-040.
3 – Limits for individual petroleum components.
A – Laboratory testing of wetland-EC system (See Appendix F).
B – Concentration in groundwater at plume center well KM-6 (October 2006).
C – Concentration in groundwater at Compliance Wells KMCP-3B and -4B (May 2013).
D – Petroleum hydrocarbons (fuels or wastes) were not identified as waste materials in the Site Characterization Analysis (Hart Crowser, 1988) or Feasibility Study (RETEC, 1993).
E – Results of analysis of groundwater samples collected from wells KMCP-3B, KMCP-4B, KM-16, and KM-5 on September 24, 2018.
F – Wetland performance based on literature reports. See discussion in Section 4.2.3.

This alternative would not require a water right provided that no water is beneficially used (WA Ecology, 2018). No beneficial use of water is required in this alternative.

5.6 ALTERNATIVE C(50) – EX SITU TREATMENT (WETLAND-EC) AT RATE OF 50 GPM PLUS ALTERNATIVE A

5.6.1 Process Description

The process for Alternative C(50) would be identical to Alternative C(100) as described in Section 5.5.1 with the exception that pumping and treatment of water would be done at a rate of 50 gpm. Based on the retention times evaluated in the laboratory pilot test it is estimated that approximately 3.0 acres of wetland would be required to treat 50 gpm of groundwater at the Mead Site. Total land requirement for the wetland treatment system is 3.5 acres to allow room for construction and maintenance of the wetland cell.

5.6.2 Protectiveness

<u>Estimated Time to Meet Cleanup Levels at Compliance Wells</u>

Alternative C(50) would attain cleanup levels in groundwater at the Compliance Wells in an estimated in an estimated 28 to 40 years for cyanide and 38 to 80 years for fluoride. Once cleanup levels are met, continued operation of the pumping and treatment systems is required to maintain cleanup levels at the Compliance Wells. The duration of continued ex situ treatment is estimated based on the Partition Model to range from approximately 30 to 80 years for cyanide and 50 to 130 years for fluoride.

<u>Mass of Contaminants Removed from Groundwater System</u>

Alternative C(50) would remove approximately 41,000 kg of fluoride and 67,000 kg of cyanide from the groundwater system over 30 years of operation; and 74,000 kg of fluoride and 106,000 kg of cyanide over 80 years of operation.

<u>Reduction in Mass Flux Beyond the Compliance Wells</u>

This alternative will remove contaminant mass from the groundwater system and reduce the mass flux of contaminants to groundwater downgradient of the extraction wells, to and beyond the Compliance Wells. Relative to Alternative A MNA, Alternative C(50) would reduce the mass flux of fluoride and cyanide by approximately 50 percent over the 30 to 80 years of operation.

5.6.3 Permanence

Alternative C(50) is less permanent than alternatives that use higher pumping and treatment rates (i.e., Alternatives C(100) and D(100)) as lower masses of fluoride and cyanide will be removed from groundwater. Consequently, lower quantities of treatment residuals will also be generated.

Destruction of Hazardous Substances

Fluoride is an element and thus cannot be destroyed by this or any other alternative. This alternative removes fluoride from groundwater and produces fluoride-bearing sludge that will be disposed in an off-Site hazardous waste landfill. This alternative will destroy free, WAD and total cyanide in a stepwise fashion, first by photo-degradation of iron cyanide complexes, followed by phytoremediation/biological degradation of WAD and free cyanide.

Reduction or Elimination of Hazardous Substance Releases and Sources of Releases

Release of contaminants from wastes on the MCT property to groundwater is currently controlled by previously completed and maintained remedial actions (e.g., containment of waste in the capped SPL pile, monitoring and maintenance of water lines, etc.). This alternative will not provide further control of contaminant releases to groundwater above that currently provided by Alternative A-MNA.

Degree of Irreversibility of Waste Treatment Process

Degree of irreversibility is identical to Alternative C(100) as identical treatment processes will be used, but at a lower pumping and treatment rate.

Characteristics and Quantity of Treatment Residuals Generated

This alternative will generate approximately 31,000 tons of cyanide and fluoride-bearing EC sludge over 30 years and 82,000 tons over 80 years (see Table 5-4, Section 5.5.3 for comparison with other wetland-EC alternatives). Following the wetlands operational life, approximately 3,000 tons of wetland media will need to be reclaimed in place or disposed.

5.6.4 Cost

Costs estimated for this alternative include:

- Costs associated with the Alternative A component (i.e., annual inspection and monitoring costs and periodic maintenance costs for asphalt repairs and weed control on the SPL pile for the next 30 to 80 years);
- Final design and engineering of the full-scale wetland-EC treatment system; and
- Construction and operation of the pumping system and wetland-EC treatment technologies for an estimated 30 to 80 years.

Costs for this alternative are derived from estimated full-scale implementation costs based on results of the wetland laboratory pilot test and quotes from Baker Corporation for a full-scale EC operation. Table 5-5 in Section 5.5.4 shows capital and operating expenses for the wetland-EC alternatives at pumping and treatment rates of 25, 50, and 100 gpm systems. Table 5-6 in Section 5.5.4 shows estimated NPVs for construction and 30 to 80 years of operation for the wetland-EC alternatives at pumping and treatment rates of 25, 50, and 100 gpm systems.

5.6.5 Long-Term Effectiveness

Alternative C(50) ranks high relative to Ecology’s order of preference for types of cleanup action as it results in destruction of cyanide and immobilizes a portion of the cyanide and fluoride contaminants by removing them from the environment/groundwater system at rates that are estimated to capture approximately 50 percent of the groundwater contaminant plume.

<u>Degree of Certainty that Alternative will be Successful</u>

The methods of treatment provided in Alternative C(50) (pumping of conventional wells for groundwater extraction; removal of cyanide by wetland treatment; removal of fluoride by

EC) are well established and commonly employed for water treatment as described above for Alternative C(100) in Section 5.5.5.

Reliability

The reliability of Alternative C(50) is good and similar to reliability of Alternative C(100) described in Section 5.5.5, above.

Residual Risk

Implementation of this alternative would reduce risk by reducing concentrations of cyanide and fluoride in groundwater downgradient of the extraction wells.

Residual risk would vary with location and would be similar to Alternative A MNA upgradient of the extraction wells and lower than Alternative A downgradient of the extraction wells and Compliance Wells. This alternative does not provide any additional controls than Alternative A upgradient of the extraction wells. Identical to Alternative A, upgradient of the extraction wells, groundwater concentrations within the contaminant plume area (approximately 30 acres) are predicted by the Partitioning Model to exceed cleanup levels for 33 to 80 years for cyanide and 52 to 130 years for fluoride. Over time, the areal extent of the groundwater contaminant plume would shrink and the concentrations of fluoride and cyanide would decline. The residual risk from groundwater concentrations exceeding cleanup levels is estimated to be low as institutional controls will restrict access to groundwater.

Within the contaminant plume from the extraction wells to the Compliance Wells, an area of approximately 3 acres, groundwater concentrations would be cleaned up to cleanup levels within 28 to 40 years for cyanide and 38 to 80 years for fluoride following full implementation of ex situ treatment. Prior to attainment of cleanup levels, risk in this area would be lower than under Alternative A as groundwater concentrations would be lower. After attainment of cleanup levels in 28 to 80 years, residual risk from groundwater in this area is low as groundwater concentrations would be better than MCLs and institutional controls will restrict access to groundwater.

Groundwater concentrations downgradient of the Compliance Wells is not monitored by MCT and was not simulated with the Partitioning Model. However, groundwater conditions downgradient of the Compliance Wells can be qualitatively estimated by extrapolation of observed and Partitioning Model-simulated upgradient groundwater concentrations and trends. By extrapolation, groundwater concentrations for some distance downgradient of the Compliance Wells is expected to exceed cleanup levels for a roughly a similar amount of time as for upgradient areas, perhaps a few to several decades. The residual risk from groundwater concentrations exceeding cleanup levels is estimated to be low as State and Spokane County restrictions on groundwater use will restrict access to groundwater.

Pumping of groundwater to the surface for treatment would increase potential human and wildlife exposure to the contaminated water, most notably in the wetland where the water will necessarily be open and exposed to sunlight and the atmosphere. This risk would be mitigated through institutional controls (e.g., fencing, signage, bird netting etc.) to prohibit human contact and limit wildlife contact with water in the wetland; however, it is not practical to prevent all wildlife contact.

<u>Management of Treatment Residuals</u>

Ex situ treatment will create treatment residuals (quantified in Table 5-4 above) consisting of cyanide and fluoride-bearing sludge during operation and wetland media at the cessation of treatment. These residuals will be disposed off-Site in permitted hazardous waste landfills and will not pose further risk. Media within the wetland system (soil and vegetation) at the end of treatment is not expected to be hazardous and the wetland system would be reclaimed in place at the end of its operational life.

5.6.6 Management of Short-Term Risks

Short-term risks for Alternative C(50) are similar to those described for Alternative C(100) in Section 5.5.6, above:

1. Installation of groundwater extraction wells will expose workers to sediment and water containing cyanide and fluoride. Worker exposure would be limited by the use of proper personal protective equipment (PPE).

2. Purge water with concentrations exceeding cleanup levels has been classified as hazardous and will be sent off-Site for proper disposal at a permitted facility.
3. Certain reagents (e.g., sodium hydroxide) that might be employed may be harmful if mishandled or spilled. Proper engineering controls, PPE and standard operating procedures will be developed for storage, handling and use of potentially harmful chemicals.
4. The wetland will provide potential habitat for aquatic species, waterfowl, and other wildlife. Testing during system startup will be required to confirm that cyanide and fluoride concentrations in the wetland do not cause risk to ecological receptors. Waterfowl could be excluded through the use of bird netting as is commonly employed for industrial and waste water treatment ponds. The need for bird netting would be further evaluated during engineering design based on the actual concentrations of contaminants in the wetland and available toxicity data. The wetland will also potentially attract human visitors and therefore will be fenced and signed to prevent non-authorized access.

5.6.7 Technical and Administrative Implementability

This alternative is technically possible although there are uncertainties regarding optimal operating conditions of the wetland-EC system that would be addressed during system start up. This alternative requires access to land outside MCT property for groundwater extraction well installation and maintenance and monitoring. This alternative requires approximately 3.5 acres of land for the wetland treatment system and groundwater infiltration pond (if this disposal option is selected during engineering design) and because of smaller size than Alternative C(100) possibly could be Sited on MCT property to the west of the SPL pile. Agreements for land access for the wetland system and infiltration pond will be needed unless the system is located on Mead Custodial Trust property. Possible locations for the wetland ponds include areas to the north of the sludge pond (Kaiser Aluminum Properties, Inc. property), west and south of the SPL pile (Spokane Recycling property) and land within the BPA power line easement. This alternative may require an easement for pipeline access to the municipal sewer system if that disposal option is selected during engineering design. The Trust currently has an easement across Parcel 6 that would provide access to the municipal waste line. There is potentially a cheaper access to the waste line that would require a new easement.

As described in Section 5.5.7 for Alternative C(100), this alternative also would require a permit, or meeting the substantive requirements of a permit, for discharge to either groundwater through an infiltration pond or to the Spokane County Riverside Park Water Reclamation Facility and subsequently to the Spokane River. A comparison of expected treated water quality for this alternative and groundwater quality standards and Spokane County Local Limits is provided in Table 5-7 in Section 5.5.7. With the possible exception of nitrate in discharge to groundwater, the quality of treated water is not expected to pose any impediments to discharge permitting.

This alternative would not require a water right provided that no water is beneficially used (WA Ecology, 2018). No beneficial use of water is required in this alternative.

5.7 ALTERNATIVE C(25) – EX SITU TREATMENT (WETLAND-EC) AT RATE OF 25 GPM PLUS ALTERNATIVE A

5.7.1 Process Description

The process for Alternative C(25) would be identical to Alternative C(100) as described in Section 5.5.1 with the exception that pumping and treatment of water would be done at a rate of 25 gpm. Based on the retention times evaluated in the laboratory pilot test it is estimated that approximately 1.5 acres of wetland would be required to treat 25 gpm of groundwater at the Mead Site. Total land requirement for the wetland treatment system is 1.75 acres to allow room for construction and maintenance of the wetland cell.

As described in Section 5.5.1, a pilot test is anticipated prior to construction and design of the Alternative C(100) 100 gpm system. However, since the proposed pilot test rate of 10 gpm is relatively close to the treatment rate of Alternative C(25), it may be desirable and more cost effective to omit the 10 gpm pilot scale test before building the 25 gpm wetland system. In this implementation approach, the 25 gpm system would serve as the pilot-scale test and if found to function adequately would then serve as the full-scale system. If the pilot scale test identified the need for modifications, then the 25 gpm system would be expanded or modified to serve as the full-scale system.

5.7.2 Protectiveness

Estimated Time to Meet Cleanup Levels at Compliance Wells

Alternative C(25) would attain cleanup levels in groundwater at the Compliance Wells in an estimated in an estimated 32 to 66 years for cyanide and 46 to 110 years for fluoride. Once cleanup levels are met, continued operation of the pumping and treatment systems is required to maintain cleanup levels at the Compliance Wells. The duration of continued ex situ treatment is estimated based on the Partition Model to range from approximately 30 to 80 years for cyanide and 50 to 130 years for fluoride.

Mass of Contaminants Removed from Groundwater System

Alternative C(25) would remove approximately 20,000 kg of fluoride and 34,000 kg of cyanide from the groundwater system over 30 years of operation; and 37,000 kg of fluoride and 58,000 kg of cyanide over 80 years of operation.

Reduction in Mass Flux Beyond the Compliance Wells

This alternative will remove contaminant mass from the groundwater system and reduce the mass flux of contaminants to groundwater downgradient of the extraction wells, to and beyond the Compliance Wells. Relative to Alternative A MNA, Alternative C(25) would reduce the mass flux of fluoride and cyanide by approximately 25 percent over the 30 to 80 years of operation.

5.7.3 Permanence

Alternative C(25) is less permanent than alternatives that use higher pumping and treatment rates (i.e., Alternatives C(100), D(100), C(50), D(50)) as lower masses of fluoride and cyanide will be removed from groundwater. Consequently, lower quantities of treatment residuals will also be generated.

Destruction of Hazardous Substances

Fluoride is an element and thus cannot be destroyed by this or any other alternative. This alternative removes fluoride from groundwater and produces fluoride-bearing sludge that will be disposed in an off-Site hazardous waste landfill. This alternative will destroy free, WAD and total cyanide in a stepwise fashion, first by photo-degradation of iron cyanide complexes, followed by phytoremediation/biological degradation of WAD and free cyanide.

Reduction or Elimination of Hazardous Substance Releases and Sources of Releases

Release of contaminants from wastes on the MCT property to groundwater is currently controlled by previously completed and maintained remedial actions (e.g., containment of waste in the capped SPL pile, monitoring and maintenance of water lines, etc.). This alternative will not provide further control of contaminant releases to groundwater above that currently provided by Alternative A-MNA.

Degree of Irreversibility of Waste Treatment Process

Degree of irreversibility is identical to Alternatives C(100) and C(50) as identical treatment processes will be used, but at a lower pumping and treatment rate.

Characteristics and Quantity of Treatment Residuals Generated

This alternative will generate approximately 16,000 tons of cyanide and fluoride-bearing EC sludge over 30 years and 41,000 tons over 80 years (see Table 5-4, Section 5.5.3 for comparison with other wetland-EC alternatives). Following the wetlands operational life, approximately 1,500 tons of wetland media will need to be reclaimed in place or disposed.

5.7.4 Cost

Costs estimated for this alternative include:

- Costs associated with the Alternative A component (i.e., annual inspection and monitoring costs and periodic maintenance costs for asphalt repairs and weed control on the SPL pile for the next 30 to 80 years);
- Final design and engineering of the full-scale wetland-EC treatment system; and

- Construction and operation of the pumping system and wetland-EC treatment technologies for an estimated 30 to 80 years.

Costs for this alternative are derived from estimated full-scale implementation costs based on results of the wetland laboratory pilot test and quotes from Baker Corporation for a full-scale EC operation. Table 5-5 in Section 5.5.4 shows capital and operating expenses for the wetland-EC alternatives at pumping and treatment rates of 25, 50, and 100 gpm systems. Table 5-6 in Section 5.5.4 shows estimated NPVs for construction and 30 to 80 years of operation for the wetland-EC alternatives at pumping and treatment rates of 25, 50, and 100 gpm.

5.7.5 Long-Term Effectiveness

Alternative C(25) ranks high relative to Ecology’s order of preference for types of cleanup action as it results in destruction of cyanide and immobilizes a portion of the cyanide and fluoride contaminants by removing them from the environment/groundwater system at rates that are estimated to capture approximately 25 percent of the groundwater contaminant plume.

Degree of Certainty that Alternative will be Successful

The methods of treatment provided in Alternative C(25) (pumping of conventional wells for groundwater extraction; removal of cyanide by wetland treatment; removal of fluoride by EC) are well established and commonly employed for water treatment as described above for Alternative C(100) in Section 5.5.5.

Reliability

The reliability of Alternative C(25) is good and similar to reliability of Alternative C(100) described in Section 5.5.5, above.

Residual Risk

Implementation of this alternative would reduce risk by reducing concentrations of cyanide and fluoride in groundwater downgradient of the extraction wells.

Residual risk would vary with location and would be similar to Alternative A MNA upgradient of the extraction wells and lower than Alternative A downgradient of the extraction wells and Compliance Wells. This alternative does not provide any additional controls than Alternative A upgradient of the extraction wells. Identical to Alternative A, upgradient of the extraction wells, groundwater concentrations within the contaminant plume area (approximately 30 acres) are predicted by the Partitioning Model to exceed cleanup levels for 33 to 80 years for cyanide and 52 to 130 years for fluoride. Over time, the areal extent of the groundwater contaminant plume would shrink and the concentrations of fluoride and cyanide would decline. The residual risk from groundwater concentrations exceeding cleanup levels is estimated to be low as institutional controls will restrict access to groundwater.

Within the contaminant plume from the extraction wells to the Compliance Wells, an area of approximately 3 acres, groundwater concentrations would be cleaned up to cleanup levels within 32 to 66 years for cyanide and 46 to 110 years for fluoride following full implementation of ex situ treatment. Prior to attainment of cleanup levels, risk in this area would be lower than under Alternative A as groundwater concentrations would be lower. After attainment of cleanup levels, residual risk from groundwater in this area is low as groundwater concentrations would be better than MCLs and institutional controls will restrict access to groundwater.

Groundwater concentrations downgradient of the Compliance Wells is not monitored by MCT and was not simulated with the Partitioning Model. However, groundwater conditions downgradient of the Compliance Wells can be qualitatively estimated by extrapolation of observed and Partitioning Model-simulated upgradient groundwater concentrations and trends. By extrapolation, groundwater concentrations for some distance downgradient of the Compliance Wells is expected to exceed cleanup levels for a roughly a similar amount of time as for upgradient areas, perhaps a few to several decades. The residual risk from groundwater concentrations exceeding cleanup levels is estimated to be low as State and Spokane County restrictions on groundwater use will restrict access to groundwater.

Pumping of groundwater to the surface for treatment would increase potential human and wildlife exposure to the contaminated water, most notably in the wetland where the water will necessarily be open and exposed to sunlight and the atmosphere. This risk would be mitigated through institutional controls (e.g., fencing, signage, bird netting etc.) to prohibit human contact and limit wildlife contact with water in the wetland; however, it is not practical to prevent all wildlife contact.

<u>Management of Treatment Residuals</u>

Ex situ treatment will create treatment residuals (quantified in Table 5-4 above) consisting of cyanide and fluoride-bearing sludge during operation and wetland media at the cessation of treatment. These residuals will be disposed off-Site in permitted hazardous waste landfills and will not pose further risk. Media within the wetland system (soil and vegetation) at the end of treatment is not expected to be hazardous and the wetland system would be reclaimed in place at the end of its operational life.

5.7.6 Management of Short-Term Risks

Short-term risks for Alternative C(25) are similar to those described for Alternative C(100) in Section 5.5.6, above:

1. Installation of groundwater extraction wells will expose workers to sediment and water containing cyanide and fluoride. Worker exposure would be limited by the use of proper personal protective equipment (PPE).
2. Purge water with concentrations exceeding cleanup levels has been classified as hazardous and will be sent off-Site for proper disposal at a permitted facility.
3. Certain reagents (e.g., sodium hydroxide) that might be employed may be harmful if mishandled or spilled. Proper engineering controls, PPE and standard operating procedures will be developed for storage, handling and use of potentially harmful chemicals.
4. The wetland will provide potential habitat for aquatic species, waterfowl, and other wildlife. Testing during system startup will be required to confirm that cyanide and fluoride concentrations in the wetland do not cause risk to ecological receptors. Waterfowl could be excluded through the use of bird netting as is commonly

employed for industrial and waste water treatment ponds. The need for bird netting would be further evaluated during engineering design based on the actual concentrations of contaminants in the wetland and available toxicity data. The wetland will also potentially attract human visitors and therefore will be fenced and signed to prevent non-authorized access.

5.7.7 Technical and Administrative Implementability

This alternative is technically possible although there are uncertainties regarding optimal operating conditions of the wetland-EC system that would be addressed during system start up.

This alternative requires access to land outside the MCT property for groundwater extraction well installation and maintenance and monitoring. This alternative requires approximately 2.25 acres of land for the wetland treatment system and groundwater infiltration pond if that disposal option is selected during engineering design. Agreements for land access for the wetland system and infiltration pond will be needed unless the system is located on Mead Custodial Trust property. Possible locations for the wetland ponds include areas to the north of the sludge pond (Kaiser Aluminum Properties, Inc. property), west and south of the SPL pile (Spokane Recycling property) and land within the BPA power line easement. This alternative may require an easement for pipeline access to the municipal sewer system if that disposal option is selected during engineering design. The Trust currently has an easement across Parcel 6 that would provide access to the municipal waste line. There is potentially a cheaper access to the waste line that would require a new easement.

As described in Section 5.5.7 for Alternative C(100), this alternative also would require a permit, or meeting the substantive requirements of a permit, for discharge to either groundwater through an infiltration pond or to the Spokane County Riverside Park Water Reclamation Facility and subsequently to the Spokane River. A comparison of expected treated water quality for this alternative and groundwater quality standards and Spokane County Local Limits is provided in Table 5-7 in Section 5.5.7. With the possible exception of nitrate in discharge to groundwater, the quality of treated water is not expected to pose any impediments to discharge permitting.

This alternative would not require a water right provided that no water is beneficially used (WA Ecology, 2018). No beneficial use of water is required in this alternative.

5.8 ALTERNATIVE D(100) – EX SITU TREATMENT (IRON PRECIPITATION-EC) AT RATE OF 100 GPM PLUS ALTERNATIVE A

5.8.1 Process Description

Alternative D(100) is the same as Alternative C(100) with the exception that Alternative D(100) would employ iron precipitation (FeP) for the removal of total, WAD and free cyanide rather than a constructed wetland system as in Alternative C(100). Alternative D(100) is the same as Alternatives D(50) and D(25) with the exception that in Alternative D(100) water is treated at a higher rate (100 gpm) to accommodate capture of all or most of the groundwater contaminant plume. Because similar levels of cyanide and fluoride treatment and removal would be provided by Alternatives D(100) and C(100), similar environmental benefits (contaminant mass reduction and attainment of cleanup levels at the Compliance Wells) are estimated for the two alternatives. Because Alternative D(100) provides a higher rate of extraction and treatment than other pump and treat Alternatives D(50), D(25), C(50), and C(25); Alternative D(100) provides greater potential environmental benefits than these alternatives, albeit at greater cost.

Ex situ groundwater treatment in Alternative D(100) would consist of extraction of contaminated groundwater by conventional water wells, water treatment by an iron-precipitation (FeP)-electrocoagulation (EC) system, and treated water discharge either to the Spokane municipal sewer or to infiltration pond to return water to the groundwater system. The cyanide removal technology (FeP) was proven to be effective and implementable based on the success of laboratory-scale tests on Site groundwater in 2013 (described in Appendix B). The fluoride removal technology (EC) was proven to be effective and implementable by laboratory-scale testing on Site groundwater in 2016 (described in Appendix C). Although these technologies have been tested individually they have not been tested as a complete process train. Additionally, free cyanide removal was not determined in the 2013 testing as the relevant cyanide form at the time was WAD cyanide (see footnote 1, page 2-1 for description of forms of cyanide for regulatory purposes). Thus additional laboratory or field-scale testing of Site waters would be required to confirm design parameters for a full-scale system. Full-scale implementation of Alternative D(100) would require approximately one to two years for confirmation testing, final design, contracting and bidding, regulatory approval, and construction and start-up.

Table 5-8 compares the size, estimated costs, estimated time to attain compliance, and contaminant mass removal for the iron-precipitation-EC Alternatives D(100), D(50), and D(25). For the ex situ treatment alternatives, once cleanup levels are met, continued operation of the pumping and treatment systems is required to maintain cleanup levels at the Compliance Wells. The duration of continued ex situ treatment is estimated based on the Partitioning Model to range from approximately 30 to 80 years for cyanide and 50 to 130 years for fluoride.

TABLE 5-8. ALTERNATIVE D(100), D(50), AND D(25) SIZING COMPARISON

Alternative	**Treatment Capacity (gpm)**	**Estimated Cost ($ Million, 30 years, NPV)[1]**	**Estimated Time to Cleanup at Compliance Wells Following Implementation (years)**		**Estimated Mass (kg) of Contaminants Removed from Groundwater in 30 years**	
			F	**CN**	**F**	**CN**
D(100)	100 gpm	$71.3	<2	<2	82,068	134,345
D(50)	50 gpm	$39.1	38 to 80	28 to 40	41,034	67,189
D(25)	25 gpm	$22.5	46 to 110	32 to 66	20,517	33,595

Alternative	**Treatment Capacity (gpm)**	**Estimated Cost ($ Million, 80 years, NPV)[1]**	**Estimated Time to Cleanup at Compliance Wells Following Implementation (years)**	**Estimated Mass (kg) of Contaminants Removed from Groundwater in 80 years**	
				F	**CN**
D(100)	As above	$152.9	As above	148,881	212,173
D(50)		$83.1		73,578	106,086
D(25)		$47.3		34,968	53,043

Notes:
1) Net Present Value (NPV) assuming discount rate of 0.7 percent. Estimated costs are intended to provide a relative comparison between alternatives, and are considered to be +/-25 percent of actual costs. The 30-year and 80-year costs represent approximate durations of remedial actions (pumping, treatment, and disposal) under approximate best case (30) and worst case (80) conditions for cyanide and intermediate case (80) conditions for fluoride. Assumes sludge disposal as hazardous waste.

The groundwater extraction component would be identical to Alternative C(100) as described in Section 5.5.1, above.

Ex situ water treatment would consist of an iron precipitation circuit for total, WAD and free cyanide removal and an electrocoagulation (EC) system for removal of fluoride. The fluoride removal system will consist of EC as described for Alternative C(100) in Section 5.5.1, above.

The treated water discharge system would consist of either an unlined infiltration pond or discharge to Spokane municipal sewer as described for Alternative C(100) in Section 5.5.1, above.

5.8.2 Protectiveness

Estimated Time to Meet Cleanup Levels at Compliance Wells

Alternative D(100) would attain cleanup levels in groundwater for both fluoride and cyanide at the Compliance Wells in approximately two years following full implementation. Once cleanup levels are met, continued operation of the pumping and treatment systems is required to maintain cleanup levels at the Compliance Wells. The duration of continued ex situ treatment is estimated based on the Partitioning Model to range from approximately 30 to 80 years for cyanide and 50 to 130 years for fluoride.

Reduction in Mass Flux Beyond the Compliance Wells

This alternative will remove contaminant mass from the groundwater system and reduce the mass flux of contaminants to groundwater downgradient of the extraction wells, and to and beyond the Compliance Wells. Relative to Alternative A MNA, Alternative D(100) would reduce the mass flux of fluoride and cyanide by approximately 99 percent over 30 years of operation; and 98 to 99 percent over 80 years of operation.

Mass of Contaminants Removed from Groundwater System

Identical to Alternative C(100), Alternative D(100) would remove approximately 82,000 kg of fluoride and 134,000 kg of cyanide from the groundwater system over 30 years of operation; and 149,000 kg of fluoride and 212,000 kg of cyanide over 80 years of operation.

5.8.3 Permanence

Destruction of Hazardous Substances

Fluoride is an element and thus cannot be destroyed by this or any other alternative. This alternative will convert the more toxic free and WAD forms of cyanide to stable iron cyanide solids. This alternative removes fluoride and cyanide from groundwater and produces cyanide and fluoride-bearing sludge that will be disposed in an off-Site hazardous waste landfill.

Reduction or Elimination of Hazardous Substance Releases and Sources of Releases

Release of contaminants from wastes on the MCT property to groundwater is currently controlled by previously completed and maintained remedial actions (e.g., containment of waste in the capped SPL pile, monitoring and maintenance of water lines, etc.). This alternative will not provide further control of contaminant releases to groundwater above that currently provided by Alternative A-MNA.

Degree of Irreversibility of Waste Treatment Process

This alternative treats contaminated groundwater rather than source materials. Fluoride and cyanide removed from groundwater will be concentrated into a sludge that will be disposed off-Site in a hazardous waste landfill.

Characteristics and Quantity of Treatment Residuals Generated

Table 5-9 summarizes the quantities of treatment residuals generated by the iron-precipitation-EC treatment Alternatives D(100), D(50), and D(25). Ex situ treatment will create treatment residuals consisting of cyanide and fluoride-bearing sludge that will be disposed off-Site in a hazardous waste landfill.

TABLE 5-9. ALTERNATIVES D(100), D(50), AND D(25) TREATMENT RESIDUAL GENERATION

Alternative	Treatment Capacity (gpm)	EC Sludge Generated in 30 Years (tons)[1]	Iron Precipitation Cyanide Sludge Generated in 30 Years (tons)	Total Sludge Generated in 30 Years (tons)
D(100)	100 gpm	62,000	14,600	76,600
D(50)	50 gpm	31,000	7,300	38,300
D(25)	25 gpm	15,500	3,600	19,100
Alternative	**Treatment Capacity (gpm)**	**EC Sludge Generated in 80 Years (tons)[1]**	**Iron Precipitation Cyanide Sludge Generated in 80 Years (tons)**	**Total Sludge Generated in 80 Years (tons)**
D(100)	100 gpm	165,000	39,000	204,000
D(50)	50 gpm	83,000	19,000	102,000
D(25)	25 gpm	41,000	9,600	51,000

Notes:

1) Sludge mass at 91.4 percent moisture.

5.8.4 Cost

Costs estimated for this alternative include:

- Costs associated with the Alternative A component (i.e., annual inspection and monitoring costs and periodic maintenance costs for asphalt repairs and weed control on the SPL pile for the next 30 to 80 years);
- Costs for a pilot test and final design/engineering of the iron precipitation and EC technologies; and
- Construction and operation of the pumping system and iron precipitation-EC treatment technologies for an estimated 30 to 80 years.

Costs for this alternative are derived from estimated full-scale implementation costs based on results of the 2013 Ex Situ treatability study (Appendix B) and quotes from Baker Corporation for a full-scale EC operation. Table 5-10 shows capital and operating expenses for the iron precipitation-EC alternatives at pumping and treatment rates of 25, 50, and 100 gpm systems. Table 5-11 shows estimated NPVs for construction and 30 to 80 years of operation for the iron precipitation-EC alternatives at pumping and treatment rates of 25, 50, and 100 gpm systems.

TABLE 5-10. ASSUMPTIONS FOR ALTERNATIVES D(100), D(50) AND D(25) ESTIMATED COSTS

	Alternative D(100)	**Alternative D(50)**	**Alternative D(25)**
	Treatment Rate of 100 gpm	**Treatment Rate of 50 gpm**	**Treatment Rate of 25 gpm**
Capital Costs			
Iron precipitation process equipment	$1,043,078	$656,843	$656,843
EC process equipment	$3,000,000	$1,800,000	$1,000,000
Extraction wells and pumps	$107,000	$89,000	$71,000
Infiltration pond or pipeline to municipal sewer construction	$3,300	$3,300	$3,300
Pilot Test	$100,000	$100,000	$100,000
WA Sales Tax (8%)	$340,270	$211,931	$146,491
Legal & Admin (5%)	$212,669	$132,457	$91,557
Engineering (20%)	$850,676	$529,829	$366,229
Mobilization/Bonding (7%)	$297,736	$185,440	$128,180
Contingency (20%)	$850,676	$529,829	$366,229
Total Capital Costs	$6,805,404	$4,238,628	$2,929,828
Operation and Monitoring Costs (annual)			
	$2,357,952	$1,257,865	$693,332

TABLE 5-11. ALTERNATIVES D(100), D(50) AND D(25) ESTIMATED COSTS (30 AND 80 YEAR LIFE)

	Alternative C(100)	**Alternative C(50)**	**Alternative C(25)**
	Treatment Rate of 100 gpm	**Treatment Rate of 50 gpm**	**Treatment Rate of 25 gpm**
Pilot Test cost	$100,000	$100,000	$100,000
Capital cost	$6,805,404	$4,238,628	$2,929,828
O&M cost /year	$2,357,952	$1,257,865	$693,332
Alternative A Cost	$903,786	$903,786	$903,786
Total cost for 30 years (NPV)	$71,314,096	$39,072,871	$22,536,010
Total cost for 80 years (NPV)	$71,314,096	$39,072,871	$22,536,010

Notes:

Estimated costs are intended to provide a relative comparison between alternatives, and are considered to be +/-25 percent of actual costs. The 30-year and 80-year costs represent approximate durations of remedial actions under approximate best case (30) and worst case (80) conditions for cyanide and intermediate case (80) conditions for fluoride.

5.8.5 Long-Term Effectiveness

Alternative D(100) ranks high relative to Ecology's order of preference for types of cleanup action as it results in immobilization of the cyanide and fluoride contaminants by removing them from the environment/groundwater system at rates that are estimated to capture all or most of the groundwater contaminant plume.

Degree of Certainty that Alternative will be Successful

The methods of treatment provided in Alternative D(100) (pumping of conventional wells for groundwater extraction; removal of cyanide by iron precipitation treatment; removal of fluoride by EC) are well established and commonly employed for water treatment. The level of effectiveness of the treatment methods was verified under laboratory conditions as described in Appendices B and C, but the combination of the iron precipitation process with the EC process has not been verified. Although no problems are anticipated by combination of these processes, additional verification of the effectiveness of these combined treatments will be determined during confirmation testing prior to final design.

Reliability

The reliability of this alternative is predicted to be good, provided that appropriate process equipment is utilized and operators have sufficient training and experience in utilizing the process equipment. This alternative assumes employment of 1.5 full-time operators for operation and maintenance of the system.

Residual Risk

Implementation of this alternative would reduce risk by reducing concentrations of cyanide and fluoride in groundwater downgradient of the extraction wells. Residual risk of alternative D(100) would be similar to but slightly less than alternative C(100) due to the absence of the C(100) wetland treatment system and associated potential for human and wildlife exposure.

Residual risk would vary with location and would be similar to Alternative A MNA upgradient of the extraction wells and lower than Alternative A downgradient of the extraction wells and Compliance Wells. This alternative does not provide any additional controls than Alternative A upgradient of the extraction wells. Identical to Alternative A, upgradient of the extraction wells, groundwater concentrations within the contaminant plume area (approximately 30 acres) are predicted by the Partitioning Model to exceed cleanup levels for 33 to 80 years for cyanide and 52 to 130 years for fluoride. Over time, the areal extent of the groundwater contaminant plume would shrink and the concentrations of fluoride and cyanide would decline. The residual risk from groundwater concentrations exceeding cleanup levels is estimated to be low as institutional controls will restrict access to groundwater.

Within the contaminant plume from the extraction wells to the Compliance Wells, an area of approximately 3 acres, groundwater concentrations would be cleaned up to cleanup levels for fluoride and cyanide within approximately two years following full implementation of ex situ treatment. The residual risk from groundwater in this area is low as groundwater concentrations would be better than cleanup levels and MCLs and institutional controls will restrict access to groundwater.

Groundwater concentrations downgradient of the Compliance Wells is not monitored by MCT and was not simulated with the Partitioning Model. However, groundwater conditions downgradient of the Compliance Wells can be qualitatively estimated by extrapolation of observed and Partitioning Model-simulated upgradient groundwater concentrations and trends. By extrapolation, groundwater concentrations for some distance downgradient of the Compliance Wells is expected to meet cleanup levels in roughly a similar amount of time as for upgradient areas, perhaps two to five years. The residual risk is estimated to be low as groundwater concentrations would be better than cleanup levels and MCLs and State and Spokane County restrictions on groundwater use will restrict access to groundwater.

Management of Treatment Residuals

Ex situ treatment will create treatment residuals (quantified in Table 5-9 above) consisting of cyanide and fluoride-bearing sludge during operation. These residuals will be disposed off-Site in permitted hazardous waste landfills and will not pose further risk.

5.8.6 Management of Short-Term Risks

This alternative will require installation of approximately four groundwater extraction wells which will expose workers to sediment and water containing cyanide and fluoride. Workers would also be exposed to purge water from well monitoring activities. During these activities, worker exposure would be limited by the use of proper personal protective equipment (PPE). Purge water with concentrations exceeding cleanup levels has been classified as hazardous and will be sent off-Site for proper disposal at a permitted facility.

Certain reagents (e.g., sodium hydroxide) that might be employed may be harmful if mishandled or spilled. Proper engineering controls, PPE and standard operating procedures will be developed for storage, handling and use of potentially harmful chemicals.

5.8.7 Technical and Administrative Implementability

This alternative is technically possible although there are uncertainties regarding optimal operating conditions for the combined iron precipitation - EC system that would be addressed during pilot testing.

This alternative requires access to land outside the MCT property for groundwater extraction well installation and maintenance and monitoring. This alternative requires approximately 0.5 acres of land for the groundwater infiltration pond if that disposal option is selected during engineering design. Agreements for land access for the infiltration pond will be needed unless the system is located on Mead Custodial Trust property. Possible locations for the infiltration pond includes areas to the north of the sludge pond (Kaiser Aluminum Properties, Inc. property), west and south of the SPL pile (Spokane Recycling property) and land within the BPA power line easement. This alternative may require an easement for pipeline access to the municipal sewer system if that disposal option is selected during engineering design. The Trust currently has an easement across Parcel 6 that would provide access to the municipal waste line. There is potentially a cheaper access to the waste line that would require a new easement.

As described in Section 5.5.7 for Alternative C(100), this alternative also would require a permit, or meeting the substantive requirements of a permit, for discharge to either groundwater through an infiltration pond or to the Spokane County Riverside Park Water Reclamation Facility and subsequently to the Spokane River. A comparison of expected treated water quality for this alternative and groundwater quality standards and Spokane County Local Limits is provided in Table 5-7 in Section 5.5.7. With the possible exception of nitrate in discharge to groundwater, the quality of treated water is not expected to pose any impediments to discharge permitting.

This alternative would not require a water right provided that no water is beneficially used (WA Ecology, 2018). No beneficial use of water is required in this alternative.

5.9 ALTERNATIVE D(50) – EX SITU TREATMENT (IRON PRECIPITATION-EC) AT RATE OF 50 GPM PLUS ALTERNATIVE A

5.9.1 Process Description

The process for Alternative D(50) would be identical to Alternative D(100) as described in Section 5.8.1 with the exception that pumping and treatment of water would be done at a rate of 50 gpm.

5.9.2 Protectiveness

Estimated Time to Meet Cleanup Levels at Compliance Wells

Alternative D(50) would attain cleanup levels in groundwater at the Compliance Wells in an estimated in an estimated 28 to 40 years for cyanide and 38 to 80 years for fluoride. Once cleanup levels are met, continued operation of the pumping and treatment systems is required to maintain cleanup levels at the Compliance Wells. The duration of continued ex situ treatment is estimated based on the Partitioning Model to range from approximately 30 to 80 years for cyanide and 50 to 130 years for fluoride.

Mass of Contaminants Removed from Groundwater System

Alternative D(50) would remove approximately 41,000 kg of fluoride and 67,000 kg of cyanide from the groundwater system over 30 years of operation; and 74,000 kg of fluoride and 106,000 kg of cyanide over 80 years of operation.

Reduction in Mass Flux Beyond the Compliance Wells

This alternative will remove contaminant mass from the groundwater system and reduce the mass flux of contaminants to groundwater downgradient of the extraction wells, to and beyond the Compliance Wells. Relative to Alternative A MNA, Alternative D(50) would reduce the mass flux of fluoride and cyanide by approximately 50 percent over the 30 to 80 years of operation.

5.9.3 Permanence

Alternative D(50) is less permanent than alternatives that use higher pumping and treatment rates (i.e., Alternatives C(100) and D(100)) as lower masses of fluoride and cyanide will be removed from groundwater. Consequently, lower quantities of treatment residuals will also be generated.

Destruction of Hazardous Substances

Fluoride is an element and thus cannot be destroyed by this or any other alternative. This alternative will convert the more toxic free and WAD forms of cyanide to stable iron cyanide solids. This alternative removes cyanide and fluoride from groundwater and produces cyanide and fluoride-bearing sludge that will be disposed in an off-Site hazardous waste landfill.

Reduction or Elimination of Hazardous Substance Releases and Sources of Releases

Release of contaminants from wastes on the MCT property to groundwater is currently controlled by previously completed and maintained remedial actions (e.g., containment of waste in the capped SPL pile, monitoring and maintenance of water lines, etc.). This alternative will not provide further control of contaminant releases to groundwater above that currently provided by Alternative A-MNA.

Degree of Irreversibility of Waste Treatment Process

This alternative treats contaminated groundwater rather than source materials. Fluoride and cyanide removed from groundwater will be concentrated into a sludge that will be disposed off-Site in a hazardous waste landfill.

Characteristics and Quantity of Treatment Residuals Generated

This alternative will generate approximately 38,000 tons of cyanide and fluoride-bearing water treatment sludge over 30 years and 101,000 tons over 80 years (see Table 5-9, above comparison with other FeP-EC alternatives).

5.9.4 Cost

Costs estimated for this alternative include:

- Costs associated with the Alternative A component (i.e., annual inspection and monitoring costs and periodic maintenance costs for asphalt repairs and weed control on the SPL pile for the next 30 to 80 years);
- Costs for a pilot test and final design/engineering of the iron precipitation and EC technologies; and
- Construction and operation of the pumping system and iron precipitation-EC treatment technologies for an estimated 30 to 80 years.

Costs for this alternative are derived from estimated full-scale implementation costs based on results of the 2013 Ex Situ treatability study (Appendix B) and quotes from Baker Corporation for a full-scale EC operation. Table 5-10 in Section 5.8.4 above shows capital and operating expenses for the iron precipitation-EC alternatives at pumping and treatment rates of 25, 50, and 100 gpm systems. Table 5-11 in Section 5.8.4 shows estimated NPVs for construction and 30 to 80 years of operation for the iron precipitation-EC alternatives at pumping and treatment rates of 25, 50, and 100 gpm systems.

5.9.5 Long-Term Effectiveness

Alternative D(50) ranks moderately high relative to Ecology's order of preference for types of cleanup action as it results in immobilization of the cyanide and fluoride contaminants by removing them from the environment/groundwater system at rates that are estimated to capture approximately one half of the groundwater contaminant plume.

Degree of Certainty that Alternative will be Successful

The methods of treatment provided in Alternative D(50) (pumping of conventional wells for groundwater extraction; removal of cyanide by iron precipitation treatment; removal of fluoride by EC) are well established and commonly employed for water treatment. The level of effectiveness of the treatment methods was verified under laboratory conditions as described in Appendices B and C, but the combination of the iron precipitation process with the EC process has not been verified. Additional verification of the effectiveness of these treatments will be determined during confirmation testing.

Reliability

The reliability of this alternative is predicted to be good, provided that appropriate process equipment is utilized and operators have sufficient training and experience in utilizing the process equipment. This alternative assumes employment of 1.5 full-time operators for operation and maintenance of the system.

Residual Risk

Implementation of this alternative would reduce risk by reducing concentrations of cyanide and fluoride in groundwater downgradient of the extraction wells.

Residual risk would vary with location and would be similar to Alternative A MNA upgradient of the extraction wells and lower than Alternative A downgradient of the extraction wells and Compliance Wells. This alternative does not provide any additional controls than Alternative A upgradient of the extraction wells. Identical to Alternative A, upgradient of the extraction wells, groundwater concentrations within the contaminant plume area (approximately 30 acres) are predicted by the Partitioning Model to exceed cleanup levels for 33 to 80 years for cyanide and 52 to 130 years for fluoride. Over time, the areal extent of the groundwater contaminant plume would shrink and the concentrations of fluoride and cyanide would decline. The residual risk from groundwater concentrations exceeding cleanup levels is estimated to be low as institutional controls will restrict access to groundwater.

Within the contaminant plume from the extraction wells to the Compliance Wells, an area of approximately 3 acres, groundwater concentrations would be cleaned up to cleanup levels within 28 to 40 years for cyanide and 38 to 80 years for fluoride following full implementation of ex situ treatment. Prior to attainment of cleanup levels, risk in this area would be lower than under Alternative A as groundwater concentrations would be lower. After attainment of cleanup levels in 28 to 80 years, residual risk from groundwater in this area is low as groundwater concentrations would be better than MCLs and institutional controls will restrict access to groundwater.

Groundwater concentrations downgradient of the Compliance Wells is not monitored by MCT and was not simulated with the Partitioning Model. However, groundwater conditions downgradient of the Compliance Wells can be qualitatively estimated by extrapolation of observed and Partitioning Model-simulated upgradient groundwater concentrations and trends. By extrapolation, groundwater concentrations for some distance downgradient of the Compliance Wells is expected to exceed cleanup levels for a roughly a similar amount of time as for upgradient areas, perhaps a few to several decades. The residual risk from groundwater concentrations exceeding cleanup levels is estimated to be low as State and Spokane County restrictions on groundwater use will restrict access to groundwater.

<u>Management of Treatment Residuals</u>

Ex situ treatment will create treatment residuals (quantified in Table 5-9 above) consisting of cyanide and fluoride-bearing sludge during operation. These residuals will be disposed off-Site in permitted hazardous waste landfills and will not pose further risk.

5.9.6 Management of Short-Term Risks

This alternative will require installation of approximately four groundwater extraction wells which will expose workers to sediment and water containing cyanide and fluoride. Workers would also be exposed to purge water from well monitoring activities. During these activities, worker exposure would be limited by the use of proper personal protective equipment (PPE). Purge water with concentrations exceeding cleanup levels has been classified as hazardous and will be sent off-Site for proper disposal at a permitted facility.

Certain reagents (e.g., sodium hydroxide) that might be employed may be harmful if mishandled or spilled. Proper engineering controls, PPE and standard operating procedures will be developed for storage, handling and use of potentially harmful chemicals.

5.9.7 Technical and Administrative Implementability

This alternative is technically possible although there are uncertainties regarding optimal operating conditions for the combined iron precipitation - EC system that would be addressed during conformational testing. This alternative requires access to land outside the MCT property for groundwater extraction well installation and maintenance and monitoring. This alternative requires approximately 0.5 acres of land for the groundwater infiltration pond (if this disposal option is selected during engineering design). Agreements for land access for the infiltration pond will be needed unless the system is located on Mead Custodial Trust property. Possible locations for the infiltration pond includes areas to the north of the sludge pond (Kaiser Aluminum Properties, Inc. property), west and south of the SPL pile (Spokane Recycling property) and land within the BPA power line easement. This alternative may require an easement for pipeline access to the municipal sewer system if that disposal option is selected during engineering design. The Trust currently has an easement across Parcel 6 that would provide access to the municipal waste line. There is potentially a cheaper access to the waste line that would require a new easement.

As described in Section 5.5.7 for Alternative C(100), this alternative also would require a permit, or meeting the substantive requirements of a permit, for discharge to either groundwater through an infiltration pond or to the Spokane County Riverside Park Water

Reclamation Facility and subsequently to the Spokane River. A comparison of expected treated water quality for this alternative and groundwater quality standards and Spokane County Local Limits is provided in Table 5-7 in Section 5.5.7. With the possible exception of nitrate in discharge to groundwater, the quality of treated water is not expected to pose any impediments to discharge permitting.

This alternative would not require a water right provided that no water is beneficially used (WA Ecology, 2018). No beneficial use of water is required in this alternative.

5.10 ALTERNATIVE D(25) – EX SITU TREATMENT (IRON PRECIPITATION-EC) AT RATE OF 25 GPM PLUS ALTERNATIVE A

5.10.1 Process Description

The process for Alternative D(25) would be identical to Alternative D(100) as described in Section 5.8.1 with the exception that pumping and treatment of water would be done at a rate of 25 gpm.

5.10.2 Protectiveness

Estimated Time to Meet Cleanup Levels at Compliance Wells

Alternative D(25) would attain cleanup levels in groundwater at the Compliance Wells in an estimated in an estimated 32 to 66 years for cyanide and 46 to 110 years for fluoride. Once cleanup levels are met, continued operation of the pumping and treatment systems is required to maintain cleanup levels at the Compliance Wells. The duration of continued ex situ treatment is estimated based on the Partition Model to range from approximately 30 to 80 years for cyanide and 50 to 130 years for fluoride.

Mass of Contaminants Removed from Groundwater System

Alternative D(25) would remove approximately 20,000 kg of fluoride and 34,000 kg of cyanide from the groundwater system over 30 years of operation; and 37,000 kg of fluoride and 58,000 kg of cyanide over 80 years of operation.

Reduction in Mass Flux Beyond the Compliance Wells

This alternative will remove contaminant mass from the groundwater system and reduce the mass flux of contaminants to groundwater downgradient of the extraction wells, to and beyond the Compliance Wells. Relative to Alternative A MNA, Alternative C(25) would reduce the mass flux of fluoride and cyanide by approximately 25 percent over the 30 to 80 years of operation.

5.10.3 Permanence

Alternative D(25) is less permanent than alternatives that use higher pumping and treatment rates (i.e., Alternatives C(100), D(100), C(50), D(50)) as lower masses of fluoride and cyanide will be removed from groundwater. Consequently, lower quantities of treatment residuals will also be generated.

Destruction of Hazardous Substances

Fluoride is an element and thus cannot be destroyed by this or any other alternative. This alternative will convert the more toxic free and WAD forms of cyanide to stable iron cyanide solids. This alternative removes cyanide and fluoride from groundwater and produces cyanide and fluoride-bearing sludge that will be disposed in an off-Site hazardous waste landfill.

Reduction or Elimination of Hazardous Substance Releases and Sources of Releases

Release of contaminants from wastes on the MCT property to groundwater is currently controlled by previously completed and maintained remedial actions (e.g., containment of waste in the capped SPL pile, monitoring and maintenance of water lines, etc.). This alternative will not provide further control of contaminant releases to groundwater above that currently provided by Alternative A-MNA.

Degree of Irreversibility of Waste Treatment Process

This alternative treats contaminated groundwater rather than source materials.

Characteristics and Quantity of Treatment Residuals Generated

This alternative will generate approximately 16,000 tons of cyanide and fluoride-bearing water treatment sludge over 30 years and 41,000 tons over 80 years (see Table 5-9, Section 5.8.3 for comparison with other FeP-EC alternatives).

5.10.4 Cost

Costs estimated for this alternative include:

- Costs associated with the Alternative A component (i.e., annual inspection and monitoring costs and periodic maintenance costs for asphalt repairs and weed control on the SPL pile for the next 30 to 80 years);
- Costs for a pilot test and final design/engineering of the iron precipitation and EC technologies; and
- Construction and operation of the pumping system and iron precipitation-EC treatment technologies for an estimated 30 to 80 years.

Costs for this alternative are derived from estimated full-scale implementation costs based on results of the 2013 Ex Situ treatability study (Appendix B) and quotes from Baker Corporation for a full-scale EC operation. Table 5-10 in Section 5.8.4 above shows capital and operating expenses for the iron precipitation-EC alternatives at pumping and treatment rates of 25, 50, and 100 gpm systems. Table 5-11 in Section 5.8.4 shows estimated NPVs for construction and 30 to 80 years of operation for the iron precipitation-EC alternatives at pumping and treatment rates of 25, 50, and 100 gpm.

5.10.5 Long-Term Effectiveness

Alternative D(25) ranks moderately high relative to Ecology's order of preference for types of cleanup action as it results in immobilization of the cyanide and fluoride contaminants by removing them from the environment/groundwater system at rates that are estimated to capture approximately 25 percent of the groundwater contaminant plume.

Degree of Certainty that Alternative will be Successful

The methods of treatment provided in Alternative D(25) (pumping of conventional wells for groundwater extraction; removal of cyanide by iron precipitation treatment; removal of fluoride by EC) are well established and commonly employed for water treatment. The level of effectiveness of the treatment methods was verified under laboratory conditions as described in Appendices B and C, but the combination of the iron precipitation process with the EC process has not been verified. Additional verification of the effectiveness of these treatments will be done during confirmation testing.

Reliability

The reliability of this alternative is predicted to be good, provided that appropriate process equipment is utilized and operators have sufficient training and experience in utilizing the process equipment. This alternative assumes employment of 1.5 full-time operators for operation and maintenance of the system.

Residual Risk

Implementation of this alternative would reduce risk by reducing concentrations of cyanide and fluoride in groundwater downgradient of the extraction wells.

Residual risk would vary with location and would be similar to Alternative A MNA upgradient of the extraction wells and lower than Alternative A downgradient of the extraction wells and Compliance Wells. This alternative does not provide any additional controls than Alternative A upgradient of the extraction wells. Identical to Alternative A, upgradient of the extraction wells, groundwater concentrations within the contaminant plume area (approximately 30 acres) are predicted by the Partitioning Model to exceed cleanup levels for 33 to 80 years for cyanide and 52 to 130 years for fluoride. Over time, the areal extent of the groundwater contaminant plume would shrink and the concentrations of fluoride and cyanide would decline. The residual risk from groundwater concentrations exceeding cleanup levels is estimated to be low as institutional controls will restrict access to groundwater.

Within the contaminant plume from the extraction wells to the Compliance Wells, an area of approximately 3 acres, groundwater concentrations would be cleaned up to cleanup levels within 32 to 66 years for cyanide and 46 to 110 years for fluoride following full implementation of ex situ treatment. Prior to attainment of cleanup levels, risk in this area would be lower than under Alternative A as groundwater concentrations would be lower. After attainment of cleanup levels, residual risk from groundwater in this area is low as groundwater concentrations would be better than MCLs and institutional controls will restrict access to groundwater.

Groundwater concentrations downgradient of the Compliance Wells is not monitored by MCT and was not simulated with the Partitioning Model. However, groundwater conditions downgradient of the Compliance Wells can be qualitatively estimated by extrapolation of observed and Partitioning Model-simulated upgradient groundwater concentrations and trends. By extrapolation, groundwater concentrations for some distance downgradient of the Compliance Wells is expected to exceed cleanup levels for a roughly a similar amount of time as for upgradient areas, perhaps a few to several decades. The residual risk from groundwater concentrations exceeding cleanup levels is estimated to be low as State and Spokane County restrictions on groundwater use will restrict access to groundwater.

Management of Treatment Residuals

Ex situ treatment will create treatment residuals (quantified in Table 5-9 above) consisting of cyanide and fluoride-bearing sludge during operation. These residuals will be disposed off-Site in permitted hazardous waste landfills and will not pose further risk.

5.10.6 Management of Short-Term Risks

This alternative will require installation of approximately four groundwater extraction wells which will expose workers to sediment and water containing cyanide and fluoride. Workers would also be exposed to purge water from well monitoring activities. During these activities, worker exposure would be limited by the use of proper personal protective equipment (PPE). Purge water with concentrations exceeding cleanup levels has been classified as hazardous and will be sent off-Site for proper disposal at a permitted facility.

Certain reagents (e.g., sodium hydroxide) that might be employed may be harmful if mishandled or spilled. Proper engineering controls, PPE and standard operating procedures will be developed for storage, handling and use of potentially harmful chemicals.

5.10.7 Technical and Administrative Implementability

This alternative is technically possible although there are uncertainties regarding optimal operating conditions for the combined iron precipitation - EC system that would be addressed during confirmation testing.

This alternative requires access to land outside the MCT property for groundwater extraction well installation and maintenance and monitoring. This alternative requires approximately 0.5 acres of land for the groundwater infiltration pond (if this disposal option is selected during engineering design). Agreements for land access for the infiltration pond will be needed unless the system is located on Mead Custodial Trust property. Possible locations for the infiltration pond includes areas to the north of the sludge pond (Kaiser Aluminum Properties, Inc. property), west and south of the SPL pile (Spokane Recycling property) and land within the BPA power line easement. This alternative may require an easement for pipeline access to the municipal sewer system if that disposal option is selected during engineering design. The Trust currently has an easement across Parcel 6 that would provide access to the municipal waste line. There is potentially a cheaper access to the waste line that would require a new easement.

As described in Section 5.5.7 for Alternative C(100), this alternative also would require a permit, or meeting the substantive requirements of a permit, for discharge to either groundwater through an infiltration pond or to the Spokane County Riverside Park Water Reclamation Facility and subsequently to the Spokane River. A comparison of expected treated water quality for this alternative and groundwater quality standards and Spokane County Local Limits is provided in Table 5-7 in Section 5.5.7. With the possible exception of nitrate in discharge to groundwater, the quality of treated water is not expected to pose any impediments to discharge permitting.

This alternative would not require a water right provided that no water is beneficially used (WA Ecology, 2018). No beneficial use of water is required in this alternative.

6.0 COMPARISON OF CLEANUP ALTERNATIVES

As per the Consent Decree governing this cleanup action (Task 5 of the RAP), the purpose of this SFS is to develop and evaluate groundwater remedial action alternatives for the Kaiser Mead Site. The Oversight Agency (Ecology) has the authority to select a Supplemental Groundwater Remedial Action based on the SFS, the administrative record for the Site, and in accordance with the applicable MTCA and CERCLA regulations. This Section summarizes the comparative evaluation of the eight remedial alternatives described in Section 5 and provides a qualitative/semi-quantitative evaluation of each alternative with respect to the MTCA criteria included in WAC 173-340-360(3)(e) as part of the DCA procedures.

6.1 DISPROPORTIONATE COST ANALYSIS (DCA)

MTCA requirements for conducting a DCA (WAC 173-340-360(3)(e)(ii)(A)) specify that:

> *"alternatives evaluated in the feasibility study shall be ranked from most to least permanent, based on the evaluation of the alternatives under [the criteria listed above]. The most practicable permanent solution evaluated in the feasibility study shall be the baseline cleanup action alternative against which cleanup action alternatives are compared. If no permanent solution has been evaluated in the feasibility study, the cleanup action alternative evaluated in the feasibility study that provides the greatest degree of permanence shall be the baseline cleanup alternative."*

MTCA further notes (WAC 173-340-360(3)(e)(ii)(C)) that:

> *The comparison of benefits and costs may be quantitative, but will often be qualitative and require the use of best professional judgment. In particular, the department has the discretion to favor or disfavor qualitative benefits and use that information in selecting a cleanup action.*

Ecology provided the scoring, rationale, and category weighting for the DCA provided in this Section based on a review of the information in the draft SFS (Hydrometrics, 2017b).

DCA scoring matrices for each criterion are included in Appendix H. Figures 6-1 and 6-2 and Table 6-1 summarize the DCA results in graphical and tabular format. The DCA analysis was conducted as follows:

1. Each DCA criterion was given a weighting factor:
    a. 30% for protectiveness;
    b. 25% for permanence;
    c. 25% for long-term effectiveness;
    d. 10% for short-term risks; and
    e. 10% for technical and administrative implementability.
2. Weighted criteria scores were calculated for each alternative.
3. Overall Preliminary Environmental Benefit (EB) Score was calculated as the sum of the weighted criteria scores for each alternative. The highest possible Preliminary Environmental Benefit Score is 10.
4. The Alternatives were ranked according to Preliminary EB Score (rank of 1 for highest score, 8 for lowest score).
5. Two DCA criteria, cost and public concerns, were not scored and included in the EB Score. Costs are scaled versus the EB Score in the DCA. Public concerns will be considered by Ecology following public comment.
6. Costs were based on 30-year and 80-year net present value (NPV) costs. Estimated costs are intended to provide a relative comparison between alternatives, and are considered to be +/-25 percent of actual costs. Costs are carried out to life of remedy operation, estimated to range from 30 to 80 years for all alternatives for cost comparison. The 30-year remedial action duration corresponds to a "best case" situation where fluoride and cyanide concentrations are reduced by MNA at rates equal or better than Partitioning Model simulations that yield the shortest estimated time to meet cleanup levels at Compliance Wells. The 30-year remedial action duration also corresponds to the estimated shortest duration that pumping and treatment would be required under ex situ treatment alternatives. The 80-year

FIGURE 6-1. COMPARISON OF ESTIMATED 30 YEAR NPV COST AND ENVIRONMENTAL BENEFIT FOR CLEANUP ALTERNATIVES

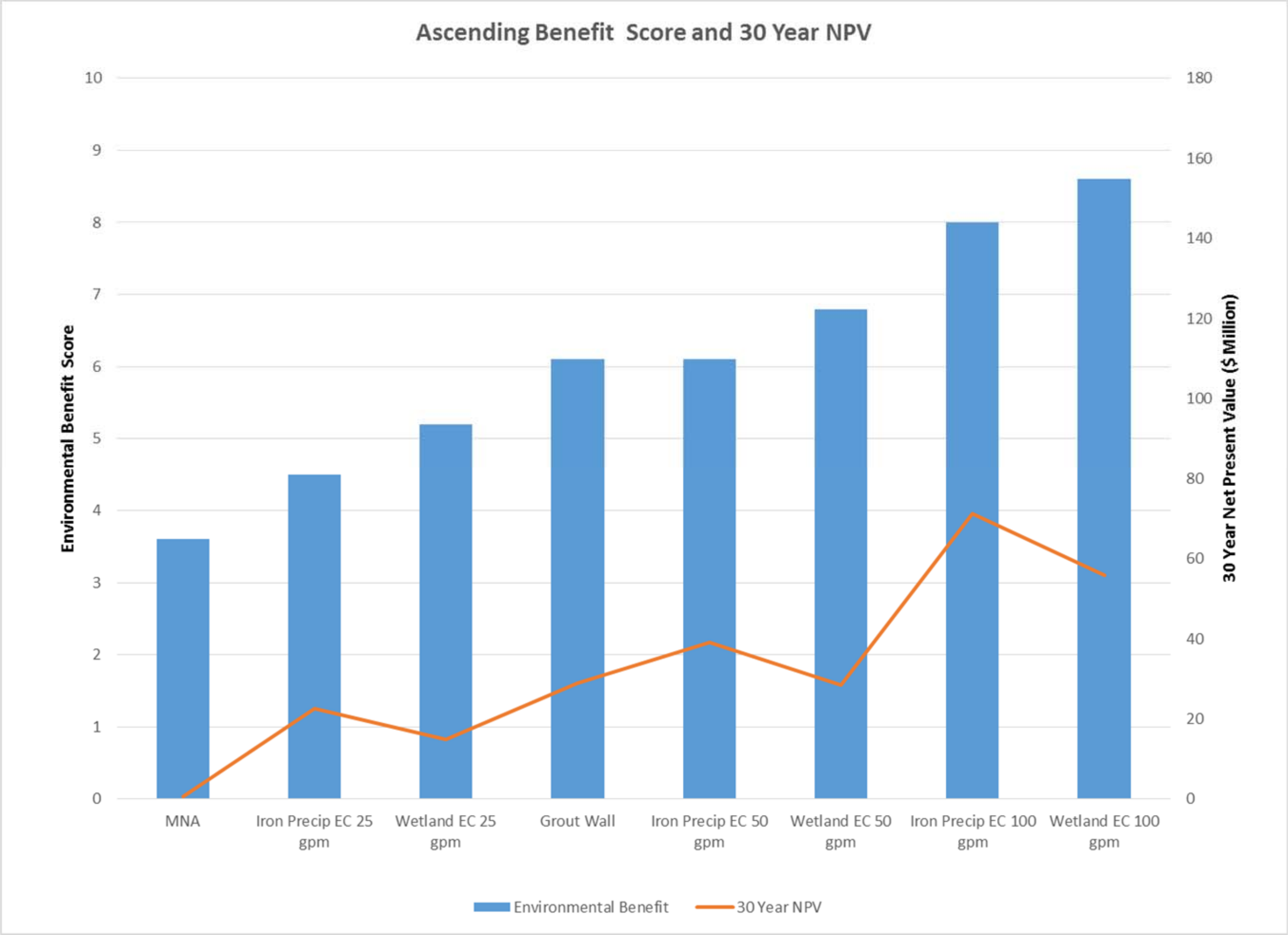


FIGURE 6-2. COMPARISON OF ESTIMATED 80 YEAR NPV COST AND ENVIRONMENTAL BENEFIT FOR CLEANUP ALTERNATIVES

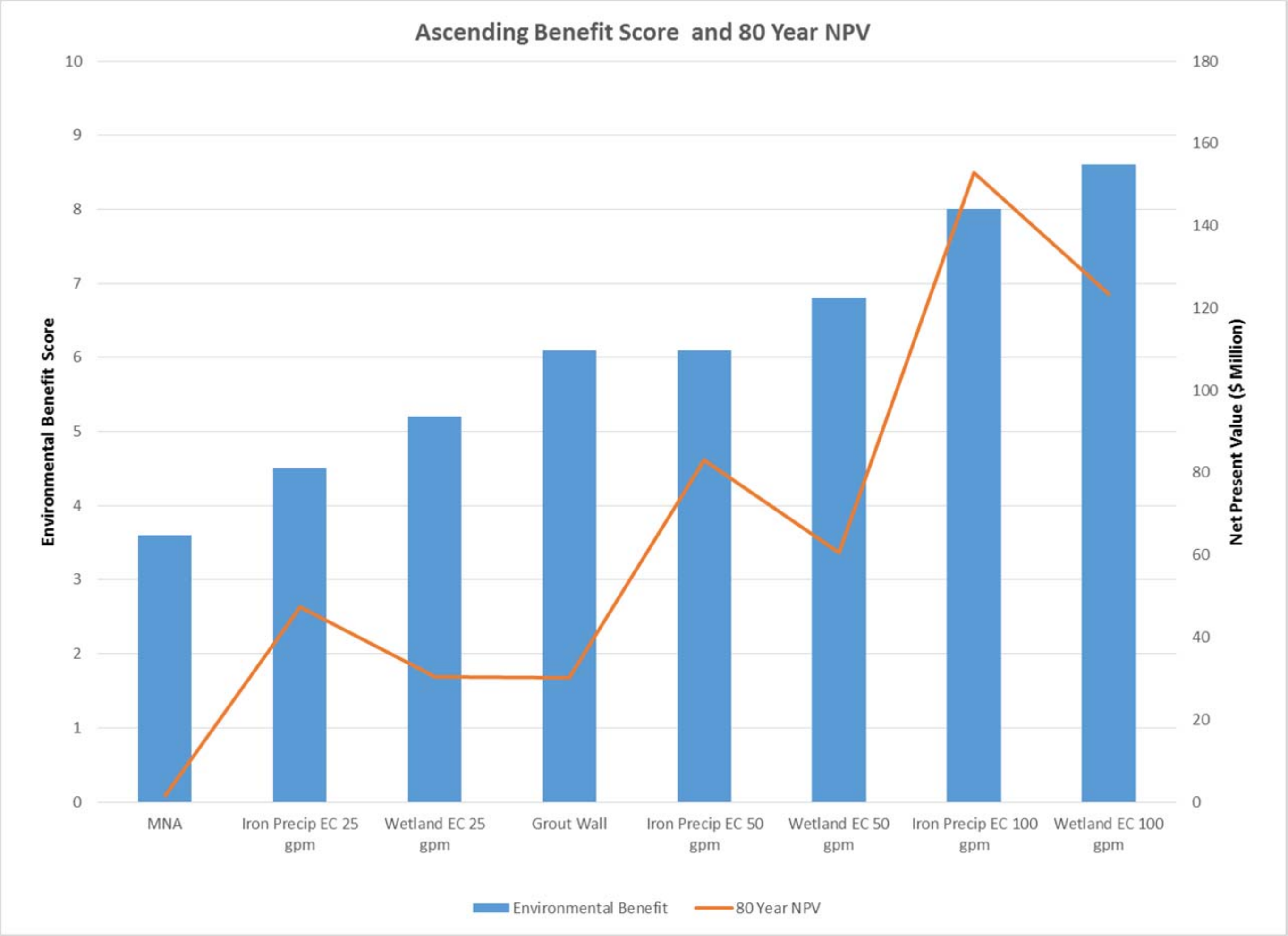


TABLE 6-1. SUMMARY OF PRELIMINARY DISPROPORTIONATE COST ANALYSIS

Scoring of Environmental Benefit by Evaluation Criteria (WAC 173-340-360(3)(f)							COST	
Remedial Alternative	Protectiveness (30%)	Permanence (25%)	Long-Term Effectiveness (25%)	Short Term Risk Management (10%)	Technical and Administrative Implementability (10%)	Environmental Benefit Score	30 yr cost ($ Millions, NPV)	80 yr cost ($ Millions, NPV)
Alternative A-MNA	2	2	2	10	10	3.6	$ 0.7	$ 1.5
Alternative B Grout Wall	7	5	5	8	7	6.1	$ 29.0	$ 30.1
Alternative C(100) Wetland EC 100 gpm	10	8	8	9	7	8.6	$ 55.8	$ 123.4
Alternative C(50) Wetland EC 50 gpm	7	6	6	9	8	6.8	$ 28.4	$ 60.7
Alternative C(25) Wetland EC 25 gpm	5	4	4	9	8	5.2	$ 14.8	$ 30.5
Alternative D(100) Iron Precip EC 100 gpm	9	7	7	9	9	8.0	$ 71.3	$ 152.9
Alternative D(50) Iron Precip EC 50 gpm	6	5	5	9	9	6.1	$ 39.1	$ 83.1
Alternative D(25) Iron Precip EC 25 gpm	4	3	3	9	9	4.5	$ 22.5	$ 47.3

remedial action duration corresponds to a “worst case” situation for cyanide treatment and an “average case” situation for fluoride. For cyanide, the 80-year duration assumes that concentrations are reduced by MNA at rates equal to Partitioning Model simulations that yield the longest estimated time to meet cleanup levels at Compliance Wells. For fluoride, the 80-year duration assumes that concentrations are reduced by MNA at rates equal to Partitioning Model simulations that yield the mid-range estimated time to meet cleanup levels at Compliance Wells. The 80-year remedial action duration corresponds to the estimated longest duration that pumping and cyanide treatment would be required under ex situ treatment alternatives and the average duration that pumping and fluoride treatment would be required under ex situ treatment alternatives.

The DCA scoring process is qualitative to semi-quantitative and requires subjective judgments to rank or score the alternatives. The primary uncertainties or variables in the DCA scoring process are:

1. Weighting of criteria – MTCA includes no guidance on weighting of the criteria. The selected weighting factors were prepared with input from Ecology.
2. Some criteria are qualitative in nature but must be represented numerically. Thus, the scoring requires quantification of qualitative descriptors (e.g., good = 5, better = 7 etc.). The approach that was taken in this preliminary scoring was to establish the best and worst alternative for each criterion; establish an estimated range of numeric values (e.g., 5 for worst, 9 for best), and then assign intermediate scores to intermediate ranked alternatives. In these cases, the selection of range (ex., 5 to 9 vs 0 to 10, or 8 to 10) and the relative scoring of qualitative descriptors exerts a strong control on overall final scores.

6.2 SUMMARY OF ENVIRONMENTAL BENEFITS AND COSTS

The purpose of this section is to summarize several key factors that were considered in the DCA: time to meet cleanup levels, contaminant mass removed from groundwater, contaminant mass remaining in aquifer sediment, and reduction in the flux of contaminants past the Compliance Wells to downgradient groundwater over 30 and 80 year operational life of the Alternatives. Tables 6-2 through 6-5 summarize the environmental benefits for these key factors that are predicted to be attained by each alternative for fluoride and cyanide.

Figures 6-3 through 6-6 show the fate and distribution of sediment contaminant mass after 30 and 80 years for each alternative. Because it is assumed that all ex situ treatment alternatives would achieve similar levels of contaminant removal, alternatives C(100) and D(100); C(50) and D(50); and C(25) and D(25) are predicted to perform identically with respect to these key factors.

TABLE 6-2. ESTIMATED COST AND ENVIRONMENTAL BENEFITS FOR FLUORIDE OVER 30 YEARS

Alternative	Estimated Cost ($ Million, 30 years, NPV)[1]	Estimated Time to Meet Cleanup Levels at Compliance Wells After Implementation (years)	Mass of Fluoride in Aquifer Sediment Upgradient of Compliance Wells after 30 years (kg)	Mass of Fluoride Removed from Groundwater by Pump & Treat over 30 Years (kg)	Mass of Fluoride Flowing Past Compliance Wells over 30 Years (kg)	Percent Reduction in Mass of Fluoride Flowing Past Compliance Wells over 30 Years[2]
A – MNA	$0.674	52 to 130	103,653	None	81,377	-
B + A Grout Wall + MNA	$28.99	31 to 51	137,748	None	45,563	44%
C(100) Pump & Treat Wetland-EC @ 100 gpm + MNA	$55.8	<2	101,066	82,068	1,170	96%
C(50) Pump & Treat Wetland-EC @ 50 gpm + MNA	$28.4	38 to 80	102,360	41,034	40,911	50%
C(25) Pump & Treat Wetland-EC @ 25 gpm + MNA	$14.8	46 to 110	103,006	20,517	60,781	25%
D(100) Pump & Treat (w/Iron Precipitation-EC) @ 100 gpm + MNA	$71.3	Same as Alternative C(100)				
D(50) Pump & Treat (w/Iron Precipitation-EC) @ 50 gpm + MNA	$39.1	Same as Alternative C(50)				
D(25) Pump & Treat (w/Iron Precipitation-EC) @ 25 gpm + MNA	$22.5	Same as Alternative C(25)				

Notes:

1) Net Present Value (NPV) assuming discount rate of 0.7 percent. Estimated costs are intended to provide a relative comparison between alternatives, and are considered to be +/-25 percent of actual costs.
2) Reduction relative to Alternative A-MNA.

TABLE 6-3. ESTIMATED COST AND ENVIRONMENTAL BENEFITS FOR CYANIDE OVER 30 YEARS

Alternative	Estimated Cost ($ Million, 30 years, NPV)[1]	Estimated Time to Meet Cleanup Levels at Compliance Wells After Implementation (years)	Mass of Total Cyanide Remaining in Sediment Upgradient of Compliance Wells after 30 years (kg)	Mass of Total Cyanide Removed from Groundwater by Pump & Treat over 30 Years (kg)	Mass of Total Cyanide Flowing Past Compliance Wells over 30 Years (kg)	Percent Reduction in Mass of Total Cyanide Flowing Past Compliance Wells over 30 Years[2]
A – MNA	$0.674	33 to 80	88,523	None	130,725	-
B + A Grout Wall + MNA	$28.99	<2 to 70	179,629	None	39,765	70%
C(100) Pump & Treat Wetland-EC @ 100 gpm + MNA	$55.8	<2	87,611	134,345	<1	>99%
C(50) Pump & Treat Wetland-EC @ 50 gpm + MNA	$28.4	28 to 40	87,035	67,189	66,012	50%
C(25) Pump & Treat Wetland-EC @ 25 gpm + MNA	$14.8	32 to 66	87,611	33,595	99,035	24%
D(100) Pump & Treat (w/Iron Precipitation-EC) @ 100 gpm + MNA	$71.3	Same as Alternative C(100)				
D(50) Pump & Treat (w/Iron Precipitation-EC) @ 50 gpm + MNA	$39.1	Same as Alternative C(50)				
D(25) Pump & Treat (w/Iron Precipitation-EC) @ 25 gpm + MNA	$22.5	Same as Alternative C(25)				

Notes:

1) Net Present Value (NPV) assuming discount rate of 0.7 percent. Estimated costs are intended to provide a relative comparison between alternatives, and are considered to be +/-25 percent of actual costs.
2) Reduction relative to Alternative A-MNA.

TABLE 6-4. ESTIMATED COST AND ENVIRONMENTAL BENEFITS FOR FLUORIDE OVER 80 YEARS

Alternative	Estimated Cost ($ Million, 80 years, NPV)[1]	Estimated Time to Meet Cleanup Levels at Compliance Wells After Implementation (years)	Mass of Fluoride Remaining in Sediment Upgradient of Compliance Wells after 80 years (kg)	Mass of Fluoride Removed from Groundwater by Pump & Treat over 80 Years (kg)	Mass of Fluoride Flowing Past Compliance Wells over 80 Years (kg)	Percent Reduction in Mass of Fluoride Flowing Past Compliance Wells over 80 Years[2]
A – MNA	$1.53	52 to 130	32,350	None	151,865	-
B + A Grout Wall + MNA	$30.1	31 to 51	106,319	None	78,650	48%
C(100) Pump & Treat Wetland-EC @ 100 gpm + MNA	$123.4	<2	32,336	148,881	3,087	98%
C(50) Pump & Treat Wetland-EC @ 50 gpm + MNA	$60.7	38 to 80	32,336	73,578	78,390	48%
C(25) Pump & Treat Wetland-EC @ 25 gpm + MNA	$30.5	46 to 110	32,336	34,968	117,000	23%
D(100) Pump & Treat (w/Iron Precipitation-EC) @ 100 gpm + MNA	$152.9	Same as Alternative C(100)				
D(50) Pump & Treat (w/Iron Precipitation-EC) @ 50 gpm + MNA	$83.1	Same as Alternative C(50)				
D(25) Pump & Treat (w/Iron Precipitation-EC) @ 25 gpm + MNA	$47.3	Same as Alternative C(25)				

Notes:

1) Net Present Value (NPV) assuming discount rate of 0.7 percent. Estimated costs are intended to provide a relative comparison between alternatives, and are considered to be +/-25 percent of actual costs.
2) Reduction relative to Alternative A-MNA.

TABLE 6-5. ESTIMATED COST AND ENVIRONMENTAL BENEFITS FOR CYANIDE OVER 80 YEARS

Alternative	Estimated Cost ($ Million, 80 years, NPV)[1]	Estimated Time to Meet Cleanup Levels at Compliance Wells After Implementation (years)	Mass of Total Cyanide Remaining in Aquifer Sediment after 80 years (kg)	Mass of Total Cyanide Removed from Groundwater by Pump & Treat over 80 Years (kg)	Mass of Total Cyanide Flowing Past Compliance Wells over 80 Years (kg)	Percent Reduction in Mass of Total Cyanide Flowing Past Compliance Wells over 80 Years[2]
A – MNA	$1.53	33 to 80	7,044	None	212,491	-
B + A Grout Wall + MNA	$30.1	<2 to 70	117,996	None	101,398	52%
C(100) Pump & Treat Wetland-EC @ 100 gpm + MNA	$123.4	<2	6,820	212,173	543	>99%
C(50) Pump & Treat Wetland-EC @ 50 gpm + MNA	$60.7	28 to 40	6,932	106,086	106,517	50%
C(25) Pump & Treat Wetland-EC @ 25 gpm + MNA	$30.5	32 to 66	6,988	53,043	159,504	25%
D(100) Pump & Treat (w/Iron Precipitation-EC) @ 100 gpm + MNA	$152.9	Same as Alternative C(100)				
D(50) Pump & Treat (w/Iron Precipitation-EC) @ 50 gpm + MNA	$83.1	Same as Alternative C(50)				
D(25) Pump & Treat (w/Iron Precipitation-EC) @ 25 gpm + MNA	$47.3	Same as Alternative C(25)				

Notes:

1) Net Present Value (NPV) assuming discount rate of 0.7 percent. Estimated costs are intended to provide a relative comparison between alternatives, and are considered to be +/-25 percent of actual costs.
2) Reduction relative to Alternative A-MNA.

FIGURE 6-3. FLUORIDE MASS DISTRIBUTION AFTER 30 YEARS OF CLEANUP ACTION

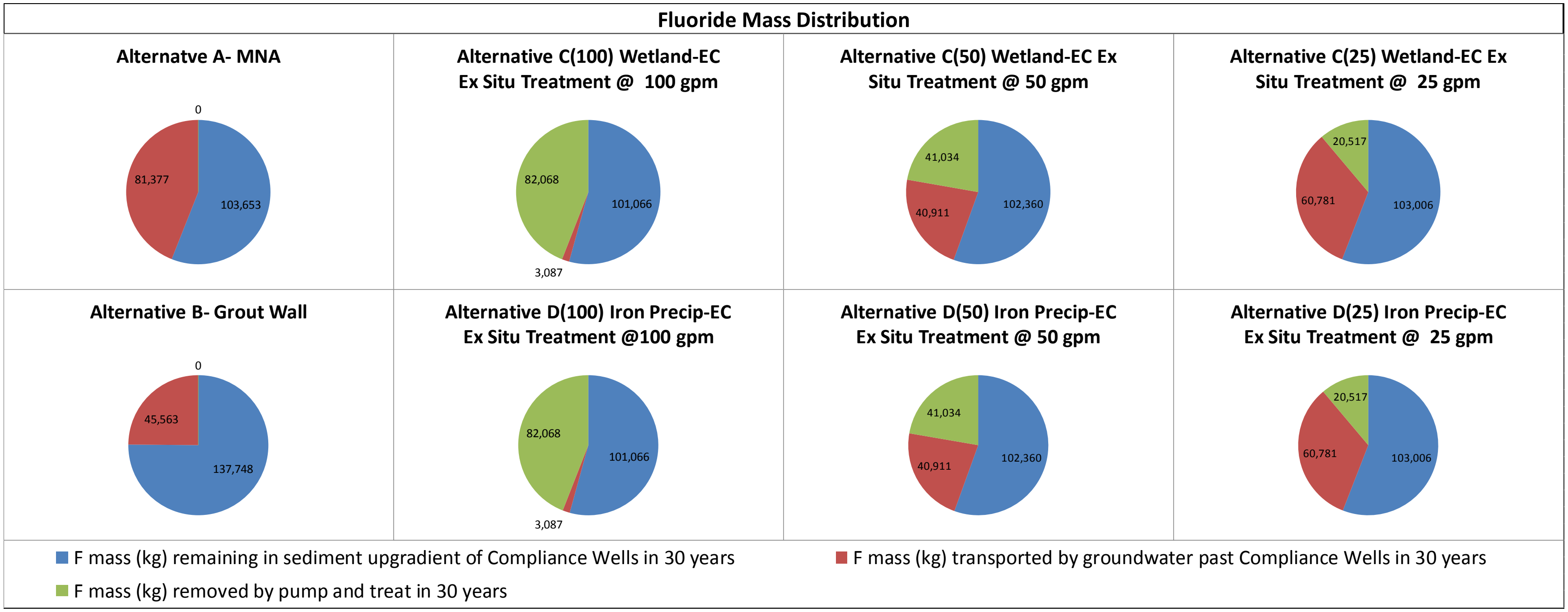


FIGURE 6-4. FLUORIDE MASS DISTRIBUTION AFTER 80 YEARS OF CLEANUP ACTION

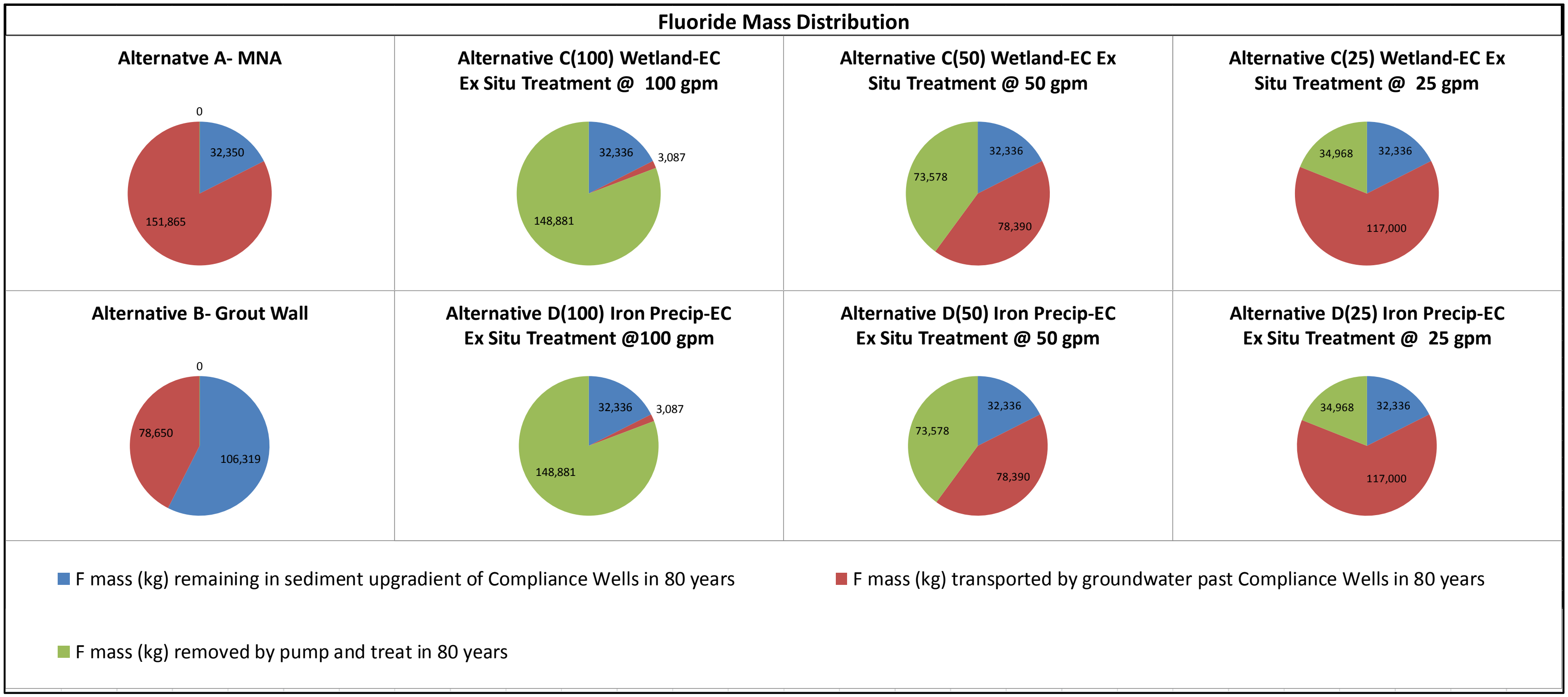


FIGURE 6-5. TOTAL CYANIDE MASS DISTRIBUTION AFTER 30 YEARS OF CLEANUP ACTION

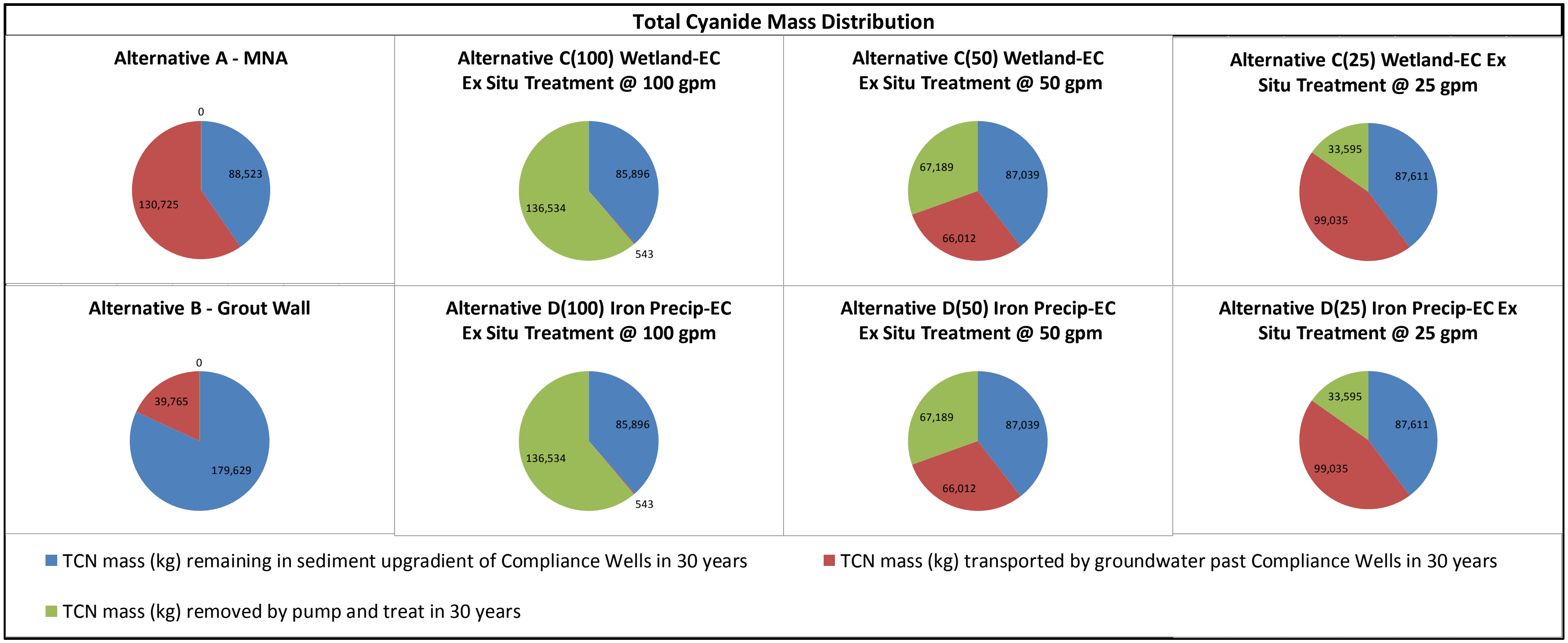
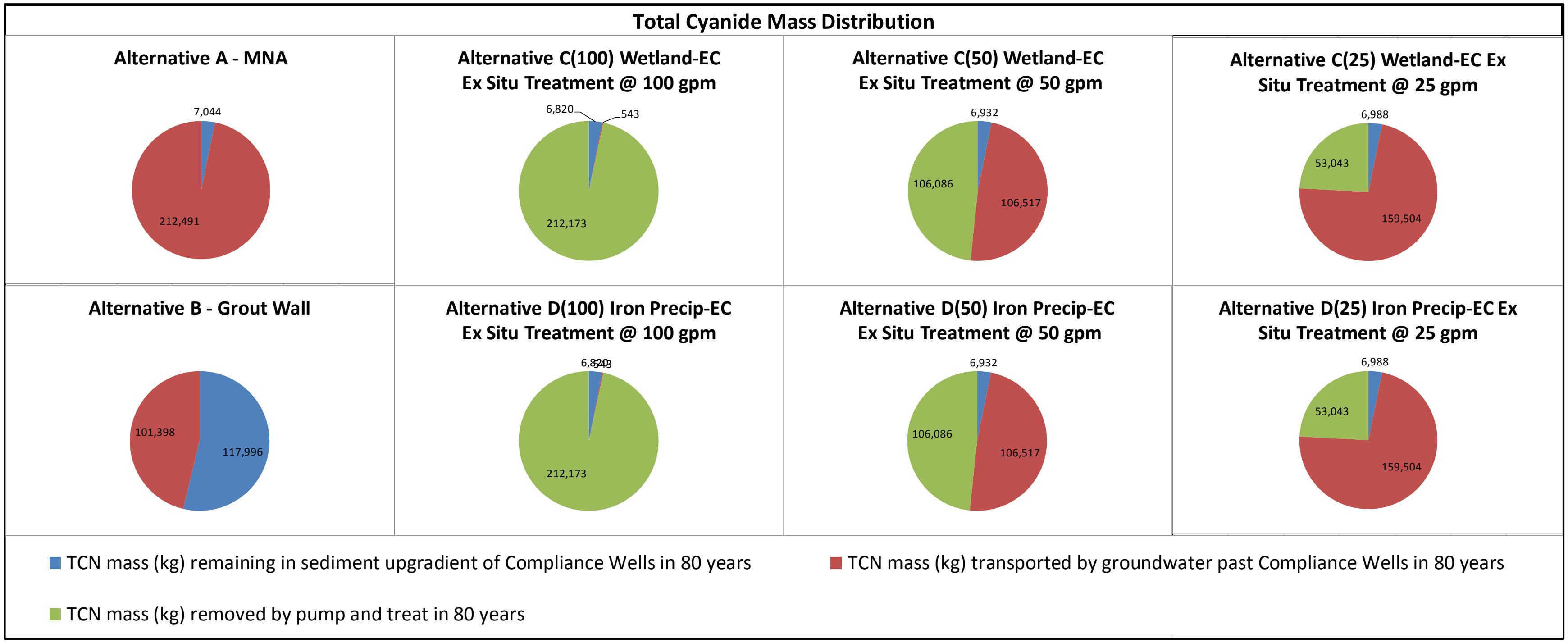


FIGURE 6-6. TOTAL CYANIDE MASS DISTRIBUTION AFTER 80 YEARS OF CLEANUP ACTION



6.3 REASONABLE RESTORATION TIMEFRAME

MTCA (WAC 173-340-360(2)(b)(ii)) requires that cleanup alternatives “Provide for a reasonable restoration time frame.” Under MTCA, “restoration time frame” means “the period of time needed to achieve the required cleanup levels at the points of compliance established for the Site.” Thus, the values for “Estimated Time to Meet Cleanup Levels at Compliance Wells After Implementation” given in Tables 6-3 through 6-6 (above) are the restoration time frames for the remedial alternatives. For the ex situ treatment alternatives C(100), C(50), C(25), D(100), D(50), and D(25), once cleanup levels are attained at the Compliance Wells, maintaining concentrations at cleanup levels requires continued operation of the pumping and treatment for an estimated 30 to 80 years for cyanide and 50 to 130 years for fluoride.

To determine whether a cleanup alternative provides for a reasonable restoration time frame, MTCA (WAC 173-340-360(4)(b)) specifies consideration of the following factors:

- Potential risks posed by the Site to human health and the environment;
- Practicability of achieving a shorter restoration time frame;
- Current use of the Site, surrounding areas, and associated resources that are, or may be, affected by releases from the Site;
- Potential future use of the Site, surrounding areas, and associated resources that are, or may be, affected by releases from the Site;
- Availability of alternative water supplies;
- Likely effectiveness and reliability of institutional controls;
- Ability to control and monitor migration of hazardous substances from the Site;
- Toxicity of the hazardous substances at the Site; and
- Natural processes that reduce concentrations of hazardous substances and have been documented to occur at the Site or under similar Site conditions.

As described in Tables 6-3 through 6-6 (above), potential restoration time frames range from relatively short periods of a few years for Alternatives C(100) and D(100) to relatively long periods of greater than 30 years for all other alternatives.

7.0 REFERENCES

Arconic, 2017. Draft Final Report for Ex Situ Treatability Study 2016 Activities for Kaiser Mead NPL Site. Prepared for Mead Custodial Trust. February 2017.

Dzombak, D, RS Ghosh, GM Wong-Chong, 2006. Cyanide in Water and Soil; chemistry, Risk, and Management. CRC Press, Taylor and Francis Group. 602 pp.

Hart Crowser, 1988. Site Characterization Analysis, KACC – Mead Plant. Prepared for Kaiser Aluminum & Chemical Corporation, December 1988.

Hydrometrics, Inc., 2012. Kaiser Mead NPL MTCA/CERCLA Performance Evaluation Report. Prepared for Mead Custodial Trust, March 2012.

Hydrometrics, Inc., 2013. Aquifer Characterization and Groundwater Capture Analysis for the Kaiser Mead Facility. Prepared for Mead Custodial Trust, June 2013.

Hydrometrics, Inc., 2017a. Data Report on Additional Field Characterization for the Kaiser Mead Facility. Prepared for Mead Custodial Trust, March 2017.

Hydrometrics, Inc., 2017b. Supplemental Feasibility Study Report for the Kaiser Mead Facility. Prepared for Mead Custodial Trust, November 2017.

Kadlec, RH and SD Wallace, 2009. Treatment Wetlands, 2nd. Ed. CRC Press - Taylor and Francis Group, LLC. Boca Raton.

McCulley, Frick & Gilman, 2002. Technical Memorandum. Groundwater Treatment Alternative Evaluation; Kaiser Mead Works. Prepared for Kaiser Aluminum & Chemical Corp. Mead, Washington. March 29, 2002.

McCulley, Frick & Gilman, 2004. Supplemental Groundwater Modeling Report Kaiser Aluminum & Chemical Corp. Mead, Washington. Draft January 29, 2004.

McDonald, M.G., and Harbaugh, A.W., 1988. A modular three-dimensional finite-difference ground-water flow model, Techniques of Water-Resources Investigations of the United States Geological Survey, Book 6, Chapter A1.

Panday, Sorab, Langevin, C.D., Niswonger, R.G., Ibaraki, Motomu, and Hughes, J.D., 2013. MODFLOW–USG version 1: An unstructured grid version of MODFLOW for simulating groundwater flow and tightly coupled processes using a control volume finite-difference formulation: U.S. Geological Survey Techniques and Methods, book 6, chap. A45, 66 p.

RETEC, 1993. Remediation Technologies, Inc. Feasibility Study for Cleanup Actions at the Kaiser-Mead NPL Site. February 1993.

Smith, A and T Mudder, 1991. The Chemistry and Treatment of Cyanidation Wastes. Mining Journal Books Limited, London. 345 pp.

United States Bankruptcy Court for the District of Delaware, 2004. Consent Decree Relating to Mead Aluminum Reduction Works; *In re Kaiser Aluminum Corporation*, Case No. 02-10429.

United States Environmental Protection Agency, 1999. Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action and Underground Storage Tank Sites. Office of Solid Waste and Emergency Response Directive 9200.4-17P. April 1999.

United States Environmental Protection Agency, 2000. Wastewater Technology Fact Sheet Free Water Surface Wetlands. Office of Water. EPA-832-F-00-024. September 2000.

United States Office of Management and Budget, 2016. Memorandum for the Heads of Departments and Agencies. 2017 Discount Rates for OMB Circular No. A-94. December 12, 2016.

Washington Department of Ecology, 2002. Cleanup Action Plan Kaiser Aluminum National Priorities List Site Mead, Washington. Prepared by Washington Department of Ecology; May 1, 2002.

Washington Department of Ecology, 2010. Spokane River and Lake Spokane, Dissolved Oxygen Total Maximum Daily Load, Water Quality Improvement Report Pub. No. 07-10-073, revised February 2010.

Washington Department of Ecology, 2011. Fact Sheet for NPDES Permit WA-0093317. Spokane Regional Water Reclamation Facility. Final Fact Sheet – November 28, 2011.

Washington Department of Ecology, 2015a. Ecology Review of May 2015 Kaiser Mead NPL Site – Submittal of Revised Draft Work Plan for Supplemental Feasibility Study 2015 Activities – In Situ Treatment Phase II Steps A and B Testing. Letter to Mead Custodial Trust. July 2, 2015.

Washington Department of Ecology, 2015b. Water Quality Program Permit Writer’s Manual. Revised January 2015. Publication no. 92-109.

Washington Department of Ecology, 2016. October 31, 2016 letter from Guy Barrett (Ecology) to Daniel J. Silver (Trustee); RE: Ecology Review of Cyanide in Determining Compliance with Groundwater Cleanup Levels at Kaiser Mead Site, FSID #3.

Washington Department of Ecology, 2018. August 20, 2018 email from Chad Goodwin (Ecology) to Scott Mason (Hydrometrics); RE: Water rights for pump and treat.

APPENDIX A

GROUNDWATER MODEL REPORT

GROUNDWATER MODEL REPORT
KAISER MEAD NPL SITE
MEAD, WASHINGTON

Prepared for:

Mead Custodial Trust
606 Columbia St. NW, Ste. 212
Olympia, WA 98501

Prepared by:

Hydrometrics, Inc.
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Helena, MT 59601

February 2017

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

GROUNDWATER MODEL REPORT
KAISER MEAD NPL SITE
MEAD, WASHINGTON

1.0 INTRODUCTION

A groundwater flow model of the Kaiser Mead NPL site (Kaiser Mead) was constructed as one aspect of the continuation of the Supplemental Feasibility Study (SFS) per the request by the Washington Department of Ecology (Ecology, 2014). The purpose of the SFS is to develop and evaluate cleanup action alternatives for the contaminated groundwater stemming from Kaiser Mead and to summarize the feasibility of the different remedial alternatives to achieve compliance with cleanup requirements established for this site.

1.1 MODEL OBJECTIVES

The following modeling objectives were developed in coordination with Ecology to evaluate potential remedial alternatives:

- Support refinement of the site conceptual model with respect to groundwater flow;
- Estimate groundwater flow rates within the A and B-Zone aquifers;
- Assess the effects on the groundwater flow system from potential remedies that impact flow through identified source areas by installation of a low permeability barrier (grout wall) or operation of extraction wells;
- Provide a tool that in conjunction with empirical data can assist in design of selected potential remedial alternatives (e.g., location, permeability and height of grout wall or location and number of capture wells); and
- Provide the ability to assess the effectiveness of an implemented alternative(s) (e.g., water level response to grout walls or extraction wells).

1.2 PREVIOUS MODELS

Groundwater models were constructed prior to the one presented in this report. In 2004, MFG prepared a model to predict effects of remedy implementation. This model proved inaccurate as discussed in the current CSM report (Hydrometrics, 2016a). In 2013, a simple analytical simulation of the flow field in the A-Zone aquifer was developed to show the potential effects of the grout curtain on groundwater flow in the SPL area (Hydrometrics, 2013a).

2.0 CONCEPTUAL MODEL

2.1 REGIONAL SETTING

The Kaiser Mead site is located approximately seven miles north of downtown Spokane in the western end of the Spokane Valley-Rathdrum Prairie (SVRP) aquifer near the northern end of the Hillyard Trough (Figure 2-1). The site lies at an elevation of 1930 to 1940 feet above mean sea level (amsl). The local alluvial aquifer system underlying the site is bound to the south by the Spokane River (5.5 miles from site), to the west by the Little Spokane River (2.5 miles from site), and Deadman Creek to the north (1.5 miles from site). The alluvial system is bound by bedrock uplands to the east.

2.2 GEOLOGIC SETTING

The SVRP aquifer is known as one of the most productive aquifers in the United States and is considered a "Sole Source Aquifer" as it is the only significant source of quality water supply in the Spokane Valley (Kahle et. al., 2005). The aquifer was formed from deposition of sand, gravel, cobble, and boulder sized material from a series of catastrophic glacial flood deposits from Glacial Lake Missoula. The high energy depositional environment resulted in a coarse grained aquifer system through the center of the SVRP aquifer (Kahle and Bartolino, 2007). The Kaiser Mead site is located on the surface of the Hillyard Trough, which is a unique component of the SVRP aquifer. The deposition in the Hillyard Trough is generally finer and typically consists of sands and fine gravels with layers of finer grained silts and clay that act as confining/semi-confining units and is reported to be approximately 255 to 280 feet thick (Kahle and Bartolino, 2007). The deposition of the finer grained material is likely due to "eddy" effect that occurred in this area during the catastrophic floods. The finer grained deposition has been well documented in the numerous monitoring wells and boreholes that have been completed beneath the Kaiser Mead Site.

The stratigraphy beneath the site is shown in multiple cross-sections compiled from historic and more recent drilling activities. The locations of the cross sections are shown on Figure 2-2 and the cross-sections are included on Figures 2-3 through 2-5. The aquifer is

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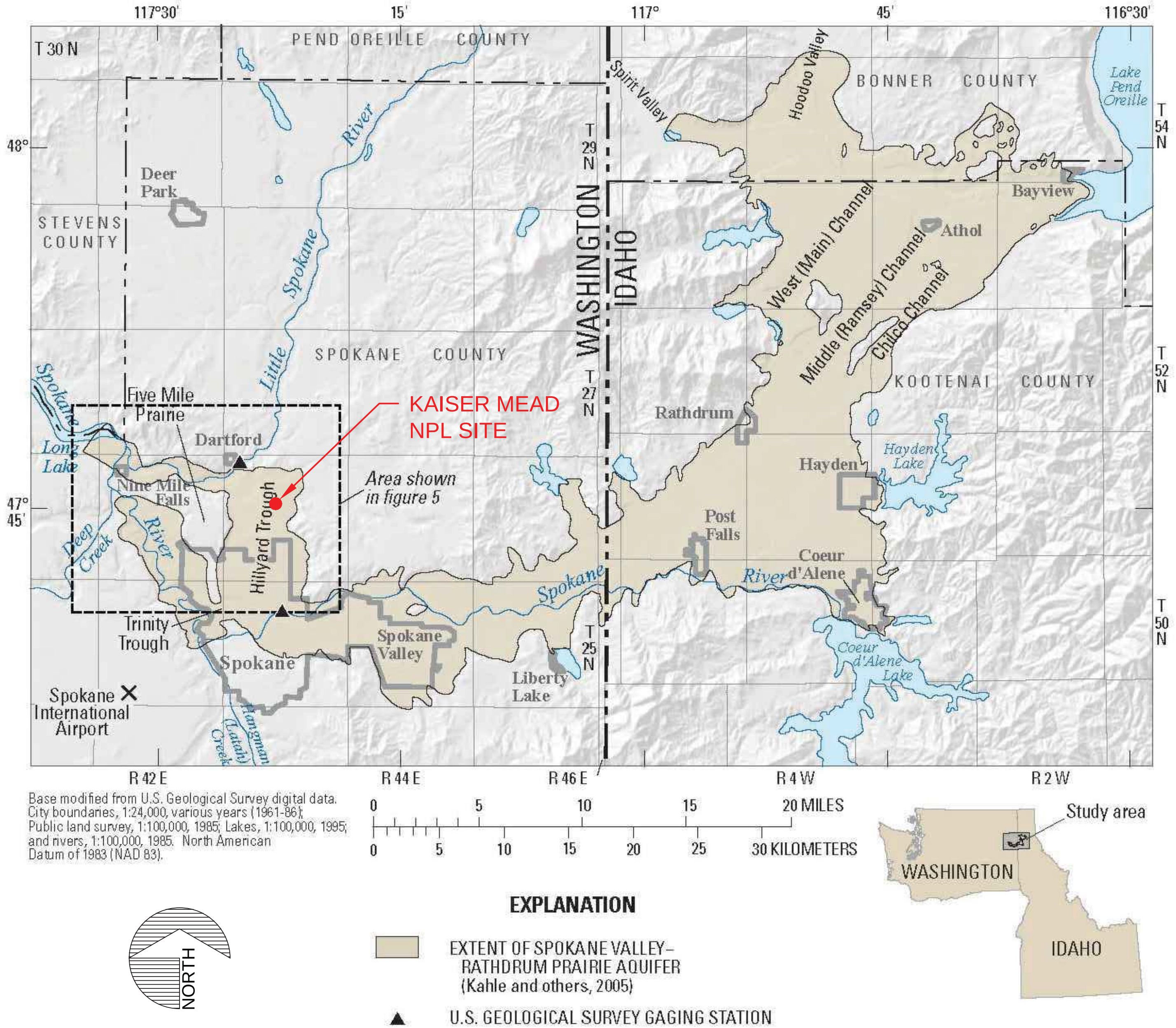

Base modified from U.S. Geological Survey digital data. City boundaries, 1:24,000, various years (1961-86); Public land survey, 1:100,000, 1985; Lakes, 1:100,000, 1995; and rivers, 1:100,000, 1985. North American Datum of 1983 (NAD 83).

SOURCE: KAHLE AND BARTOLINO, 2007

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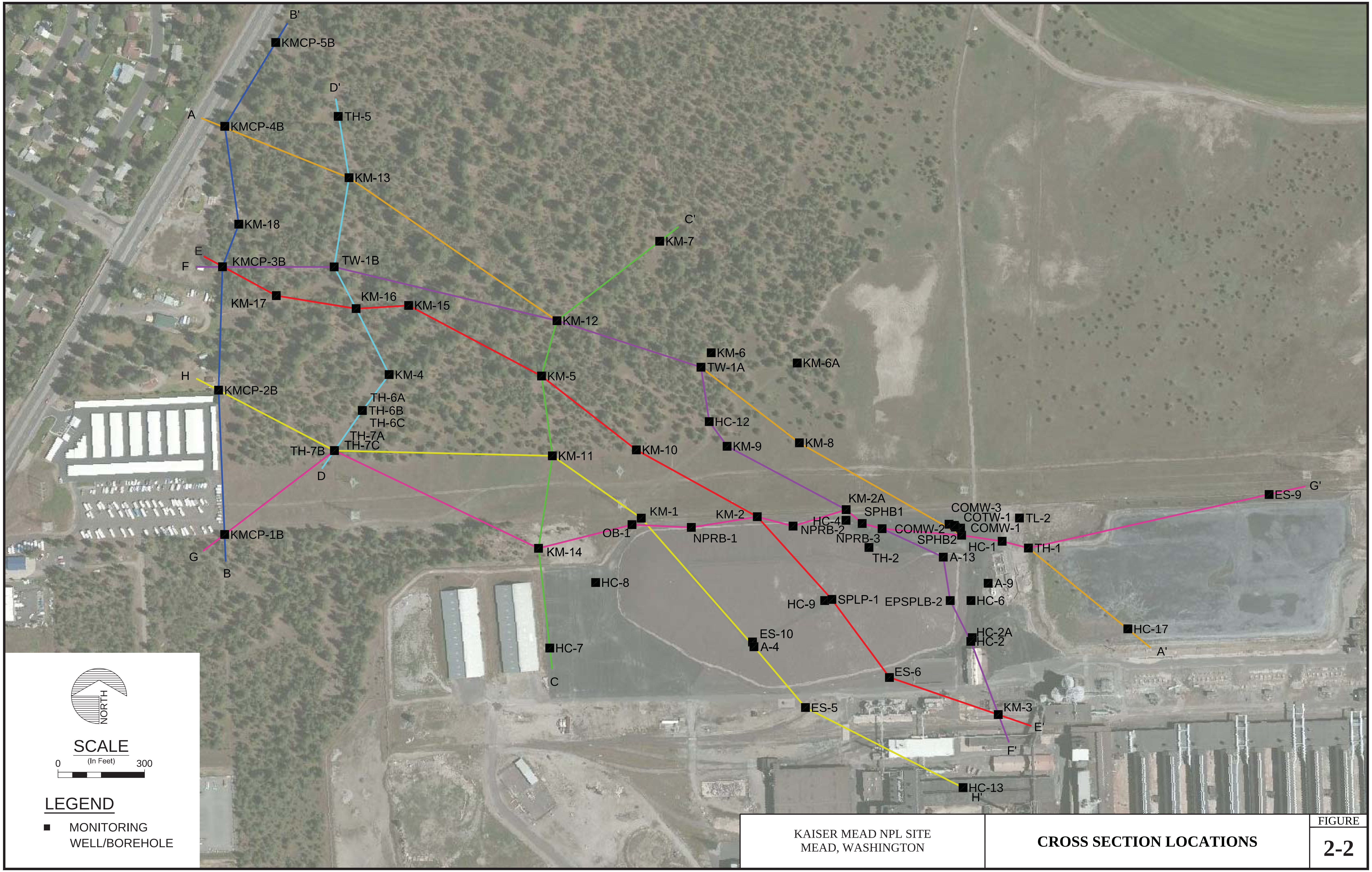
GROUNDWATER FLOW MODEL REPORT
KAISER MEAD NPL SITE

SPOKANE VALLEY-RATHDRUM PRAIRIE AQUIFER

FIGURE
2-1



KAISER MEAD NPL SITE
MEAD, WASHINGTON

CROSS SECTION LOCATIONS

FIGURE

2-2

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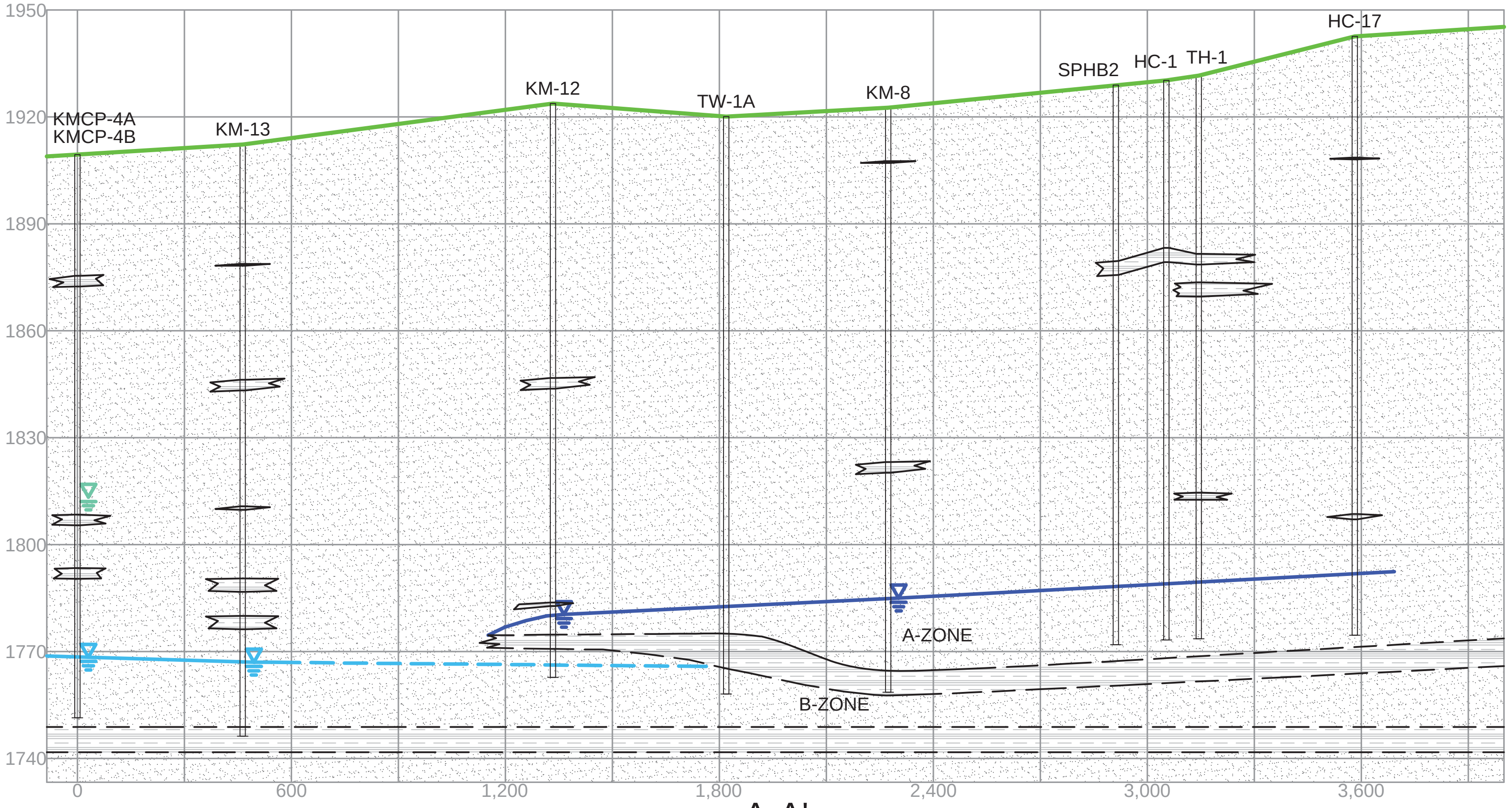

A-A'

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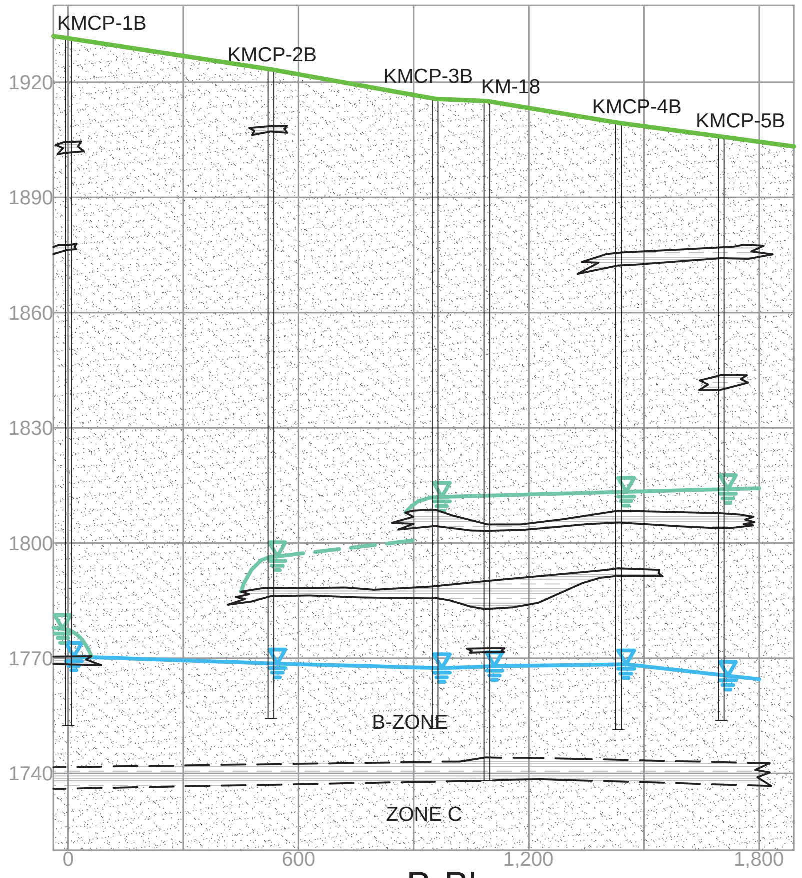

B-B'

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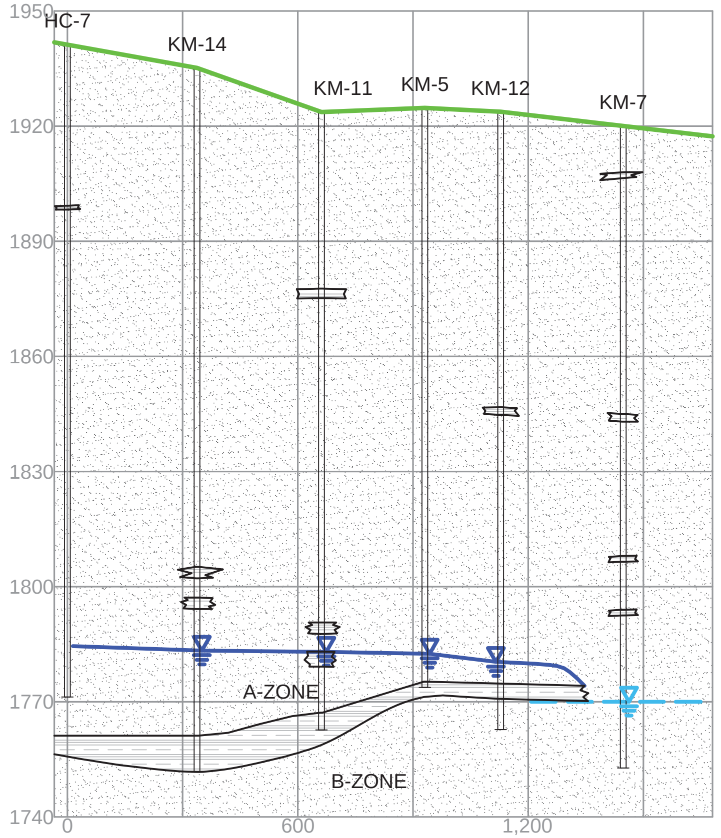

C-C'

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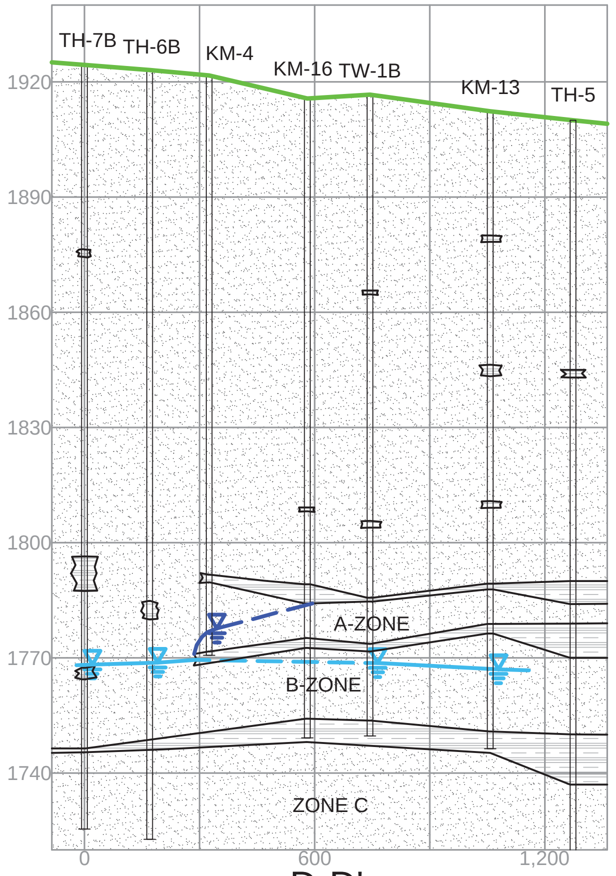

D-D'

SCALE: H: 1"=500', V: 1"=50'

LEGEND

░ FINE-COARSE SAND WITH MINOR GRAVELS

▤ SILT/CLAY

🟧 SPL PILE

--- GROUND SURFACE

▽ A-ZONE WATER LEVEL ELEVATION (AUG/SEP 2016)

▽ B-ZONE WATER LEVEL ELEVATION (AUG/SEP 2016)

▽ PERCHED WATER TABLE (AUG/SEP 2016)

KAISER MEAD NPL SITE MEAD, WASHINGTON	**CROSS SECTIONS A-A', B-B', C-C', AND D-D'**	FIGURE **2-3**

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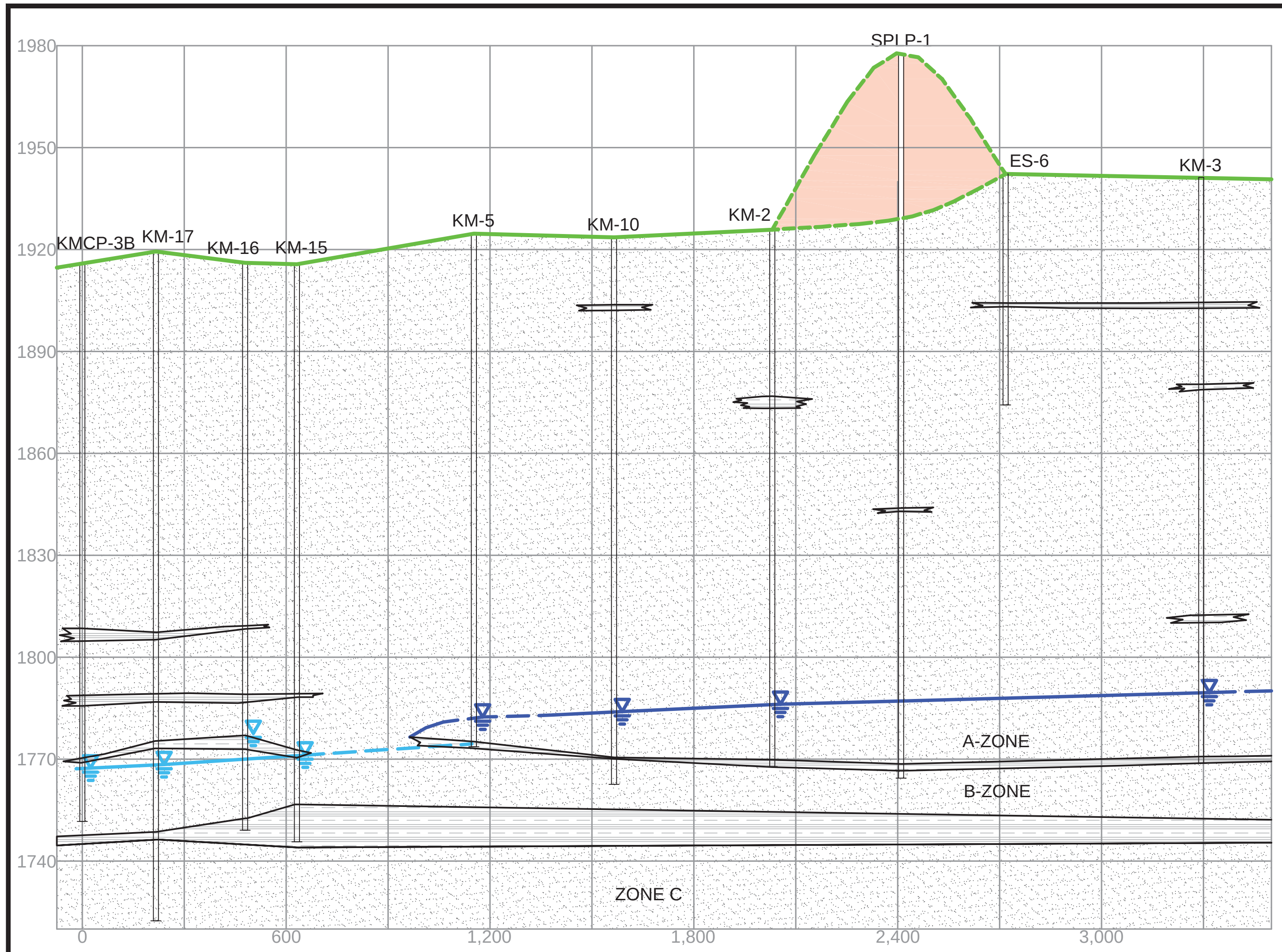

E-E'

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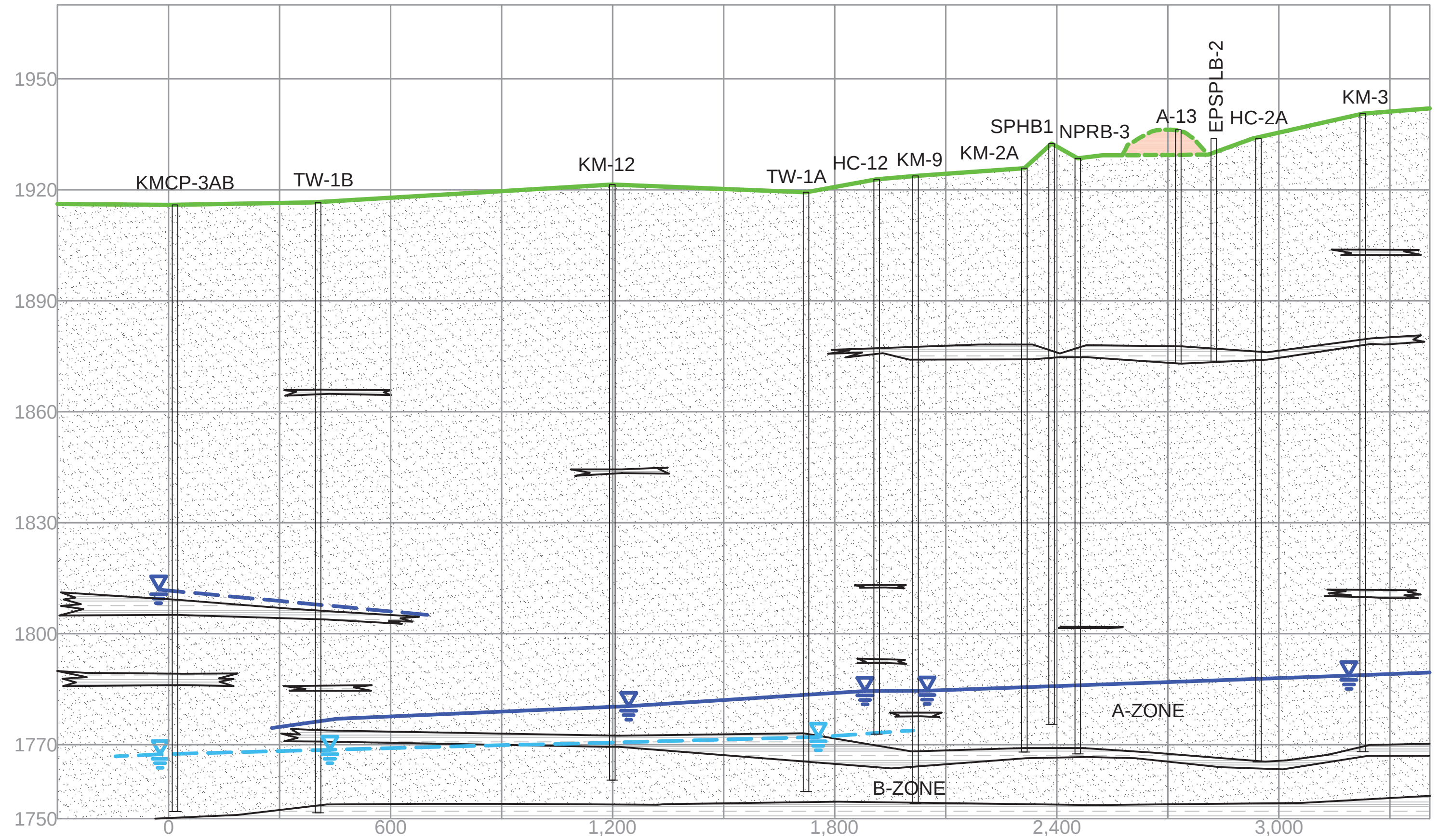

F-F'

SCALE: H: 1"=500', V: 1"=50'

LEGEND

▨ FINE-COARSE SAND WITH MINOR GRAVELS

▤ SILT/CLAY

🟧 SPL PILE

— — — GROUND SURFACE

— — ▽ A-ZONE WATER LEVEL ELEVATION (AUG/SEP 2016)

— — ▽ B-ZONE WATER LEVEL ELEVATION (AUG/SEP 2016)

— — ▽ PERCHED WATER TABLE (AUG/SEP 2016)

KAISER MEAD NPL SITE MEAD, WASHINGTON	CROSS SECTIONS E-E' AND F-F'	FIGURE 2-4

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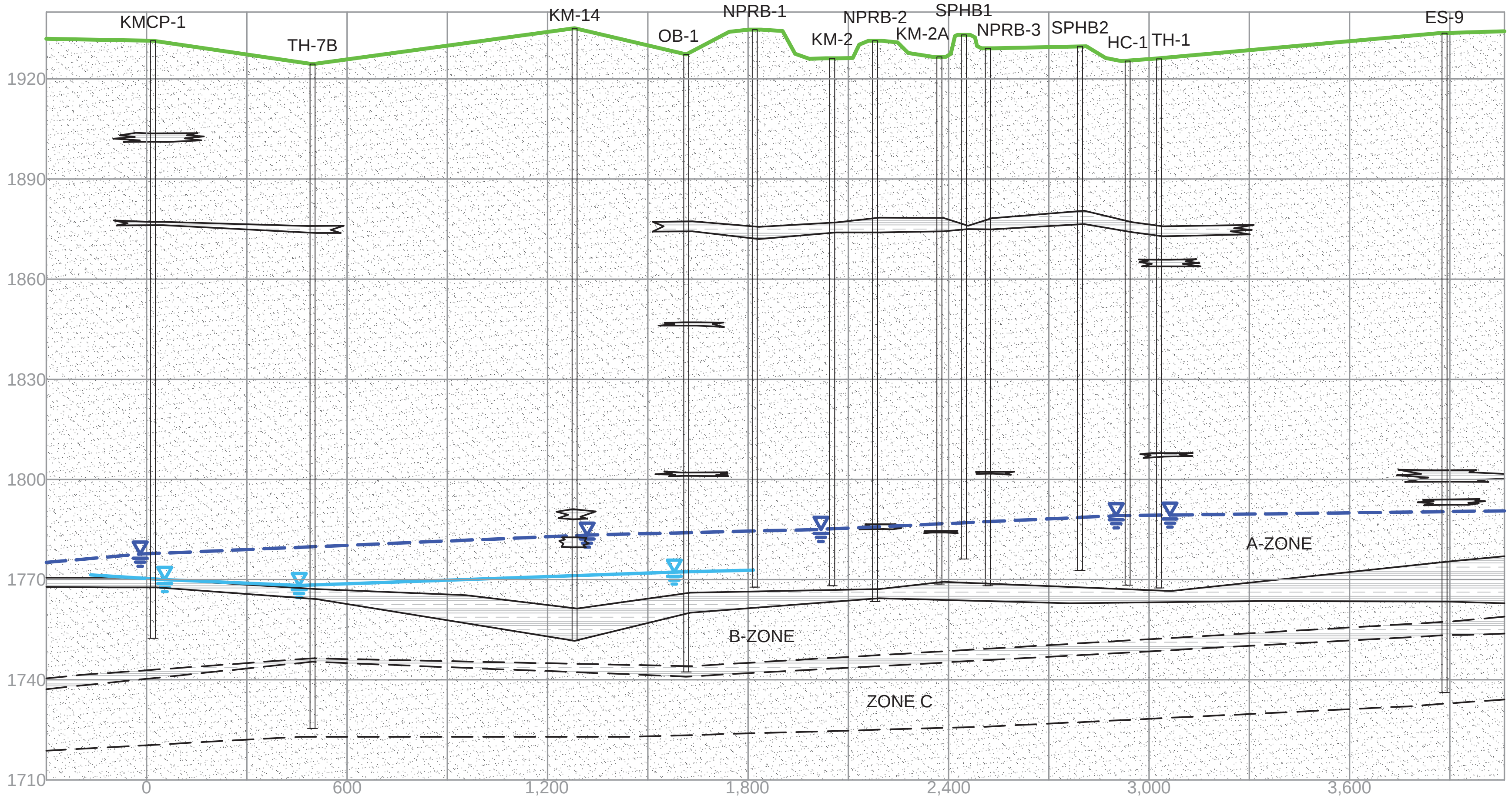

G-G'

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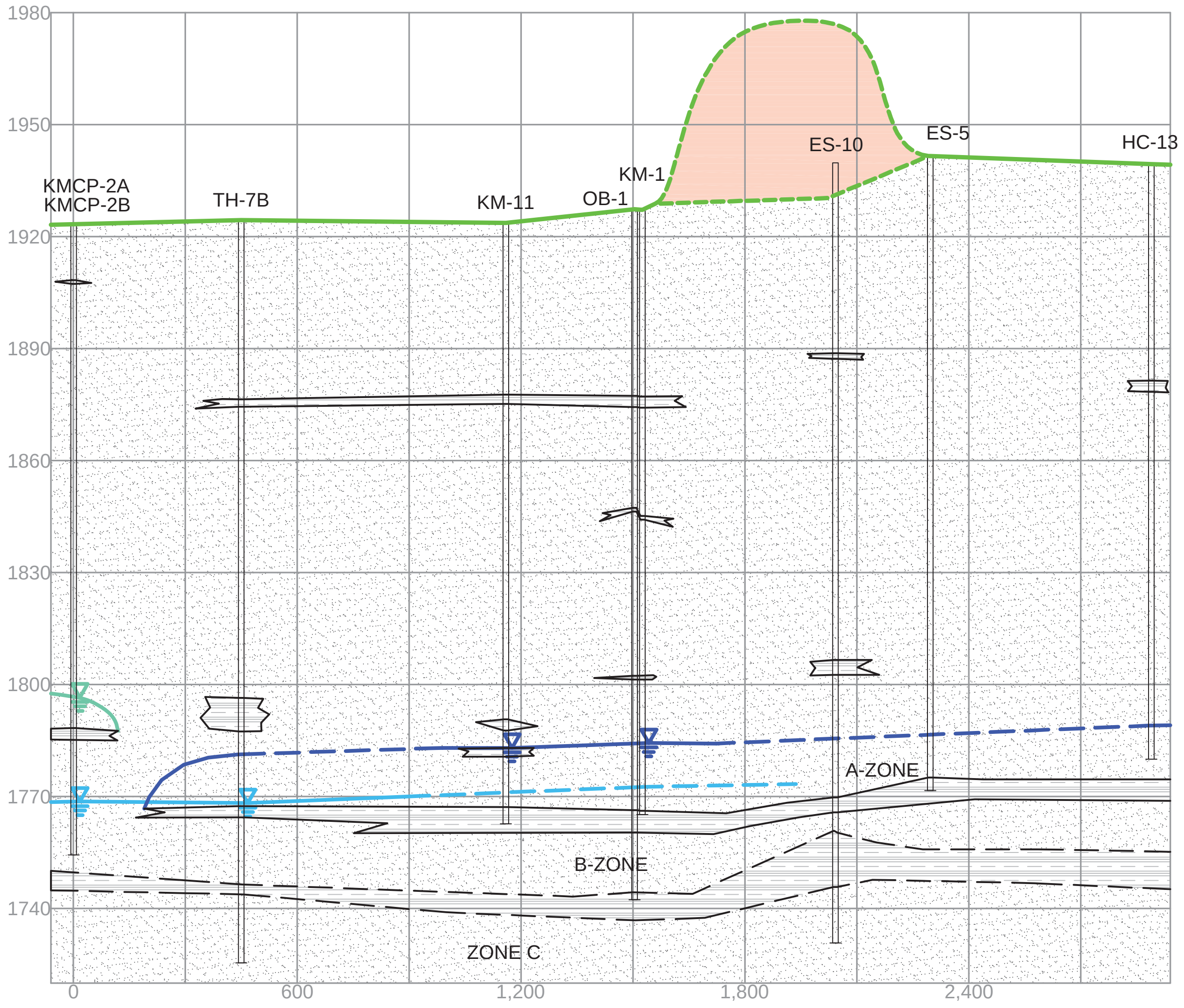

H-H'

SCALE: H: 1"=500', V: 1"=50'

LEGEND

▨ FINE-COARSE SAND WITH MINOR GRAVELS

▤ SILT/CLAY

🟧 SPL PILE

– – – GROUND SURFACE

– – – ▽ A-ZONE WATER LEVEL ELEVATION (AUG/SEP 2016)

– – – ▽ B-ZONE WATER LEVEL ELEVATION (AUG/SEP 2016)

– – – ▽ PERCHED WATER TABLE (AUG/SEP 2016)

KAISER MEAD NPL SITE
MEAD, WASHINGTON

CROSS SECTIONS
G-G'AND H-H'

FIGURE
2-5

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predominantly made up of fine to coarse grained sand with intervening layers of thin/discontinuous silts and clay. A thick (100 to 150 feet) unsaturated zone above the aquifer consists of fine to coarse grained sands and thin layers of sandy gravels and silt/clay lenses. A silt/clay lens is present at approximately 50 to 60 feet below ground surface (bgs) along the northern and eastern portion of the spent pot liner (SPL) pile, as shown in the E-E' and F-F' cross sections in Figure 2-4.

Previous investigations have divided the aquifer stratigraphy into three zones for purposes of defining contaminant transport at the site. The uppermost zone, A-Zone, is composed of fine to coarse sand with discrete zones of silt and very fine sand. The saturated portion of the A-Zone is generally 10 to 20 feet thick and underlain by a silt and clay layer that is laterally discontinuous to the west. The A-Zone aquifer thins to approximately 6 feet near the western edge of the underlying fine-grained layer. The B-Zone consists of fine to coarse sand, sometimes silty or with silt layers (MFG, 2000). B-Zone thickness reported in boring logs ranges from 6 to 24 feet and is underlain by a silt/clay layer. The C-Zone is the lower most zone identified as part of the contaminant transport; it consists of fine to medium sands or fine to coarse sands with some gravel. Sediments in the lower half of the C-Zone are cleaner and coarser-grained containing coarse sand and fine to coarse gravel with boulders. The C-Zone is up to 100 feet thick, however, the few monitoring wells on the site that are completed in this zone only penetrate the upper 10 to 25 feet. To the northwest of the site, near the line of compliance wells, there is a perched groundwater system that appears to be a source of un-impacted groundwater to the B-Zone aquifer.

2.3 HYDRO-STRATIGRAPHIC UNITS

The modeled hydro-stratigraphic units are associated with the two upper zones (A and B) of the shallow aquifer described in Section 2.2. Only the A-Zone, B-Zone, and the silt/clay aquitards separating the two zones were included in the model as these are the zones with known contamination associated with the Kaiser Mead site.

Aquifer testing has been conducted on wells within all three aquifer zones. The range of hydraulic conductivities for the A-Zone and the B-Zone is summarized in Table 2-1. The hydraulic conductivity at monitoring well HC-12 (0.5 ft/day) is much lower than other A-Zone wells. Well HC-12 is completed in silty sand and represents the lower conductivity heterogeneities in the A-Zone aquifer. The higher conductivity sands appear to make up a majority of the aquifer and similarly dominate groundwater flow and contaminant transport. The B-Zone aquifer appears to be slightly more conductive than the A-Zone aquifer.

TABLE 2-1. SUMMARY OF HYDRAULIC PROPERTIES OF MAJOR AQUIFER ZONES

Hydrogeologic Unit	Hydraulic Conductivity[1] (ft/day)	Specific Yield	Specific Storage (ft^{-1})
A-Zone Sand	75-300	0.15 - 0.25	$1*10^{-5}$-$1*10^{-8}$
B-Zone Sand	270-640	0.15 - 0.25	$1*10^{-5}$-$1*10^{-8}$
Silty Sand	0.1-10	0.05 - 0.2	$1*10^{-5}$-$1*10^{-8}$
Silt/Clay	0.001 - 0.01	0.02 - 0.05	$1*10^{-5}$-$1*10^{-8}$

1. Hydraulic conductivities derived from tests that did not adequately stress the aquifer are not reported.

A-Zone

The aquifer is unconfined across the site and is typically saturated between 140 to 150 feet bgs and is 10 to 20 feet thick. Numerous aquifer tests have been conducted on wells completed in this zone with reported hydraulic conductivities ranging from approximately 0.5 to 900 ft/day. The lower hydraulic conductivity is from well HC-12, which is characteristic of the fine-grained heterogeneities present in the A-Zone. The majority of the wells are completed in higher conductivity material than present at HC-12. Some A-Zone wells completed in sandy material have hydraulic conductivities that are higher than typical literature values for well sorted sand/glacial outwash, which are reported to range from 3 to 300 ft/day (Fetter, 2001). Aquifer tests have been completed at the site that did not adequately stress the aquifer resulting in estimates of hydraulic conductivities that are much greater than the typical values for the materials encountered in the aquifer. Therefore, hydraulic conductivity values from these tests are not included in Table 2-1. More recent aquifer test results from the site indicate hydraulic conductivities of approximately 75 to 300 ft/day for A-Zone wells (Hydrometrics, 2013b) and specific yields of approximately 1% to 25%.

A-Zone Aquitard

The A-Zone aquitard lies immediately below the A-Zone sand aquifer and is composed of 0.5 to 9.5 feet thick grey silt and clay with minor sand. The aquitard is typically encountered at depths of 160 to 165 feet beneath the site. The A-Zone aquitard is limited in extent and appears to pinch out approximately 800 feet downgradient of the SPL pile (near monitoring wells KM-4 and KM-15). A flexible wall permeameter test was conducted on an undisturbed sample from the A-Zone aquitard to estimate the hydraulic conductivity of the silt/clay. The resultant hydraulic conductivity (1.1×10^{-4} ft/day) is approximately six orders of magnitude lower than the A-Zone sands.

B-Zone

The B-Zone is generally coarser grained than the A-Zone, which is represented in higher hydraulic conductivities (270 to 640 ft/day). The B-Zone is a confined to semi-confined aquifer beneath the SPL pile as the A-Zone aquitard acts as a confining layer. The aquifer becomes unconfined approximately 800 feet northwest of the SPL pile. The B-Zone aquifer ranges between 16 and 20 feet thick where it is confined and 15 to 25 feet where it is unconfined.

B-Zone Aquitard

The B-Zone aquitard separates the B-Zone aquifer from the underlying C-Zone aquifer. Few wells penetrate the B-Zone aquitard. It is similar in composition to the A-Zone aquitard; dominantly grey clay plus or minus sand and silt. Noted thicknesses range from approximately 1 foot to approximately 7 feet. There is no known measurement of the hydraulic conductivity of the B-Zone aquitard.

2.4 GROUNDWATER FLOW CONDITIONS

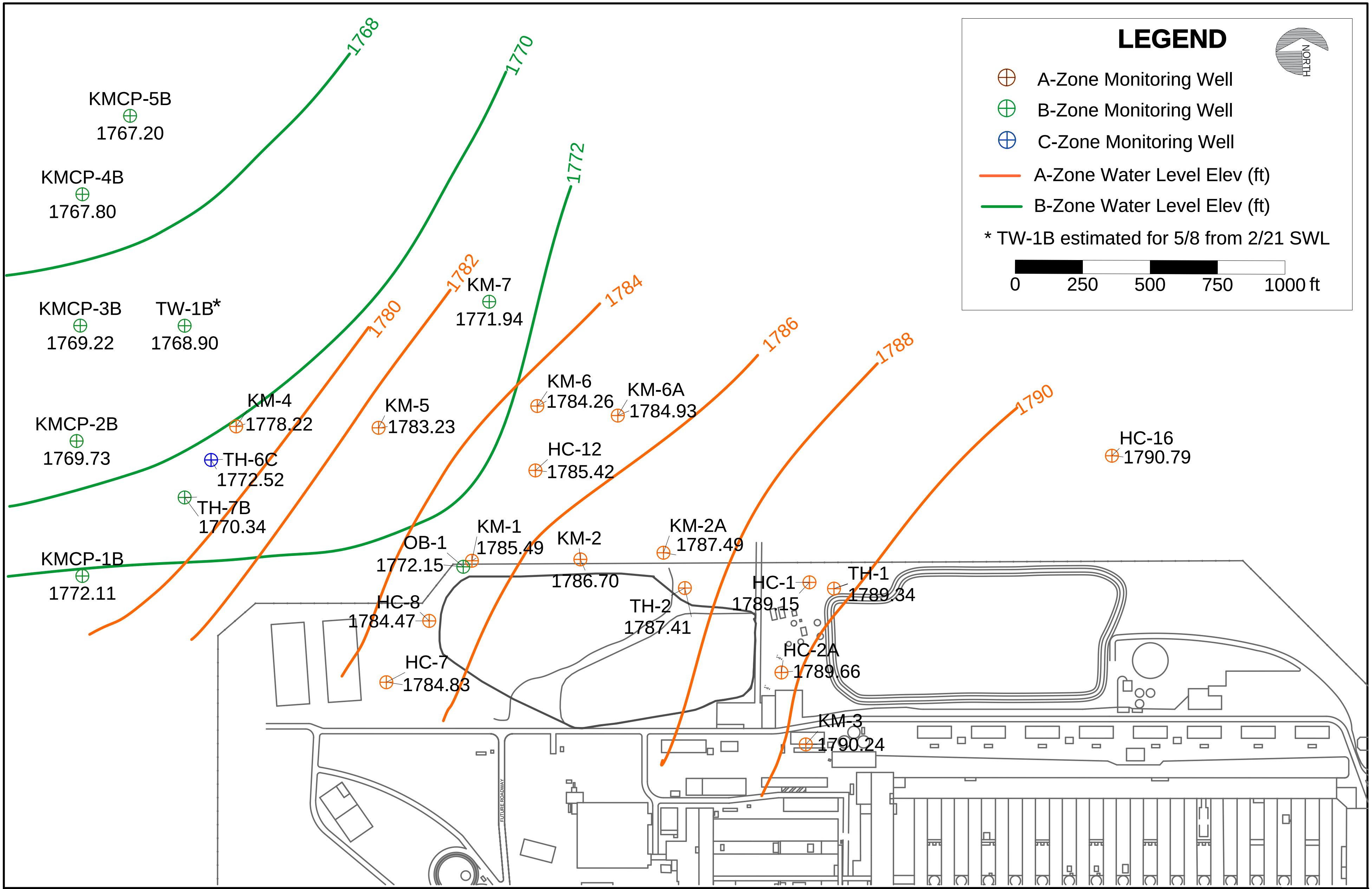
Groundwater flows to the northwest in the A-Zone aquifer as shown in Figure 2-6. There is a more northerly trend in the immediate vicinity of the SPL pile. The average hydraulic gradient across the A-Zone aquifer is approximately 0.005, the hydraulic gradient is more flat in the vicinity of the SPL pile (0.003) and more steep near KM-4 (0.01).

The larger hydraulic gradient observed near KM-4 is likely due to the flow of A-Zone water into the underlying B-Zone in the area, which also leads to the smaller saturated thickness observed in the area (Figure 2-4).

The general groundwater flow direction in the B-Zone aquifer is to the west and northwest in the northeast portion of the facility and to the north in the western portion of the facility. The hydraulic gradient in the B-Zone aquifer ranges from 0.003 to 0.007.

There is a general downward vertical hydraulic gradient between the A-Zone and B-Zone aquifers as shown in the potentiometric surfaces shown on Figure 2-6 and in cross sections on Figures 2-3 through 2-5. Based on the May 2013 water level elevations in KM-1 (1785.49), completed in the A-Zone aquifer and OB-1 (1772.15 feet), completed in the B-Zone aquifer, the vertical hydraulic gradient between and A-Zone and B-Zone aquifers is approximately 0.5 near the northwest corner of the SPL.

Groundwater flux at the site was estimated based on Darcy's Law (Q=KAi). Due to variations across the site in hydraulic conductivity, hydraulic gradient, and saturated thickness, estimates of the groundwater flux through the A-Zone and B-Zone aquifers beneath the site produce a large range of potential values (Table 2-2). A-Zone estimates of groundwater flux range from 0.02 gpm per linear foot width of aquifer to 0.09 gpm/ft. B-Zone estimates of groundwater flux range from 0.13 gpm per linear foot width of aquifer to 0.30 gpm/ft. The groundwater flux through the fluoride plume (width of 1,400 feet) in the A-Zone aquifer ranges between approximately 30 and 130 gpm. Regional studies of the



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KAISER MEAD NPL SITE
MEAD, WASHINGTON

MAY 2013
POTENTIOMETRIC SURFACE
A & B-ZONE AQUIFERS

FIGURE
2-6

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Spokane Valley Rathdrum Prairie aquifer focus on deeper water producing layers than those of concern at the Kaiser site and therefore do not provide regional estimates of the hydraulic gradient or flux.

TABLE 2-2. ESTIMATED GROUNDWATER FLUX

Aquifer	**Hydraulic Conductivity (ft/day)**	**Average Thickness (ft)**	**Average Hydraulic Gradient**	**Estimated Groundwater Flux (gpm/ft)**
A-Zone	75-300	12	0.005	0.02 to 0.09
B-Zone	270-640	18	0.005	0.13 to 0.30

2.5 AREAL RECHARGE

Infiltration of rainfall and snow melt is the primary sources of areal recharge to the groundwater system in the SVRP Aquifer. Areal recharge of the SVRP aquifer was evaluated by the USGS using multiple methods at several weather stations; the closest station to the Kaiser Mead site was the Spokane Weather Service Office (WSO) Airport. Average annual recharge for the entire SVRP aquifer varied greatly between methods with the highest recharge being about 10 in/yr (64% of precipitation) and the lowest being 0 in/yr (0% of precipitation) and an average recharge between the methods of approximately 3 in/yr (15% of precipitation) (Bartolino, 2007). However, the recharge estimates for the entire SVRP aquifer includes infiltration of storm water, which likely increases the recharge compared to natural conditions. The recharge in the vicinity of the Kaiser Mead site is likely to be less than 15% of precipitation there are not any known large storm water infiltration areas in the vicinity of the site. Assuming recharge in the vicinity of the site is approximately 10% of precipitation the groundwater flux flowing into the Kaiser Mead site is much greater than the recharge from precipitation. Recharge only accounts for 3.5 gpm (assuming recharge is 10% of annual precipitation) in the plume center, which is only 3 to 12% of the estimated A-Zone groundwater flux through the plume.

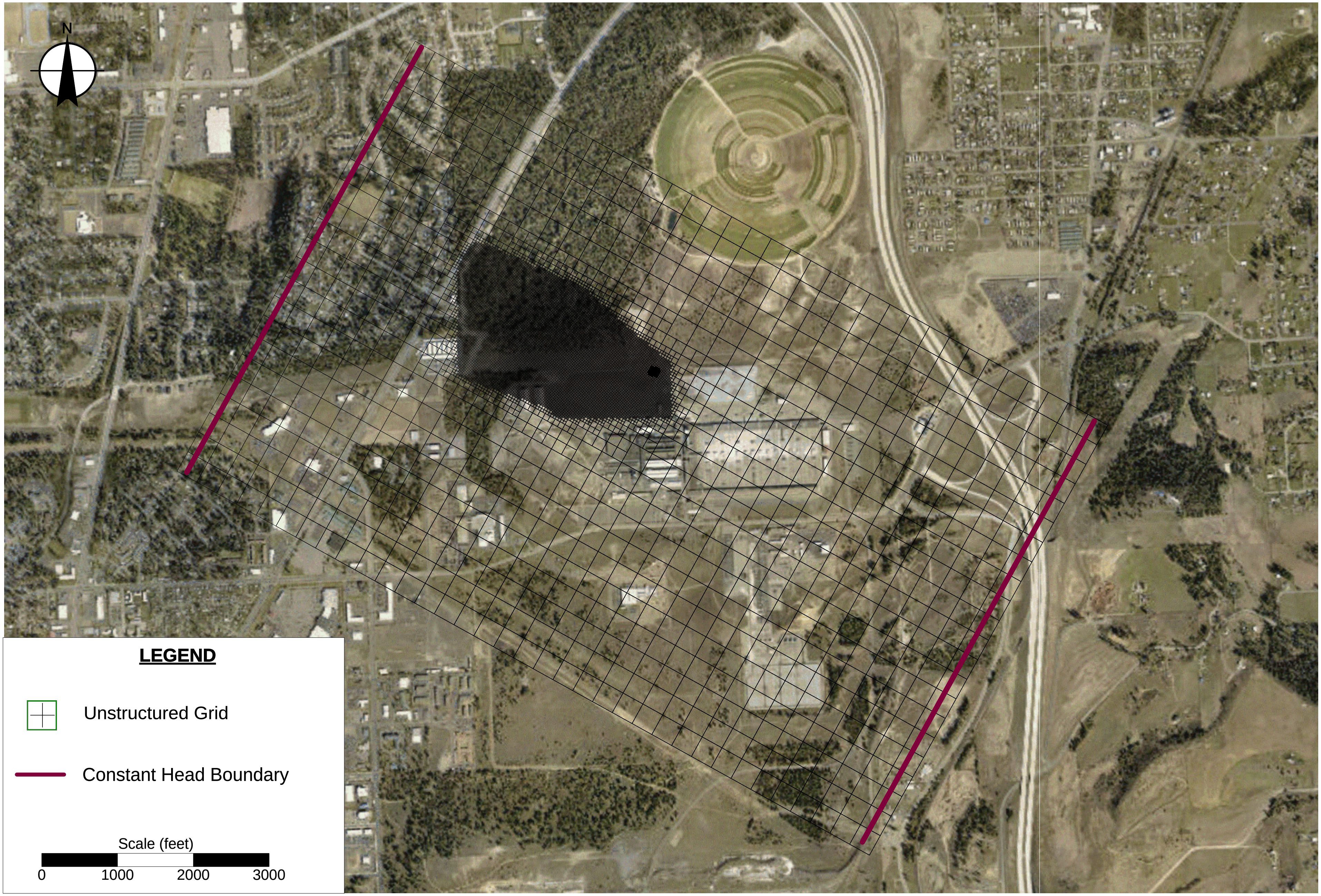
3.0 MODEL DESIGN

3.1 MODEL SELECTION AND APPROACH

The model utilized MODFLOW-USG (Panday et al., 2013) to simulate the physical flow system. MODFLOW-USG is an updated version of the U.S. Geological Survey's modular 3D finite difference groundwater flow model, MODFLOW (McDonald and Harbaugh, 1988). MODFLOW-USG was chosen for the current model of the Kaiser Mead site due to its flexibility in grid design (unstructured grids), which can be used to focus resolution at areas of interest, and its ability to fully pinch-out individual model layers to better represent hydro-stratigraphic units. To facilitate model development and data processing, the flow model was implemented utilizing the software program GMS (Groundwater Modeling System, version 10.1; Aquaveo, 2015). MODFLOW-USG and GMS were selected because of their comprehensive capabilities for simulating flow in the groundwater systems under a wide range of hydrogeological conditions.

3.2 MODEL DOMAIN

The model domain encompasses the saturated portions of the A-Zone and B-Zone aquifers. Due to the limited extent of detailed data and the desire for a relatively high-precision model, this model was constructed as a local model. The model was built with the understanding that the precision of the model must be balanced with ensuring there are no superfluous boundary effects. The horizontal extent of the model was set so that boundary effects do not unrealistically alter/control the flow within the model domain. The model domain is 6,472 feet by 10,681 feet with the long dimension approximately parallel to the regional groundwater flow direction (southeast to northwest). The model domain is shown in Figure 3-1. The southeast edge of the model is near N. Market St. and the northwest extent is approximately 2,100 feet to the northwest of the compliance wells. The northeast and southwest boundaries of the model are approximately 2,710 and 3,780 feet, respectively, from the center of the SPL pile.



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GROUNDWATER FLOW MODEL REPORT
KAISER MEAD NPL SITE
MEAD, WA

MODEL DOMAIN AND BOUNDARIES

FIGURE
3-1

K:\project\9088 Kaiser\GW Flow Model\PostProcessing\Model Domain.srf

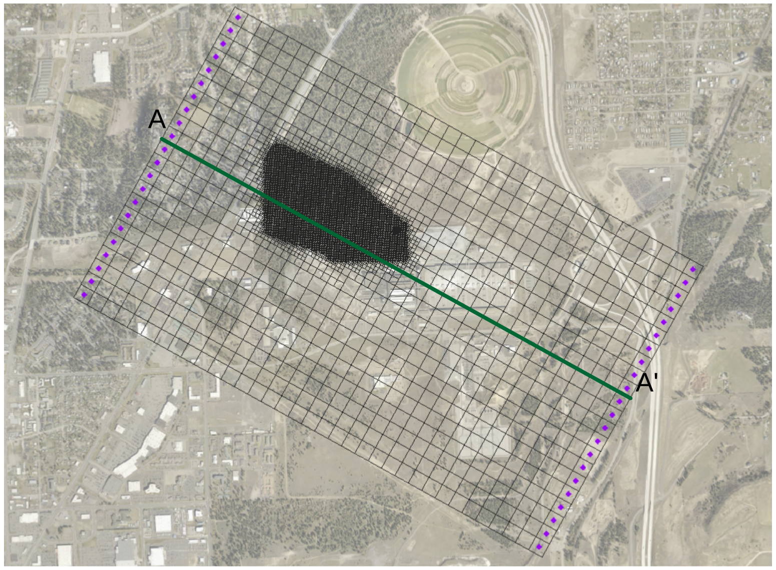
The model incorporates a variable spaced quadtree grid with 261,564 cells in the model with cell sizes ranging from approximately 0.5 x 0.5 feet to 300 x 300 feet. The unstructured grid is more tightly refined around the SPL pile and downgradient of the SPL pile to have the greatest precision where remedial alternatives may be implemented (Figure 3-1).

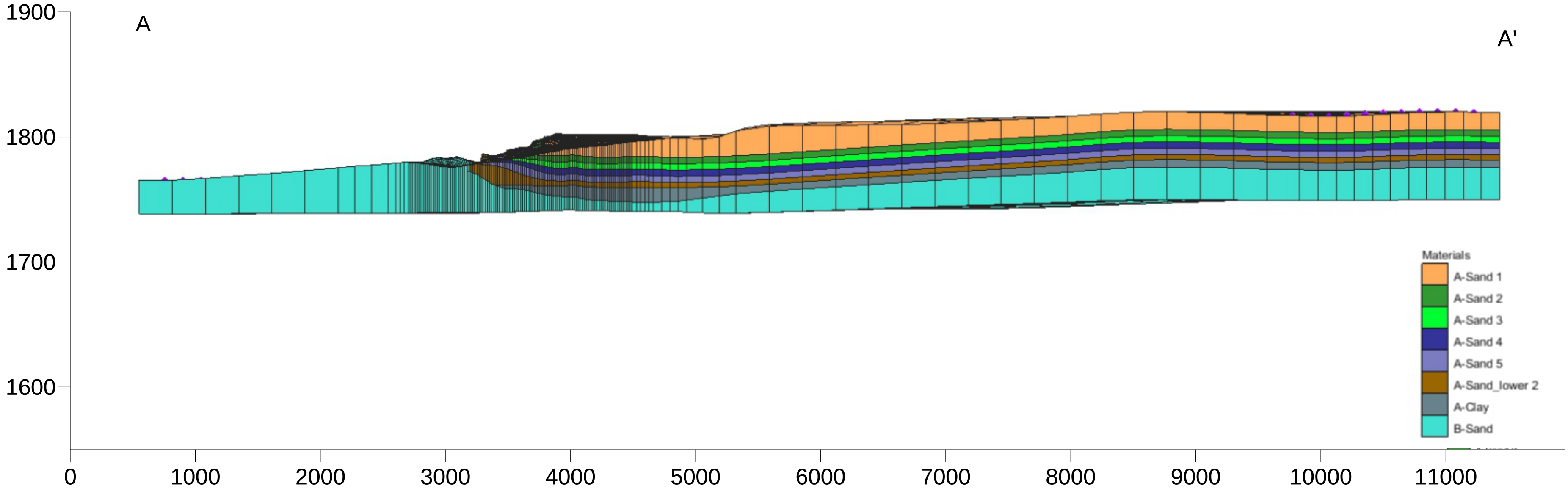
The model is discretized vertically using eight layers. The A-Zone sand is represented by layers one through five; layer six represents a transition between the A-Zone sand and A-Zone aquitard. The transition layer was inserted to increase model stability at the boundary between the low permeability clay and the relatively high permeability sand. The A-Zone aquitard is represented by layer seven and the underlying B-Zone is modeled as layer eight. The A-Zone was modeled with multiple layers in an effort to provide better calibration to observed water levels and in order to provide flexibility in defining horizontal flow barriers discussed further in Section 3.4.3. Layers 1-7 extend from the southeast boundary of the model to approximately 800 feet downgradient of the SPL pile, where the A-Zone aquitard pinches out and the A-Zone water mixes with the B-Zone. A cross section of the model grid along the plume center is shown in Figure 3-2. The range in thickness of each layer is summarized in Table 3-1. Horizontal refinement was kept constant through the eight layers within the model.

TABLE 3-1. LAYER THICKNESS SUMMARY

Layer	Minimum Thickness (ft)	Maximum Thickness (ft)	Average Thickness (ft)
1	0.2	24	5
2	0.2	15	5
3	0.1	8	5
4	0.1	7	5
5	0.1	8	5
6	0.5	20	4
7	0.2	14	4
8	5	43	15

Cross Section Location





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GROUNDWATER FLOW MODEL REPORT
KAISER MEAD NPL SITE
MEAD, WA

CROSS SECTION OF MODEL LAYERS

FIGURE
3-2

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3.3 MODEL BOUNDARY CONDITIONS

Boundary conditions are used to simulate hydrogeologic conditions at the extents of the model domain. Constant head boundaries are used to simulate the groundwater flux in and out of the model on the eastern (groundwater inflow) and western (groundwater outflow) boundaries, respectively (Figure 3-1). The constant head on the eastern boundary represents groundwater flow into the A-Zone and B-Zone aquifers along with the aquitard between (model layers 1-8), whereas the constant head on the western boundary represents only flow out of the B-Zone (model layer 8). Constant heads were estimated by extending the water table/potentiometric surface obtained from the May 2013 water level measurements to the upgradient and downgradient boundaries; the heads assigned to the upgradient boundaries were 1,811 (layers 1-6), 1815 (layer 7), and 1788 (layer 8) and the head assigned to the downgradient boundary was 1,762 feet (layer 8). No-flow boundaries are utilized for the north and south edges of the model domain where the flow direction is assumed to be parallel to the model boundary.

3.4 MODEL INPUT VARIABLES

3.4.1 Aquifer Properties

Aquifer properties for the different hydro-stratigraphic units were applied to the model for different material types. These include A-Zone Sands, a transition material, A-Zone Aquitard, and B-Zone Sands/Gravel. The initial aquifer properties applied to each material property were based on the data summarized in the conceptual model (Section 2.3). The material properties were adjusted during steady state and transient calibration. The final properties used in the calibrated model are summarized in Table 3-2. The changes in aquifer properties from the initial values are discussed further in the Model Calibration summary and sensitivity analysis (Sections 4.0 and 6.0).

TABLE 3-2. CALIBRATED MODEL HYDRAULIC PROPERTIES

Material	Horizontal Conductivity (ft/day)	Vertical Conductivity (ft/day)	Horizontal Anisotropy	Vertical Anisotropy	Specific Storage	Specific Yield
A-Sand 1	100	5	1	20	1E-07	0.005
A-Sand 2	100	5	1	20	1E-07	0.005
A-Sand 3	100	5	1	20	1E-07	0.005
A-Sand 4	100	5	1	20	1E-07	0.005
A-Sand 5	100	5	1	20	1E-07	0.005
Transition	20	1	1	20	1E-07	0.005
Aquitard	0.0001	2.5E-06	1	40	1E-07	0.005
B-Sand	225	22.5	1	10	1E-07	0.005

3.4.2 Sources and Sinks

Sources and sinks included in the steady state model consist of areal recharge from precipitation. Areal recharge for the majority of the model domain was applied as a percentage of precipitation. The average annual precipitation for Spokane, Washington Western Regional Climate Center (WRCC) site 457933 from 1981 to 2010 is approximately 20 inches (WRCC, 2016). Assuming the site specific recharge is 7% of the average annual precipitation yields a recharge rate 1.44 inches per year, which is within the range calculated by the USGS (see Section 2.5). Consolidated waste materials were most recently capped in the current SPL pile area in 2001. A past estimate of recharge to the aquifer below the capped SPL pile is 0.1 inch per year (2.3E-5 ft/day), which was utilized in the model for the capped area (MFG, 2004).

Extraction wells were simulated as part of the transient calibration. The extraction wells were simulated using the Well package in MODFLOW. Details of the transient calibration are discussed in Sections 4.2.

3.4.3 Horizontal Flow Barriers

The Horizontal Flow Barrier (HFB) package was utilized to simulate installation of a grout wall as a remedial alternative. The HFB package simulates a discrete barrier between two cells by limiting the cell to cell conductance. This is done by assigning the wall a hydraulic characteristic, which is defined as the barrier hydraulic conductivity divided by the thickness of the barrier. Therefore, a grout wall with a hydraulic conductivity of 1×10^{-6} cm/s (0.0028 ft/day) and a thickness of 3 feet has a hydraulic characteristic of 9.45×10^{-4} per day. The HFB is applied between adjacent model cells; therefore, the barrier geometry is aligned with the cell geometry and refinement (Figure 3-3).

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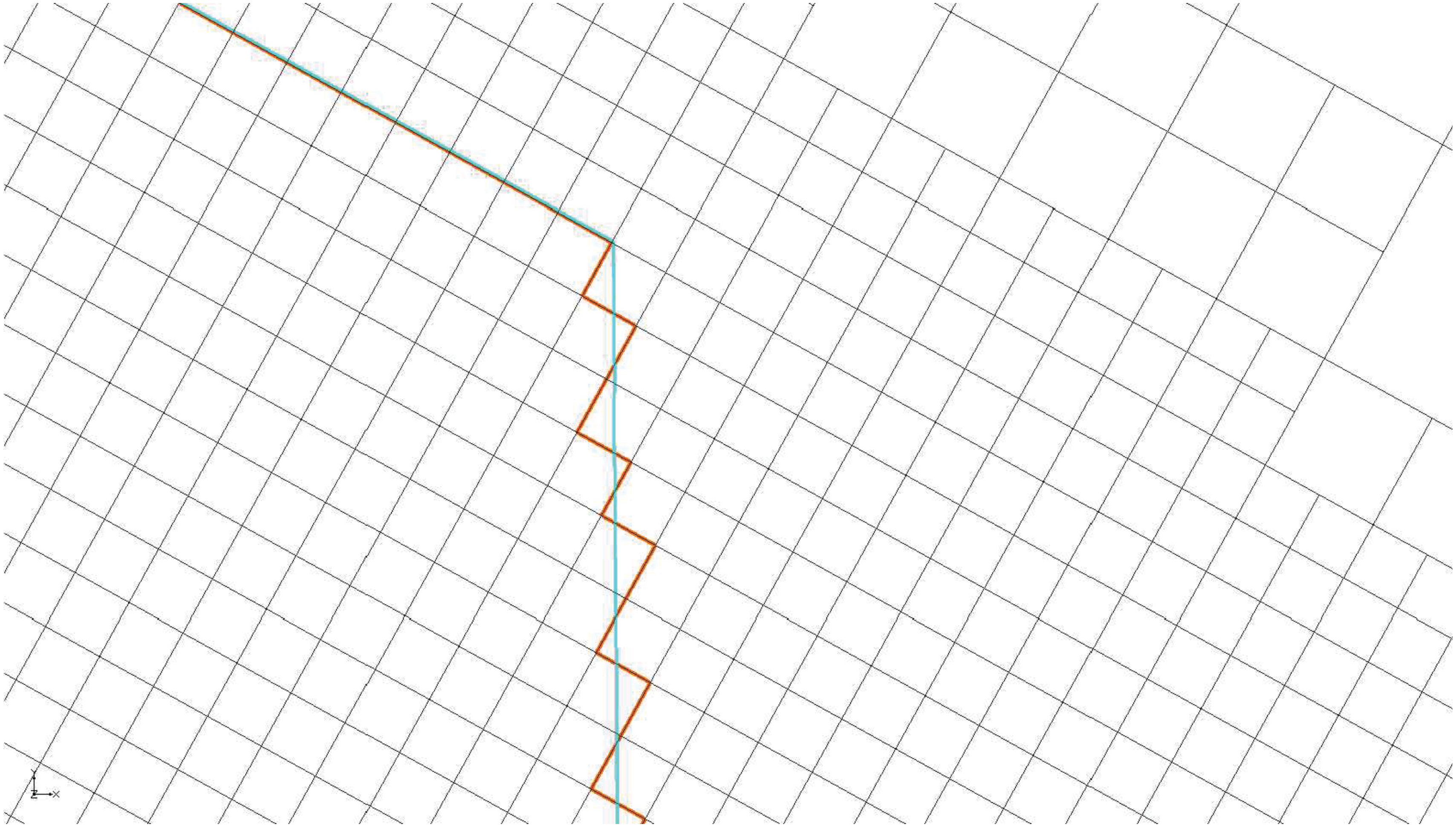

LEGEND

RESULTANT HORIZONTAL FLOW BARRIER
INPUT BARRIER PATH LINE

SCALE
(In Feet)
0 50

NORTH

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HORIZONTAL FLOW BARRIER GEOMETRY

FIGURE
3-3

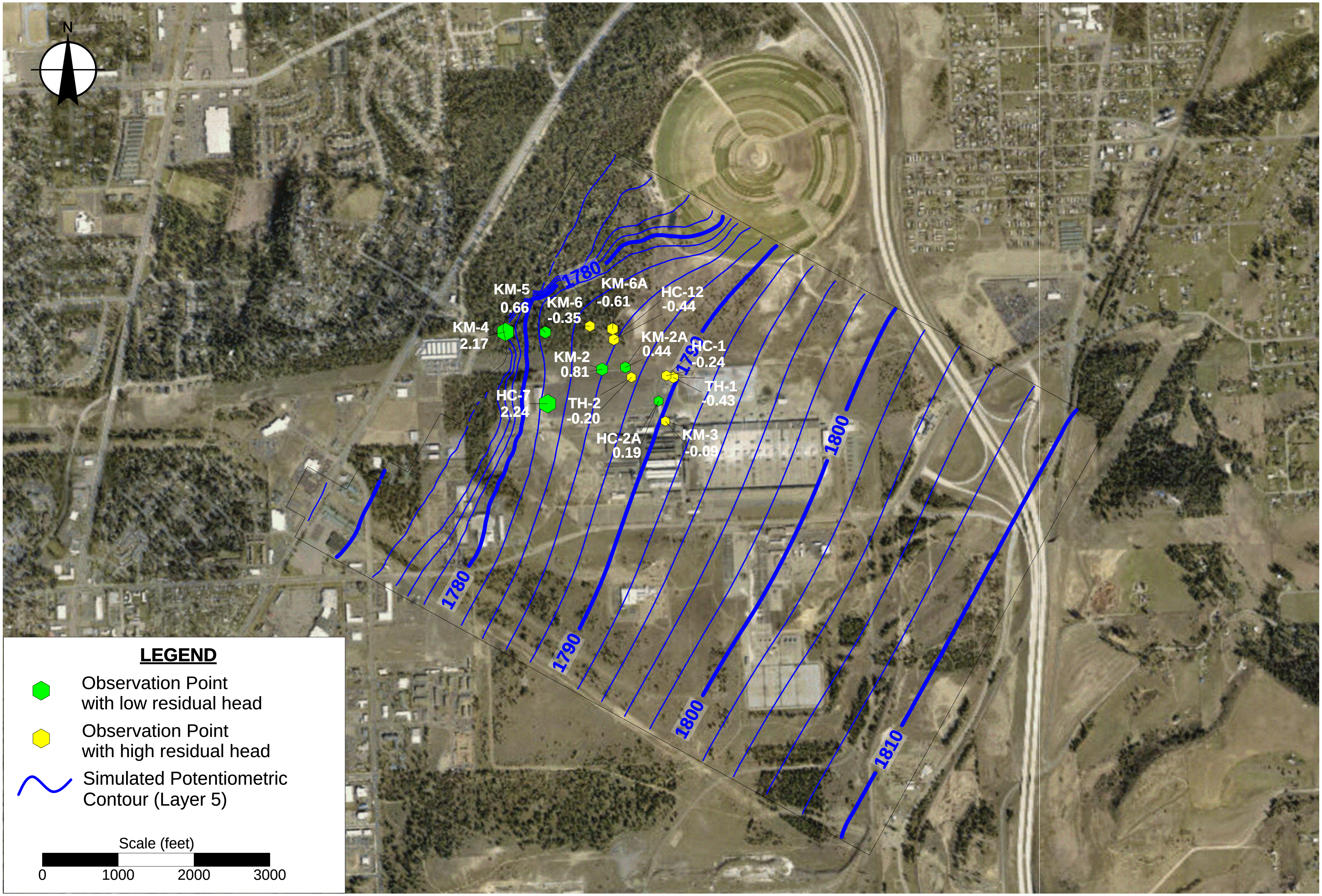
4.0 MODEL CALIBRATION

The numerical groundwater flow model was developed as described in Section 3.0 above, and the model parameters (primarily hydraulic conductivity) were refined within established ranges from aquifer test data and literature values to optimize the degree to which the model simulations match observed potentiometric data and estimated groundwater flux through specific zones. A steady-state model calibration was quantified based on the difference in simulated versus observed heads used to calibrate the model with a target set based on 10% of the difference in observed heads used in the model calibration, which is a typical standard used in groundwater modeling (Anderson and Woessner, 1992). A transient calibration was conducted on the numerical flow model to calibrate the model to a known stress applied to the flow system, which allows for improved certainty in the hydraulic conductivity used in the vicinity of the aquifer test and allows for calibration of aquifer storage in the model. The calibration targets used for the steady-state and transient model are as follows:

- Simulated Heads: +/- 2.3 feet;
- Groundwater Flux: within range in estimated flux;
- Match general flow direction and gradient; and
- Transient Calibration – Qualitative Calibration – trend and magnitude of drawdown curve from 24 hour pumping test.

4.1 STEADY-STATE CALIBRATION

The groundwater flow model was calibrated to May 2013 observed water level elevations from 20 observation sites. The May 2013 data was selected as it is the most comprehensive data set for the site. In general, the hydraulic conductivities applied to the A-Zone layers were reduced from the initial values, as higher values resulted in higher heads in the A-Zone observation wells. The B-Zone hydraulic conductivities were also reduced to near the lower end observed from aquifer tests, as higher values resulted in lower heads in the B-Zone observation points. The steady state calibration results can be evaluated through residual heads (observed – simulated heads) for each observation site. The calibrated potentiometric surface and residuals for the A-Zone and B-Zone are shown on Figures 4-1 and 4-2 and are tabulated in Table 4-1.



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A-ZONE SIMULATED POTENTIOMETRIC SURFACE

FIGURE
4-1

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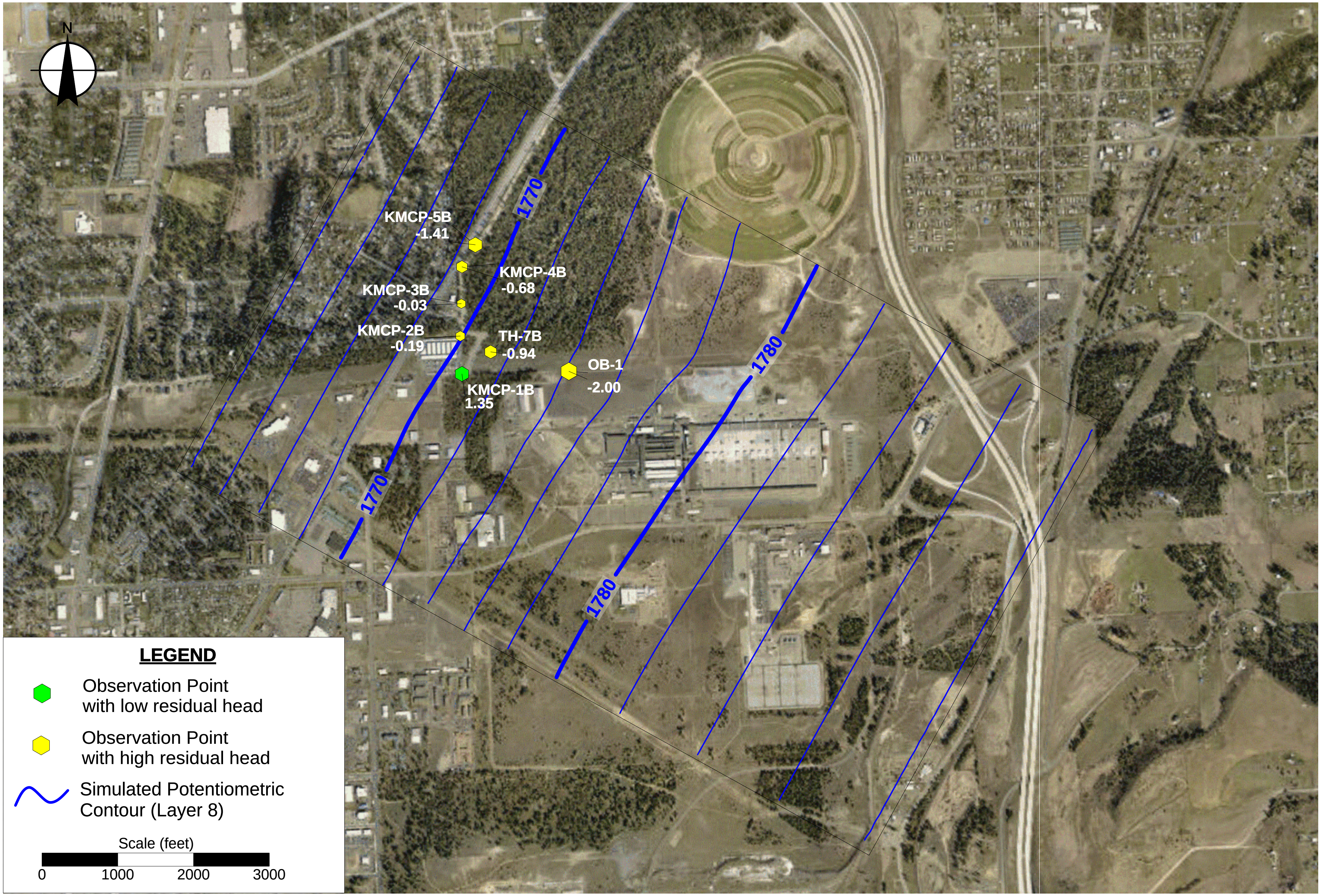

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B-ZONE SIMULATED POTENTIOMETRIC SURFACE

FIGURE
4-2

K:\project\9088 Kaiser\GW Flow Model\PostProcessing\Layer8_Potentiometric.srf

TABLE 4-1. CALIBRATION STATISTICS

Well Name	Model Layer	Observed Head (ft)	Computed Head (ft)	Residual Head (ft)
HC-1	5	1789.15	1789.391	-0.241
HC-12	4	1785.42	1785.855	-0.435
HC-2A	4	1789.66	1789.472	0.188
HC-7	3	1784.83	1782.592	2.238
KM-2	6	1786.7	1785.888	0.812
KM-2A	5	1787.49	1787.049	0.441
KM-3	5	1790.24	1790.329	-0.089
KM-4	5	1778.22	1776.052	2.168
KM-5	2	1783.23	1782.569	0.661
KM-6	6	1784.26	1784.61	-0.35
KM-6A	5	1784.93	1785.544	-0.614
OB-1	8	1772.15	1774.154	-2.004
TH-1	4	1789.34	1789.766	-0.426
TH-2	3	1787.41	1787.608	-0.198
TH-7B	8	1770.34	1771.275	-0.935
KMCP-1B	8	1772.11	1770.759	1.351
KMCP-2B	8	1769.73	1769.921	-0.191
KMCP-3B	8	1769.22	1769.248	-0.028
KMCP-4B	8	1767.8	1768.475	-0.675
KMCP-5B	8	1767.2	1768.605	-1.405

Mean Residual (Head)	0.01
Mean Absolute Residual (Head)	0.77
Root Mean Squared Residual (Head)	1.03
Range of Observations (KM-3 to KMCP-5B)	23.04
Mean Absolute Residual / Range of Observations	3.3%

The simulated heads of the steady state calibrated model are within the calibration target at all observation points (Table 4-1). The mean absolute residual of all of the observations points (0.8 feet) is approximately 3.5% of the change in head in the observed values (Table 4-2), which is much less than our calibration target of 10%. The greatest discrepancy in simulated and observed heads was near the area where the A-Zone aquitard pinches out. The simulated potentiometric surface of the A-Zone has a similar flow direction (northwest) and gradient (0.0048) as observed in May 2013 (Figure 4-1). Similarly, the simulated heads in the B-Zone reproduced the observed flow direction and gradient (Figure 4-2). The observed versus simulated heads for the observation points are shown in Figure 4-3. This graph shows that the observed and simulated heads are mostly distributed on either side of the 1:1 correlation line with a slight distribution bias above the line in the lower elevations.

TABLE 4-2. CALIBRATED MODEL FLUX SUMMARY

Sources/Sinks	Flow In (ft^3/day)	Flow Out (ft^3/day)
CONSTANT HEAD	157,255.0	-178,069.5
RECHARGE	20,814.6	0.0
Total Source/Sink	178,069.6	-178,069.5
Summary	**In - Out (ft^3/day)**	**% difference**
Sources/Sinks	0.12	0.000069
Cell To Cell	0.00	0.00
Total	0.12	0.000069

The model predicted flux through the A-Zone and B-Zone aquifers compares well to the estimated flux through the model domain (model width is approximately 6,500 feet, see Table 2-2). The simulated flux through the A-Zone is approximately 380 gpm, which is within the estimated range in flux through the A-Zone (130 to 580 gpm). The flux leaving the model through the B-Zone is 925 gpm, which is near the lower range of the estimated flux through the B-Zone (840 to 1,940 gpm). The model has less than 0.01% discrepancy in the volumetric flow budget into and out of the model domain showing that the model is numerically stable.

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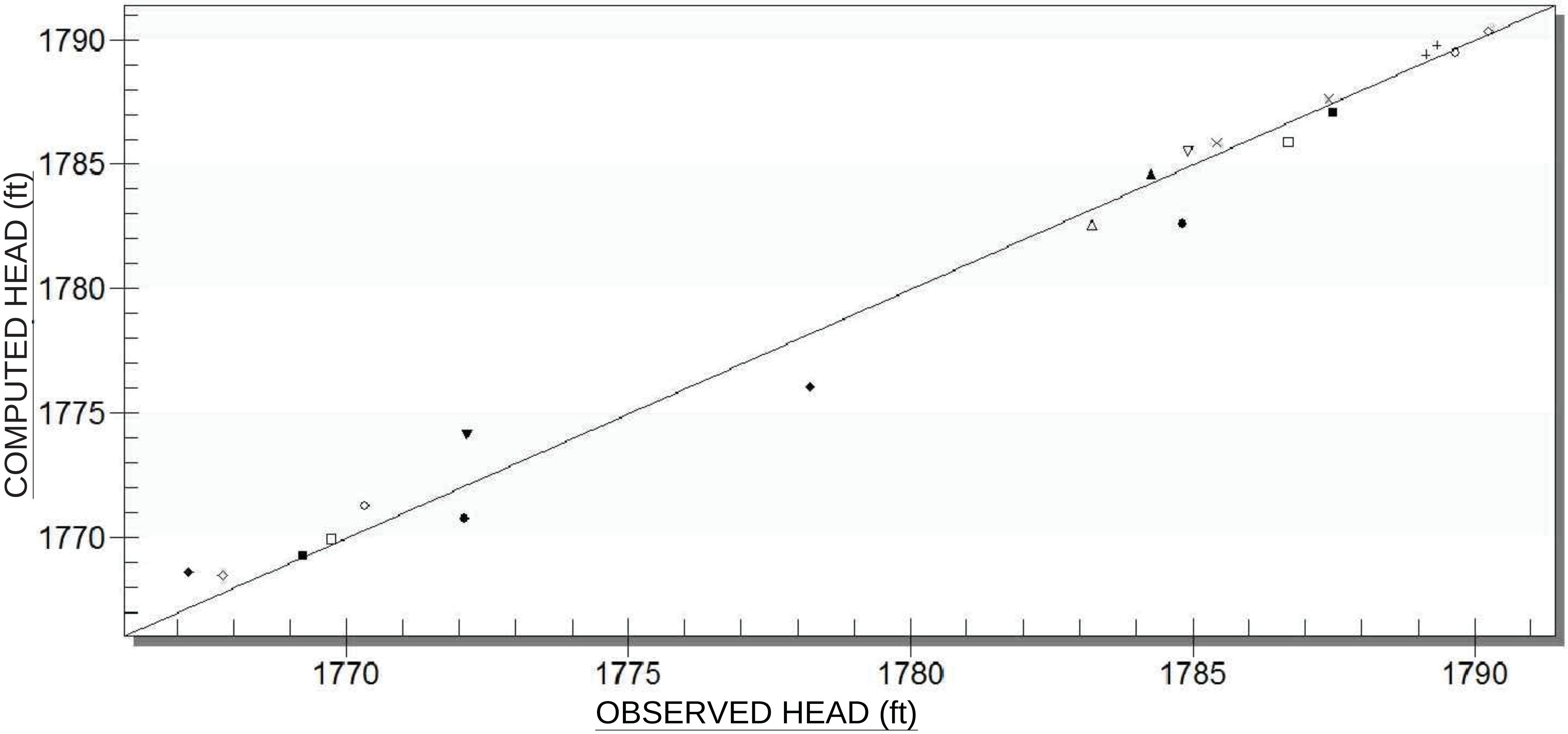

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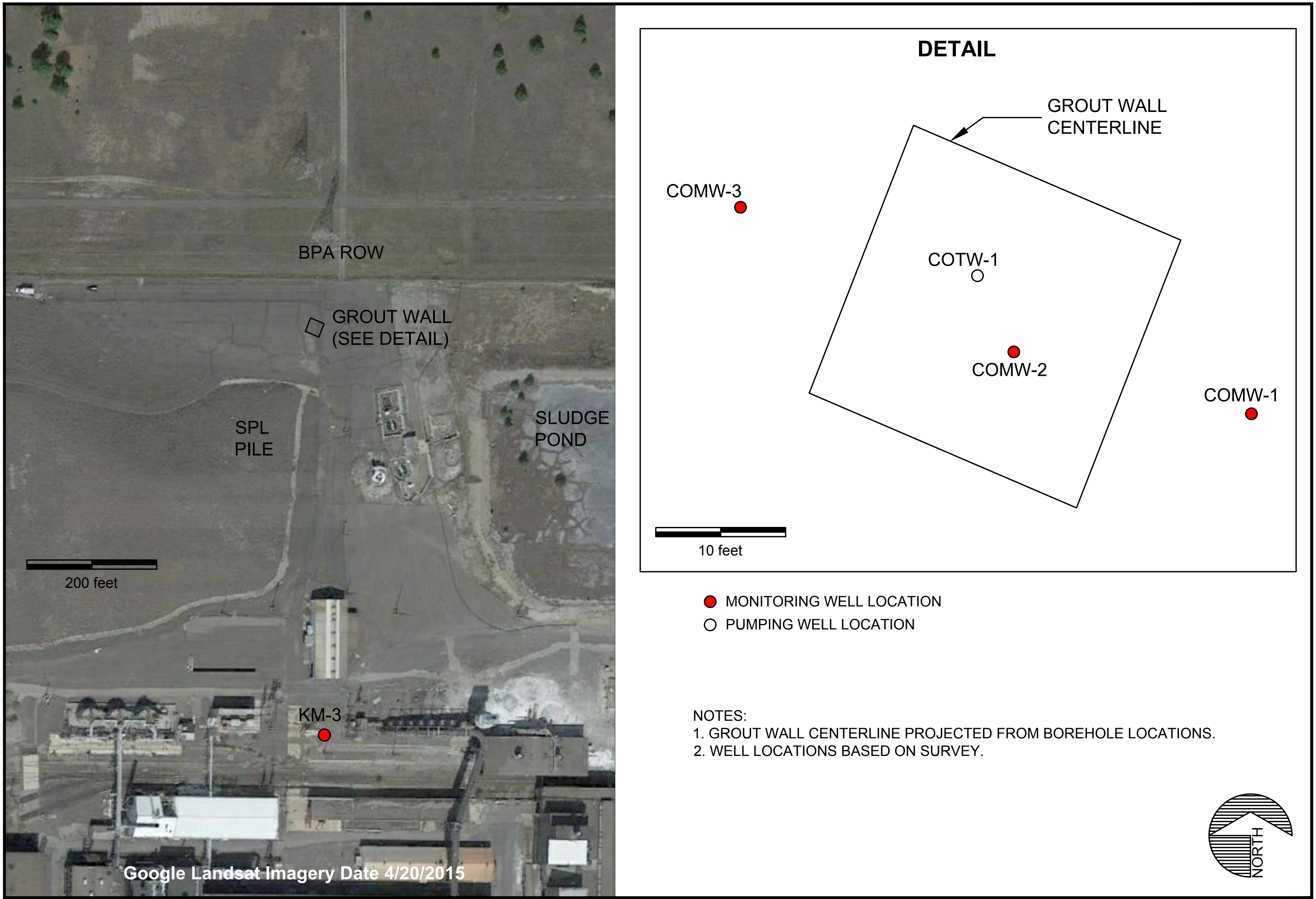
GROUNDWATER FLOW MODEL REPORT KAISER MEAD NPL SITE	**OBSERVED VS COMPUTED HEAD**	FIGURE **4-3**

4.2 TRANSIENT CALIBRATION

A 24-hour pumping test was performed on COTW-1 to determine the aquifer reaction to pumping prior to construction of a pilot test grout wall. Details of the aquifer test were described in the Grout Wall Pilot Test Report (Hydrometrics, 2016b). Data from the 24-hour pumping test were used to conduct a transient calibration to simulate the observed drawdown at each of the observation wells. Material properties for the model layers and horizontal flow barrier (grout wall) were adjusted to match the drawdown curves observed at four observation points (COTW-1, COMW-1, COMW-2, and COMW-3). The locations of the pumping and observation wells are shown on Figure 4-4. The COTW-1 pumping test was simulated by applying a 25 gpm pumping rate to the model at the COTW-1 location for 24 hours. The transient simulation was conducted for 48 hours to evaluate how the simulated pumping and recovery curves match those observed in the four wells. Changes to hydraulic conductivities were applied to the steady state model prior to running the pumping test simulations to be able to evaluate drawdown in the observation wells from steady state conditions. The parameters were adjusted to match both steady state observations and the transient drawdown curves.

The observed and simulated drawdown and recovery curves at the four observation points are shown on Figure 4-5. The drawdown simulated at the pumping well (COTW-1) do not match the magnitude of drawdown observed. This is expected due to the efficiency of the pumping well being approximately 41% at 25 gpm (Hydrometrics, 2016b) and the fact that drawdown simulated by the model represents the average drawdown within the area of the cell containing the pumping well, rather than the drawdown within the pumping well itself. The model provides a better representation of the water levels at monitoring points where stresses are not applied to that specific cell. Therefore, observation wells COMW-1, COMW-2, and COMW-3 were used to evaluate the transient calibration of the model.



● MONITORING WELL LOCATION

○ PUMPING WELL LOCATION

NOTES:
1. GROUT WALL CENTERLINE PROJECTED FROM BOREHOLE LOCATIONS.
2. WELL LOCATIONS BASED ON SURVEY.

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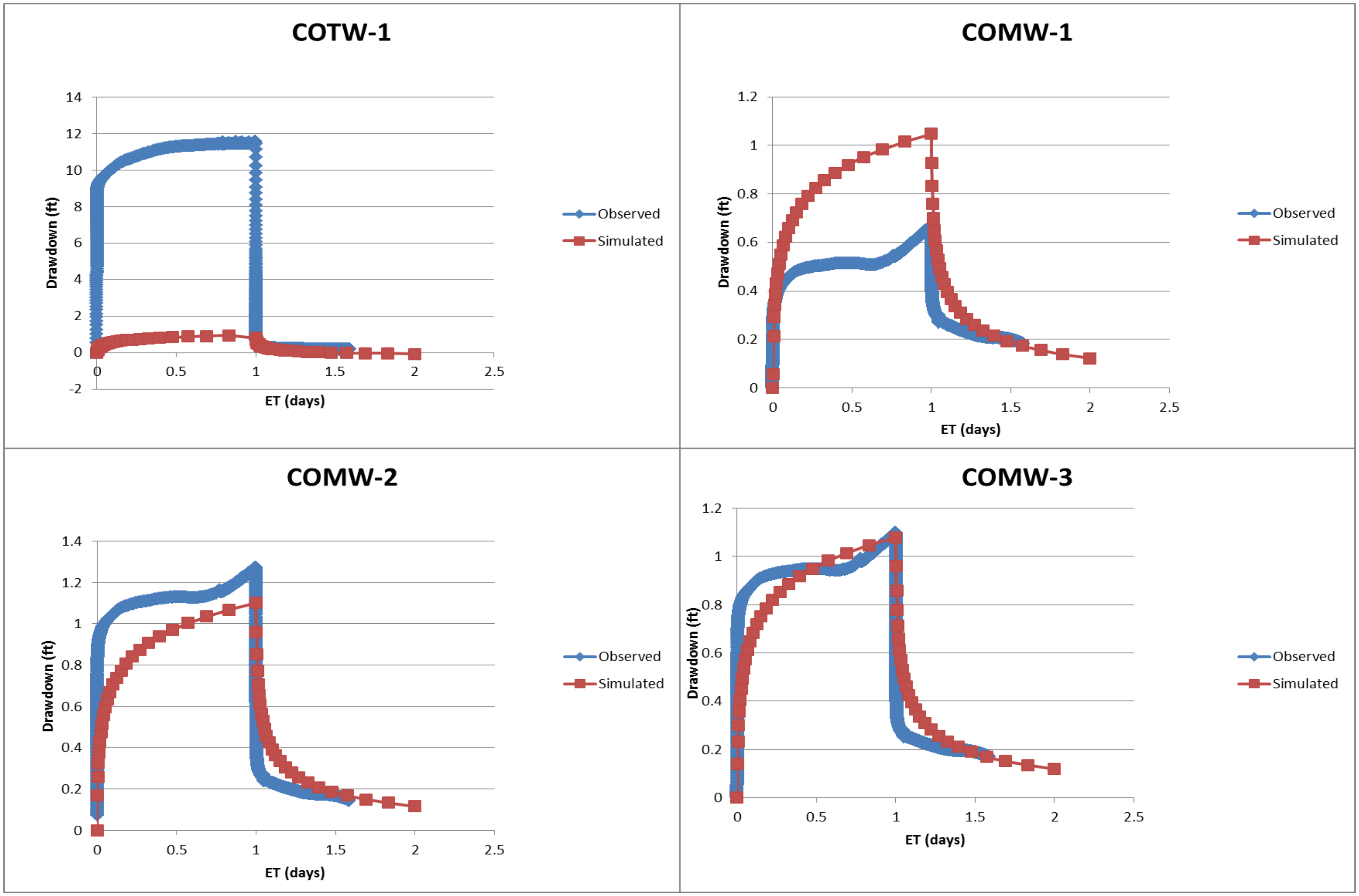
PUMPING TEST WELL LOCATIONS

FIGURE
4-4



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GROUNDWATER FLOW MODEL REPORT KAISER MEAD NPL SITE MEAD, WA	SIMULATED VERSUS OBSERVED DRAWDOWN FOR PRE-WALL AQUIFER TEST	FIGURE 4-5

The observed drawdown in the three observation wells stabilized relatively quickly (4 to 6 hours after pumping began) and remained stable until approximately 18 hours into the test when drawdown started to increase. Evaluation of the background data suggests that the increase in drawdown is likely due to an unidentified stress on the groundwater system (Hydrometrics, 2016b). The model does not include the unidentified stress, therefore, the transient calibration focuses on the portion of the curve prior to the increase in drawdown. Simulated drawdown and recovery trends at COMW-2 and COMW-3 are a good match to those observed during the pumping test with both sites being within approximately 0.1 feet of the observed drawdown. Simulated drawdown at COMW-1 are approximately two times greater than observed during the pumping phase; this is likely due to heterogeneities in the A-Zone aquifer that are not represented in the numerical model as there is insufficient information on the vertical and horizontal extent of the heterogeneities to properly model them. Observed drawdown and recovery values stabilized sooner than simulated values, which might indicate that aquifer storage properties in the model are too high; however, aquifer storage properties do not impact steady-state predictive model simulations. The aquifer characteristics applied to the steady state and transient calibrations are summarized in Table 4-3.

TABLE 4-3. PRE-WALL TRANSIENT CALIBRATION AQUIFER COEFFICIENTS

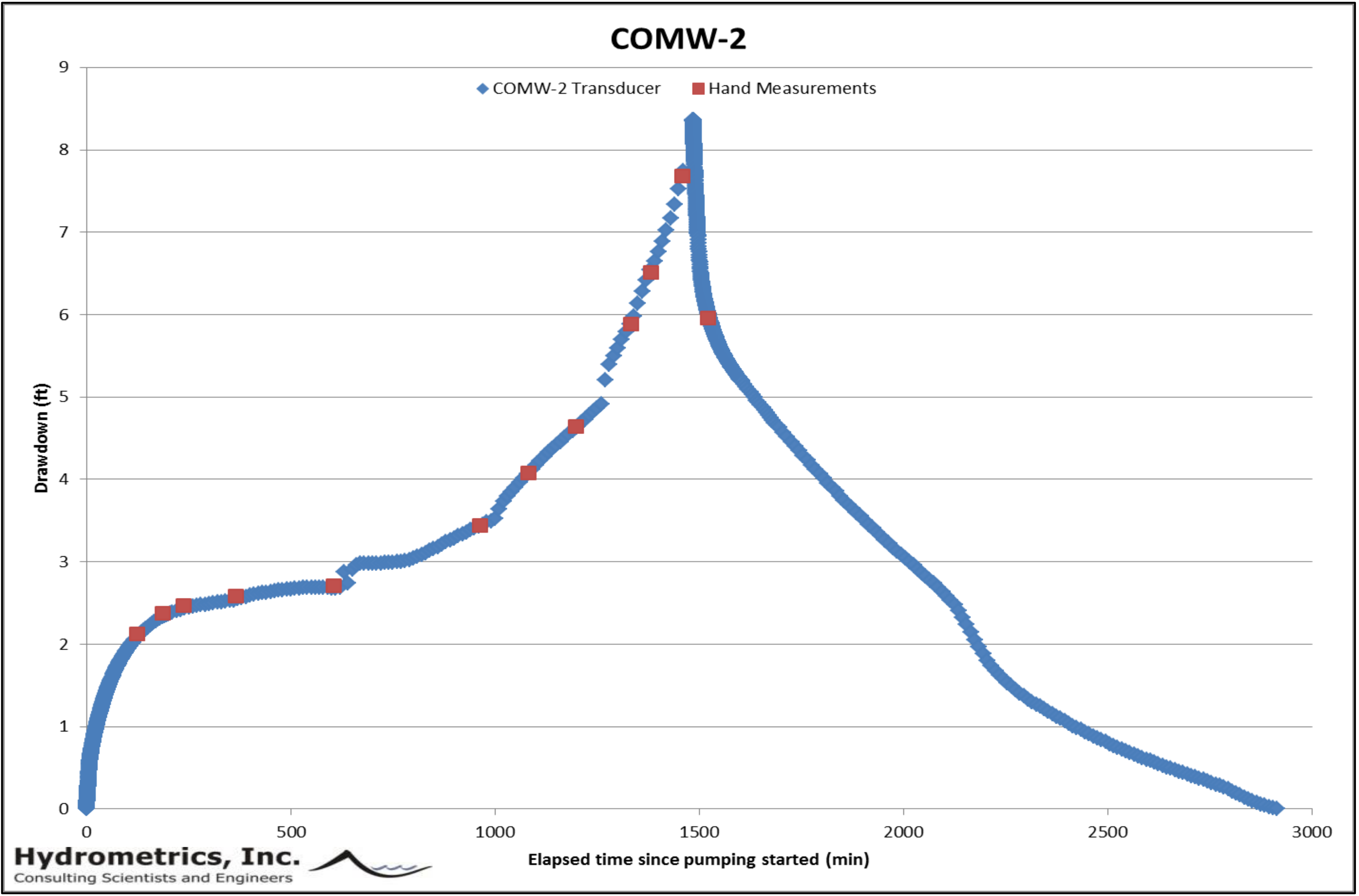
	Horizontal K (ft/day)	Vertical K (ft/day)	Horizontal Anisotropy	Vertical Anisotropy	Specific Storage	Specific Yield
A-Sand 1	100	5	1	20	1.00E-07	0.005
A-Sand 2	100	5	1	20	1.00E-07	0.005
A-Sand 3	100	5	1	20	1.00E-07	0.005
A-Sand 4	100	5	1	20	1.00E-07	0.005
A-Sand 5	100	5	1	20	1.00E-07	0.005
Transition	20	1	1	20	1.00E-07	0.005
A-Aquitard	0.0001	2.5E-06	1	40	1.00E-07	0.005
B-Sand	225	22.5	1	10	1.00E-07	0.005

4.3 EVALUATION OF GROUT WALL CHARACTERISTICS

As noted in Section 3.4.3, the Horizontal Flow Barrier (HFB) package is used to simulate the grout wall. A pilot test grout wall was installed northeast of the SPL pile. Pre and Post wall aquifer tests were conducted to evaluate the effectiveness of the grout wall installation method in limiting groundwater flux. Details of the grout wall pilot test construction and aquifer testing are described in the Grout Wall Pilot Test Report (Hydrometrics, 2016b). Hydraulic conductivity of the grout wall was evaluated during the wall installation through laboratory permeability testing of soil/grout returns during injection of the cement grout; laboratory results ranged from $2.8x10^{-3}$ to $2.8x10^{-5}$ ft/day ($1x10^{-6}$ to $1x10^{-8}$ cm/sec; Hydrometrics 2016b). Based on inspection of a shallow test panel installed prior to injection of the pilot test wall, the grout wall panels range in thickness from about 1 to 6 feet. The characteristics observed from the grout wall installation were used to parameterize the HFB to simulate the pilot test grout wall. The models ability to simulate the grout wall pilot test was evaluated by simulating the post-wall aquifer test conducted as part of the grout wall pilot test.

The drawdown curve from observation well COMW-2 (located within the grout wall box) is shown in Figure 4-6. The observed recovery in well COMW-2 was used to evaluate the models ability to simulate the grout wall aquifer test. The observed drawdown during the pumping phase was not used to evaluate the effectiveness of the model to simulate the grout wall for the following reasons:

- The pumping rate was varied throughout the test resulting in short term drawdown effects due to changes in stress on the aquifer; short term effects are not readily simulated in a groundwater flow model due to the averaging of heads across a cell;
- Drawdown in the pumping well and observation well results in drying of some model cells (not the layer to which pumping is assigned—layer 5), which can cause drawdown in the model to be greater than observed in the natural system; and
- Pumping simulated in the model adds an additional variable that may affect the drawdown; the recovery phase does not include this additional variable making it the most reliable characteristic to evaluate the effectiveness of the HFB to simulate the grout wall.

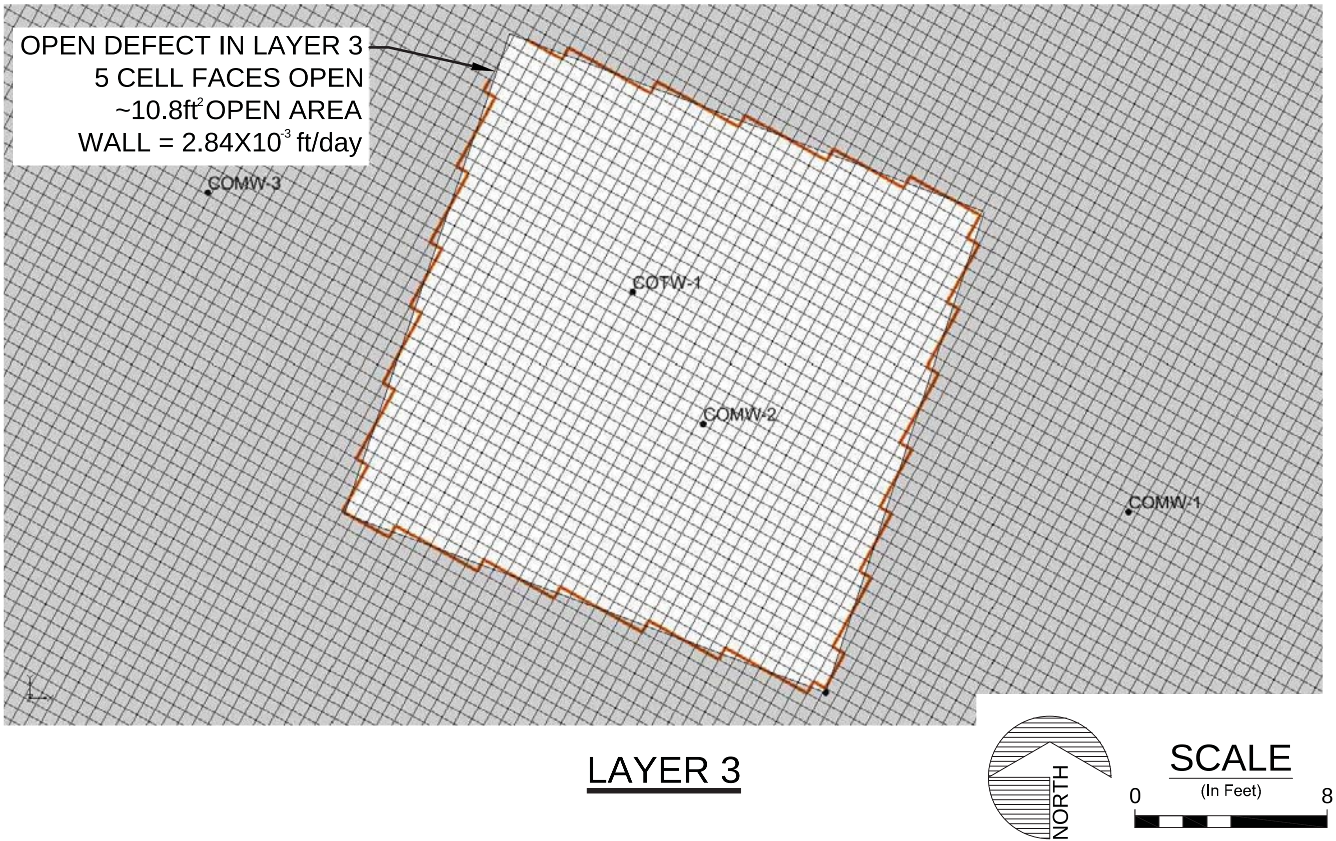


GROUNDWATER FLOW MODEL REPORT KAISER MEAD NPL SITE MEAD, WA	COMW-2 POST-WALL TEST DRAWDOWN AND RECOVERY	FIGURE 4-6

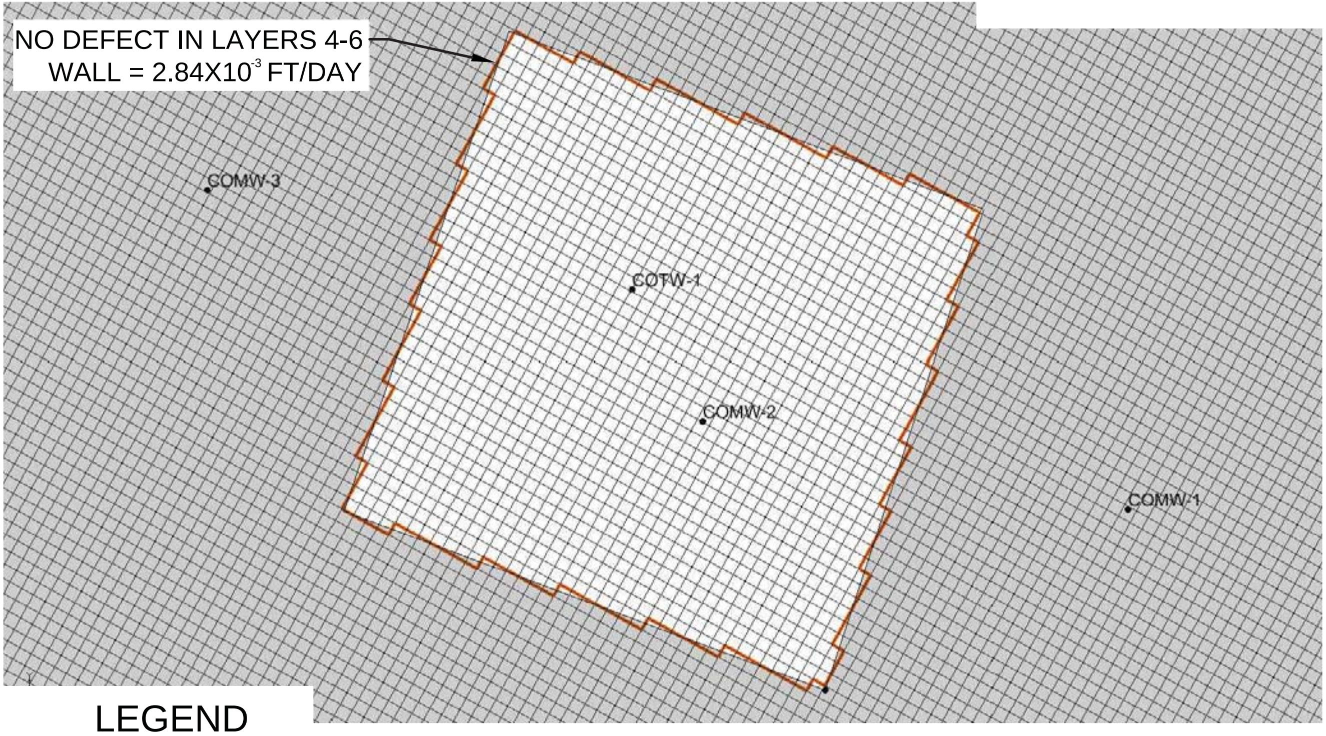
In addition to matching the observed recovery trends, the ability for the HFB to simulate the grout wall pilot test was evaluated based on the estimated flux into the grout wall box during the recovery phase. The flux into the grout wall box during recovery was estimated based on the relatively steady recovery slope seen in Figure 4-6 between approximately 1,600 and 2,100 minutes (7.56 ft/day), which results in a flow rate into the box of 3.5 to 5.2 gpm (Hydrometrics, 2016b). A flow rate into the box between 3.5 and 5.2 gpm suggests the wall permeability is much higher than the laboratory data or there is a flaw in the wall. As noted in the Grout Wall Pilot Test Report (Hydrometrics, 2016b), the grout wall contractor indicated that there was a potential flaw in the wall near the northwest corner of the grout wall box.

Data from the post-wall pump tests were compared with output from the groundwater model in order to estimate the permeability of the completed grout wall. Data from the post-wall pump test are represented in the water level drawdown and recovery chart for monitoring well COMW-2 (Figure 4-6), the well adjacent to the pumping well and located within the area enclosed by the grout wall box. Numerous modeling scenarios were investigated when attempting to fit output from the groundwater flow model to the observed COMW-2 recovery data. The best fit to the observed recovery curve was simulated with a grout wall permeability of $2.83\text{x}10^{-3}$ ft/day, a thickness of 3 feet, and a defect in the wall near the northwest corner of the grout wall box. The defect in the grout wall was simulated by removing the HFB in layer 3 of the model in the northwest corner of the grout wall box (Figure 4-7). The simulated and observed drawdown and recovery curves are shown on Figure 4-8.

During the pumping phase, simulated drawdown was greater than observed at COMW-2; this may be due to the effects dry cells have on the drawdown curve or the other factors discussed above regarding the potentially inaccurate modeling of the pumping phase. The simulated recovery curve provides a reasonable fit to the key data observed in COMW-2. The initial steep recovery likely represents the filling of the drawdown cone within the grout wall box; although the curves are offset due to the pumping phase the magnitude and slope of this



LAYER 3



LAYER 4

LEGEND

―	GROUT WALL BOX
•	OBSERVATION POINT

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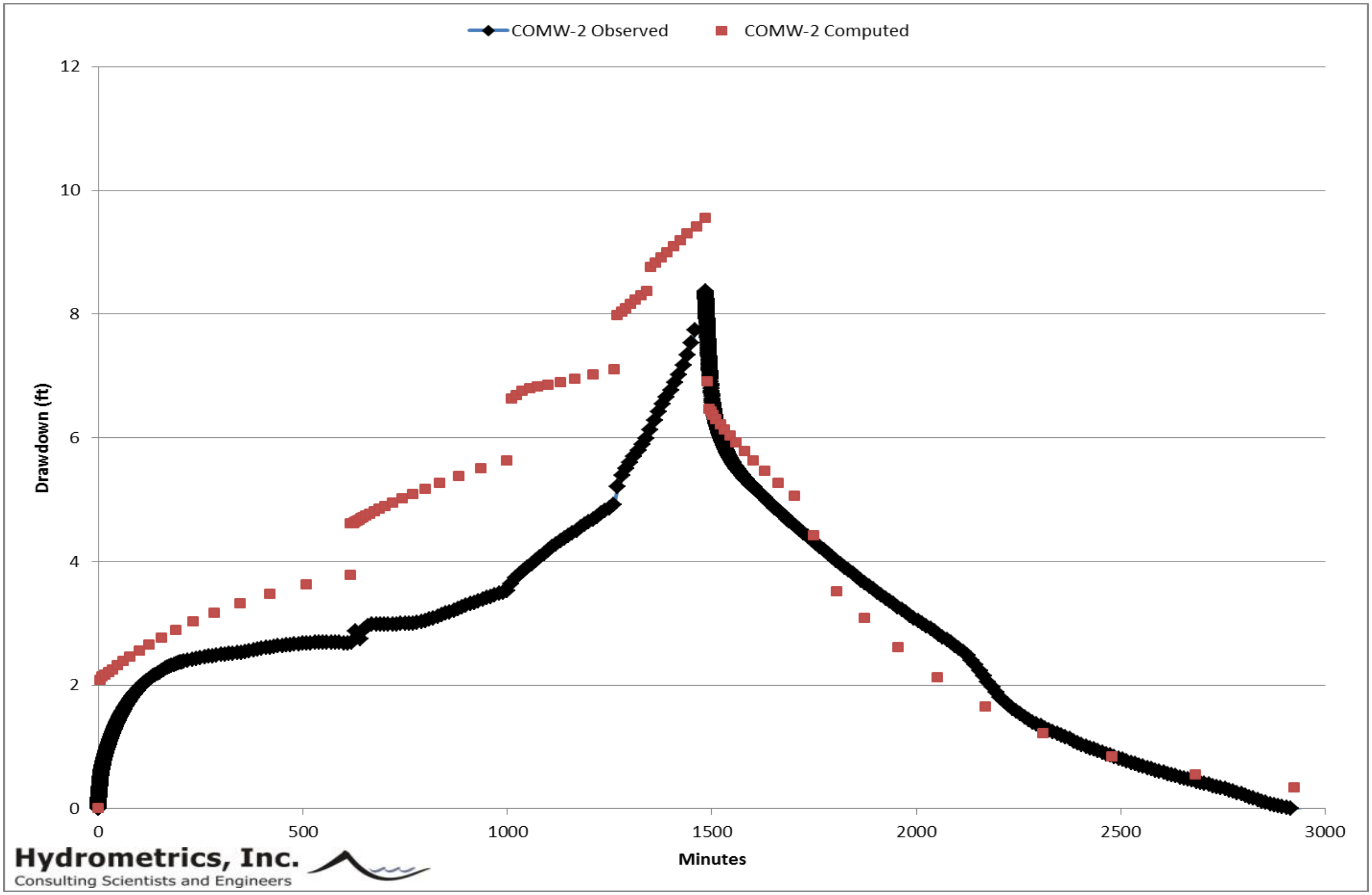
MODELED BOX WALL CONFIGURATION

FIGURE

4-7



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POST-WALL AQUIFER TEST
SIMULATED VS. OBSERVED
DRAWDOWN AT COMW-2

FIGURE

4-8

portion of the recovery are similar to the initial observed recovery. A second relatively constant slope representing a constant flux into the wall (which was used to calculate the flux into the grout wall box) is seen in the simulated recovery; however, the duration of the constant recovery and slope deviate slightly from that observed. The simulated groundwater flux into the grout wall box associated with this portion of the recovery curve ranged between 3.6 and 4.2 gpm, which compares well to the estimated groundwater flux from the observed recovery curve. The constant slope is followed by a short-term steep recovery that likely represents the water levels recovering to the elevation of the defect in the wall and groundwater flux through the defect becomes saturated flow from the outside to the inside of the box. This steep recovery is present in the simulated recovery, but it occurs sooner in the simulated recovery curve and is slightly greater than that observed; which are likely due to the model not simulating unsaturated flow and/or the defect being larger in the model than in the pilot test grout wall box. Lastly, the recovery curve returns to a more gradual recovery which decreases in slope over time. This is also seen in the simulated recovery; however, the timing in slightly different due to the potential discrepancies noted above.

In summary, the calibrated model provides a detailed evaluation of its ability to match observed heads and fluxes under both steady state conditions and under stresses applied to the groundwater system. The steady state calibrated model met head calibration criteria throughout the model domain and the simulated groundwater flux in the A-Zone and B-Zone aquifers are within the range of estimated flux. The model was also able to simulate similar response in heads and flux during the grout wall pilot test. All of these factors represent a well calibrated model for the purpose of evaluating the selected remedial alternatives.

5.0 REMEDIAL ALTERNATIVE FORECASTING ANALYSIS

The calibrated numerical model was used to evaluate multiple remediation alternatives through steady state forecasting analyses. One of the remedial alternatives evaluated in 2013 included a combination of a grout wall and extraction wells. This alternative was not evaluated in the groundwater model because saturated thicknesses downgradient of highest concentration of the plume are too thin (5 to 8 feet) for extraction wells; additionally, the saturated thickness is decreased downgradient of the grout wall limiting the feasibility of extraction wells in the center of the highest concentrations of the plumes. Due to the limited saturated thickness downgradient of the plume center, remedial alternatives evaluated with this numerical model were limited to evaluation of grout walls to limit flow through the plume area, pumping from the A-zone near the center of the plume without a grout wall in place, and pumping from the B-Zone upgradient of the compliance line.

5.1 FINDINGS OF PRELIMINARY MODELING

In 2015, a steady state calibrated model was developed (prior to the pump tests discussed in Section 4) as a preliminary framework for development of the model presented in this report. Although the preliminary model differed in the number of layers and hydraulic properties from the final model utilized for analysis of potential remedial alternatives, the findings from the preliminary model provided important insights on how grout wall construction may affect flux reduction. The preliminary model was calibrated to within the calibration targets noted above prior to conducting any predictive analyses. Development of the preliminary model resulted in findings that guided simulation of potential remedial alternatives. A summary of these findings is presented prior to discussing the modeling analyses of remedial alternatives associated with installation of a grout wall.

The preliminary model was utilized to determine the relationship between barrier conductivity and the amount of flow reduction through the area enclosed by a barrier (grout wall). The effect of the wall was quantified by comparing the total flux leaving two zones (zone #2 and zone #3) within the area enclosed by the barrier (Figure 5-1). The two zones

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LEGEND

- BARRIER WALL
- ZONE BUDGET AREA BORDER

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SPL GROUT WALL LAYOUT FOR PRELIMINARY ANALYSIS

FIGURE
5-1

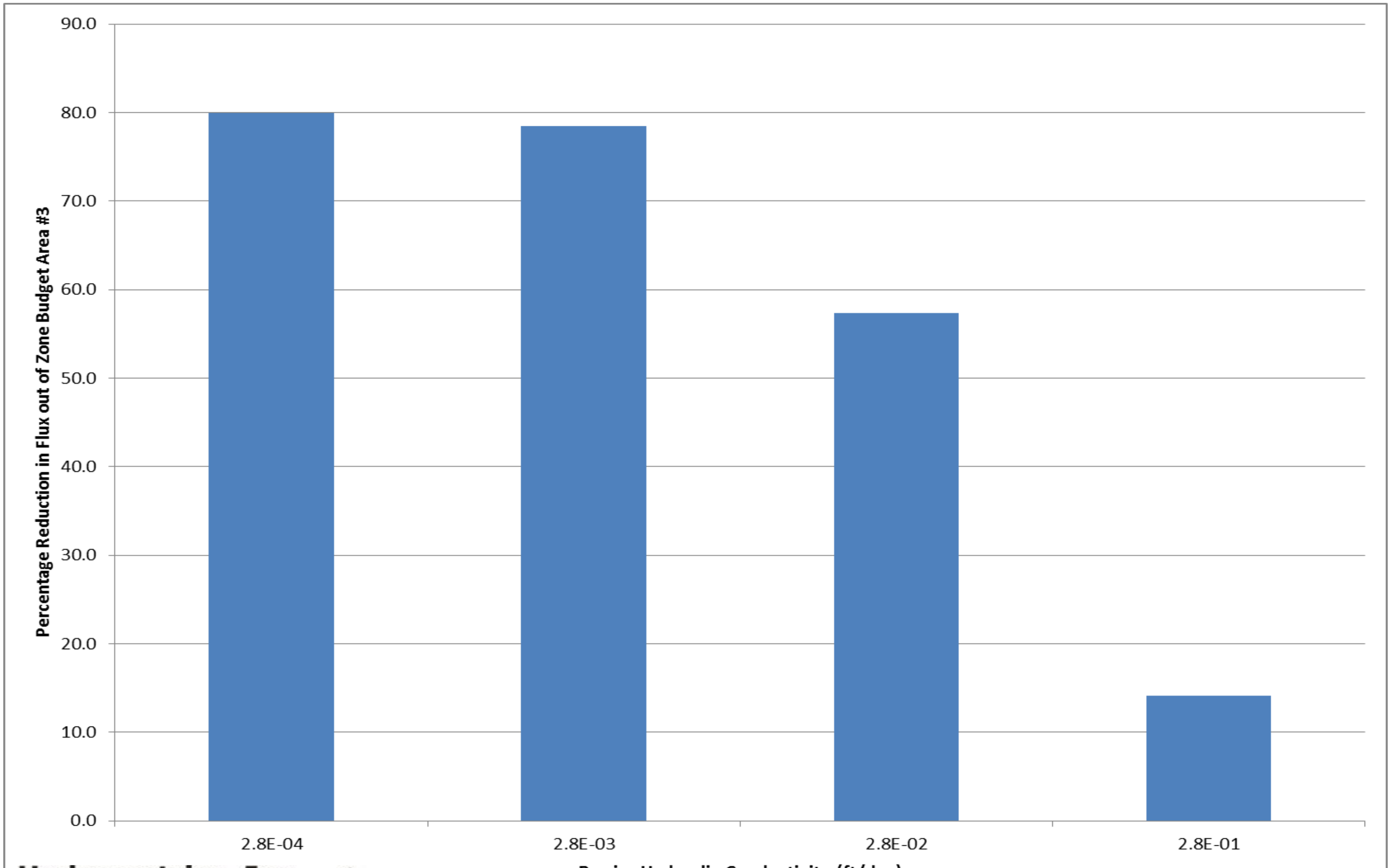
were utilized because water flows through the wall to a varying degree based on the orientation of the wall relative to the direction of groundwater flow and because flow tends to wrap around the open ends of the wall, which results in higher flux into and out of zone #3 versus zone #2. For the purpose of this evaluation, the grout wall was simulated around three sides of the SPL pile area with the downgradient end remaining open. Simulations were run with a range of barrier hydraulic conductivities (2.84×10^{-1} to 2.84×10^{-4} ft/day).

The percent reduction was evaluated based on the flux out of zone #3. As seen in Table 5-1 and Figure 5-2, the reduction in flow ranged from 14% to 80% for the range in hydraulic conductivities applied to the grout wall. The simulations show there is a large difference in flux reduction between barrier hydraulic conductivity of 2.84×10^{-1} ft/day (14%) and 2.84×10^{-2} ft/day (57%) and between 2.84×10^{-2} ft/day (57%) and 2.84×10^{-3} ft/day (79%), however, the difference between 2.84×10^{-3} ft/day (79%) and 2.84×10^{-4} ft/day (80%) is relatively small.

TABLE 5-1. GROUT WALL PERMEABILITY SUMMARY

Model Scenario	Wall Conductivity (ft/day)	Flux out of Zone #2 (gpm)	Flux out of Zone #3 (gpm)	Reduction vs No Wall	Drawdown (ft)	Mounding (ft)	Head Difference Across Wall (ft)
No Wall	NA	124	175	NA	NA	NA	NA
Wall-1	2.84×10^{-4}	0.7	35	80%	9.9	2.3	12.2
Wall-2	2.84×10^{-3}	5	38	79%	9.3	2.2	11.5
Wall-3	2.84×10^{-2}	35	75	57%	6.0	1.7	7.7
Wall-4	2.84×10^{-1}	88	150	14%	1.7	0.8	2.5

The drawdown downgradient of the wall and the mounding upgradient of the wall was recorded for each simulation. The difference from one side of the wall to the other varied from 2.5 to 12.2 feet. At the target barrier hydraulic conductivity (2.84×10^{-3} ft/day), the mounding was 2.2 feet and the drawdown was 9.3 feet, which indicates the grout wall should be built to extend more than five feet above the highest water table (assumes a factor of safety of 2).



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GROUNDWATER FLOW MODEL REPORT KAISER MEAD NPL SITE MEAD, WA	PERCENT REDUCTION IN FLOW PER BARRIER PERMEABILITY	FIGURE 5-2

As noted above, drawdown downgradient of a barrier has potential implications for pumping as part of an ex-situ treatment alternative since it reduces already small saturated thicknesses.

In order to determine the potential effects of imperfect wall construction, simulations were conducted with a barrier of variable conductivity. The model grid in the area of the barrier was refined with less than 1-foot cells faces so that small scale imperfections could be modeled. The HFB package allows individual cell length portions of the barrier to be turned off (a complete void in the wall) or have a different hydraulic characteristic.

For this analysis, a version of a full scale grout curtain was modeled at various conductivities to establish a baseline for the given barrier shape (see Figure 5-3). Next, the varying impact of a single flaw at different locations in the barrier was investigated by simulating one flaw at a time at different locations and comparing the flux leaving the area enclosed by the barrier. The barrier was modeled with a hydraulic conductivity of 2.84×10^{-3} ft/day and the flaw was modeled with a hydraulic conductivity of 2.84 ft/day. The flawed portion is one cell wide (~1-foot) and covers the entire height of the barrier (model layers 1 and 2—approximately 35 feet—note, the preliminary model utilized for this analysis was a four layer model with two layers representing the A-Zone). This analysis showed that the most sensitive portion of the barrier to a flaw is that which is most perpendicular to the direction of groundwater flow (Flaw #3). The increase in flux leaving the area enclosed by the barrier ranged from 0% to 1.2%, or up to 3.7 gpm due to Flaw #3.

Finally, two simulations were conducted with many flaws spread equally across the length of a barrier (different barrier shape than utilized in previous analyses). The total length of the barrier is approximately 2,510 feet. The first simulation modeled approximately 1% of the wall length being flawed (flaw conductivity of 2.84 ft/day versus a barrier conductivity of 2.84×10^{-3} ft/day). The un-flawed wall with a barrier conductivity of 2.84×10^{-3} ft/day resulted in a 79.4% reduction in flux leaving the area enclosed by the barrier versus the simulation with no barrier. The same barrier with 1% of the length being flawed resulted in a 69.8% reduction in flux leaving the area enclosed by the barrier versus the simulation with no barrier, which is approximately 10% or about 28 gpm higher than the un-flawed wall.

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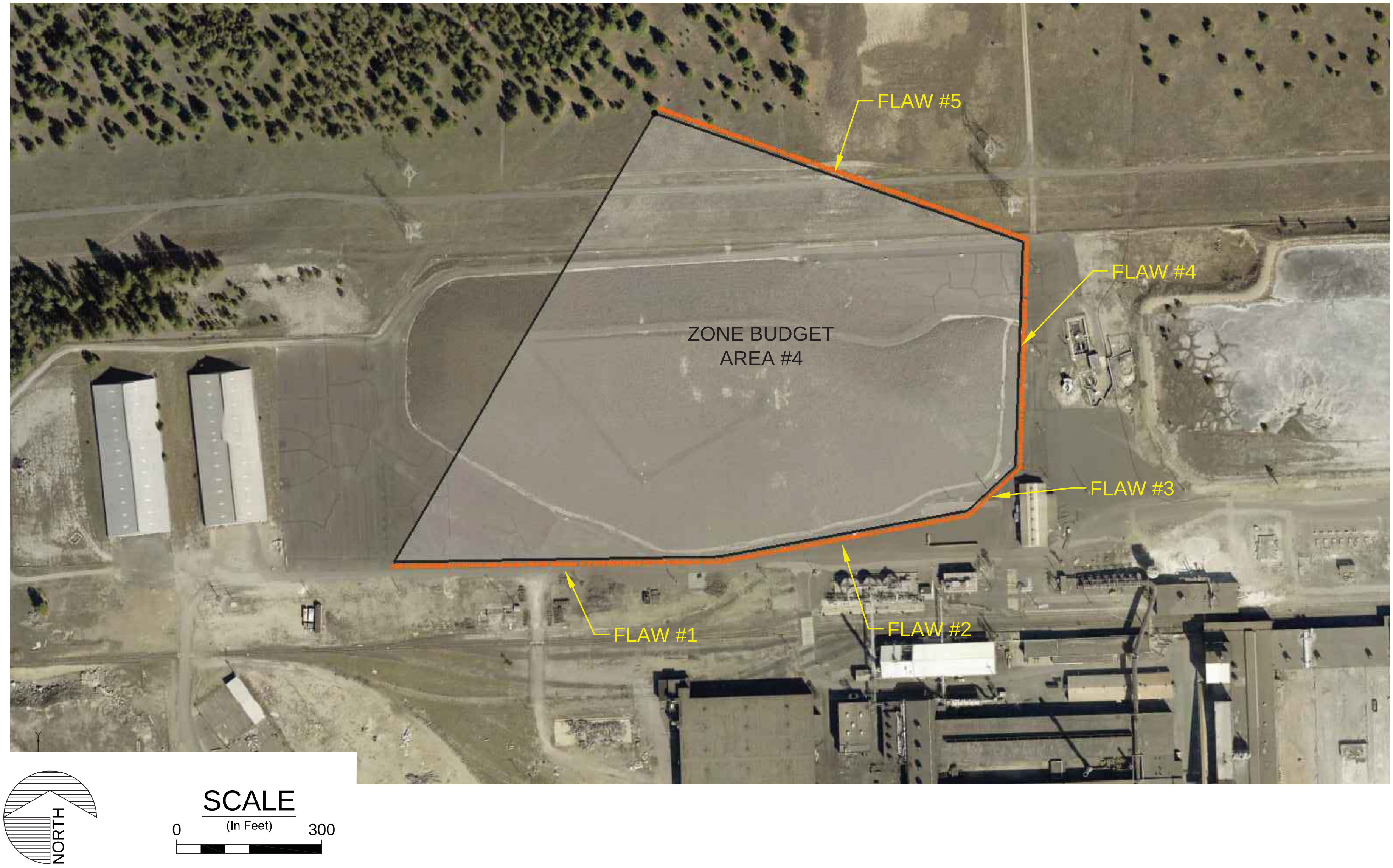

LEGEND

┅ BARRIER WALL

— ZONE BUDGET AREA BORDER

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FLAWED GROUT WALL LAYOUT

FIGURE
5-3

The second simulation modeled approximately 10% of the wall length being flawed (flaw conductivity of 2.84 ft/day versus a barrier conductivity of 2.84x10^{-3} ft/day). The simulation with 10% of the length being flawed resulted in a 30.4% reduction in flux leaving the area enclosed by the barrier versus the simulation with no barrier, which is approximately 50% or 143 gpm higher than the un-flawed wall (see Table 5-2).

TABLE 5-2. SUMMARY OF FLAWED GROUT WALL ANALYSES

Model Scenario	Wall Conductivity (ft/day)	Flaw Conductivity (ft/day)	Total flux out of zone budget area #2 (ft^3/day)	Percentage flux reduction vs. no wall
No wall	NA	NA	56051	NA
Full wall	2.84	NA	53189	5.1
Full wall	0.284	NA	40707	27.4
Full wall	0.0284	NA	17954	68.0
Full wall	2.84x10^{-3}	NA	11520	79.4
Full wall	2.84x10^{-4}	NA	11039	80.3
Flaw #1 alone	2.84x10^{-3}	2.84	11544	79.4
Flaw #2 alone	2.84x10^{-3}	2.84	11977	78.6
Flaw #3 alone	2.84x10^{-3}	2.84	12238	78.2
Flaw #4 alone	2.84x10^{-3}	2.84	12092	78.4
Flaw #5 alone	2.84x10^{-3}	2.84	11603	79.3
~10% of wall length	2.84x10^{-3}	2.84	39023	30.4
~1% of wall length	2.84x10^{-3}	2.84	16934	69.8

Subsequent transient calibration of the final model to the pilot test box post-wall aquifer test data indicated a best-fit to the observed data when approximately 2.9% of the box wall length was flawed (no grout). A more informative way of looking at the amount of flawed or defective wall is by area not length. The best fit was achieved when approximately 0.7% (10.8 ft^2) of the wall area contained no grout.

5.2 FULL SCALE GROUT WALL REMEDIAL ALTERNATIVES

5.2.1 Grout Wall Simulation Model Construction

Two full scale grout wall configurations were evaluated for final analyses. The two alternatives include a wall around the capped spent potliner (SPL) pile and a larger wall around the SPL pile and the downgradient groundwater plume center area (Figures 5-4 and 5-5, respectively). The modeled SPL only wall was approximately 2,950 feet long and the larger SPL and plume center wall was approximately 4,940 feet long. A grout wall around the plume center was intended to route groundwater around some of the secondary source area confirmed by wells installed in 2015 and 2016 (KM-8 through KM-18). The grout walls were modeled under steady-state conditions utilizing the aquifer coefficients obtained during model calibration (Table 4-1).

The two grout wall configurations were evaluated with and without defects and with and without fully enclosing the wall on the downgradient side. In areas without flaws, it is assumed that a full scale grout wall will be constructed with similar results seen in the pilot test; therefore, the grout wall simulations were completed with a 2.84×10^{-3} ft/day grout wall hydraulic conductivity and a thickness of 3 feet; resulting in a hydraulic characteristic of 9.45×10^{-4} day^{-1}.

For simulations with defects, the percent of wall with defects was based on the transient model calibration to the post pilot wall aquifer test. As described in Section 4.3, simulation of the post pilot wall aquifer test data was achieved by simulating 10.8 ft^2 of void in the grout wall or 0.7% of the total wall area exposed to the aquifer. This same percentage of open area was targeted when simulating defects in the grout wall scenarios. Based on the limitations of fixed cell sizes and varying water levels, which result in varying defect open area, an exact match to the defect area simulated for the pilot test wall was not obtainable for grout wall scenarios. Defects were modeled at a hydraulic conductivity equal to the native aquifer material (100 ft/day) with the remainder of the wall at 2.84×10^{-3} ft/day.

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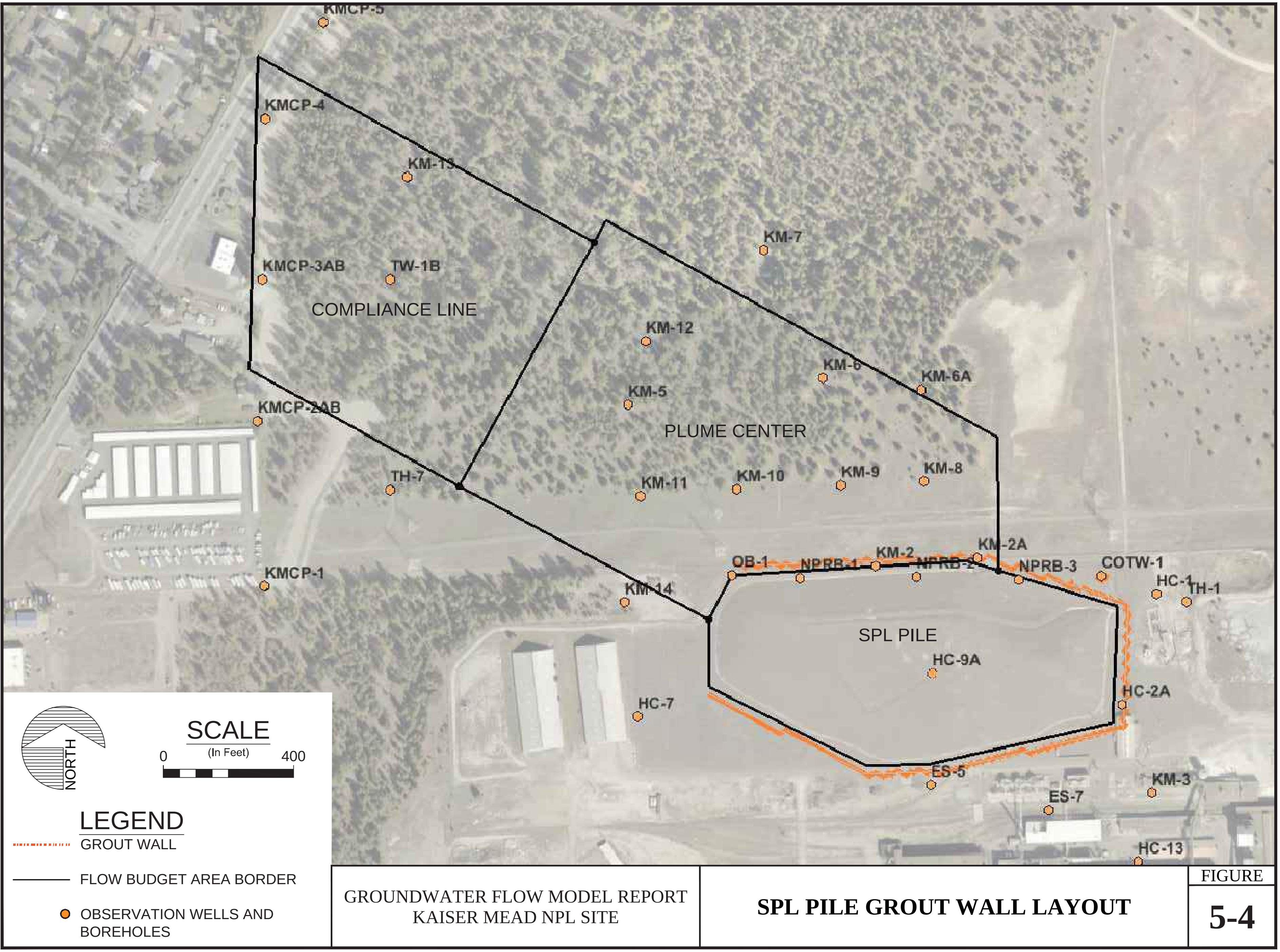

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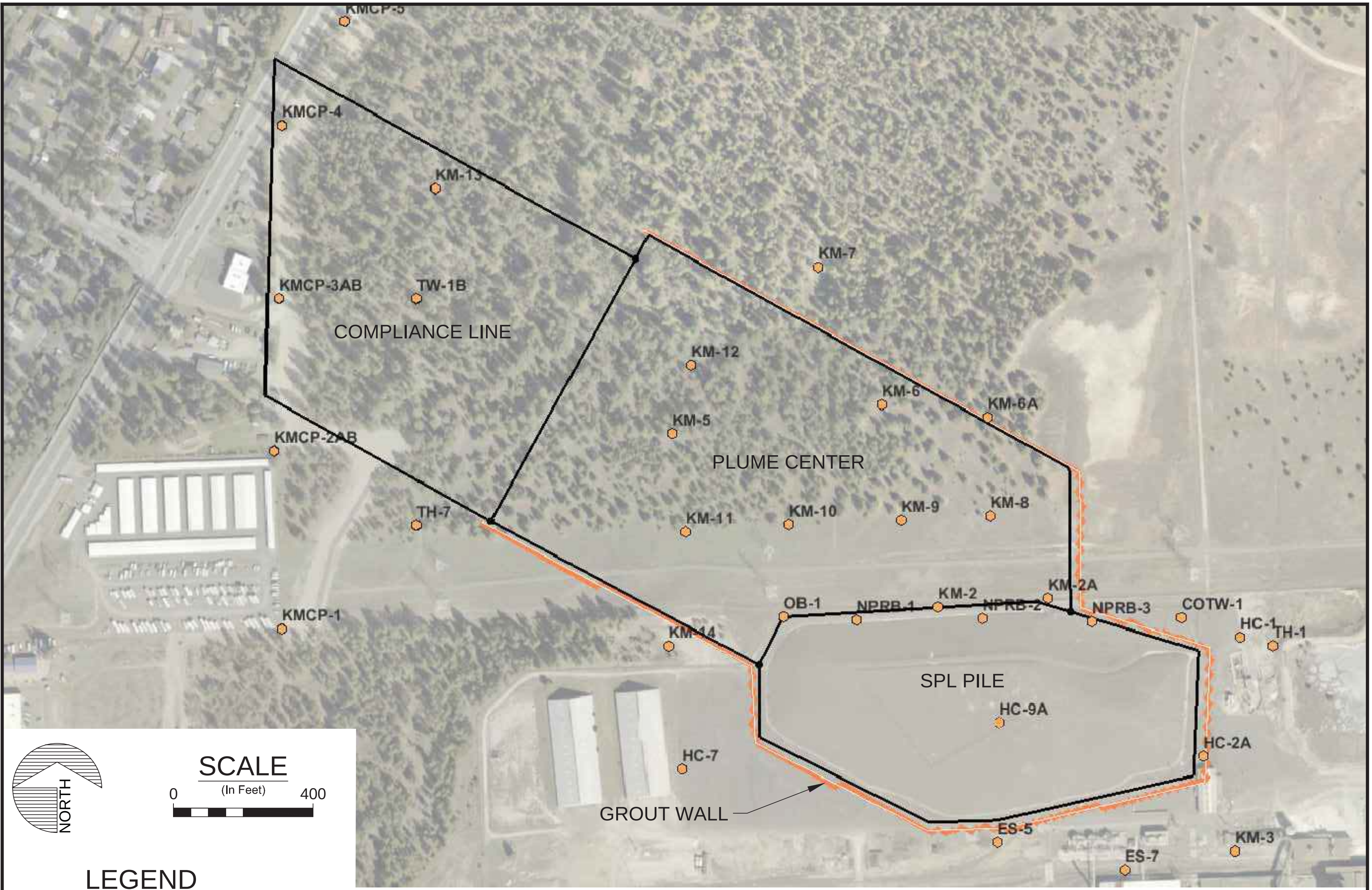
SPL PILE GROUT WALL LAYOUT

FIGURE
5-4



SCALE
(In Feet)
0 400

LEGEND

GROUT WALL

FLOW BUDGET AREA BORDER

● OBSERVATION WELLS AND BOREHOLES

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EXTENDED
GROUT WALL LAYOUT

FIGURE
5-5

The SPL pile grout wall was simulated with one defect spanning all layers resulting in approximately 0.7% of the wall having defects. The plume center grout wall included two voids, each one cell wide and including all layers in the A-Zone resulted in an approximate void area of 1% of the total grout wall, which is slightly more than the targeted 0.7%.

Preliminary modeling discussed in Section 5.1 indicated that defects in a grout wall made the largest impact to flux when the defect was located on an upgradient portion of the wall where the wall is most perpendicular to flow. Therefore, the defects were placed on the upgradient wall faces around the SPL pile so that they would have the largest potential impact on the flux through the wall.

5.2.2 Grout Wall Simulation Results

Grout wall alternatives were evaluated based on the percent reduction in groundwater flux through three specific areas—the SPL pile, the plume center area immediately downgradient of the SPL pile, and the B-Zone aquifer leading up to the compliance line wells. Each grout wall alternative was compared to the steady state calibration of the model discussed in Section 4.1. Figure 5-6 shows the three areas analyzed for flux reduction and the ambient groundwater flux into each area. The same areas were utilized in geochemical modeling of remedial alternatives described in the Draft Kaiser Mead Sediment: Groundwater Partitioning and Mass Balance Report (Hydrometrics, 2016c). The reduction in flux for each of the grout wall constructions and defect analyses are discussed below.

<u>SPL Pile Grout Wall</u>

Four simulations were conducted to evaluate the effectiveness of a grout wall around the SPL pile, which included two configurations (open on downgradient end and fully enclosed) and both configurations simulated with and without a defect as described in Section 5.2.1. The results of the SPL pile grout wall simulations are summarized in Table 5-3.

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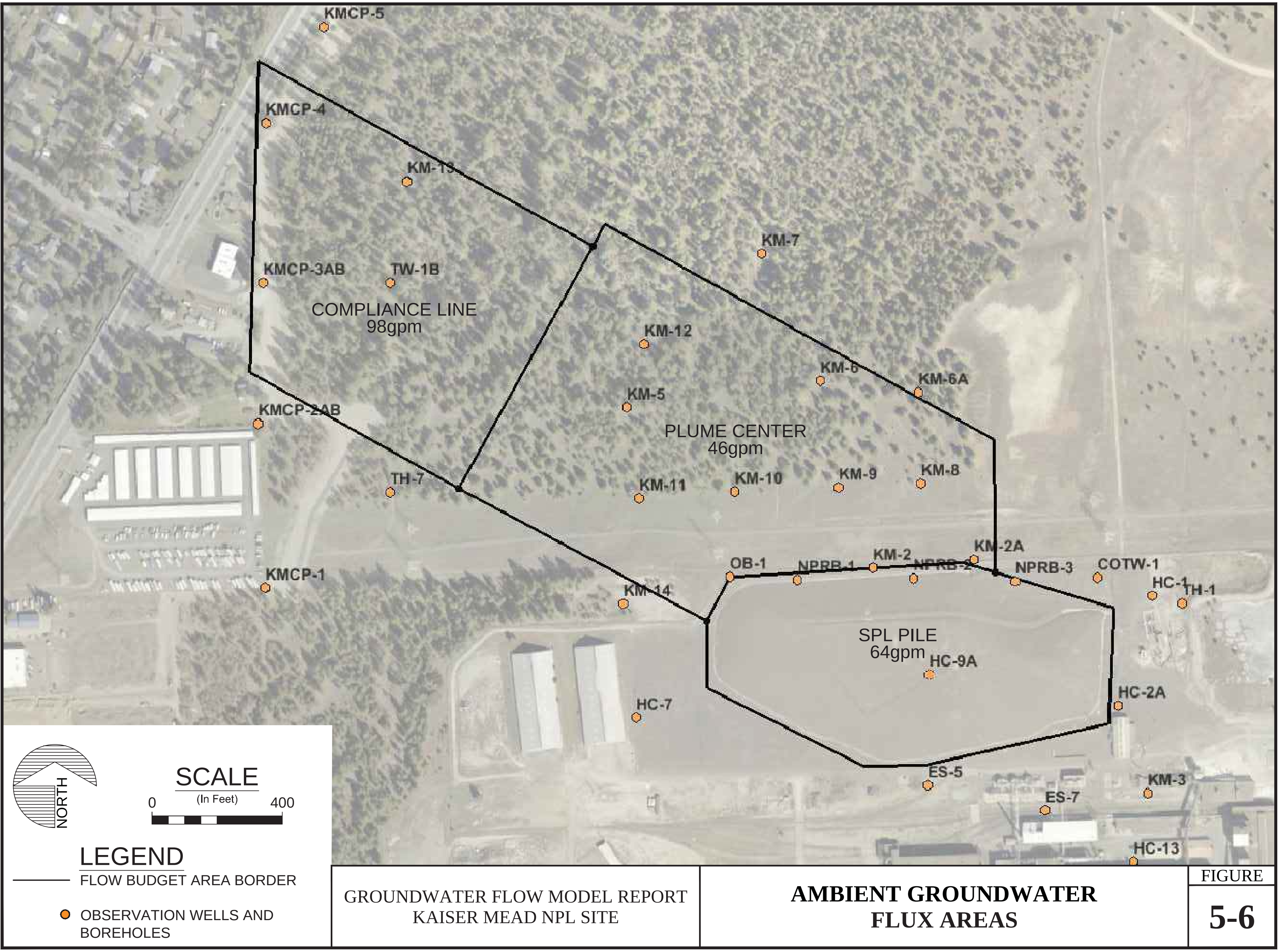

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AMBIENT GROUNDWATER FLUX AREAS

FIGURE
5-6

TABLE 5-3. FLUX REDUCTION FROM SPL PILE GROUT WALL

Model Area	Ambient Groundwater Flux (gpm)	Flux with Grout Wall (gpm)	% Reduction	% Ambient Remaining after Grout Wall
SPL Pile Wall Open West End – No Defects				
Total into SPL	64	6	91%	9%
Total into Plume Center	46	33	27%	73%
Total into Compliance Line	98	97	1%	99%
SPL Wall Fully Enclosed - No Defects				
Total into SPL	64	1	98%	2%
Total into Plume Center	46	32	30%	70%
Total into Compliance Line	98	97	1%	99%
SPL Wall Open West End – 0.7% Defect				
Total into SPL	64	43	32%	68%
Total into Plume Center	46	43	6%	94%
Total into Compliance Line	98	97	1%	99%
SPL Wall Fully Enclosed – 0.6% Defects				
Total into SPL	64	4	94%	6%
Total into Plume Center	46	32	30%	70%
Total into Compliance Line	98	97	1%	99%

The simulation of the open ended SPL pile grout wall without defects resulted in a 91% reduction in flux into the SPL area. The flux reduction was only 27% into the downgradient plume center area as groundwater flowed around the wall and back into the plume center. At the compliance line area, there was a 1% reduction in flux versus the ambient condition with no wall. Installation of the grout wall resulted in mounding upgradient of the wall and lowering of the water table downgradient of the wall. The maximum difference in water level from one side of the wall to the other was approximately 8.6 feet; with 1.7 feet of mounding upgradient of the wall and a lowering of the water level by 6.9 downgradient of the wall.

Closing the west end of the wall added approximately 480 feet to the length of the wall. The flux into the SPL pile area was reduced an additional 7% to a total flux reduction of 98%

versus the ambient condition. Flux into the plume center area was decreased an additional 3%, and flux into the compliance line area did not change. The maximum difference in water level from one side of the fully enclosed wall to the other was approximately 5.4 feet. In this case, the maximum difference occurred at the downgradient or west end of the wall where there was 3.7 feet of mounding within the closed wall and a lowering of the water level by 1.7 feet on the downgradient outside of the wall. The model does not simulate any mounding above the grout wall; this is likely due to the very low recharge rate under the capped SPL pile which is less than the leakage through the wall.

Adding a defect to the grout wall on the eastern side resulted in much greater flow through the SPL pile area (43 gpm, 32% reduction) and plume center (43 gpm, 6% reduction) than without defects. However, if the wall is enclosed on the downgradient end, the reduction in flow is similar to the wall without defect; with flow being reduced by 94% in SPL area and 30% in the plume center. With no defect in the downgradient end of the wall, minimal flux enters the upgradient defect as the water level inside and outside the wall reach a state of equilibrium. A fully enclosed grout wall is more sensitive to defect location than a grout wall with an open downgradient end.

SPL Pile and Plume Center Grout Wall

The grout wall extended around the plume center area was simulated to encompass the known and projected secondary sources based on sediment data and water quality data. Similar to the SPL pile grout wall, the extended grout wall to the plume center was evaluated with an open end on the downgradient side and a fully enclosed wall. The open and enclosed wall configurations were simulated with and without defects. The results of the simulations and the corresponding reduction in groundwater flux are summarized in Table 5-4.

TABLE 5-4. FLUX REDUCTION FROM EXTENDED GROUT WALL

Model Area	Ambient Groundwater Flux (gpm)	Flux with Grout Wall (gpm)	Percent Reduction	% Ambient Remaining after Grout Wall
SPL and Plume Center Wall Open West End – No Defects				
Total into SPL	64	4	93%	7%
Total into Plume Center	46	6	87%	13%
Total into Compliance Line	98	96	2%	98%
SPL and Plume Center Wall Open West End – 1.0% Defects				
Total into SPL	64	41	35%	65%
Total into Plume Center	46	29	36%	64%
Total into Compliance Line	98	102	-4%	104%
SPL and Plume Center Wall Fully Enclosed – 0.7% Defects				
Total into SPL	64	14	78%	22%
Total into Plume Center	46	10	79%	21%
Total into Compliance Line	98	96	2%	98%

The open ended extended grout wall with no defects simulation resulted in a similar reduction in groundwater flux into the SPL area (93%) as seen in the SPL Pile grout wall. The groundwater flux through the plume center area was greatly reduced (87% reduction) when the grout wall was extended to the plume center. At the compliance line area, there was a 2% reduction in flux versus the ambient condition with no wall. If defects are present in the open ended extended grout wall, the reduction in groundwater flux in the SPL pile area and plume center areas is much less 35% and 36%, respectively.

The open ended extended grout wall with no defects wall had a maximum difference in water level from one side of the wall to the other of approximately 11.6 feet; with 2.3 feet of mounding upgradient of the wall and a lowering of the water level by 9.3 feet downgradient of the wall. The fully enclosed extended grout wall with defects had a maximum difference in water level from one side of the wall to the other of approximately 8.7 feet, which occurred at the downgradient (west) end of the wall; with 7 feet of mounding inside the enclosed area and 1.7 feet of drawdown outside the grout wall. The same defects were modeled in the open ended and enclosed grout wall scenarios; thus, the differing percentage of the entire wall being defective in Table 5-4. Fixed cell sizes and varying water levels result in varying defect open area. An exact match to the defect area simulated for the pilot test wall was not obtainable for predictive grout wall scenarios.

Water levels in the simulation of a fully enclosed extended grout wall without defects are predicted to rise above the top of the model at the inside downgradient end of the grout wall, which indicate areal recharge is greater than the flux through the wall. If recharge to the plume center area is greater than the leakage through the grout wall, an enclosed grout wall would eventually result in water mounding above the top of the grout wall. Since this model does not simulate the unsaturated zone and cannot simulate flow over the grout wall, the modeled flux reduction for the enclosed wall without defects does not represent the actual flux in and out of the grout wall; therefore, these results were not reported for this scenario.

5.3 EX-SITU PUMPING REMEDIAL ALTERNATIVES

Ex-situ pumping remedial evaluations included extraction systems near the highest concentrations of the cyanide and fluoride plume in the A-Zone, and an extraction system upgradient of the compliance line in the B-Zone. The purposes of the pumping simulations were to:

- Estimate the pumping rates and drawdown that the aquifer may sustain at the two locations; and
- Estimate the approximate capture area at varying pumping rates

5.3.1 A-Zone Plume Center Pumping

Extraction wells were located along a transect between monitoring wells KM-14 and KM-6. A minimum of eight feet of saturated thickness during steady-state pumping was desired to allow sufficient water over the pump and five feet of well screen. KM-10 was utilized as the limiting well in the vicinity due to a measured saturated thickness of approximately 12.7 feet; thus, drawdown was limited to 4.7 feet at KM-10. Extracted water was infiltrated back into the groundwater system through the recharge package via a conceptual infiltration basin (~4,132 square feet) located to the west of the warehouses west of the SPL pile.

Three scenarios were modeled: four wells pumping 25 gpm each (Wells 1, 2, 3, and 4), two wells pumping 25 (Wells 2 and 3) gpm each, and one well pumping 25 gpm (Well 5) (Figure 5-7). Four wells pumping 25 gpm each resulted in a steady-state drawdown at KM-10 of 4.4 feet and a maximum drawdown at a pumping well of 7.5 feet (Well 3) (Figure 5-8). Two wells pumping 25 gpm each resulted in a steady-state drawdown at KM-10 of 2.1 feet and a maximum drawdown at a pumping well of 4.9 feet (Well 3) (Figure 5-9). One well pumping 25 gpm resulted in a steady-state drawdown at KM-10 of one foot and a maximum drawdown at a pumping well of 3.7 feet (Well 5) (Figure 5-10). Actual drawdown within a well would be greater than model predicted due to well efficiency not accounted for in the model.

Capture areas shown on Figures 5-8 through 5-10 indicate water sources for each extraction scenario. All extraction wells are located near the highest concentration portion of the plume (>50 ppm fluoride); however, capture areas for the two northern wells (Well 3 and Well 4) extend primarily into low contaminant concentration areas to the east and northeast of the SPL pile. Heterogeneities in the A-Zone aquifer are not represented in the numerical model as there is insufficient information on the vertical and horizontal extent of the heterogeneities to properly model them. Heterogeneities would affect capture areas and thus the concentration of contaminants in the pumped water. The rate of groundwater reaction with sediment near the extraction wells would also affect the concentration of fluoride and cyanide in pumped water.

5.3.2 B-Zone Pumping

An extraction well was inserted into the model at the apparent narrowing of the cyanide and fluoride plume seen near KM-16 in Figure 5-7. The single extraction well was modeled pumping 100 gpm and 50 gpm with 2.5 feet and 1.2 feet, respectively, of drawdown in the pumped well. Saturated thickness in KM-16 and KM-17 averages approximately 22 feet, which would support higher pumping rates. Vertical flow from the A-Zone to the B-Zone does not significantly increase due to increases in pumping rate from the B-Zone. Increased B-Zone pumping rates result in larger contributions from upgradient (relatively uncontaminated) portions of the B-Zone.

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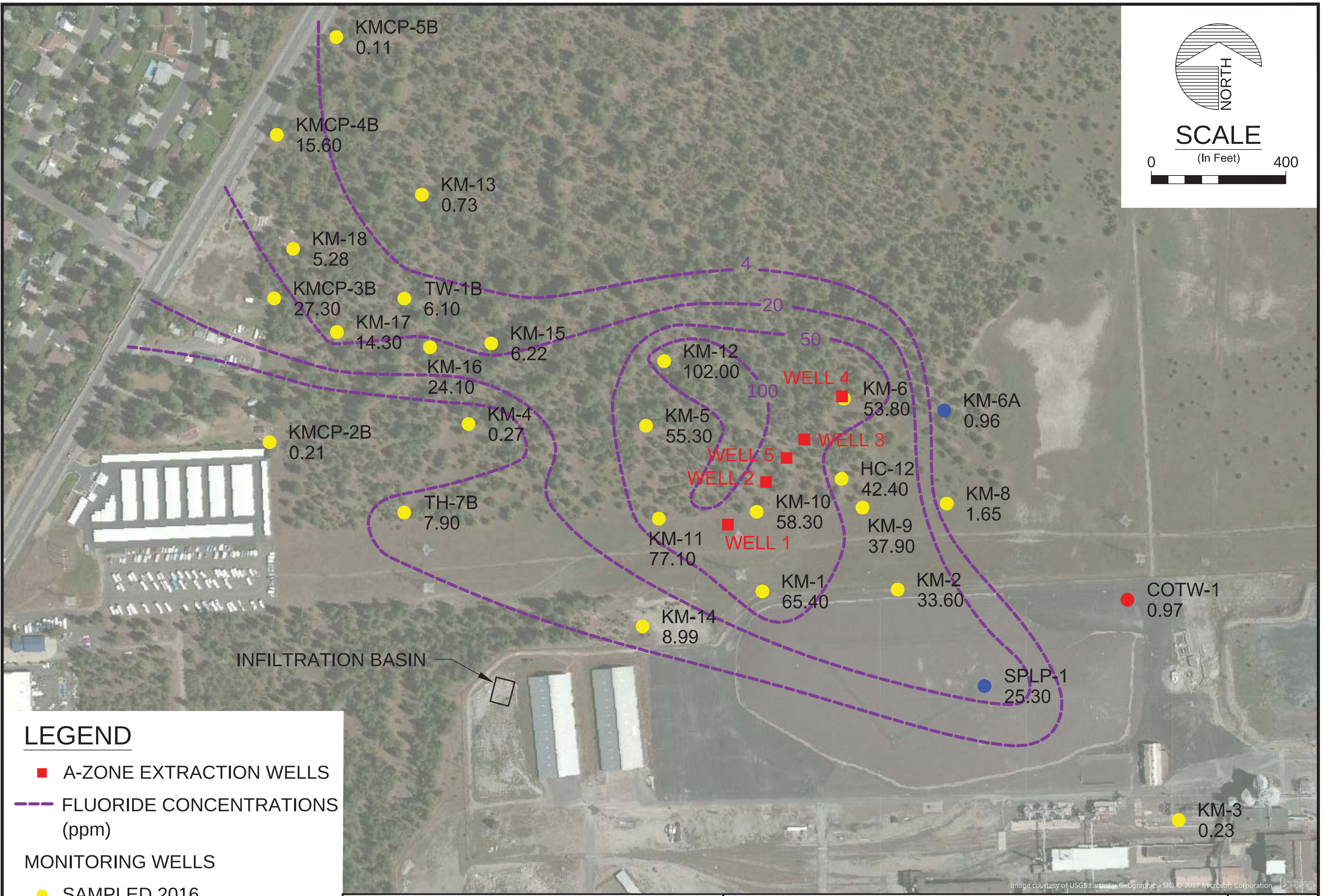

LEGEND

🟥 A-ZONE EXTRACTION WELLS

--- FLUORIDE CONCENTRATIONS (ppm)

MONITORING WELLS

● SAMPLED 2016

● SAMPLED 2015

● SAMPLED 2013

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A-ZONE EXTRACTION WELLS

FIGURE
5-7

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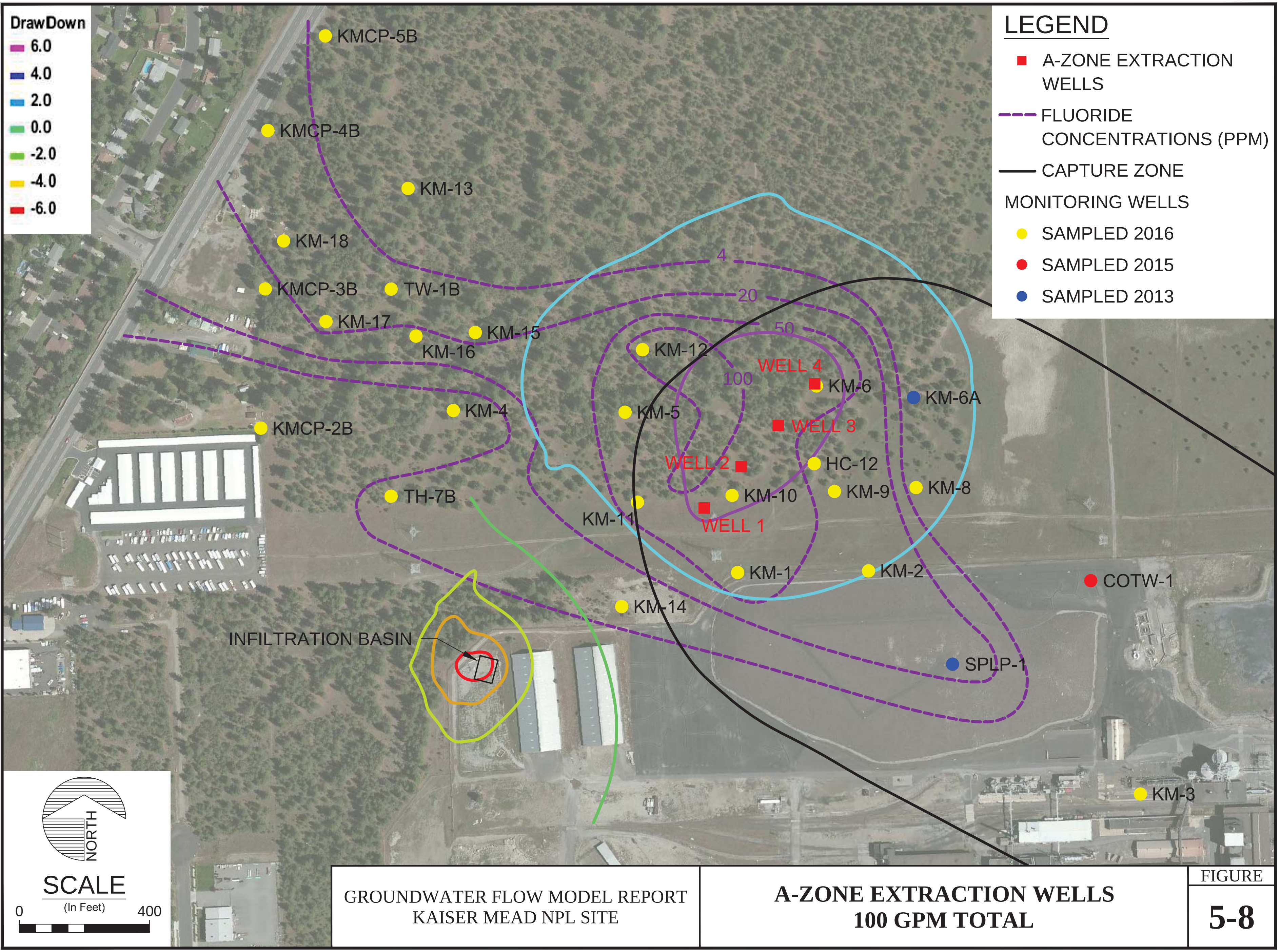

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A-ZONE EXTRACTION WELLS
100 GPM TOTAL

FIGURE
5-8

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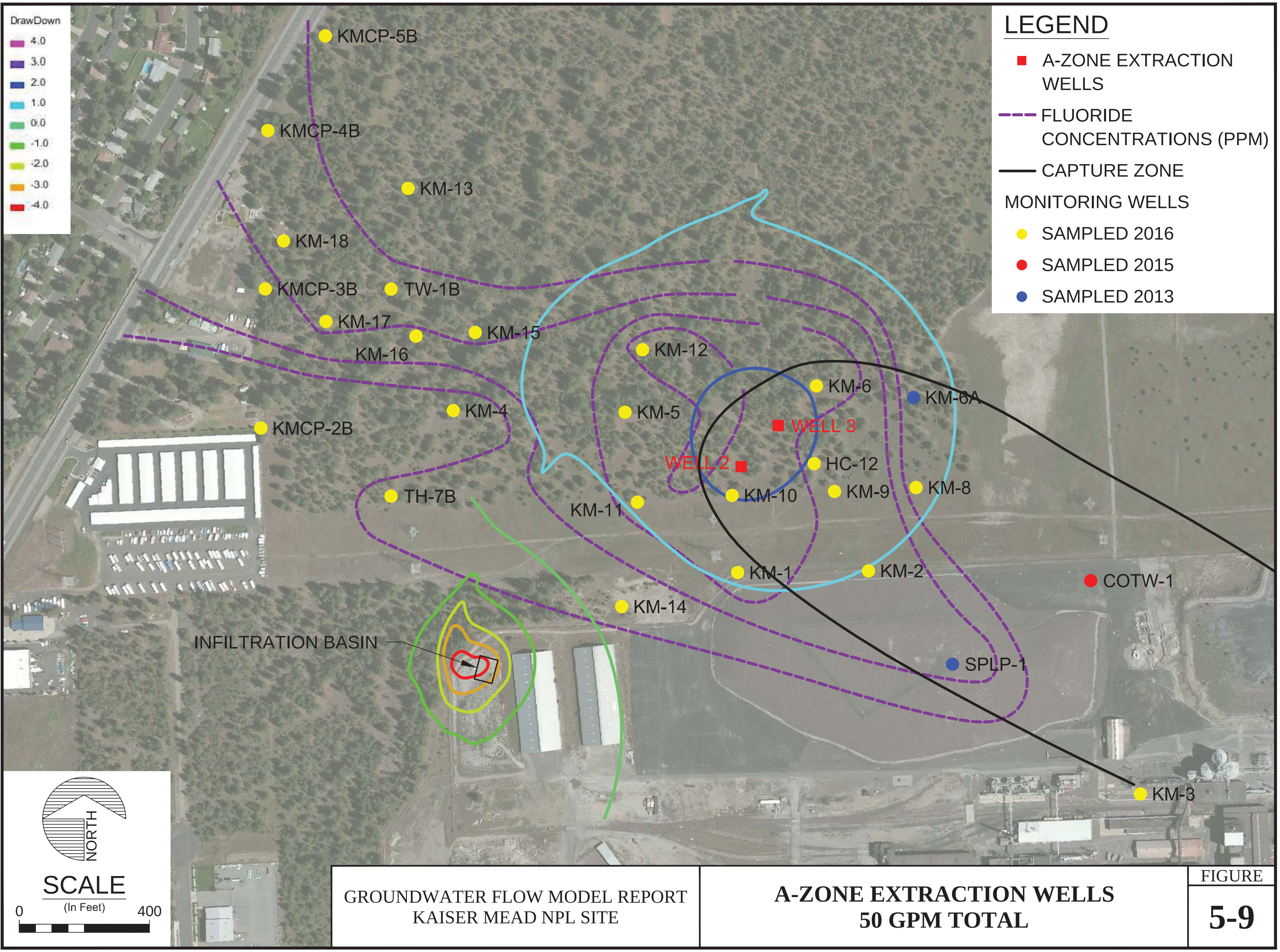

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A-ZONE EXTRACTION WELLS
50 GPM TOTAL

FIGURE
5-9

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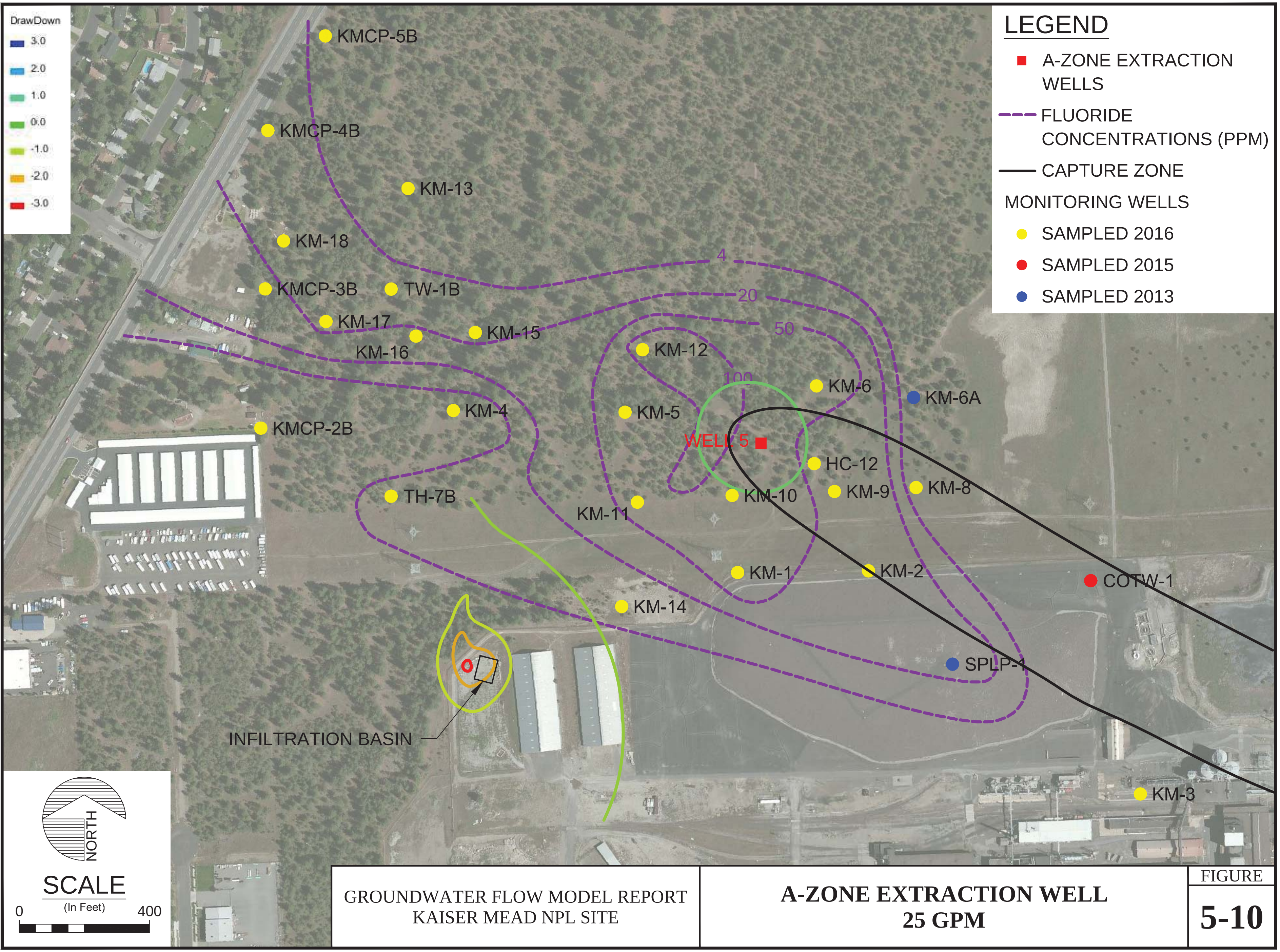

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A-ZONE EXTRACTION WELL
25 GPM

FIGURE
5-10

6.0 SENSITIVITY ANALYSIS

A sensitivity analysis was conducted to assess the effects to the model from input parameter uncertainty. The sensitivity of the model was evaluated qualitatively through the calibration process. The residual heads at the observation points in the steady state model were most sensitive to changes in hydraulic conductivities of the A-Zone sands in layers one through five and to a lesser degree to changes in hydraulic conductivity of the B-Zone material. In addition to A-Zone hydraulic conductivity, the transient calibration was also sensitive to changes in vertical anisotropy (K_H/K_V) and specific yield.

The sensitivity of the model was further evaluated by quantitatively assessing parameter sensitivity using manual techniques on parameters listed in Table 6-1. The manual analysis included an evaluation of the sensitivity of parameters to the observed head at project area observation points. The quantitative sensitivity analysis of the steady state model ability to match observed heads is summarized in Table 6-2. Similar to the qualitative analysis, the model was most sensitive to changes in changes in hydraulic conductivity of the A-Zone layers, with heads typically decreasing with lower hydraulic conductivities and increasing with higher conductivities. The steady state model was not particularly sensitive to changes in vertical anisotropy or changes in recharge. However, as noted above the transient model was sensitive to vertical anisotropy. The lack of sensitivity to recharge reinforces that infiltration of precipitation is a minor component of the groundwater flow system in the vicinity of the site.

TABLE 6-1. SUMMARY OF SENSITIVITY PARAMETER ADJUSTMENT

Parameter	Steady State	Low Adjustment 1	Low Adjustment 2	High Adjustment 1	High Adjustment 2
A-Zone Hydraulic Conductivity (ft/day)	100	50	NA	200	500
Vertical Anisotropy (K_H/K_V)	20	1	10	50	100
B-Zone Hydraulic Conductivity (ft/day)	225	100	NA	400	650
Recharge (in/yr)	1.45	0.9	NA	1.8	3.0

TABLE 6-2. SENSITIVITY ANALYSIS SUMMARY

Model Simulation	**Calibrated Model**	**KH-1**	**KH-2**	**KH-3**	**Kh/Kv-1**	**Kh/Kv-2**	**Kh/Kv-3**	**Kh/Kv-4**	**BK-1**	**BK-2**	**BK-3**	**R-1**	**R-2**	**R-3**
Parameter	**NA**	**A-Zone Hydraulic Conductivity**			**A-Zone Vertical Anisotropy (K_H/K_V)**				**B-Zone Hydraulic Conductivity**			**Recharge**		
Sensitivity Factor[1]	**NA**	**0.5**	**2**	**5**	**0.05**	**0.5**	**2.5**	**5**	**0.4**	**1.8**	**2.9**	**0.6**	**1.2**	**2.1**
A-Zone Observation Point	**Residual Head[2]**													
HC-1	-0.24	0.38	-1.16	**-3.53**	0.53	-0.05	-0.49	-0.65	-1.09	0.00	0.12	-0.02	-0.42	-0.95
HC-12	-0.44	0.52	-1.65	**-4.47**	0.37	-0.24	-0.72	-0.92	-1.40	-0.17	-0.03	-0.25	-0.59	-1.05
HC-2A	0.19	0.84	-0.76	**-3.18**	1.02	0.39	-0.06	-0.22	-0.69	0.44	0.57	0.42	0.01	-0.52
HC-7	2.24	**4.04**	0.31	**-3.67**	**3.68**	**2.52**	1.92	1.72	0.72	**2.69**	**2.91**	**2.39**	2.09	1.69
KM-2	0.81	1.86	-0.48	**-3.44**	1.74	1.02	0.54	0.37	-0.23	1.11	1.26	1.00	0.65	0.19
KM-2A	0.44	1.32	-0.70	**-3.44**	1.31	0.65	0.17	0.00	-0.53	0.71	0.85	0.65	0.28	-0.21
KM-3	-0.09	0.49	-0.97	**-3.28**	0.73	0.10	-0.32	-0.47	-0.94	0.16	0.28	0.15	-0.27	-0.82
KM-4	2.17	**3.17**	0.27	**-6.56**	**2.56**	2.26	2.06	2.00	0.46	**2.48**	**2.62**	2.22	2.07	1.86
KM-5	0.66	2.18	-0.94	**-4.10**	1.40	0.82	0.45	0.32	-0.38	0.95	1.10	0.80	0.54	0.19
KM-6	-0.35	0.74	-1.65	**-4.51**	0.41	-0.17	-0.62	-0.80	-1.31	-0.08	0.05	-0.18	-0.49	-0.90
KM-6A	-0.61	0.35	-1.82	**-4.63**	0.16	-0.42	-0.90	-1.11	-1.56	-0.35	-0.22	-0.43	-0.76	-1.21
TH-1	-0.43	0.17	-1.31	**-3.63**	0.34	-0.24	-0.67	-0.83	-1.26	-0.19	-0.07	-0.20	-0.60	-1.14
TH-2	-0.20	0.64	-1.30	**-3.98**	0.68	0.01	-0.46	-0.64	-1.15	0.08	0.21	0.01	-0.36	-0.86
B-Zone Observation Point	**Residual Head[2]**													
OB-1	-2.00	-0.79	**-4.24**	**-9.80**	-1.71	-1.95	-2.06	-2.08	**-5.19**	-0.81	-0.19	-1.93	-2.09	**-2.30**
TH-7B	-0.94	0.33	**-3.27**	**-8.89**	-0.76	-0.91	-0.96	-0.97	**-4.33**	0.34	1.01	-0.86	-1.02	-1.23
KMCP-1B	1.35	**2.62**	-0.96	**-6.46**	1.45	1.36	1.35	1.34	-2.01	**2.63**	**3.30**	1.43	1.27	1.06
KMCP-2B	-0.19	0.91	-2.22	**-7.22**	-0.09	-0.18	-0.20	-0.20	**-3.15**	0.93	1.50	-0.12	-0.26	-0.45
KMCP-3B	-0.03	0.95	-1.84	**-6.51**	0.07	-0.02	-0.03	-0.04	**-2.68**	0.96	1.47	0.04	-0.09	-0.26
KMCP-4B	-0.68	0.16	-2.26	**-6.54**	-0.60	-0.67	-0.67	-0.67	**-3.01**	0.18	0.62	-0.61	-0.73	-0.88
KMCP-5B	-1.41	-0.59	**-2.97**	**-7.33**	-1.33	-1.40	-1.40	-1.39	**-3.73**	-0.56	-0.13	-1.34	-1.46	-1.61
Model Area	**Mean Absolute Residual[3]**													
Model Domain	0.77	1.15	1.55	**5.26**	1.05	0.77	0.80	0.84	1.79	0.79	0.92	0.75	0.80	0.97
A-Zone	0.68	1.29	1.02	**4.03**	1.15	0.68	0.72	0.77	0.90	0.72	0.79	0.67	0.70	0.89
B-Zone	0.94	0.91	**2.54**	**7.53**	0.86	0.93	0.95	0.96	**3.44**	0.92	1.17	0.90	0.99	1.11

1) Sensitivity Factor represents the factor by which each parameter was changed from the calibrated model

2) Residual Head is the difference between the observed and simulated heads (Obs. - Sim.). Negative residual indicates the modeled head is higher than the observed. Residual heads that exceed the calibration target (+/- 2.3 feet) are bolded red for low simulated heads and bolded blue for high simulated heads

3) Mean Absolute Residual are bolded black if they are greater than the calibration target (2.3 feet)

The models sensitivity to changes in A-Zone hydraulic conductivity suggests the bulk permeability of the A-Zone aquifer is likely near the lower end of observed conductivities; however, there may be discrete areas or channels of higher permeability within the aquifer. If the extent of these areas is not expansive and it does not connect to a drain of the A-Zone aquifer they likely have little effect on the rate of transport of contaminants. However, if there are high permeable channels that extend to where the A-Zone connects to the B-Zone aquifer the rate and transport of contaminants would likely be much faster. It is uncertain what affects higher permeable areas or channels may have on the grout wall; potential effects to the groundwater system are as follows:

- Higher permeable wall in these areas leading to more leakance through the wall;
- Greater mounding upgradient of the wall within the higher permeable material; and
- Additional drawdown downgradient of the wall.

There is insufficient data to determine the location and extents of these higher permeable zones; therefore, it is not possible to model them in the groundwater model to quantify the potential affects they may have on the system.

7.0 DISCUSSION

A groundwater model of the Kaiser Mead NPL site (Kaiser Mead) has been completed as one aspect of the continuation of the SFS as requested by the Washington Department of Ecology (Ecology, 2014). The purpose of the SFS is to develop and evaluate cleanup action alternatives for the contaminated groundwater at Kaiser Mead and to recommend a remedial alternative to be implemented to achieve compliance with cleanup requirements established for this site. The model evaluated changes in the groundwater flow system and advective transport as a result of potential grout wall designs.

Two full scale grout wall alternatives—a wall around the SPL pile and a wall around the SPL pile and plume center area—were analyzed. The primary metric for evaluating effectiveness of the grout wall alternatives was the amount of groundwater flux reduction through the area enclosed by the wall. Reduction in flux values ranged from 32% to 93% through the enclosed area versus ambient flow conditions for grout walls that were open on the downgradient (west end). For grout walls with closed downgradient ends (fully enclosed), reduction in flux versus ambient flow conditions varied from 78% to 98%.

A properly placed grout wall with no defects and a grout hydraulic conductivity of $1x10^{-6}$ cm/s or less will reduce the flux through an area by approximately 90%. The pilot test grout wall completed during the summer of 2015 showed that defects in wall construction can occur. The amount of flux reduction is highly dependent on the size and location of any defects in a grout wall.

The model is currently being used to evaluate additional remedial alternatives, specifically a capture well system. This report does not include this analysis as the analysis is not complete. However, it should be noted that there is limited feasibility for capture wells to be used in the A-Zone as the saturated thickness is approximately 5 to 8 feet downgradient of the center of the plume. Assuming a minimum screen length of five feet would leave 0 to 3 feet available for the pump intake and available drawdown, which is not sufficient in developing a capture system. A capture analysis will be evaluated for the B-Zone aquifer.

8.0 REFERENCES

Anderson and Woessner, 1992. Applied Groundwater Modeling, Simulation of Flow and Advective Transport, First Edition. Elsevier Inc. – Academic Press.

Aquaveo, 2015. Groundwater Modeling System (GMS) version 10.1. Aquaveo LLC.

Bartolino, J.R., 2007. Assessment of areal recharge to the Spokane Valley-Rathdrum Prairie aquifer, Spokane County, Washington, and Bonner and Kootenai Counties, Idaho: U.S. Geological Survey Scientific Investigations Report 2007-5038, 38 p.

Ecology, 2014. Washington Department of Ecology, Kaiser Mead Supplemental Feasibility Study Next Steps, Letter to Mead Custodial Trust, December 8, 2014.

Fetter, C.W., 2001. Applied Hydrogeology. 4th Edition. Upper Saddle River, NJ: Prentice Hall, Inc.

Hydrometrics, Inc., 2013a. Technical Memorandum for Source Control Evaluation for Cleanup Actions at the Kaiser Mead NPL Site – Draft. December 2013.

Hydrometrics, Inc., 2013b. Aquifer Characterization and Groundwater Capture Analysis for the Kaiser Mead Facility, June 2013.

Hydrometrics, Inc., 2016a. Draft Conceptual Site Model Report for Kaiser Mead Facility,

Hydrometrics, Inc., 2016b. Supplemental Feasibility Study Grout Wall Pilot Test Report for the Kaiser Mead Facility, July 2016.

Hydrometrics, Inc. 2016c. Draft Kaiser Mead Sediment: Groundwater Partitioning and Mass Balance Model Report, December 2016.

Kahle, S.C., Caldwell, R.R., and Bartolino, J.R., 2005. Compilation of geologic, hydrologic, and ground-water flow modeling information for the Spokane Valley-Rathdrum Prairie Aquifer, Spokane County, Washington, and Bonner and Kootenai Counties, Idaho: U.S. Geological Survey Scientific Investigations Report 2005-5227, 64 p., 1 pl.

Kahle, S.C. and Bartolino, J.R., 2007. Hydrogeologic framework and ground-water budget of the Spokane Valley-Rathdrum Prairie aquifer, Spokane County, Washington, and Bonner and Kootenai Counties, Idaho, USGS Scientific Investigations Report 2007-5041.

McDonald, M.G., and Harbaugh, A.W., 1988. A modular three-dimensional finite-difference ground-water flow model, Techniques of Water-Resources Investigations of the United States Geological Survey, Book 6, Chapter A1.

MFG, 2000. Technical Memorandum – Evaluation of Groundwater Extraction and Re-Injection Alternatives, Kaiser Mead Works. Memorandum to Kaiser Aluminum & Chemical Corporation. December 2000.

MFG, 2004. McCulley, Frick & Gilman, Supplemental Groundwater Modeling Report Kaiser Aluminum & Chemical Corp. Mead, Washington, Draft January 29, 2004.

Panday, Sorab, Langevin, C.D., Niswonger, R.G., Ibaraki, Motomu, and Hughes, J.D., 2013. MODFLOW–USG version 1: An unstructured grid version of MODFLOW for simulating groundwater flow and tightly coupled processes using a control volume finite-difference formulation: U.S. Geological Survey Techniques and Methods, book 6, chap. A45, 66 p.

WRCC, 2016. Spokane, Washington (457933) 1981-2010 Monthly Climate Summary, http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?wa7933, 2016

APPENDIX B

EX SITU TREATABILITY STUDY FOR CLEANUP ACTIONS AT THE KAISER MEAD NPL SITE – DRAFT

DECEMBER 2013

Note: The following report and supporting studies were completed in December 2013. At the time of these studies, Ecology specified monitoring of WAD cyanide, rather than free cyanide for determination of compliance with groundwater cleanup levels (0.2 mg/L as free cyanide). Thus the focus of this report is treatment of WAD and total cyanide. Since that time, newer methods for analysis of free CN have been approved by US EPA that are more reliable than current WAD CN methods. Therefore, Ecology directed MCT to adopt free CN analysis in lieu of WAD CN at Kaiser Mead (Ecology, 2016).

EX SITU TREATABILITY STUDY FOR CLEANUP ACTIONS AT THE KAISER MEAD NPL SITE

-DRAFT-

Prepared for:

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December 2013

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

APPENDIX A	WATER TREATMENT ANALYTICAL REPORTS
APPENDIX B	TREATED WATER AND GROUNDWATER MIXING TESTS AND SEDIMENT LEACHING TEST RESULTS

EX SITU TREATABILITY STUDY FOR CLEANUP ACTIONS AT THE KAISER MEAD NPL SITE

-DRAFT-

1.0 INTRODUCTION

This Ex Situ Treatability Study (Study) has been conducted on behalf of Mead Custodial Trust (MCT) as a component of the Supplemental Feasibility Study (SFS) for the Kaiser Mead NPL site (the Site), as identified in the Draft Work Plan for Supplemental Feasibility Study for Cleanup Actions at the Kaiser Mead NPL Site that was approved by the Washington Department of Ecology on November 9, 2012.

This Study was undertaken as outlined in the Work Plan for Ex Situ Water Treatability Study for Cleanup Actions at the Kaiser Mead NPL Site (Work Plan) (Hydrometrics, 2013) that was approved by the Washington Department of Ecology on May 14, 2013.

1.1 PURPOSE AND SCOPE

The purpose of this Study is to further develop and evaluate ex situ water treatment technologies for contaminated groundwater at the Site. As described in the Work Plan, the Study was structured to meet the following goals and objectives for the Site:

- The discharge effluent from the treatment system will meet identified groundwater compliance levels (4 mg/L fluoride; 0.2 mg/L WAD cyanide).
- The list of treatment methods studied will be based upon a review of previous work related to the site and proven methods for similar applications.
- Waste residuals produced by the water treatment processes will be evaluated for chemical, volume, and disposal characteristics.

The scope of the treatability testing focuses on four main treatment processes as described in the Work Plan:

1. Chemical/physical separation to include chemical precipitation, oxidation, filtration, and sludge recycling;
2. Adsorption and sludge recycling;
3. Ion exchange; and
4. Membrane using reverse osmosis.

The Study also includes simulation and evaluation of re-injection of treated water to the groundwater system through a series of batch mixing tests with treated water, groundwater and sediment from the Site. The purpose of this testing is to evaluate:

1. The potential for injected waters to mix and react with groundwater to form insoluble precipitates (either common minerals or contaminant-bearing minerals) or to leach contaminants from sediments; and
2. The potential for injected water to mix and react with groundwater causing degradation or formation of different cyanide species.

1.2 WASTE STREAM DESCRIPTION

Samples for the treatability testing were collected from existing monitoring well KM-2 that is routinely sampled as part of the quarterly groundwater monitoring program. The well initially identified in the Work Plan as the source for testing was KM-6 which typically exhibits the highest levels of all contaminants of concern. Well KM-2 was selected instead because based on its location (near the SPL pile), its water quality would likely be more representative of water extracted from a capture system. It is recognized that final design of ex situ treatment systems will need to be based on anticipated water characteristics from a full-scale extraction system which may include groundwater from a variety of wells with variable water quality. However, results from testing of a single water source will allow an evaluation of treatment options and associated costs that will be suitable for feasibility study detail. Groundwater quality of KM-2 groundwater on May 17, 2013 is summarized in the following Table 1-1.

TABLE 1-1. WATER QUALITY OF GROUNDWATER USED IN TREATABILITY TESTING

Parameter	Concentration (mg/L)
Total Cyanide	66.9
WAD Cyanide	0.532
Fluoride	56.1
pH	9.79

Groundwater sampled collected May 17, 2013.

The samples were pumped from the well using low flow methods and a dedicated bladder pump in the well. The pump discharge was collected in clean 5 and 7-gallon containers until a total of 32 gallons of sample was collected. Field parameters (pH, specific conductance, and temperature) for each 5-gallon subsample were recorded. The sample (unpreserved) was delivered to SVL Analytical in Kellogg, Idaho where the treatability testing was conducted. Chain-of-custody protocols were followed.

1.3 SUMMARY OF PREVIOUS TREATABILITY STUDIES

Previous treatability studies for the Site include chemical precipitation for removal of cyanide and fluoride, UV oxidation for treatment of cyanide, alkaline hydrolysis for treatment of cyanide, and reverse osmosis for treatment of cyanide and fluoride. Treatability studies were conducted on the first three methods while the evaluation of reverse osmosis was limited to literature search and discussions with technology manufacturers.

The Work Plan contains a detailed description of these previous treatability studies conducted on the waste stream collected from the Site.

2.0 TEST METHODS

2.1 WATER TREATMENT

The Work Plan identified four types of treatment processes for testing, including:

1. Chemical/physical separation to include chemical precipitation, oxidation, filtration, and sludge recycling;
2. Adsorption and sludge recycling;
3. Ion exchange (IX); and
4. Membrane using reverse osmosis (RO).

A summary of the treatability tests performed are listed in Table 2-1.

All treatability testing and water/sludge analyses were performed at the SVL Analytical in Kellogg, ID. Water chemistry analyses were conducted on the un-treated well water and the treated water samples produced in the study. All water chemistry analyses performed by SVL are included in Appendix A. The un-treated well water was first analyzed for the parameters listed in Table 2-2. This list of parameters is based on analytical work previously conducted on Site groundwater and was developed to identify the concentrations of minerals and compounds that may impact the efficacy of a particular treatment process. This provided us with sufficient information to develop a range of chemical dosages to utilize in the jar tests.

During initial jar tests for each of the chemical/physical separation processes, only the primary constituent being targeted (i.e., total or weak-acid dissociable [WAD] cyanide or fluoride) was analyzed in order to determine correct chemistry dosages and reaction times. Once those dosages were determined and a preferred treatment process train was established, the treated sample from the preferred process train was analyzed for the parameters listed in Table 2-2.

TABLE 2-1. TREATABILITY STUDY MATRIX

Treatment Process and Chemical Reagent Used[1]	Target Constituent (CN/F)	Primary Treatment	Polishing Treatment
Chemical precipitation-ferrous sulfate	CN	X	
Chemical precipitation-ferric chloride	CN	X	
Chemical precipitation-combination of ferrous+ferric+copper sulfate (depending on results of individual ferric and ferrous tests)	CN	X	
Oxidation-hydrogen peroxide + copper sulfate	CN	X	
Chemical precipitation-calcium chloride	F	X	
Chemical precipitation-lime	F	X	
Chemical precipitation-alum	F	X	
Chemical precipitation-aluminum chlorohydrate (ACH)	F	X	
Chemical precipitation-combination of calcium chloride+alum/ACH	F	X	x
Chemical precipitation-Xsorbex® coagulant	F	X	
Specialty media (MAR®) adsorption	F	X	x
Activated Alumina adsorption	F	X	x
Reverse Osmosis	CN+F		x
Ion Exchange	F		x

[1] Acid and/or caustic will be used to optimize pH for all tests as required.

TABLE 2-2. TREATABILITY STUDY ANALYTICAL LIST FOR WATER

Analytes	**Proposed Reporting Limit (ug/L unless specified)**
Bench Parameters	
ORP (Redox; Eh or pe)	
Dissolved Oxygen	
Major Minerals	
Calcium	1000
Magnesium	1000
Sodium	1000
Hardness as CaCO3	Calculated
Total Alkalinity as CaCO3	1000
Carbonate	1000
Bicarbonate	1000
Hydroxide	1000
Chloride	1000
Fluoride	100
Sulfate	1000
pH	0.1 standard pH units
Total Dissolved Solids	10 mg/L
Silica (dissolved)	100
Total Organic Carbon	
Chemical Oxygen Demand	
Nitrogen Compounds	
Nitrate plus Nitrite as “N”	10
Total Kjeldahl Nitrogen	500
Cyanide Forms	
Total Cyanide (manual distillation)	5
WAD Cyanide	5
Dissolved Metals	
Iron	50

The testing was intended to indicate whether or not a treatment process is suitable to achieve the desired results, e.g., meet a target effluent limit, or reduce the mass of a target constituent. This information is achieved by trying various process types, a range of reagent dosages based on previous experience and literature reports, and typical reaction times. The tests were not designed to optimize a treatment process by testing and selecting exact chemical dosages and reaction times that give optimal treatment effectiveness. Further evaluation of these optimization criteria is recommended for select processes at the next stage of process design if ex-situ treatment is selected as a component of the selected remedy.

Test procedures used to conduct the tests listed in Table 2-1 are described below. Table 2-3 lists general information about the individual tests. Section 3 provides details for the individual tests and test results.

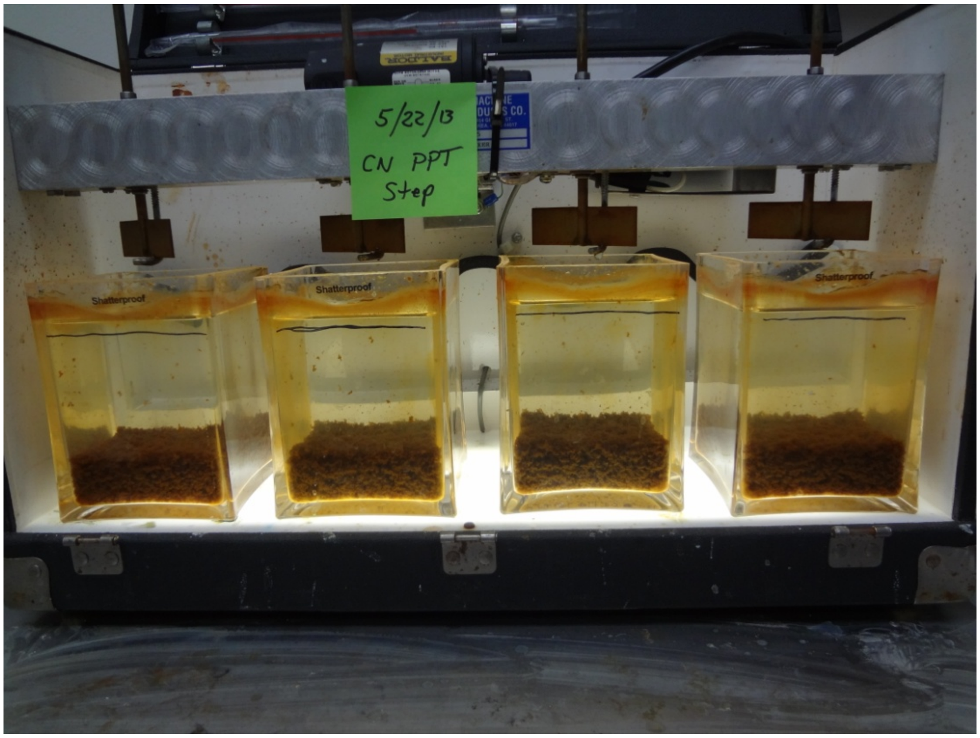
2.1.1 Test Procedures

1. Solutions were prepared for ferrous sulfate, copper sulfate, acids, and caustic.
2. A gang stirrer apparatus was used with one liter square jars to test cyanide treatment processes (Figure 2-1). Testing was done to try to minimize reagent dosages and reaction times. Testing was started at a low ferrous iron to total cyanide ratio of 0.5:1 for cyanide precipitation at unaltered pH and then at the expected ideal pH of 6.5.
3. Ferric chloride was tested as the total cyanide and WAD cyanide precipitant with and without sludge recycle.
4. Additional jar tests were run using peroxide and copper sulfate as oxidation catalyst and also precipitant. This test was also done with ferric chloride at different dosages and conditions.
5. The initial test results for cyanide removal were rather poor, so much higher ferrous iron to total cyanide ratios were tested. Tests using a 10:1 ferrous iron to total cyanide at pH 6.5 were completed.

TABLE 2-3. TREATABILITY TESTS CONDUCTED

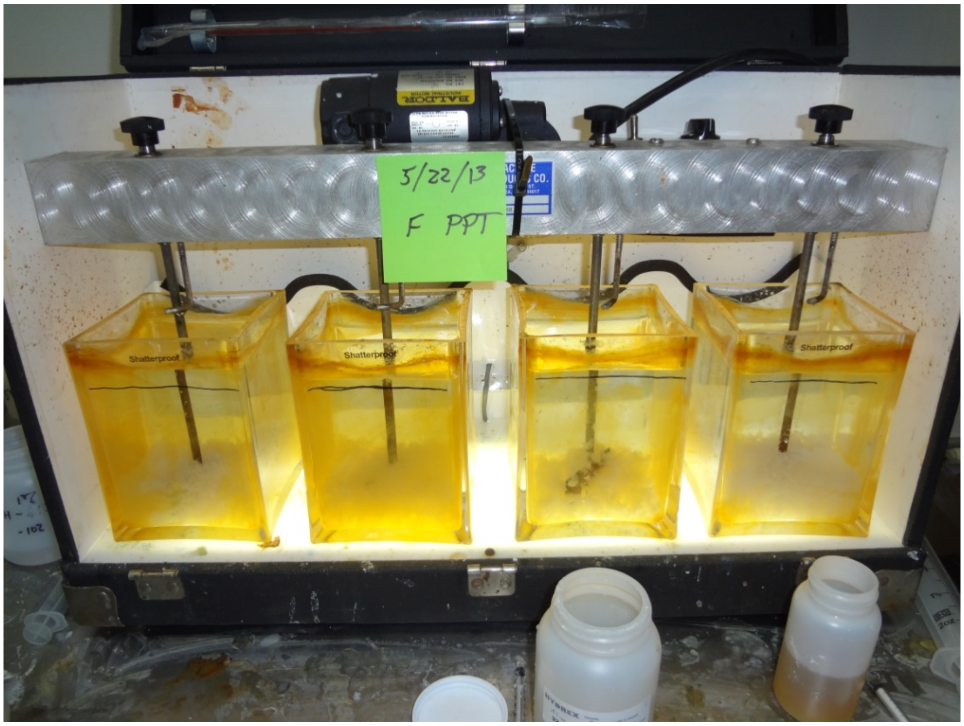
Test ID	Process Summary	Target Constituent	Water Tested
1	Ferrous Precipitation	Cyanide	Raw water
2	Ferrous Precipitation	Cyanide	Raw water
3	Ferric Precipitation	Cyanide	Raw water
4	Ferric Precipitation	Cyanide	Raw water
5	Peroxide Oxidation	Cyanide	Raw water
6	Peroxide Oxidation	Cyanide	Raw water
7	Peroxide Oxidation	Cyanide	Raw water
8	Peroxide Oxidation	Cyanide	Raw water
9	Ferrous/Ferric Precipitation	Cyanide	Raw water
10	Ferrous/Ferric Precipitation	Cyanide	Raw water
11	Ferric Precipitation	Cyanide	Raw water
12	Ferric Precipitation	Cyanide	Raw water
13	Ferrous Precipitation	Cyanide	Raw water
14	Ferrous Precipitation	Cyanide	Raw water
15	Peroxide Oxidation	Cyanide	Raw water
18	Test 13 (repeat) + Test K (repeat)	Cyanide & Fluoride	Raw water
A	Calcium Chloride Precipitation	Fluoride	Raw water
B	Calcium Chloride Precipitation	Fluoride	Raw water
C	Alum Precipitation	Fluoride	Raw water
D	ACH Precipitation	Fluoride	Raw water
E	XSORBX 100 Precipitation	Fluoride	Raw water
F	XSORBX 100 Precipitation	Fluoride	Raw water
G	XSORBX 100 Precipitation	Fluoride	Raw water
H	Lime Precipitation	Fluoride	Raw water
I	Calcium Chloride Precipitation	Fluoride	Raw water
J	Alum Precipitation	Fluoride	Raw water
K	Alum/XSORBX 100 Precipitation	Fluoride	Raw water
I	Activated Alumina Adsorption	Cyanide & Fluoride	Raw Water
II	Activated Alumina Adsorption	Cyanide & Fluoride	Raw Water
III	Sorbster F Adsorption	Cyanide & Fluoride	Raw Water
IX	Ion Exchange Polish	Cyanide & Fluoride	Test 13 + Test K water
RO	Reverse Osmosis Polish	Cyanide & Fluoride	Test 18 water

FIGURE 2-1. GANG STIRRER DURING CYANIDE PRECIPITATION TESTING



6. Jar tests were run using ferrous sulfate and ferric chloride with and without sludge recycle at relatively low dosages. Ferric chloride by itself was also tested with and without sludge recycle.
7. Samples were provided to SVL Analytical for cyanide analysis to determine effectiveness of treatment process including pH and chemical dosages.
8. Jar tests were next performed for fluoride removal. Initially calcium precipitation at different pHs was tested. Tests were also performed using alum and aluminum chlorohydrate (ACH) at a relatively low dosages based upon the literature and experience. Figure 2-2 shows the gang stirrer and jars during this test period.
9. Site water was then jar tested for fluoride removal with a proprietary rare earth coagulant, XSORBX-100™ AT various concentrations and pH conditions.
10. Adsorption testing using a packed column was done as a primary treatment for fluoride removal using activated aluminum and Mar Systems Sorbster F, a proprietary adsorption media. Three bed volumes were circulated through the column and then water was sampled for analysis of fluoride.

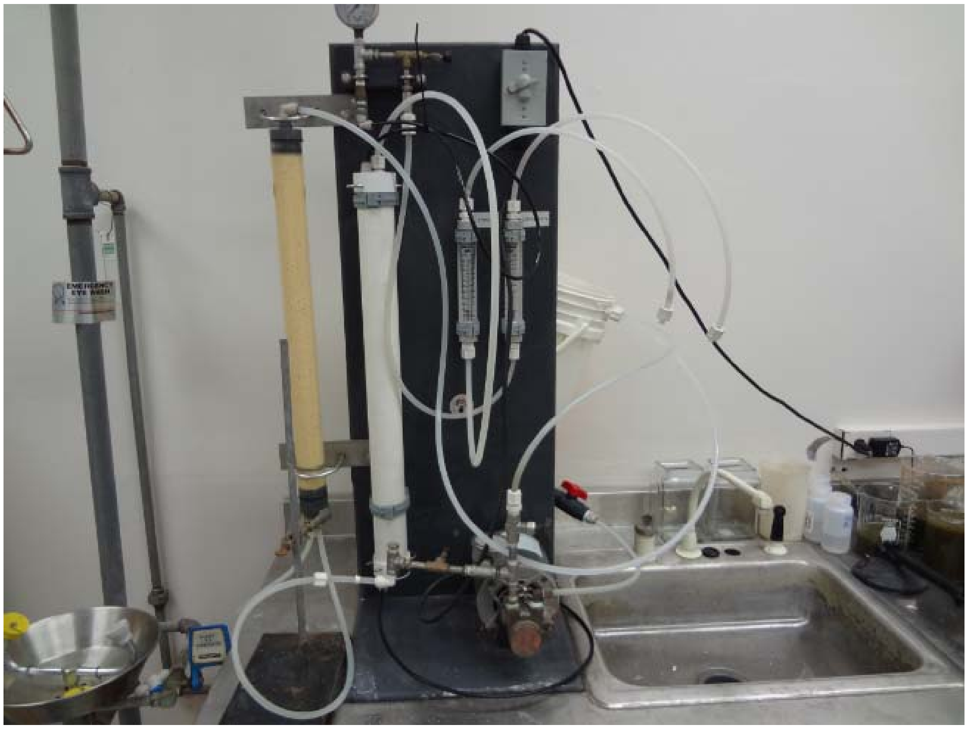
FIGURE 2-2. GANG STIRRER DURING FLUORIDE PRECIPITATION TESTING



11. Ion exchange (IX) resin was tested as a polishing treatment step using 1.5-inch inside diameter x 23-inch column at a flow rate of 20 – 40 ml / min (Figure 2-3). A chelating resin, where the hydrogen exchange sites were close to being exhausted with aluminum, was used for the testing. Aluminum replaces the hydrogen sites and holds the fluoride to the exchange site. This polishing test was run on water having been previously treated using chemical precipitation for cyanide and fluoride removal.
12. RO was tested as a polishing treatment using a Filmtec TW30-2026 membrane (2-inch diameter x 26-inch long) set up for about 70% recovery (Figure 2-3). Permeate flow was around 20 mls per minute. The RO membrane fouled almost immediately due to the water chemistry, which accounts for the low flow rate used. However, a sufficient amount of water was pushed through the membrane to provide a water sample for analysis. This polishing test was run on water having been previously treated using chemical precipitation for cyanide and fluoride removal.

13. On the final day of testing, several gallons of effluent from two successful treatment process trains (ferrous precipitation+alum+IX and peroxide) was created for subsequent use during mixing tests with treated water, groundwater, and sediment as described in Section 2.3.

FIGURE 2-3. ION EXCHANGE AND RO TEST APPARATUS



Tables 2-4 and 2-5 provide details of the individual cyanide and fluoride tests conducted. These data tables data also include operating details as utilized and noted during the tests.

TABLE 2-4. CYANIDE TREATABILITY TEST DETAILS

Test ID	Process Summary	Start pH	Adjusted pH	Final pH	Ferrous Sulfate (ppm) Fe++ Added	Ferric Chloride (ppm) Fe+++ Added	Sludge Added (mls)	5 or 10% H2SO4 (mls)	Peroxide (ppm)	Copper Sulfate (ppm) Cu++ Added	Mix Time (min)	H-6161 Floc (ppm)	Color	Remarks
1	Ferrous Precipitation	9.79		9.70	34						30	2	Orange	Small Floc, grew over time
2	Ferrous Precipitation	9.79	6.50	7.13	34			16.2			30	2	Bright blue	Large floc, but blue. Turned yellow with NaOH preserve
3	Ferric Precipitation	9.79	9.05	7.00		80		10.0			30		Brown	Large floc, good settling
4	Ferric Precipitation	9.79	9.05			80	200	10.0			30		Dark Brown	Large floc, good settling
5	Peroxide Oxidation	9.79		9.00					300	13.4	30		Yellow	Lots of bubbles, no solids formed
6	Peroxide Oxidation	9.79		9.00					300	13.4	30		Orange	Few bubbles, no solids
7	Peroxide Oxidation	9.79		9.00					100	8	30		Yellow	Lots of bubbles, no solids formed
8	Peroxide Oxidation	9.79		9.00					100	8	30		Orange	Few bubbles, no solids
9	Ferrous/Ferric Precipitation	9.79	9.00	8.90	2	80		8.5			45	1	Yellow	Medium floc, slow to settle
10	Ferrous/Ferric Precipitation	9.79	9.00	8.94	2	80	200	8.0			45	1	Dark Brown	Good floc and settling
11	Ferric Precipitation	9.79	9.00	8.92		80		8.6			45	1	Yellow	Fine floc, poor settling
12	Ferric Precipitation	9.79	9.00	8.88		80	200	8.0			45	1	Dark Brown	Good floc and settling
13	Ferrous Precipitation	9.79	6.50	6.77	670			??				2	Green/Brown	Good floc and settling
14	Ferrous Precipitation	9.79	6.50	6.62	2010			??				2	Brown	Good floc and settling
15	Peroxide Oxidation	9.79	9.00					??	300	13.4	30			
18	Test 13(repeat)+ Test K (repeat)													See results from Test 13 above, and Test K in Table 2-5
I	Activated Alumina Adsorption	9.79												
II	Activated Alumina Adsorption	8												
III	Sorpster F Adsorption	6												

TABLE 2-5. FLUORIDE TREATABILITY TEST DETAILS

Test ID	Process Summary	Start pH	Adjusted pH	Final pH	Calcium Chloride (ppm) Ca Added	10N NaOH (mls)	10% H2SO4 (mls)	50% Alum (ppm)	50% ACH (ppm)	XSORBX 100 (mls)	2% Lime (mls)	Mix Time (min)	H-6161 Floc (ppm)	H-6131 Fl oc (ppm)	Color	Remarks
A	Calcium Chloride Precipitation	9.79		9.67	170							45	2		White	Small particles and small amount of floc. Frosted sides of jar
B	Calcium Chloride Precipitation	9.79	12.50	12.4	34	5						45	2		White	Small floc and small volume
C	Alum Precipitation	9.79	6.5	6.58			15.0	2240				45	1		Gray	Large and good settling floc, 50 - 100 mls
D	ACH Precipitation	9.79							2240			45	1		White	Very fluffy and voluminous floc, 400 mls
E	XSORBX 100 Precipitation	9.79		9.27						2.5		45	1	2		Poor, slow settling floc, 300 mls
F	XSORBX 100 Precipitation	9.79	7.00	7.34			10.0			2.5		45	1			Good floc and clarity, 100 mls
G	XSORBX 100 Precipitation	9.79	8.50	9.50			8.0			2.5		45	1			Good floc and clarity, 150 mls
H	Lime Precipitation	9.79	12.2	12.19							120.0	45	1	2		Very fine, poor settling, 25 mls
I	Calcium Chloride Precipitation	9.79	8.00		1000		9.0									No Floc. Did not sample
J	Alum Precipitation	9.79	6.50	6.89			2.5	5600				90	2			Good floc and clarity
K	Alum/XSORBX 100 Precipitation	9.79	6.50	6.92			4.0	3360		2.5		45	2			Good floc and clarity
I	Activated Alumina Adsorption	9.79														
II	Activated Alumina Adsorption	8														
III	Sorpster F Adsorption	6														

2.2 SLUDGE

Sludge from the cyanide (Test 13) and fluoride (Test K) precipitation testing was de-watered and the volume measured for sludge management and disposal calculations. A sample of the sludge was analyzed for the parameters in Table 2-6.

TABLE 2-6. ANALYTICAL LIST FOR SLUDGE

Test or Parameter	Test Method
TCLP metals (arsenic, barium, cadmium, chromium, lead, mercury, selenium, silver)	EPA Method 1311 (SW846)
Corrosivity – pH	EPA Method 9045D (SW846)
Total cyanide	EPA Method 9012 (SW846)
Total fluoride	EPA Method 300.0 (SW846)

2.3 SIMULATION OF INJECTION OF TREATED WATER TO GROUNDWATER

Simulation of the injection of treated water into Site groundwater was evaluated through:

- Mixing treated water from the treatability tests with impacted groundwater (formation water collected from monitoring well KM-2) to simulate re-introduction of treated water to groundwater; and
- Leaching of aquifer sediments (collected during the installation of test well TW-1A as described in the SFS Work Plan) with mixtures of treated water (from treatability testing) and groundwater from well KM-2.

A summary of the tests conducted is provided in Table 2-7.

TABLE 2-7. SUMMARY OF TREATED WATER INJECTION SIMULATION TESTS

Test ID	Treated Water Process	Treated Water to Groundwater Ratio	Sediment Present
1	Test 18 Iron-Alum-IX	1:0 (treated water only)	250g/1.5L
2	Test 18 Iron-Alum-IX	1:1	250g/1.5L
3	Test 15 Peroxide	1:0 (treated water only)	250g/1.5L
4	Test 15 Peroxide	1:1	250g/1.5L
5	Test 18 Iron-Alum-IX	None	None
6	Test 15 Peroxide	None	None
7	Test 18 Iron-Alum-IX	1:1	None
8	Test 15 Peroxide	1:1	None
9	None	0:1 (groundwater only)	None
10	Test 18 Iron-Alum-IX	1:4.63	None
11	Test 15 Peroxide	4.71:1	None

2.3.1 Materials Tested

Groundwater used in the tests was collected from well KM-2 on May 17, 2013 as described in Section 1.2. Treated water for testing was collected from treatability tests 15 (peroxide oxidation/precipitation) and 18 (ferrous iron/alum/XSORBX 100 precipitation; see Tables 2-3 through 2-4, above) conducted on May 22, 2013. Water from these treatment processes was selected because both processes provided good WAD cyanide and fluoride removal.

Sediment sample was collected during installation of Test Well 1A on January 16, 2013.

2.3.2 Test Procedures

Mixing tests with treated water and groundwater were conducted as follows:

1. Samples of treated water and groundwater were submitted to SVL Analytical for analysis of initial water quality prior to mixing of waters.

2. Samples were mixed at the ratios described in Table 2-6 and samples were placed in 1 liter polyethylene bottles. Bottles were filled as full as possible to minimize air in the headspace (estimated air volumes were 1 to 5 mL).
3. Bottles were agitated by shaking and inverting and placed in the dark at room temperature (approximately 23^{o} C).
4. At selected intervals (15, 45 and 90 days), solution pH and ORP/Eh is measured and sample aliquots are removed and analyzed for total cyanide, WAD cyanide, and fluoride. Headspace is re-filled with nitrogen gas and bottle is returned to dark storage.

Sediment leach testing with treated water and groundwater were conducted as follows:

1. Samples of treated water and groundwater were submitted to SVL Analytical for analysis of initial water quality prior to mixing of waters as described above.
2. 1.5 liters of water (either treated water or a combination of treated water and groundwater as described in Table 2-6) and 250 grams of sediment were placed in opaque 2 liter plastic (HDPE or polyethylene) extraction bottles.
3. Air space in the extraction bottles was displaced with nitrogen gas (10 liters/minute for 2 minutes).
4. Sample bottles were placed on a rotary extractor (see Figure 2-4) and rotated at 30 rpm in a temperature-controlled room (23^{o} C).
5. At selected intervals (15, 45 and 90 days), solution pH and ORP/Eh was measured and sample aliquots were removed and analyzed for total cyanide, WAD cyanide, and fluoride. Headspace was re-filled with nitrogen gas and bottle was replaced on the rotary extractor.

FIGURE 2-4. ROTARY EXTRACTOR APPARATUS

2.4 DEVIATIONS FROM THE APPROVED WORK PLAN

Treatability testing is experimental and somewhat exploratory in nature. During the testing, factors and conditions were encountered that required minor modifications and improvements of procedures in the approved Work Plan. These changes were as follows:

1. Groundwater from well KM-2 rather than KM-6 was used for testing as described above.
2. Ferrous iron was not analyzed in water samples. Based on discussion with SVL labs, the ferrous iron method was deemed to be inappropriate for site waters due to the high cyanide concentrations and presence of iron cyanide complexes that would interfere with the colorimetric analytical technique.

3. Dissolved oxygen was not measured during testing as it was felt that Eh characterization was sufficient.
4. Mixing tests to evaluate injection of treated water were conducted on two potential water treatment process trains (Test 18 Iron-Alum-IX and Test 15 Peroxide) rather than one process train as proposed in the Work Plan.
5. The ratios of treated water to groundwater in the injection simulation tests were modified. This was done primarily to allow testing of the additional treatment process water with the limited amount of treated water that was generated.
6. The ratios of treated water and groundwater to sediment were modified to use only 1 water:sediment ratio (5:1). This was also done to allow testing of the additional treatment process water with the limited amount of treated water that was generated.
7. The reaction time for the re-injection tests (i.e., time between mixing of the samples and sampling and analysis) was increased to allow more time for chemical reactions to proceed. Longer times are believed to be more representative of potential reaction times during groundwater transport.

3.0 WATER TREATMENT RESULTS

3.1 RAW (UNTREATED) INFLUENT GROUNDWATER

Raw groundwater chemistry, prior to treatment testing, is shown in Table 3-1.

TABLE 3-1. RAW WATER ANALYSIS

Analyte	Result (mg/L)
Bench Parameters	
Eh	202 mV
Dissolved Oxygen	Not Analyzed
Major Minerals	
Calcium	0.529
Magnesium	1.75
Sodium	1440
Hardness as CaCO3	8.55
Total Alkalinity as CaCO3	2470
Carbonate	1510
Bicarbonate	964
Hydroxide	<1.0
Chloride	34.3
Fluoride	56.1
Sulfate	323
pH	9.96
Total Dissolved Solids	3650
Silica (dissolved)	11.9
Total Organic Carbon	36.7
Chemical Oxygen Demand	63.4
Nitrogen Compounds	
Nitrate plus Nitrite as “N”	74.7
Total Kjeldahl Nitrogen	47.7
Cyanide Forms	
Total Cyanide (manual distillation)	66.9
WAD Cyanide	0.532
Dissolved Metals	
Iron	24.8
Ferrous Iron	Not Analyzed

3.2 CYANIDE REMOVAL

Analytical results and removal efficiencies for the cyanide treatability tests are listed in Table 3-2. WAD cyanide data listed in red exceeds the cleanup level of 0.2 mg/l established for groundwater at the point of compliance (POC).

TABLE 3-2. CYANIDE TREATABILITY TEST RESULTS

Test ID	Process Summary	Initial Total CN (mg/l)	Final CN (mg/l)	Total CN Removal (%)		Initial WAD CN (mg/l)	Final WAD CN (mg/l)	WAD CN Removal (%)
1	Ferrous Precipitation	66.9	71.2	-6.4%		0.532	0.119	77.6%
2	Ferrous Precipitation	66.9	44.5	33.5%		0.532	0.188	64.7%
3	Ferric Precipitation	66.9	59.8	10.6%		0.532	0.209	60.7%
4	Ferric Precipitation	66.9	53.4	20.2%		0.532	0.231	56.6%
5	Peroxide Oxidation	66.9	64.8	3.1%		0.532	0.142	73.3%
6	Peroxide Oxidation	66.9	63.7	4.8%		0.532	0.289	45.7%
7	Peroxide Oxidation	66.9	66.4	0.7%		0.532	0.190	64.3%
8	Peroxide Oxidation	66.9	66.3	0.9%		0.532	0.303	43.0%
9	Ferrous/Ferric Precipitation	66.9	68.2	-1.9%		0.532	0.132	75.2%
10	Ferrous/Ferric Precipitation	66.9	63.9	4.5%		0.532	0.122	77.1%
11	Ferric Precipitation	66.9	67	-0.1%		0.532	0.129	75.8%
12	Ferric Precipitation	66.9	83	-24.1%		0.532	0.119	77.6%
13	Ferrous Precipitation	66.9	0.956	98.6%		0.532	0.163	69.4%
14	Ferrous Precipitation	66.9	0.573	99.1%		0.532	0.338	36.5%
15	Peroxide Oxidation	66.9	58.1	13.2%		0.532	0.966	-81.6%
18	Ferrous Precipitation (Repeat Test 13)	66.9	0.474	99.3%		0.532	0.369	30.6%
I	Activated Alumina Adsorption	Not Analyzed						
II	Activated Alumina Adsorption	66.9	62.4	6.7%		0.532	0.287	46.1%
III	Sorbster F Adsorption	66.9	58.6	12.4%		0.532	0.340	36.1%

3.3 FLUORIDE REMOVAL

Analytical results and removal efficiencies for the fluoride treatability results are listed in Table 3-3. Fluoride data listed in red exceeds the cleanup level of 4 mg/l established for groundwater at the POC.

TABLE 3-3. FLUORIDE TREATABILITY TEST RESULTS

Test ID	Process Summary	Initial F (mg/l)	Final F (mg/l)	F Removal (%)
A	Calcium Chloride Precipitation	56.1	44.3	21.0%
B	Calcium Chloride Precipitation	56.1	57.6	-2.7%
C	Alum Precipitation	56.1	20.1	64.2%
D	ACH Precipitation	56.1	36.7	34.6%
E	XSORBX 100 Precipitation	56.1	39.6	29.4%
F	XSORBX 100 Precipitation	56.1	20.2	64.0%
G	XSORBX 100 Precipitation	56.1	30.2	46.2%
H	Lime Precipitation	56.1	41.2	26.6%
I	Calcium Chloride Precipitation	Not Analyzed		
J	Alum Precipitation	56.1	9.01	83.9%
K	Alum/XSORBX 100 Precipitation	56.1	8.33	85.2%
I	Activated Alumina Adsorption	56.1	15.8	71.8%
II	Activated Alumina Adsorption	56.1	16.8	70.1%
III	Sorbster F Adsorption	56.1	16.8	70.1%
18	Alum/XSORBX 100 Precipitation (Repeat of Test K)	56.1	5	91.1%

3.4 COMBINED PROCESSES AND POLISHING

Polishing treatment using IX and RO were tested on pre-treated water. Water treated for cyanide using Test 13 (ferrous precipitation) was then treated for fluoride using Test K (Alum/XSORBX 100 precipitation) and finally was then polished using IX. A repeat sample of water treated using Test 13 and Test K methods (labeled Test 18) was polished using RO. Analytical results and removal efficiencies of the RO treatment are shown in Table 3-4. The results for WAD cyanide and fluoride meet the cleanup levels established for groundwater at the POC.

TABLE 3-4. COMBINED PROCESSES AND POLISHING RESULTS

Test ID	Process Summary	Initial Total CN (mg/l)	Intermediate(1) Total CN (mg/l)	Final Total CN (mg/l)	Final % Total CN Removal	Initial WAD CN	Intermediate(1) WAD CN (mg/l)	Final WAD CN	Final % WAD CN Removal	Initial F (mg/l)	Intermediate(1) F (mg/l)	Final F (mg/l)	Final % F Removal
IX	Test 13 + Test K + IX	66.9	0.956	0.083	99.9%	0.532	0.163	0.014	97.4%	56.1	8.33	0.43	99.2%
RO	Test 18 + RO	66.9	0.474	0.01	99.99%	0.532	0.369	0.010	98.1%	56.1	5.0	0.15	99.7%

(1) Sample taken upstream of polishing process.
(2) Test 13 = ferrous sulfate precipitation; Test K = Alum/XSORBX 100 precipitation; Test 18 = repeat of Test 13 +Test K.

Water treated using the protocol for Test 18 (ferrous sulfate+Alum/XSORBX100 precipitation) polished by IX was utilized for the groundwater and sediment mixing tests (Section 3.3 below). A complete water chemistry analysis of the IX polish testing (Test 18 + IX) is shown in Table 3-5.

TABLE 3-5. IX POLISHING WATER CHEMISTRY

Analyte	Result (mg/L)
Bench Parameters	
Eh	2.5mV
Dissolved Oxygen	Not Analyzed
Major Minerals	
Calcium	3.12
Magnesium	1.97
Sodium	1700
Hardness as CaCO3	15.9
Total Alkalinity as CaCO3	<1.0
Carbonate	<1.0
Bicarbonate	<1.0
Hydroxide	<1.0
Chloride	579
Fluoride	<1.0
Sulfate	3180
pH (1)	3.28
Total Dissolved Solids	5380
Silica (dissolved)	2.29
Total Organic Carbon	7.54
Chemical Oxygen Demand	24.8
Nitrogen Compounds	
Nitrate plus Nitrite as “N”	57.9
Total Kjeldahl Nitrogen	16.1
Cyanide Forms	
Total Cyanide (manual distillation)	0.339
WAD Cyanide	0.235
Dissolved Metals	
Iron	0.782
Ferrous Iron	Not Analyzed

(1) The resin used for testing contained H^+ ions and was not fully regenerated, hence the low pH. When sequenced in an operational setting, the pH would be buffered to near neutral following IX.

3.5 SLUDGE

Analytical data for the cyanide and fluoride sludge are listed in Table 3-6. All constituents analyzed had values better than the Toxicity Characteristic Leaching Procedure (TCLP) regulatory limits.

TABLE 3-6. SLUDGE TEST RESULTS

Analyte	Cyanide Sludge from Test 13	Fluoride Sludge from Test K	TCLP Limit (1)
pH (S.U.)	6.38	6.25	No limit
Cyanide (total) (mg/kg)	210	7.9	No limit
Fluoride (mg/kg)	35.2	13.9	No limit
Dry Solids (%)	13.4	14.6	No limit
Final pH (S.U. after TCLP extraction)	5.18	5.60	> 2
Arsenic (mg/l extract)	<0.50	<0.250	5
Barium (mg/l extract)	<1.0	<2.00	100
Cadmium (mg/l extract)	<0.0100	<0.0200	1.0
Chromium (mg/l extract)	<0.0500	<0.0600	5.0
Lead (mg/l extract)	<0.0500	0.239	5.0
Selenium (mg/l extract)	<0.050	<0.400	1.0
Silver (mg/l extract)	<0.0500	0.15	5.0
Mercury (mg/l extract)	<0.00020	<0.00020	0.2

(1) 40 CFR 261.22 and 261.24.

3.6 GROUNDWATER AND SEDIMENT MIXING AND LEACHING

Groundwater and sediment mixing tests were conducted as described in Section 2.3 and summarized in Table 2-7. Tests consisted of mixing two types of treated water (Test 18 representing Iron-Alum-IX treatment process and Test 15 representing Peroxide treatment process) with untreated groundwater and/or sediment. Initial composition of the waters used in this testing has been previously described in this report as follows:

- Raw groundwater is described in Table 3-1;
- Test 18 treated water is described in Table 3-5; and
- Test 15 total and WAD cyanide content is in Table 3-2.

Cyanide and fluoride content of the sediment sample used in the tests is provided in Table 3-7. Laboratory analytical reports and a tabulation of data for this phase of the testing are in Appendix B.

TABLE 3-7. CYANIDE AND FLUORIDE
CONTENT OF SEDIMENT USED IN TESTING

Sediment Sample	Total Cyanide (mg/kg or ppm)	WAD Cyanide (mg/kg or ppm)	Method 300 Water Soluble Fluoride (mg/kg or ppm)
TW-1A @ 145’	30.7	<0.5	16.3

3.6.1 Test 18 (Iron-Alum-IX) Results

Test 18 water was analyzed for a full constituent list prior to the test and at the end of the 68 day test period. On days 15 and 47 of the test period, water sample aliquots were tested for Eh, pH, fluoride, total cyanide and WAD cyanide. Full constituent results (days 0 and 68) are summarized in Table 3-8.

During the test with only treated water, little change in major ion composition was observed during the course of the 68 day test period (Table 3-8). At the beginning of the test, the treated water was acidic (pH 3.12), had very low alkalinity, and sodium and sulfate were the

TABLE 3-8. TEST 18 TREATED WATER COMPOSITION AFTER 68 DAYS OF AGING

Analyte	Initial (Day 0) Treated Water Result (mg/L)	Treated Water after 68 days of aging (mg/L)	Relative Percent Difference between Treated Water and Treated Water after 68 days of aging	Treated Water + Sediment after 68 days of aging (mg/L)	Relative Percent Difference between Treated Water and Treated Water + Sediment after 68 days of aging
Bench Parameters					
Eh (millivolts)	2.5	516		165	
Dissolved Oxygen	Not Analyzed				
Major Minerals					
Calcium	3.12	3.21	3%	22.3	151%
Magnesium	1.97	1.91	-3%	9.81	133%
Sodium	1700	1540	-10%	1540	-10%
Hardness as $CaCO_3$	15.9	15.9	0%	96	143%
Total Alkalinity as $CaCO_3$	<1.0	<1.0	0%	222	
Carbonate	<1.0	<1.0	0%	43.4	
Bicarbonate	<1.0	<1.0	0%	179	
Hydroxide	<1.0	<1.0	0%	<1	
Chloride	579	557	-4%	537	-8%
Fluoride	<1.0	<2.5	0%	6.47	>647%
Sulfate	3180	3100	-3%	3030	-5%
pH (1)	3.28	3.44	5%	8.87	92%
Total Dissolved Solids	5380	5250	-2%	5550	3%
Silica (dissolved)	2.29	2.39	4%	7.76	109%
Total Organic Carbon	7.54	8	6%	7.57	0%
Chemical Oxygen Demand	24.8	22.6	-9%	20.1	-21%
Nitrogen Compounds					
Nitrate plus Nitrite as "N"	57.9	64.3	10%	63.7	10%
Total Kjeldahl Nitrogen	16.1	14.9	-8%	21.6	29%
Cyanide Forms					
Total Cyanide (manual distillation)	0.339	0.463	31%	5.38	176%
WAD Cyanide	0.235	0.326	32%	0.074	-104%
Dissolved Metals					
Iron	0.782	1.26	47%	1.95	86%

(1) The IX resin used for testing contained H^+ ions and was not fully regenerated, hence the low initial pH. When sequenced in an operational setting, the pH would be buffered to near neutral following IX.

predominant ions present. As noted above, the low pH of the treated water is a residual effect of insufficient regeneration of the IX resins prior to the treatment tests. This low pH condition is not expected to occur in a fully operational IX system. At the end of the test, the water remained acidic (pH 3.21) with low alkalinity and high sodium and sulfate. Under the conditions of this test, there was no observable significant loss of dissolved ions, indicating that the treated water is chemically stable and did not precipitate minerals.

During the test with treated water and sediment, changes in major ion composition indicate that the acidic low pH treated water reacted with the sediment to dissolve minerals from the sediment. During the 68 day period, pH rose from 3.12 to 8.87 and total alkalinity increased from <1 to 222 mg/L. Calcium and magnesium also rose, suggesting that the increase in pH and carbonate alkalinity may have been due to the dissolution of calcium carbonate and magnesium carbonate from the sediment. Similar to the water only test, there was no observable significant loss of dissolved ions, indicating that in the presence of aquifer sediment, the treated water did not precipitate minerals.

Figures 3-1 through 3-3 present results for cyanide and fluoride for days 0, 15, 47, and 68 of the test. During the test, the raw groundwater sample served as a "control" sample to provide an indication of the variability or uncertainty in replicate laboratory procedures/ measurements and the variation or changes that might occur in natural untreated water over the course of the test period. A comparison of results for raw groundwater (red line in figures) with treated water results thus may be used to determine whether changes in other waters are potentially significant (i.e., significantly greater than raw groundwater variations).

Fluoride concentration variations in raw groundwater were approximately 3 mg/L or 5 percent. Variations in fluoride concentrations in treated water, treated water plus sediment, treated water mixed with groundwater, and treated water mixed with groundwater plus sediment were within 3 mg/L of initial concentrations and thus there is no evidence of significant changes in fluoride concentrations due to mixing with groundwater or groundwater plus sediment.

FIGURE 3-1. TEST 18 GROUNDWATER MIXING AND SEDIMENT LEACHING FLUORIDE RESULTS

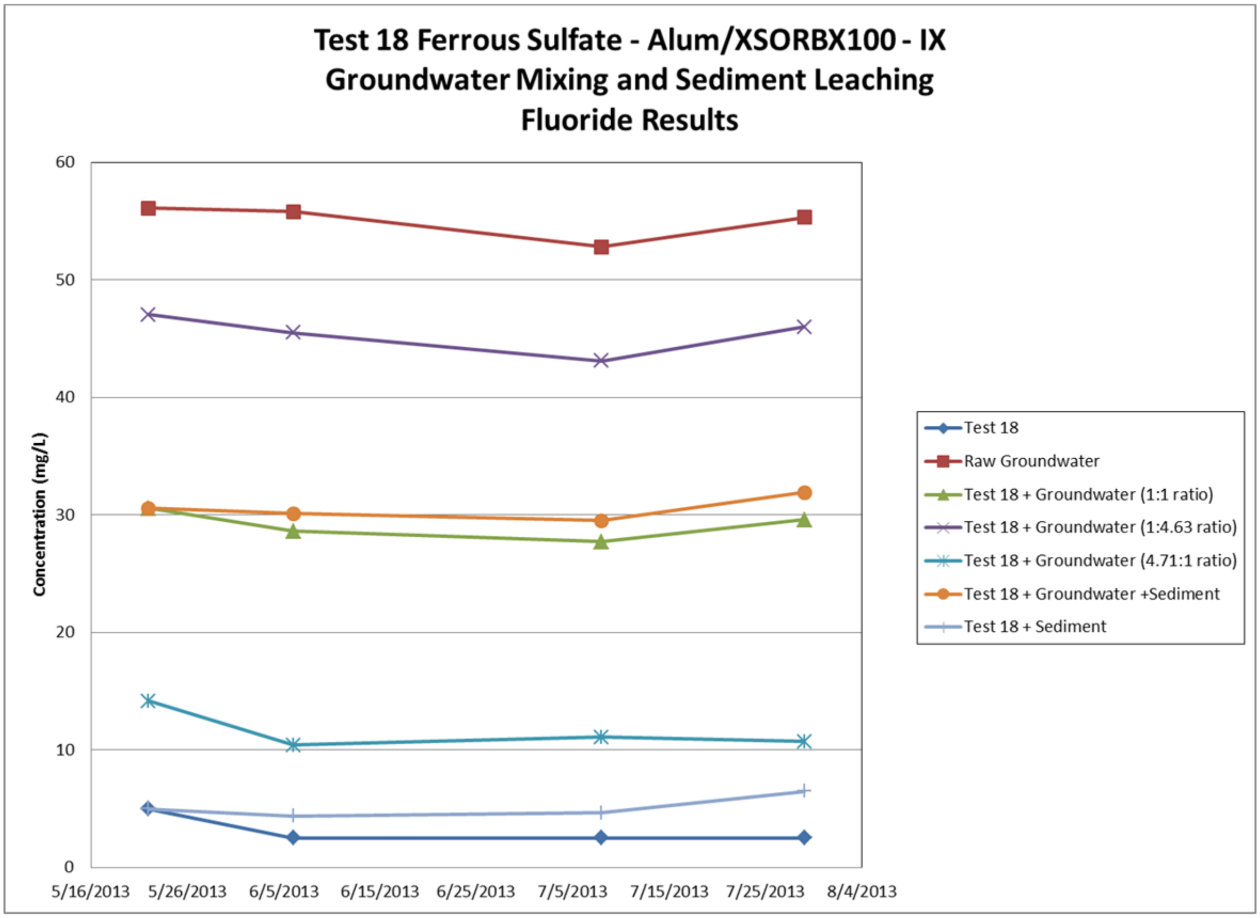


FIGURE 3-2. TEST 18 GROUNDWATER MIXING AND SEDIMENT LEACHING TOTAL CYANIDE RESULTS

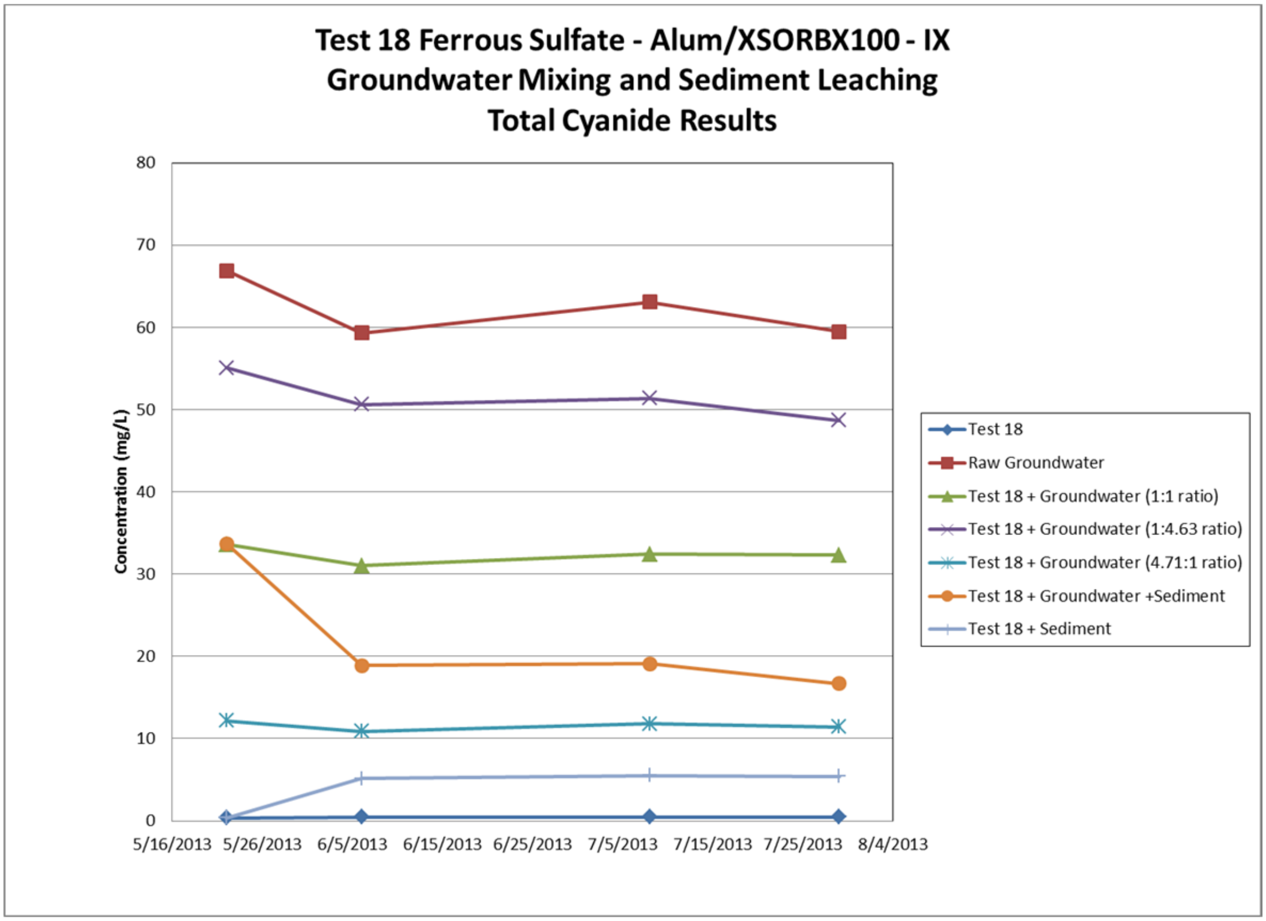
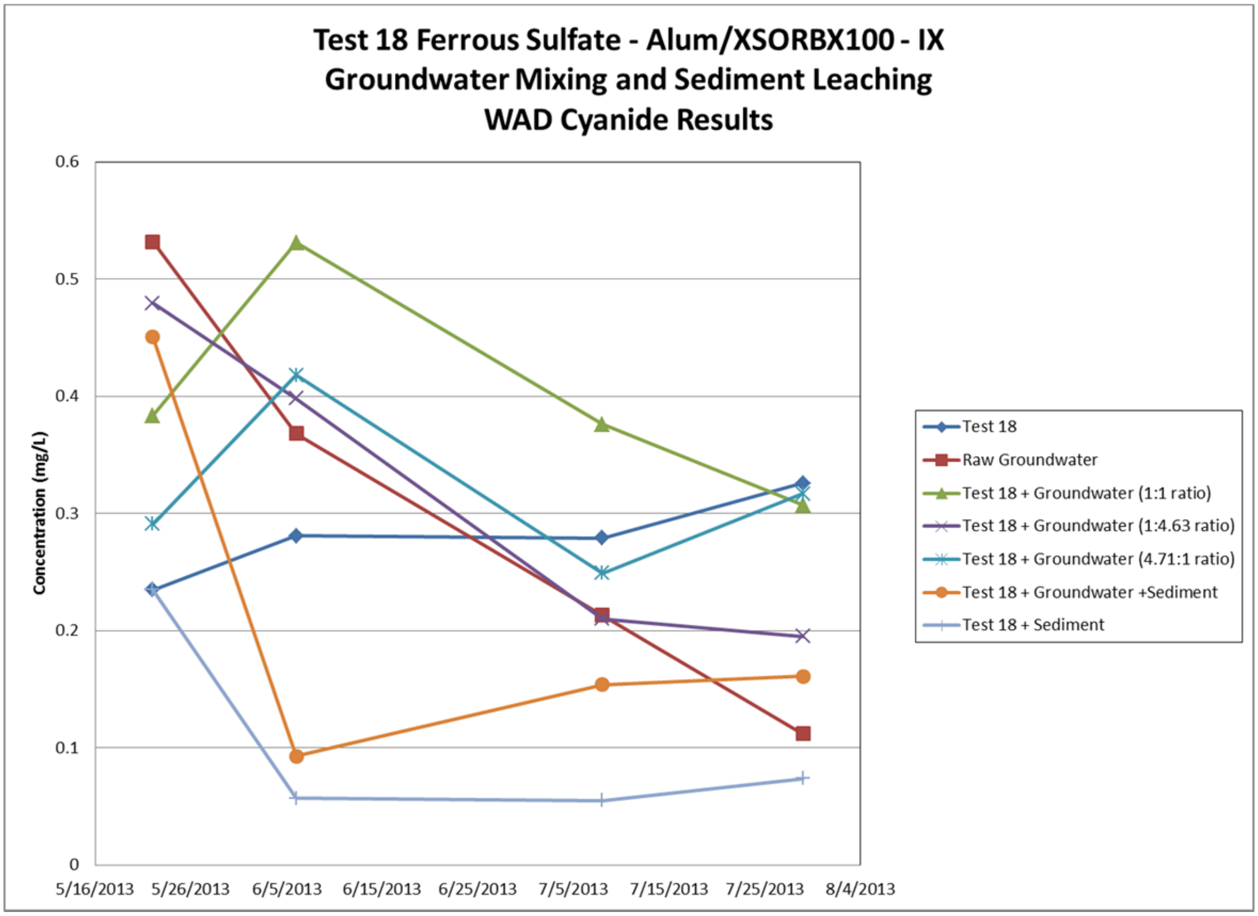


FIGURE 3-3. TEST 18 GROUNDWATER MIXING AND SEDIMENT LEACHING WAD CYANIDE RESULTS



Total cyanide concentration in raw groundwater varied approximately 7 mg/L during the test (Figure 3-2). With one exception (test 18 + groundwater + sediment), variations in total cyanide concentrations in treated water, treated water plus sediment, treated water mixed with groundwater, and treated water mixed with groundwater plus sediment were within 7 mg/L of initial concentrations and thus there is no evidence of significant changes in total cyanide concentrations due to mixing with groundwater or groundwater plus sediment. For the test mixture that included test 18 treated water plus groundwater and sediment, total cyanide concentration decreased approximately 17 mg/L, a potentially significant change, over the course of the test. This test result suggests that treated water may react with groundwater in the presence of sediment to remove additional total cyanide from groundwater. The fate of the total cyanide lost from the treated water/groundwater/sediment mixture is not known with certainty as there were no significant changes in other chemical constituents that coincide with the loss of total cyanide, as would be expected if cyanide mineral precipitates were forming (e.g., pH, Eh, dissolved iron remained nearly stable, or shifted to conditions (higher pH and Eh) favoring dissolution of iron cyanide minerals). Based solely on the lack of evidence of cyanide mineral precipitation, it is speculated that cyanide may have been removed by adsorption to the sediment.

WAD cyanide concentrations in the raw groundwater control sample varied (declined) greatly (from approximately 0.5 mg/L to 0.1 mg/L) over the course of the test (Figure 3-3). WAD cyanide concentrations of the treated water/groundwater/sediment mixtures varied somewhat less than in raw groundwater and generally declined in three mixtures and increased slightly in two mixtures. Given the high variability in WAD cyanide concentrations in the raw groundwater control sample, the apparent changes in the treated water/groundwater/sediment mixtures are not considered to be significant.

3.6.2 Test 15 (Peroxide) Results

Test 15 water was analyzed for Eh, pH, total cyanide and WAD cyanide on days 0, 15, and 47 (end) of the test period. Figures 3-4 and 3-5 present test results for total and WAD cyanide. As described above for Test 18, the raw groundwater sample served as a “control” sample during the test and provides an indication of the variability or uncertainty in replicate laboratory measurements and the variation or changes that might occur in natural untreated water over the course of the test period. A comparison of results for raw groundwater (red line in figures) with treated water results thus may be used to determine whether changes in other waters are potentially significant (significantly greater than raw groundwater variations).

Total cyanide concentration in raw groundwater varied approximately 7 mg/L during the test (Figure 3-4). Variations in total cyanide concentrations in test mixtures with only Test 15 treated water or treated water and groundwater were within the variation of the control (raw

FIGURE 3-4. TEST 15 GROUNDWATER MIXING AND SEDIMENT LEACHING TOTAL CYANIDE RESULTS

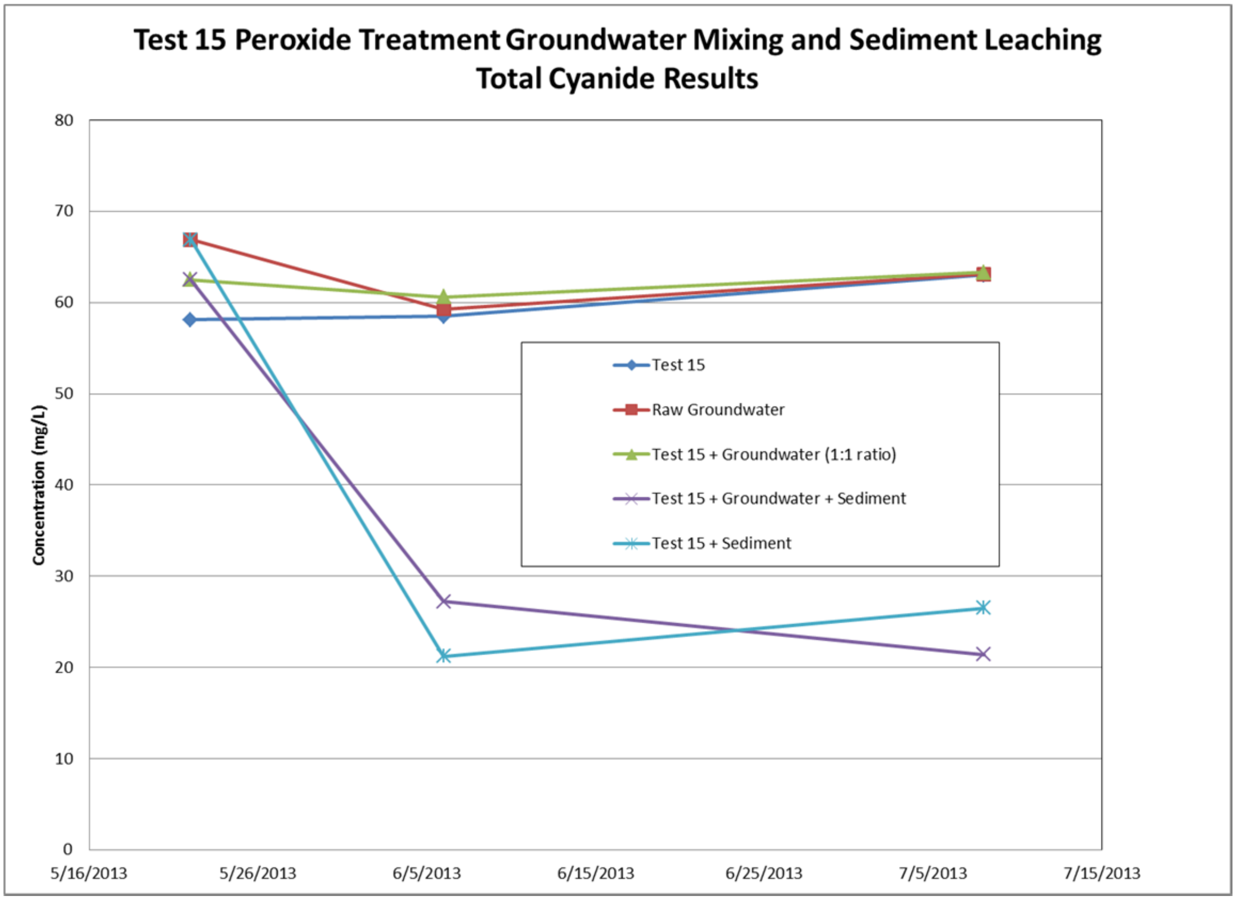
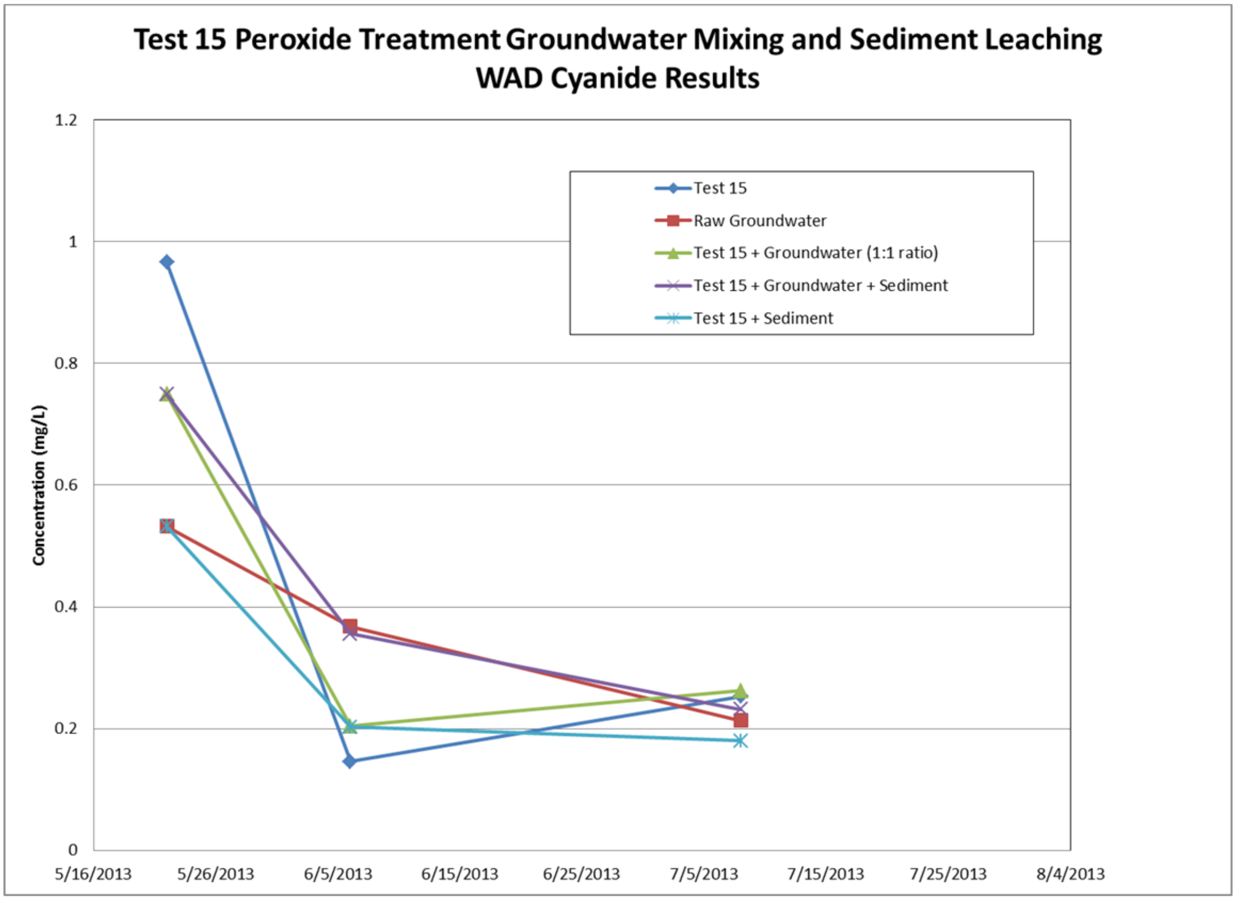


FIGURE 3-5. TEST 15 GROUNDWATER MIXING AND SEDIMENT LEACHING WAD CYANIDE RESULTS



groundwater) sample and thus there is no evidence of significant changes in total cyanide concentrations due to mixing with groundwater. However, the test mixtures containing sediment (i.e., Test 15+sediment and Test 15+groundwater+sediment) exhibited significant declines (over 30 mg/L reductions) in total cyanide. These test results suggests that treated water may react with sediment and/or with groundwater in the presence of sediment to remove additional total cyanide from groundwater. Similar to results for Test 18 noted above, the fate of the total cyanide lost from the treated water/groundwater/sediment mixture is not known with certainty as there were no significant changes in other chemical constituents that coincide with the loss of total cyanide. Based solely on the lack of evidence of cyanide mineral precipitation, it is speculated that cyanide may have been removed by adsorption to the sediment.

WAD cyanide concentrations in the raw groundwater control sample varied (declined) greatly (from approximately 0.5 mg/L to 0.1 mg/L) over the course of the test (Figure 3-5). WAD cyanide concentrations of the treated water/groundwater/sediment mixtures generally paralleled raw groundwater concentrations and generally declined in all treated water. Given the high variability in the raw groundwater control sample, the apparent changes in the treated water/groundwater/sediment mixtures are not considered to be significant.

4.0 PRELIMINARY TREATMENT FEASIBILITY

4.1 POTENTIAL EFFECTIVENESS OF METHODS

This section describes the treatability test results in terms of effectiveness, meeting compliance levels, and achieving significant contaminant mass reduction.

4.1.1 Treatment Processes Deemed Effective

The treatment processes tested for WAD and total cyanide removal included:

- Precipitation process using ferrous and ferric iron coagulants;
- Oxidation process using hydrogen peroxide and copper sulfate precipitant;
- Adsorption process using activated alumina and Sorbster F (proprietary media from Mars Systems);
- IX as polishing, downstream of precipitation process; and
- RO as polishing, downstream of precipitation process.

The treatment processes tested for fluoride removal included:

- Precipitation using calcium chloride, alum, ACH, XSORBX-100 (proprietary coagulant from Molycorp), and lime;
- Adsorption process using activated alumina and Sorbster F (proprietary media from Mars Systems);
- IX as polishing, downstream of precipitation process; and
- RO as polishing, downstream of precipitation process.

All of the treatment processes were effective at varying degrees in removing the targeted constituents of total and WAD cyanide and fluoride. The degree of effectiveness is described in more detail in the following sub-sections.

4.1.1.1 WAD Cyanide

Test results shown in Section 3 indicate that all five treatment processes remove WAD cyanide in varying amounts, ranging between (-) 81.6% to 98.1%. WAD cyanide removal varied within individual treatment process testing depending on amount of coagulant/ oxidant/adsorbent used and mixing times, for instance:

- Precipitation process:
  - Ferrous iron coagulant: 30.6% to 77.6% WAD cyanide removal
  - Ferric iron coagulant: 56.6% to 77.6% WAD cyanide removal
  - Ferrous + Ferric iron coagulant: 75.2% to 77.1% WAD cyanide removal
- Oxidation process:
  - Peroxide oxidant+ copper sulfate precipitant: (-)81% to 73.3% WAD cyanide removal
- Adsorption process:
  - Activated Alumina coagulant: 46.1% WAD cyanide removal
  - Sorbster F coagulant: 36.1% WAD cyanide removal
- IX process downstream of Ferrous precipitation process:
  - 97.4% WAD cyanide removal
- RO process downstream of Ferrous precipitation process:
  - 98.1% WAD cyanide removal. Note that the RO membrane fouled almost immediately, rendering the membrane unusable. See Implementability discussion in Section 4.2.

4.1.1.2 Total Cyanide

Test results shown in Section 3 indicate that all five treatment processes remove total cyanide in varying amounts, ranging between (-) 6.4% to 99.99%. Total cyanide removal varied within individual treatment process testing depending on amount of coagulant/oxidant/ adsorbent used and mixing times, for instance:

- Precipitation process:
  - Ferrous iron coagulant: (-)6.4% to 99.3% total cyanide removal
  - Ferric iron coagulant: (-)24.1% to 20.2% total cyanide removal

  - Ferrous + Ferric iron coagulant: (-)1.9% to 4.5% total cyanide removal
- Oxidation process:
  - Peroxide oxidant + copper sulfate precipitant: 0.7% to 13.2% total cyanide removal
- Adsorption process:
  - Activated Alumina coagulant: 6.7% total cyanide removal
  - Sorbster F coagulant: 12.4% total cyanide removal
- IX process downstream of Ferrous precipitation process:
  - 99.9% total cyanide removal
- RO process downstream of Ferrous precipitation process:
  - 99.99% total cyanide removal. Note that the RO membrane fouled almost immediately, rendering the membrane unusable. See Implementability discussion in Section 4.2.

4.1.1.3 <u>Fluoride Removal</u>

Test results shown in Section 3 indicate that all five treatment processes remove fluoride in varying amounts, ranging between (-) 2.7% to 99.7%. Fluoride removal varied within individual treatment process testing depending on amount of coagulant/adsorbent used and mixing times, for instance:

- Precipitation process:
  - Calcium chloride coagulant: (-)2.7% to 21.0% fluoride removal
  - Alum coagulant: 64.2% to 83.9% fluoride removal
  - ACH coagulant: 34.6% fluoride removal
  - Lime coagulant: 26.6% fluoride removal
  - XSORBX 100 coagulant: 29.4% - 64.0% fluoride removal
  - Alum + XSORBX 100 coagulants: 85.2% - 91.1% fluoride removal
- Adsorption process:
  - Activated Alumina coagulant: 70.1% to 71.8% fluoride removal
  - Sorbster F coagulant: 70.1% fluoride removal

- IX process downstream of alum/XSORBX precipitation process:
    - 99.2% fluoride removal
- RO process downstream of alum/XSORBX precipitation process:
    - 99.7% fluoride removal. Note that the RO membrane fouled almost immediately, rendering the membrane unusable. See Implementability discussion in Section 4.2.

4.1.2 Potential Treatment Process Trains Meeting Compliance Levels

In order to meet the compliance limits for both WAD cyanide (0.2 mg/l) and fluoride (4 mg/l), a combination of treatment processes need to be combined in series forming a "treatment process train." Of all the treatment processes tested only three process trains meet the compliance limits. These process trains are:

1. **Alternative 1 (Iron-Alum-IX).** Cyanide precipitation using a ferrous iron coagulant followed by fluoride precipitation using an alum coagulant or alum+XSORBX coagulants; followed by IX. The IX is required to meet the fluoride limit, and the fluoride precipitation upstream of the IX is preferred as a pre-treatment step to maximize the capability, efficiency, and longevity of the IX process. This is due to the fact that the fewer the cations/anions needing to be removed by the IX process, the longer life the IX resin has before the exchange sites need to be regenerated. This in turns decreases the amount of concentrated liquid waste produced by the IX process that requires disposal.

   For the purposes of this evaluation, it is assumed that the hydraulic design capacity of the IX system will be capable of a throughput of 100 percent of the design flow. However, in order to reduce annual chemical and waste residual disposal costs, only one-half of the flow (50 percent) would be routed through the IX system. The effluent from the IX vessel(s) is then mixed with the remaining 50 percent of the flow that is not conveyed through the IX vessels and the combined flow is then routed to the discharge location. Using this 50 percent side-stream IX treatment approach will still meet the fluoride effluent limit, while at the same time minimizing annual costs.

The IX will also remove additional WAD cyanide as shown in the data (Table 3-4).

The cyanide precipitation process using a ferrous iron coagulant also has the ability to reduce total cyanide by up to 99.3% in these un-optimized tests, which minimizes the amount of cyanide reporting to the IX process. Having low levels of total cyanide reporting to the IX will maximize the capability, efficiency and longevity of the IX process as described above.

2. **Alternative 2 (Peroxide-Alum-IX)**. Cyanide oxidation using a peroxide oxidant followed by fluoride precipitation using an alum coagulant or alum+XSORBX coagulants; followed by IX. The IX is required to meet the fluoride limit, and the fluoride precipitation upstream of the IX is necessary as a pre-treatment to maximize the capability and efficiency of the IX process. This is due to the fact that the fewer the cations/anions needing to be removed by the IX process, the longer life the IX resin has before the exchange sites need to be regenerated. This in turns decreases the amount of concentrated liquid waste produced by the IX process that requires disposal.

   As in Alternative 1, this alternative assumes an IX system handling 50 percent of the design flow, for the same reasons as stated in Alternative 1.

The IX will also remove additional WAD cyanide as shown in the data. This could be important as the cyanide oxidation process by itself only met the WAD cyanide compliance limit two tests out of five tests (40% success rate). However, these tests were not fully optimized and better WAD cyanide removal is likely from a fully-optimized treatment system.

It is noted that although this treatment process train appears to be capable of meeting the compliance limits (these three separate processes were not tested together as a process train), testing indicates that 86.8% to 99.3% of total cyanide would pass through to the IX process. The IX process will be somewhat negatively affected by this mass of total cyanide as the IX resin will utilize ion exchange sites for cyanide in addition to fluoride. This will reduce the capability, efficiency, and longevity of the

IX process. This in turn increases the amount of concentrated liquid waste produced by the IX process that requires disposal. Although this negative affect is understood, the testing conducted for this study was not sufficient to determine a quantitative affect; that is, how much more quickly will the ion exchange sites be utilized by the cyanide instead of being available for fluoride. This, quantitative affect ultimately affects the IX regeneration rate, influencing the annual cost of regeneration chemicals and regeneration disposal.

3. **Alternative 3 (Iron-Alum-RO)**. Cyanide precipitation using a ferrous iron coagulant followed by fluoride precipitation using an alum coagulant or alum+XSORBX coagulants; followed by RO. Although the data indicate this treatment process train will meet the compliance limits for WAD cyanide and fluoride, the test resulted in the RO membrane becoming immediately fouled to the point it became plugged. Therefore, this process is not considered implementable as described in Section 4.2 below.

4.1.3 Potential Treatment Process Trains Achieving Significant Mass Reduction

Treatment process trains achieving significant mass reduction but not meeting the compliance limits for both WAD cyanide (0.2 mg/l) and fluoride (4 mg/l) include the following:

1. **Alternative 4 (Iron-Alum)**. Cyanide precipitation using a ferrous and/or ferric iron coagulant followed by fluoride precipitation using an alum coagulant or alum+XSORBX coagulants. As described in previous sections, this process removes up to 77.6% of WAD cyanide and 85.2% of fluoride in the groundwater.

   The cyanide precipitation process using a ferrous and/or ferric iron coagulant also has the ability to reduce total cyanide by up to 99.3%, which minimizes the amount of total cyanide having the potential to convert to WAD cyanide downstream of the cyanide precipitation process; for instance in the fluoride precipitation process reactor or in the receiving environment. Having less total cyanide in the treated water minimizes the risk that the WAD cyanide concentration in the process effluent would increase due to downstream conversion of total cyanide to WAD cyanide.

The likelihood of total cyanide conversion to WAD cyanide at the Mead site and the effect that this conversion might have on meeting compliance limits is uncertain due to the paucity of reported studies of the conversion in the literature, the somewhat contradictory results of the two available studies, and the lack of site-specific studies. Studies by Meeussen et al (1992) suggest that the conversion may be exceptionally slow to the point that negligible conversion occurs. In contrast, a study by Ghosh et al (1999) indicated low levels of conversion (3 to 5 percent of total in approximately six months) that might generate low but significant levels of WAD cyanide.

2. **Alternative 5** (Peroxide-Alum). Cyanide oxidation using a peroxide oxidant followed by fluoride precipitation using an alum coagulant or alum+XSORBX coagulants. As described in previous sections, this process removes up to 73.3% of WAD cyanide and 85.2% of fluoride in the groundwater.

   As previously noted, cyanide oxidation only removes up to 13.2% of total cyanide in the groundwater. This means that most of the total cyanide remains in the process effluent, increasing the potential risk of total cyanide converting to WAD cyanide downstream of the process reactor. This in turn increases the potential risk of WAD cyanide increasing above the compliance limit downstream of the process reactor. As described above, the potential for total cyanide to convert to WAD cyanide is not known with certainty.

4.2 IMPLEMENTABILITY

The implementability of the five treatment trains demonstrating success at achieving significant mass reduction and/or meeting compliance levels are described below. For the purposes of this report the following definitions are used:

- Ability to construct and operate – This refers to using standard construction methods to install the water treatment equipment and the building housing the equipment, including civil, electrical, and mechanical construction disciplines; and utilize operating procedures and operator training standard to the industrial water treatment industry.
- Reliability – This refers to the process train being capable of operating on either a 24/7 or routine shift basis in a batch mode; and while in operation being able to constantly achieve the designated effluent quality, for example the required effluent limits or constituent mass reduction goals.
- Type and quantity of residuals remaining after treatment – This refers to de-watered sludge and/or concentrated liquid waste (e.g., regenerate from the IX regeneration procedure) produced by the treatment process train.
- Need and availability of offsite treatment, storage, and disposal services – This refers to the requirement of a treatment process train that may utilize the services of an offsite facility to assist with an aspect of treating the groundwater, storing chemicals, equipment, or waste residuals, or disposing of waste residuals.
- Need and availability of necessary equipment and specialists – This refers to equipment and labor required to operate and maintain the treatment process train.

Implementability is summarized in Table 4-1 and discussed in the following sections.

TABLE 4-1. IMPLEMENTABILITY OF PROCESS TRAIN ALTERNATIVES

Process Train Alternative	Ability to Construct and Operate	Reliability	Treatment Residuals	Offsite Treatment, Storage, Disposal	Need and availability of Equipment and Specialists	Overall Implementability	Overall Rationale
1. Iron-Alum- IX	Excellent	Excellent	Dewatered sludge and IX regenerate solution	CN and F sludge disposal at local landfill; regenerate solution to Arlington, OR	Readily available equipment and specialists	Excellent	Meets effluent limits; reliable; acceptable residuals disposal
2. Peroxide-Alum-IX	Excellent	Excellent	Dewatered sludge and IX regenerate solution	F sludge disposal at local landfill; regenerate solution to Arlington, OR	Readily available equipment and specialists	Excellent	Meets effluent limits; reliable; acceptable residuals disposal
3. Iron–Alum-RO	Difficult	Unreliable	Dewatered sludge; RO concentrate unknown	CN and F sludge disposal at local landfill; RO concentrate solution to Arlington, OR	Readily available equipment and specialists	Poor	Not suitable due to RO membrane fouling
4. Iron-Alum	Excellent	Excellent	Dewatered sludge	CN and F sludge disposal at local landfill	Readily available equipment and specialists	Good	Significantly reduces WAD and total cyanide; acceptable residuals disposal
5. Peroxide-Alum	Excellent	Uncertain	Dewatered sludge	F sludge disposal at local landfill	Readily available equipment and specialists	Fair-Good, but with uncertainties regarding retention of total cyanide	Significantly reduces WAD cyanide; does not reduce total cyanide; acceptable residuals disposal

4.2.1 Ability to Construct and Operate

Alternative 1 (Iron-Alum-IX) utilizes process equipment that is main-stream in the water treatment industry. The equipment primarily consists of chemical feed systems, two reaction tanks with mixers, two clarifiers, forwarding pumps, IX column(s), sludge dewatering press, IX regeneration system, instruments, and controls. This equipment is housed inside a heated building. Operational safety considerations required are also main-stream in the water treatment industry. No difficult construction or operational activities are anticipated with Alternative 1 process train.

Alternative 2 (Peroxide-Alum-IX) utilizes process equipment that is main-stream in the water treatment industry. The equipment primarily consists of chemical feed systems, two reaction tanks with mixers, one clarifier, forwarding pumps, IX column(s), sludge dewatering press, IX regeneration system, instruments, and controls. This equipment is housed inside a heated building. Operational safety considerations required are also main-stream in the water treatment industry. No difficult construction or operational activities are anticipated with Alternative 2 process train.

Alternative 3 (Iron-Alum-RO) utilizes process equipment that is main-stream in the water treatment industry. The equipment primarily consists of chemical feed systems, two reaction tanks with mixers, two clarifiers, forwarding pumps, RO system, sludge dewatering press, RO clean-in-place system, instruments, and controls. This equipment is housed inside a heated building. Operational safety considerations required are also main-stream in the water treatment industry. No difficult construction activities are anticipated with Alternative 3 process train. The operational consideration for Alternative 3 is problematic and likely insurmountable. As noted in Section 4.1.2, the RO membrane fouled almost immediately during the test. This is indicative of the number and types of fouling contaminants contained in the water chemistry. While adding certain types of ant-scalants would lessen the fouling tendency of the water, it will not lessen the impacts to the point of being able to reliably use the RO process train. Therefore, this alternative is deemed unsuitable for use at the Site.

Alternative 4 (Iron-Alum) utilizes the same process equipment as Alternative 1 except it does not utilize an IX system. No difficult construction or operational activities are anticipated with Alternative 1 process train.

Alternative 5 (Peroxide-Alum) utilizes the same process equipment as Alternative 2 except it does not utilize an IX system. No difficult construction or operational activities are anticipated with Alternative 2 process train.

4.2.2 Reliability

The Alternative 1 (Iron-Alum-IX) process treatment train should offer a reliable method for treating the site water to meet the compliance limits, provided specified process equipment is utilized and operators have sufficient training and experience in utilizing these types of process equipment.

The Alternative 2 (Peroxide-Alum-IX) process treatment train should offer a reliable method for treating the site water to meet the compliance limits, provided specified process equipment is utilized and operators have sufficient training and experience in utilizing these types of process equipment.

The Alternative 3 (Iron-Alum-RO) process treatment train does not offer a reliable method for treating the site water to meet the compliance limits, even though specified process equipment is utilized and operators have sufficient training and experience in utilizing these types of process equipment. This unreliable designation is due to the fouling of the RO membrane experienced in the testing, and the operability of the treatment process train as described in Section 4.2.1.

The Alternative 4 (Iron-Alum) process treatment train should offer a reliable method for treating the site water to meet the compliance limit for WAD cyanide and for significant mass reduction for fluoride, provided specified process equipment is utilized and operators have sufficient training and experience in utilizing these types of process equipment. This method also provides for significant mass reduction of total cyanide, minimizing the risk of total cyanide converting to WAD cyanide downstream of the cyanide reactor as described in Section 4.1.3.

The Alternative 5 (Peroxide-Alum) process treatment train offers an uncertain method for reliably treating the site water to meet the compliance limit or for achieving significant mass reduction for WAD cyanide, but offers a reliable method for achieving significant mass reduction for fluoride, provided specified process equipment is utilized and operators have sufficient training and experience in utilizing these types of process equipment. This uncertainty of reliability is due to the inability of this cyanide removal process (oxidation) to remove substantial mass of total cyanide, resulting in an unknown level of risk should total cyanide convert to WAD cyanide downstream of the cyanide reactor as described in Section 4.1.3.

4.2.3 Type and Quantity of Residuals Remaining After Treatment

Alternative 1 (Iron-Alum-IX) will produce an iron-cyanide sludge combined with fluoride sludge. In a water treatment plant, the two sludges would be combined in a thickening tank, then dewatered. The dewatered sludge has a cake-like consistency to minimize the water content and enable the sludge to be handled as a solid. The sludge passes TCLP testing. This alternative also produces a concentrated IX regenerate solution containing cyanide and fluoride. Assuming treatment of average groundwater flows of 50 gpm, this process train would generate 1,460 cy of sludge and 640,000 gallons of IX regenerate solution per year.

Alternative 2 (Peroxide-Alum-IX) will produce fluoride sludge. This sludge is de-watered to a cake-like consistency to minimize the water content and enable the sludge to be handled as a solid. The sludge passes TCLP testing. This alternative also produces a concentrated regenerate solution containing cyanide and fluoride. Assuming treatment of average groundwater flows of 50 gpm, this process train would generate 1,095 cy of sludge and 640,000 gallons[1] of IX regenerate solution per year.

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[1] For the purposes of this report, we have assumed the amount of regenerant produced in Alternative 2 is the same as Alternative 1. However, as previously discussed in Section 4.1.2, the amount of total cyanide routed through the IX resin for Alternative 2 is two orders of magnitude greater than Alternative 1. This will negatively affect the exchange capacity of the resin. Although this negative affect is understood, the testing conducted for this study was not sufficient to determine a quantitative affect; that is, how much more quickly will the ion exchange sites be utilized by the cyanide instead of being available for fluoride. This quantitative affect ultimately affects the IX regeneration rate, increasing the annual cost of regeneration chemicals, producing more regenerate than Alternative 1 and increasing regeneration disposal rates over what would be expected in Alternative 1.

Alternative 3 (Iron-Alum-RO) will generate the same type and quantity of sludge as Alternative 1. Due to the operational considerations and unreliability of Alternative 3, the quantity of RO concentrated brine is not estimated.

Alternative 4 (Iron-Alum) will produce the same type and quantity of de-watered sludge as Alternative 1. This alternative will not produce a regenerate solution.

Alternative 5 (Peroxide-Alum) will produce the same type and quantity of de-watered sludge as Alternative 2. This alternative will not produce a regenerate solution.

4.2.4 Need and Availability of Offsite Treatment, Storage and Disposal Services

Alternative 1 (Iron-Alum-IX) does not require offsite treatment or storage. This alternative will require disposal of de-watered sludge and IX regenerate solution. Disposal of this sludge can be accommodated by the local Waste Management landfill. The nearest facility that will accept the IX regenerant solution is located in Arlington, OR.

Alternative 2 (Peroxide-Alum-IX) does not require offsite treatment or storage. This alternative will require disposal of de-watered sludge and IX regenerate solution. Disposal of this sludge can be accommodated by the local Waste Management landfill. The nearest facility that will accept the IX regenerant solution is located in Arlington, OR.

Alternative 3 (Iron-Alum-RO) does not require offsite treatment or storage. This alternative will require disposal of de-watered sludge and IX regenerate solution. Disposal of this sludge can be accommodated by the local Waste Management landfill. The nearest facility that will accept the IX regenerant solution is located in Arlington, OR. As previously discussed, this alternative is not considered to be operationally viable or reliable.

Alternative 4 (Iron-Alum) does not require offsite treatment or storage. This alternative will require disposal of de-watered sludge. Disposal of this sludge can be accommodated by the local Waste Management landfill.

Alternative 5 (Peroxide-Alum) does not require offsite treatment or storage. This alternative will require disposal of de-watered sludge. Disposal of this sludge can be accommodated by the local Waste Management landfill.

4.2.5 Need and Availability of Necessary Equipment and Specialists

Alternative 1 (Iron-Alum-IX) requires equipment that is readily available in the industrial water treatment marketplace. This includes replacement parts and treatment chemicals. A possible exception is the availability of the Molycorp XSORBX™ chemistry in the future. As this is a proprietary product, it is unknown what the availability of this product or a similarly acting product will be in the marketplace. However, this alternative allows for the use of alum without the XSORBX, so in all likelihood the long-term availability of the XSORBX product is not an issue in regards to the viability of the process treatment train. No specialists are required to operate or maintain this treatment process train, other than properly trained treatment plant operators.

It should also be noted that the IX process utilizes a chemical compound – aluminum chloride ($AlCl_3$) to regenerate the IX resin. In order to remove the fluoride from the resin $AlCl_3$ is circulated through the resin bed, followed by clean (treated) water. Based on information from resin manufacturers, approximately 62.5 pounds of $AlCl_3$ is required for every pound of fluoride removed from the water. While this ratio seems reasonable when compared to other chemical processes, the testing conducted in this study did not include protocols to verify this ratio.

Alternative 2 (Peroxide-Alum-IX) requires equipment that is readily available in the industrial water treatment marketplace. This includes replacement parts and treatment chemicals. No specialists are required to operate or maintain this treatment process train, other than properly trained treatment plant operators. The same note regarding $AlCl_3$ consumption described for Alternative 1 applies to Alternative 2.

Alternative 3 (Iron-Alum-RO) requires equipment that is readily available in the industrial water treatment marketplace. This includes replacement parts and treatment chemicals. No specialists are required to operate or maintain this treatment process train, other than properly trained treatment plant operators. As previously discussed, this alternative is not considered to be operationally viable or reliable.

Alternative 4 (Iron-Alum) is evaluated the same as Alternative 1 for this category.

Alternative 5 (Peroxide-Alum) is evaluated the same as Alternative 2 for this category.

4.3 POTENTIAL COST

Capital costs (CapEx) and annual operating costs (OpEx) are estimated for the treatment alternatives except for the RO alternative, as this was ruled operationally not viable and unreliable. The estimated costs only relate to the water treatment plant and removing the waste residuals to an offsite landfill/repository. They do not include the costs associated with delivering groundwater to the water treatment plant or other aspects of managing the Site.

The costs are intended to provide a relative comparison between alternatives, and are considered to be +/-25 percent of actual costs.

4.3.1 Capital Costs

CapEx are estimated for the four treatment alternatives at operational flow rates of 50 gallons per minute (gpm) and 200 gpm. These flow rates were chosen to show comparisons of a potential minimum and maximum range that could be selected for the Site.

The CapEx components and the cost basis for each component are:

- Engineering design. Costs are factored as 8 percent of equipment costs.
- All water treatment equipment, including reactor tanks, clarifier(s), chemical feed systems, ion exchange systems (100 percent hydraulic throughput), instruments, and controls. Costs are based on vendor quotes, recent quotes for similar equipment, and allowance based on best professional judgment.

- Heated building to house all equipment. Costs are based on vendor quotes, recent quotes for similar equipment, and allowance based on best professional judgment.
- Installation of building, process equipment, electrical, mechanical, controls, system commissioning and operator training. Costs are based on best professional judgment and assumed a cost of 125 percent of the sum of engineering and equipment costs.
- Contingency of 10 percent of the sum of engineering, equipment, building and installation costs.

Estimated CapEx for the four alternatives at two flow rates are shown in Table 4-2.

TABLE 4-2. CAPITAL COST ESTIMATE

Item	Alternative 1 (Iron-Alum-IX)		Alternative 2 (Peroxide-Alum-IX)		Alternative 4 (Iron-Alum)		Alternative 5 (Peroxide-Alum)	
	50 gpm	**200 gpm**	**50 gpm**	**200 gpm**	**50 gpm**	**200 gpm**	**50 gpm**	**200 gpm**
Engineering	$71,288	$134,904	$57,064	$111,048	$57,848	$99,624	$43,624	$75,768
Process Equipment	$891,100	$1,686,300	$713,300	$1,388,100	$723,100	$1,245,300	$545,300	$947,100
Heated Pre-Fabricated Steel Building	$200,000	$250,000	$180,000	$225,000	$150,000	$180,000	$150,000	$180,000
Subtotal	**$1,162,388**	**$2,071,204**	**$950,364**	**$1,724,148**	**$930,948**	**$1,524,924**	**$738,924**	**$1,202,868**
Install of concrete slab, mechanical, electrical, process equipment	$1,452,985	$2,589,005	$1,187,955	$2,155,185	$1,163,685	$1,906,155	$923,655	$1,503,585
Subtotal	**$2,615,373**	**$4,660,209**	**$2,138,319**	**$3,879,333**	**$2,094,633**	**$3,431,079**	**$1,662,579**	**$2,706,453**
Contingency @ 10%	$261,537	$466,021	$213,832	$387,933	$209,463	$343,108	$166,258	$270,645
Total Estimated CapEx	**$2,876,910**	**$5,126,230**	**$2,352,151**	**$4,267,266**	**$2,304,096**	**$3,774,187**	**$1,828,837**	**$2,977,098**

4.3.2 Capital Cost Discussion

Some notable distinctions can be made between the four alternatives:

- The CapEx associated with Alternative 1 (Iron-Alum-IX) is the highest due to this alternative requiring the most process equipment of all alternatives.
- Alternative 2 (Peroxide-Alum-IX) requires only one clarifier and associated equipment and materials as compared to two clarifiers in Alternative 1, therefore, all components for the CapEx are less than Alternative 1.
- Neither Alternative 4 (Iron-Alum) or Alternative 5 (Peroxide-Alum) require IX, so all components of CapEx are less for these alternatives, with Alternative 5 being less than Alternative 4 due to the need for only one clarifier and associated equipment and materials.
- In a general comparison of CapEx between Alternatives 1 and 2, and Alternatives 4 and 5, it should be noted that the differences in costs are within the margin of error. That is to say the CapEx of Alternative 1 and 2 are not significantly different from each other given the assumptions used as a basis of costs. The same can be said about the difference in CapEx between Alternatives 4 and 5.

4.3.3 Operating and Maintenance Costs

OpEx are estimated for the four treatment alternatives at operational flow rates of 50 gallons per minute (gpm) and 200 gpm.

The OpEx components and the cost basis for each component are:

- Chemicals. Costs are based on types and quantities associated with the individual alternative process, and either commodity or vendor pricing (if proprietary chemical). Chemical costs for IX regeneration assumed a 50 percent side-stream flow through the IX system.
- Electricity. Costs are based on installed horsepower estimates for each alternative, and a power supply cost of $0.06 per kilowatt hour.
- Maintenance. Cost based on best professional judgment of 3 percent of equipment costs.

- Operating Labor. Cost based on 1.5 full-time equivalent (FTE) labor, 365 days per year at an annual salary of $80,000 per FTE.
- Waste Residual Disposal. Costs for removal and disposal of de-watered sludge and ion exchange regenerate based on vendor quotes of $30 per ton for sludge and $67 per ton for regenerate. IX regenerate waste disposal assumes a 50 percent side-stream flow through the IX system.
- Contingency of 10 percent of the sum of chemicals, electricity, maintenance, labor and waste residual disposal.

Estimated OpEx for the four alternatives are shown in Table 4-3.

4.3.4 Operating and Maintenance Cost Discussion

Notable distinctions can be made for the OpEx between the four alternatives:

- OpEx for Alternative 1 is the highest due to it having the highest chemical demand, the highest power requirement, the highest maintenance requirement, and highest waste residual disposal requirement.
- OpEx for Alternatives 4 and 5 are lower than Alternatives 1 and 2 due to the absence of the IX system and associated power, maintenance, and waste residual disposal requirement.
- Given that the OpEx components are based on un-optimized treatment processes, the resulting OpEx costs are not optimized. This is noted in regards to two specific points:

    - As previously discussed it is expected that the regeneration costs and regenerant produced from Alternative 2 will be higher than Alternative 1. This difference is not reflected in the OpEx cost tables due to the lack of sufficient information obtained during the course of this study.
    - The difference in OpEx between Alternatives 4 and 5 for the same flow rates are viewed as negligible.

TABLE 4-3. ANNUAL OPERATION COST ESTIMATE

Item	**Alternative 1 (Iron-Alum-IX)**		**Alternative 2 (Peroxide-Alum-IX)**		**Alternative 4 (Iron-Alum)**		**Alternative 5 (Peroxide-Alum)**	
	50 gpm	**200 gpm**	**50 gpm**	**200 gpm**	**50 gpm**	**200 gpm**	**50 gpm**	**200 gpm**
Chemicals	$862,866	$3,451,465	$767,254	$3,042,732	$760,561	$3,042,246	$664,949	$2,633,514
Electricity @ $0.06 per kWh	$44,676	$74,372	$34,690	$56,502	$43,625	$73,321	$33,638	$55,451
Equipment Maintenance	$34,872	$62,136	$28,511	$51,724	$27,928	$45,748	$22,168	$36,086
Operating labor, @ $80,000 per FTE	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000	$120,000
Waste residual disposal	$126,892	$507,567	$123,513	$507,567	$37,900	$151,598	$34,521	$151,598
Subtotal	**$1,062,414**	**$3,707,973**	**$950,454**	**$3,270,959**	**$952,115**	**$3,281,315**	**$840,755**	**$2,845,050**
Contingency @ 10%	$106,241	$370,797	$95,045	$327,096	$95,211	$328,131	$84,076	$284,505
Total Estimated Annual OpEx	**$1,168,655**	**$4,078,770**	**$1,045,500**	**$3,598,055**	**$1,047,326**	**$3,609,446**	**$924,831**	**$3,129,555**

5.0 EFFECTS OF RE-INJECTION OF TREATED WATER TO GROUNDWATER

This Treatability Study included simulation of re-injection of treated water to the groundwater system through a series of batch mixing tests with treated water, groundwater and sediment from the Site. The purpose of this testing was to evaluate:

1. The potential for injected waters to mix and react with groundwater to form insoluble precipitates (either common minerals or contaminant-bearing minerals) or to leach contaminants from sediments; and
2. The potential for injected water to mix and react with groundwater causing degradation or formation of different cyanide species.

5.1 POTENTIAL FOR MINERAL PRECIPITATION

Under the conditions of the tests, there was no observed evidence of mineral precipitation caused by mixing of treated water and groundwater. However, it should be noted that Test 18 water had a very low pH (3.2) that is not likely representative of full scale operating conditions.

5.2 POTENTIAL FOR CONTAMINANT LEACHING

Under the conditions of the tests, there was no evidence of cyanide or fluoride leaching from sediments. However, it should be noted that the sediments from test well TW-1A used in the tests had low cyanide and fluoride content relative to sediment in the vicinity of the SPL pile. Test results may not be representative of conditions in areas with high sediment contaminant content.

5.3 DEGRADATION OR CONVERSION OF CYANIDE SPECIES

Both total and WAD cyanide concentrations generally declined over the course of the test period for most test conditions (water/sediment mixtures). However, with two exceptions the changes in cyanide concentrations were within the variation of the control sample and thus are not considered to be significant. Both treated water types (Test 18 representing iron-alum/XSORBX100 –IX and Test 15 representing peroxide) when mixed with groundwater and sediment exhibited a significant decrease in total cyanide, suggesting that treated water may react with groundwater in the presence of sediment to remove additional total cyanide from groundwater. The fate of the total cyanide lost from the treated water/groundwater/sediment mixture is not known with certainty as there were no significant changes in other chemical constituents that coincide with the loss of total cyanide, as would be expected if cyanide mineral precipitates were forming (e.g., pH, Eh, dissolved iron remained nearly stable, or shifted to conditions (higher pH and Eh) favoring dissolution of iron cyanide minerals). Based solely on the lack of evidence of cyanide mineral precipitation, it is speculated that cyanide may have been removed by adsorption to the sediment.

6.0 RECOMMENDATIONS

The testing was intended to indicate whether or not a treatment process is suitable to achieve the desired results, e.g., meet a target effluent limit, or reduce the mass of a target constituent. This information was achieved by trying various process types, a range of reagent dosages based on previous experience and literature reports, and typical reaction times. The tests were not designed to optimize a treatment process by testing and selecting exact chemical dosages and reaction times that give optimal treatment effectiveness. Further evaluation of these optimization criteria is recommended for select processes at the next stage of process design if ex-situ treatment is selected as a component of the selected remedy.

7.0 REFERENCES

Ghosh, RS, DA Dzombak, RG Luthy and DV Nakles, 1999. Subsurface Fate and Transport of Cyanide Species at a Manufactured-Gas Plant Site. Water Environment Research; Sep/Oct 1999; 71,6.

Hydrometrics, Inc., 2013. Draft Work Plan for Ex Situ Water Treatability Study for Cleanup Actions at the Kaiser Mead NPL Site. Prepared for Mead Custodial Trust. January 2013.

Meeussen, JL, MG Keizer, and FAM de Haan, 1992. Chemical Stability and Decomposition Rate of Iron Cyanide Complexes in Soil Solutions. Environmental Science and Technology, 26, 511.

APPENDIX A

WATER TREATMENT ANALYTICAL REPORTS

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / Phase I
Work Order: **W3E0430**
Reported: 21-May-13 13:20

ANALYTICAL REPORT FOR SAMPLES

Sample ID	Laboratory ID	Matrix	Date Sampled	Sampled By	Date Received
KM-2 BULK WATER	W3E0430-01	Water	17-May-13 00:00	TU	17-May-2013

Solid samples are analyzed on an as-received, wet-weight basis, unless otherwise requested.
Sample preparation is defined by the client as per their Data Quality Objectives.
This report supercedes any previous reports for this Work Order. The complete report includes pages for each sample, a full QC report, and a notes section.
The results presented in this report relate only to the samples, and meet all requirements of the NELAC Standards unless otherwise noted.

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / Phase I
Work Order: **W3E0430**
Reported: 21-May-13 13:20

Client Sample ID: **KM-2 BULK WATER**
SVL Sample ID: **W3E0430-01 (Water)**

Sample Report Page 1 of 1

Sampled: 17-May-13 00:00
Received: 17-May-13
Sampled By: TU

Metals (Dissolved)

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 200.7	**Calcium**	0.529	mg/L	0.040	0.015		W321001	AS	05/19/13 11:57	
EPA 200.7	**Iron**	24.8	mg/L	0.060	0.019		W321001	AS	05/19/13 11:57	
EPA 200.7	**Magnesium**	1.75	mg/L	0.060	0.019		W321001	AS	05/19/13 11:57	
EPA 200.7	**Silica (SiO2)**	11.9	mg/L	0.17	0.05		W321001	AS	05/19/13 11:57	
EPA 200.7	**Sodium**	1440	mg/L	10.0	2.20	20	W321001	TJK	05/20/13 12:40	D2
SM 2340B	**Hardness (as CaCO3)**	8.55	mg/L	0.347	0.116		N/A		05/19/13 11:57	

Classical Chemistry Parameters

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 335.4	**Cyanide (total)**	66.9	mg/L	2.00	0.400	200	W321040	IIT	05/20/13 13:47	D2,Q5
EPA 351.2	**TKN**	47.7	mg/L	2.00	0.37	4	W321028	NCS	05/20/13 11:58	D2,Q5
EPA 353.2	**Nitrate/Nitrite as N**	74.7	mg/L	1.00	0.380	20	W321039	RHW	05/20/13 11:57	D2,M3,Q5
EPA 410.4	**Chemical Oxygen Demand**	63.4	mg/L	5.0	2.5		W321065	SM	05/21/13 08:59	
SM 2320B/2310B	**Bicarbonate**	964	mg/L as CaCO3	1.0			W321024	AGF	05/20/13 08:54	
SM 2320B/2310B	**Carbonate**	1510	mg/L as CaCO3	1.0			W321024	AGF	05/20/13 08:54	
SM 2320B/2310B	Hydroxide	< 1.0	mg/L as CaCO3	1.0			W321024	AGF	05/20/13 08:54	
SM 2320B/2310B	**Total Alkalinity**	2470	mg/L as CaCO3	1.0			W321024	AGF	05/20/13 08:54	
SM 2540 C	**Total Diss. Solids**	3650	mg/L	40			W320427	JMS	05/17/13 16:41	
SM 2580B	**Eh**	202	mV	2.50			W321025	DKS	05/20/13 08:59	
SM 4500 H B	**pH @19.0°C**	9.96	pH Units				W321024	AGF	05/20/13 08:54	H5
SM 4500-CN-I	**Cyanide (WAD)**	0.532	mg/L	0.0500	0.0085	5	W321042	IIT	05/20/13 14:49	D2,Q5
SM 5310B	**Total Organic Carbon**	36.7	mg/L	1.00	0.20		W321063	SM	05/20/13 15:55	Q5

Anions by Ion Chromatography

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 300.0	**Chloride**	34.3	mg/L	5.00	1.52	25	W321051	AEW	05/20/13 12:49	D2
EPA 300.0	**Fluoride**	56.1	mg/L	2.50	0.42	25	W321051	AEW	05/20/13 12:49	D2
EPA 300.0	**Sulfate as SO4**	323	mg/L	7.50	1.65	25	W321051	AEW	05/20/13 12:49	D2

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

John Kern

John Kern
Laboratory Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / Phase I
Work Order: **W3E0430**
Reported: 21-May-13 13:20

Quality Control - BLANK Data

Metals (Dissolved)

Method	Analyte	Units	Result	MDL	MRL	Batch ID	Analyzed	Notes
EPA 200.7	Calcium	mg/L	<0.040	0.015	0.040	W321001	19-May-13	
EPA 200.7	Iron	mg/L	<0.060	0.019	0.060	W321001	19-May-13	
EPA 200.7	Magnesium	mg/L	<0.060	0.019	0.060	W321001	19-May-13	
EPA 200.7	Silica (SiO2)	mg/L	<0.17	0.05	0.17	W321001	19-May-13	
EPA 200.7	Sodium	mg/L	<0.50	0.11	0.50	W321001	19-May-13	

Classical Chemistry Parameters

Method	Analyte	Units	Result	MDL	MRL	Batch ID	Analyzed	Notes
EPA 335.4	Cyanide (total)	mg/L	<0.0100	0.0020	0.0100	W321040	20-May-13	
EPA 351.2	TKN	mg/L	<0.50	0.09	0.50	W321028	20-May-13	
EPA 353.2	Nitrate/Nitrite as N	mg/L	<0.050	0.019	0.050	W321039	20-May-13	
EPA 410.4	Chemical Oxygen Demand	mg/L	<5.0	2.5	5.0	W321065	21-May-13	
SM 2320B/2310B	Total Alkalinity	mg/L as CaCO3	<1.0		1.0	W321024	20-May-13	
SM 2320B/2310B	Bicarbonate	mg/L as CaCO3	<1.0		1.0	W321024	20-May-13	
SM 2320B/2310B	Carbonate	mg/L as CaCO3	<1.0		1.0	W321024	20-May-13	
SM 2320B/2310B	Hydroxide	mg/L as CaCO3	<1.0		1.0	W321024	20-May-13	
SM 2540 C	Total Diss. Solids	mg/L	<10		10	W320427	17-May-13	
SM 4500-CN-I	Cyanide (WAD)	mg/L	<0.0100	0.0017	0.0100	W321042	20-May-13	
SM 5310B	Total Organic Carbon	mg/L	<1.00	0.20	1.00	W321063	20-May-13	

Anions by Ion Chromatography

Method	Analyte	Units	Result	MDL	MRL	Batch ID	Analyzed	Notes
EPA 300.0	Fluoride	mg/L	<0.10	0.02	0.10	W321051	20-May-13	
EPA 300.0	Chloride	mg/L	<0.20	0.06	0.20	W321051	20-May-13	
EPA 300.0	Sulfate as SO4	mg/L	<0.30	0.07	0.30	W321051	20-May-13	

Quality Control - LABORATORY CONTROL SAMPLE Data

Metals (Dissolved)

Method	Analyte	Units	LCS Result	LCS True	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
EPA 200.7	Calcium	mg/L	20.2	20.0	101	85 - 115	W321001	19-May-13	
EPA 200.7	Iron	mg/L	10.1	10.0	101	85 - 115	W321001	19-May-13	
EPA 200.7	Magnesium	mg/L	20.7	20.0	103	85 - 115	W321001	19-May-13	
EPA 200.7	Silica (SiO2)	mg/L	11.3	10.7	105	85 - 115	W321001	19-May-13	
EPA 200.7	Sodium	mg/L	18.5	19.0	97.2	85 - 115	W321001	19-May-13	

Classical Chemistry Parameters

Method	Analyte	Units	LCS Result	LCS True	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
EPA 335.4	Cyanide (total)	mg/L	0.159	0.150	106	90 - 110	W321040	20-May-13	
EPA 351.2	TKN	mg/L	9.38	10.0	93.8	90 - 110	W321028	20-May-13	
EPA 353.2	Nitrate/Nitrite as N	mg/L	2.01	2.00	101	90 - 110	W321039	20-May-13	
EPA 410.4	Chemical Oxygen Demand	mg/L	115	114	101	90 - 110	W321065	21-May-13	
SM 2320B/2310B	Total Alkalinity	mg/L as CaCO3	96.5	97.2	99.3	85 - 115	W321024	20-May-13	
SM 2320B/2310B	Bicarbonate	mg/L as CaCO3	96.5	97.2	99.3	85 - 115	W321024	20-May-13	
SM 2580B	Eh	mV	222	220	101	90 - 110	W321025	20-May-13	
SM 4500-CN-I	Cyanide (WAD)	mg/L	0.150	0.150	100	90 - 110	W321042	20-May-13	
SM 5310B	Total Organic Carbon	mg/L	34.7	34.3	101	80 - 120	W321063	20-May-13	

Anions by Ion Chromatography

Method	Analyte	Units	LCS Result	LCS True	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
EPA 300.0	Fluoride	mg/L	1.88	2.00	93.9	90 - 110	W321051	20-May-13	
EPA 300.0	Chloride	mg/L	2.79	3.00	93.1	90 - 110	W321051	20-May-13	
EPA 300.0	Sulfate as SO4	mg/L	9.89	10.0	98.9	90 - 110	W321051	20-May-13	

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / Phase I
Work Order: **W3E0430**
Reported: 21-May-13 13:20

Quality Control - DUPLICATE Data

Classical Chemistry Parameters

Method	Analyte	Units	Duplicate Result	Sample Result	RPD	RPD Limit	Batch ID	Analyzed	Notes
EPA 351.2	TKN	mg/L	3.22	3.42	6.1	20	W321028	20-May-13	
SM 2320B/2310B	Total Alkalinity	mg/L as CaCO3	2480	2470	0.3	20	W321024	20-May-13	
SM 2320B/2310B	Bicarbonate	mg/L as CaCO3	964	964	0.0	20	W321024	20-May-13	
SM 2320B/2310B	Carbonate	mg/L as CaCO3	1520	1510	0.4	20	W321024	20-May-13	
SM 2320B/2310B	Hydroxide	mg/L as CaCO3	<1.0	<1.0	UDL	20	W321024	20-May-13	
SM 2540 C	Total Diss. Solids	mg/L	3650	3650	0.1	10	W320427	17-May-13	
SM 2580B	Eh	mV	205	202	1.5	20	W321025	20-May-13	
SM 4500 H B	pH	pH Units	9.97	9.96	0.1	20	W321024	20-May-13	

Quality Control - MATRIX SPIKE Data

Metals (Dissolved)

Method	Analyte	Units	Spike Result	Sample Result (R)	Spike Level (S)	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
EPA 200.7	Calcium	mg/L	21.7	0.529	20.0	106	70 - 130	W321001	19-May-13	
EPA 200.7	Iron	mg/L	29.4	24.8	10.0	46.4	70 - 130	W321001	19-May-13	M2
EPA 200.7	Magnesium	mg/L	23.4	1.75	20.0	108	70 - 130	W321001	19-May-13	
EPA 200.7	Silica (SiO2)	mg/L	23.1	11.9	10.7	105	70 - 130	W321001	19-May-13	
EPA 200.7	Sodium	mg/L	1450	1440	19.0	R > 4S	70 - 130	W321001	20-May-13	D2,M3

Classical Chemistry Parameters

Method	Analyte	Units	Spike Result	Sample Result (R)	Spike Level (S)	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
EPA 335.4	Cyanide (total)	mg/L	0.108	<0.0100	0.100	108	90 - 110	W321040	20-May-13	
EPA 335.4	Cyanide (total)	mg/L	0.108	<0.0100	0.100	108	90 - 110	W321040	20-May-13	
EPA 351.2	TKN	mg/L	11.9	3.42	8.00	106	90 - 110	W321028	20-May-13	
EPA 353.2	Nitrate/Nitrite as N	mg/L	73.5	74.7	1.00	R > 4S	90 - 110	W321039	20-May-13	D2,M3
EPA 410.4	Chemical Oxygen Demand	mg/L	51.0	<5.0	50.0	102	90 - 110	W321065	21-May-13	
SM 4500-CN-I	Cyanide (WAD)	mg/L	0.0970	<0.0100	0.100	97.0	75 - 125	W321042	20-May-13	
SM 5310B	Total Organic Carbon	mg/L	51.6	1.23	50.0	101	75 - 125	W321063	20-May-13	

Anions by Ion Chromatography

Method	Analyte	Units	Spike Result	Sample Result (R)	Spike Level (S)	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
EPA 300.0	Fluoride	mg/L	1.98	<0.10	2.00	96.9	90 - 110	W321051	20-May-13	
EPA 300.0	Chloride	mg/L	3.59	0.76	3.00	94.4	90 - 110	W321051	20-May-13	
EPA 300.0	Sulfate as SO4	mg/L	23.3	12.2	10.0	111	90 - 110	W321051	20-May-13	M1

Quality Control - MATRIX SPIKE DUPLICATE Data

Metals (Dissolved)

Method	Analyte	Units	MSD Result	Spike Result	Spike Level	RPD	RPD Limit	Batch ID	Analyzed	Notes
EPA 200.7	Calcium	mg/L	21.9	21.7	20.0	1.1	20	W321001	19-May-13	
EPA 200.7	Iron	mg/L	31.2	29.4	10.0	6.0	20	W321001	19-May-13	M2
EPA 200.7	Magnesium	mg/L	23.9	23.4	20.0	2.5	20	W321001	19-May-13	
EPA 200.7	Silica (SiO2)	mg/L	23.5	23.1	10.7	1.7	20	W321001	19-May-13	
EPA 200.7	Sodium	mg/L	1420	1450	19.0	2.4	20	W321001	20-May-13	D2,M3

Classical Chemistry Parameters

Method	Analyte	Units	MSD Result	Spike Result	Spike Level	RPD	RPD Limit	Batch ID	Analyzed	Notes
EPA 335.4	Cyanide (total)	mg/L	0.107	0.108	0.100	0.9	20	W321040	20-May-13	
EPA 353.2	Nitrate/Nitrite as N	mg/L	74.0	73.5	1.00	0.7	20	W321039	20-May-13	D2,M3
EPA 410.4	Chemical Oxygen Demand	mg/L	51.0	51.0	50.0	0.1	20	W321065	21-May-13	

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / Phase I
Work Order: **W3E0430**
Reported: 21-May-13 13:20

Quality Control - MATRIX SPIKE DUPLICATE Data (Continued)

Method	Analyte	Units	MSD Result	Spike Result	Spike Level	RPD	RPD Limit	Batch ID	Analyzed	Notes
Classical Chemistry Parameters (Continued)										
SM 4500-CN-I	Cyanide (WAD)	mg/L	0.104	0.0970	0.100	7.0	20	W321042	20-May-13	
SM 5310B	Total Organic Carbon	mg/L	51.3	51.6	50.0	0.7	20	W321063	20-May-13	
Anions by Ion Chromatography										
EPA 300.0	Fluoride	mg/L	1.99	1.98	2.00	0.6	20	W321051	20-May-13	
EPA 300.0	Chloride	mg/L	3.62	3.59	3.00	1.0	20	W321051	20-May-13	
EPA 300.0	Sulfate as SO4	mg/L	22.7	23.3	10.0	2.8	20	W321051	20-May-13	

Notes and Definitions

D2	Sample required dilution due to high concentration of target analyte.
H5	This test is specified to be performed in the field within 15 minutes of sampling; sample was received and analyzed past the regulatory holding time.
M1	Matrix spike recovery was high, but the LCS recovery was acceptable.
M2	Matrix spike recovery was low, but the LCS recovery was acceptable.
M3	The spike recovery value is unusable since the analyte concentration in the sample is disproportionate to spike level. The LCS was acceptable.
Q5	Sample was received with inadequate preservation, but preserved by the laboratory.
LCS	Laboratory Control Sample (Blank Spike)
RPD	Relative Percent Difference
UDL	A result is less than the detection limit
R > 4S	% recovery not applicable, sample concentration more than four times greater than spike level
<RL	A result is less than the reporting limit
MRL	Method Reporting Limit
MDL	Method Detection Limit
N/A	Not Applicable

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / Phase I
Work Order: **W3E0461**
Reported: 22-May-13 15:44

ANALYTICAL REPORT FOR SAMPLES

Sample ID	Laboratory ID	Matrix	Date Sampled	Sampled By	Date Received
TEST #1	W3E0461-01	Ground Water	20-May-13 20:00	DC	21-May-2013
TEST #2	W3E0461-02	Ground Water	20-May-13 20:00	DC	21-May-2013
TEST #3	W3E0461-03	Ground Water	20-May-13 20:00	DC	21-May-2013
TEST #4	W3E0461-04	Ground Water	20-May-13 20:00	DC	21-May-2013
TEST #5	W3E0461-05	Ground Water	20-May-13 20:00	DC	21-May-2013
TEST #6	W3E0461-06	Ground Water	20-May-13 20:00	DC	21-May-2013
TEST #7	W3E0461-07	Ground Water	20-May-13 20:00	DC	21-May-2013
TEST #8	W3E0461-08	Ground Water	20-May-13 20:00	DC	21-May-2013
TEST #9	W3E0461-09	Ground Water	20-May-13 20:00	DC	21-May-2013
TEST #10	W3E0461-10	Ground Water	20-May-13 20:00	DC	21-May-2013
TEST #11	W3E0461-11	Ground Water	20-May-13 20:00	DC	21-May-2013
TEST #12	W3E0461-12	Ground Water	20-May-13 20:00	DC	21-May-2013
TEST A	W3E0461-13	Ground Water	20-May-13 20:00	DC	21-May-2013
TEST B	W3E0461-14	Ground Water	20-May-13 20:00	DC	21-May-2013
TEST C	W3E0461-15	Ground Water	20-May-13 20:00	DC	21-May-2013
TEST D	W3E0461-16	Ground Water	20-May-13 20:00	DC	21-May-2013
TEST E	W3E0461-17	Ground Water	21-May-13 10:30	DC	21-May-2013
TEST F	W3E0461-18	Ground Water	21-May-13 10:30	DC	21-May-2013
TEST G	W3E0461-19	Ground Water	21-May-13 10:30	DC	21-May-2013
TEST H	W3E0461-20	Ground Water	21-May-13 10:30	DC	21-May-2013

Solid samples are analyzed on an as-received, wet-weight basis, unless otherwise requested.
Sample preparation is defined by the client as per their Data Quality Objectives.
This report supercedes any previous reports for this Work Order. The complete report includes pages for each sample, a full QC report, and a notes section.
The results presented in this report relate only to the samples, and meet all requirements of the NELAC Standards unless otherwise noted.

Hydrometrics Inc. - CDA	**Project Name: Kaiser In-Lab Treatability Study 2013 / Phase I**
2736 White PIne Drive	Work Order: **W3E0461**
Coeur d Alene, ID 83815	Reported: 22-May-13 15:44

Client Sample ID: **TEST #1**
SVL Sample ID: **W3E0461-01 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 20-May-13 20:00
Received: 21-May-13
Sampled By: DC

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Classical Chemistry Parameters										
EPA 335.4	**Cyanide (total)**	71.2	mg/L	2.00	0.400	200	W321117	IIT	05/21/13 11:49	D2
SM 4500-CN-I	**Cyanide (WAD)**	0.107	mg/L	0.0100	0.0017		W321118	IIT	05/21/13 13:25	N6

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / Phase I
Work Order: **W3E0461**
Reported: 22-May-13 15:44

Client Sample ID: **TEST #2**
SVL Sample ID: **W3E0461-02 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 20-May-13 20:00
Received: 21-May-13
Sampled By: DC

Classical Chemistry Parameters

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 335.4	**Cyanide (total)**	44.5	mg/L	1.00	0.200	100	W321117	IIT	05/21/13 11:12	D2
SM 4500-CN-I	**Cyanide (WAD)**	0.169	mg/L	0.0100	0.0017		W321118	IIT	05/21/13 12:23	N6

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / Phase I
Work Order: **W3E0461**
Reported: 22-May-13 15:44

Client Sample ID: **TEST #3**
SVL Sample ID: **W3E0461-03 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 20-May-13 20:00
Received: 21-May-13
Sampled By: DC

Classical Chemistry Parameters

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 335.4	**Cyanide (total)**	59.8	mg/L	2.00	0.400	200	W321117	IIT	05/21/13 11:51	D2
SM 4500-CN-I	**Cyanide (WAD)**	0.189	mg/L	0.0100	0.0017		W321118	IIT	05/21/13 13:27	N6

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / Phase I
Work Order: **W3E0461**
Reported: 22-May-13 15:44

Client Sample ID: **TEST #4**
SVL Sample ID: **W3E0461-04 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 20-May-13 20:00
Received: 21-May-13
Sampled By: DC

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Classical Chemistry Parameters										
EPA 335.4	**Cyanide (total)**	52.4	mg/L	2.00	0.400	200	W321117	IIT	05/21/13 11:53	D2
SM 4500-CN-I	**Cyanide (WAD)**	0.208	mg/L	0.0100	0.0017		W321118	IIT	05/21/13 13:29	N6
Anions by Ion Chromatography										
EPA 300.0	**Fluoride**	44.5	mg/L	2.50	0.42	25	W321119	AEW	05/21/13 10:00	

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

Hydrometrics Inc. - CDA	**Project Name: Kaiser In-Lab Treatability Study 2013 / Phase I**
2736 White PIne Drive	Work Order: **W3E0461**
Coeur d Alene, ID 83815	Reported: 22-May-13 15:44

Client Sample ID: **TEST #5**

SVL Sample ID: **W3E0461-05 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 20-May-13 20:00
Received: 21-May-13
Sampled By: DC

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Classical Chemistry Parameters										
EPA 335.4	**Cyanide (total)**	64.8	mg/L	2.00	0.400	200	W321117	IIT	05/21/13 11:55	D2
SM 4500-CN-I	**Cyanide (WAD)**	0.128	mg/L	0.0100	0.0017		W321118	IIT	05/21/13 13:31	N6

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / Phase I
Work Order: **W3E0461**
Reported: 22-May-13 15:44

Client Sample ID: **TEST #6**
SVL Sample ID: **W3E0461-06 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 20-May-13 20:00
Received: 21-May-13
Sampled By: DC

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Classical Chemistry Parameters										
EPA 335.4	**Cyanide (total)**	63.7	mg/L	2.00	0.400	200	W321117	IIT	05/21/13 11:57	D2
SM 4500-CN-I	**Cyanide (WAD)**	0.260	mg/L	0.0100	0.0017		W321118	IIT	05/21/13 13:33	N6

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

SVL holds the following certifications:
AZ:0538, **CA**:2080, **FL**(**NELAC**):E87993, **ID**:ID00019 & ID00965 (Microbiology), **NV**:ID000192007A, **WA**:C573

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / Phase I
Work Order: **W3E0461**
Reported: 22-May-13 15:44

Client Sample ID: **TEST #7**
SVL Sample ID: **W3E0461-07 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 20-May-13 20:00
Received: 21-May-13
Sampled By: DC

Classical Chemistry Parameters

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 335.4	**Cyanide (total)**	66.4	mg/L	2.00	0.400	200	W321117	IIT	05/21/13 11:59	D2
SM 4500-CN-I	**Cyanide (WAD)**	0.171	mg/L	0.0100	0.0017		W321118	IIT	05/21/13 13:35	N6

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / Phase I
Work Order: **W3E0461**
Reported: 22-May-13 15:44

Client Sample ID: **TEST #8**
SVL Sample ID: **W3E0461-08 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 20-May-13 20:00
Received: 21-May-13
Sampled By: DC

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Classical Chemistry Parameters										
EPA 335.4	**Cyanide (total)**	66.3	mg/L	2.00	0.400	200	W321117	IIT	05/21/13 12:07	D2
SM 4500-CN-I	**Cyanide (WAD)**	0.273	mg/L	0.0100	0.0017		W321118	IIT	05/21/13 13:37	N6

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / Phase I
Work Order: **W3E0461**
Reported: 22-May-13 15:44

Client Sample ID: **TEST #9**
SVL Sample ID: **W3E0461-09 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 20-May-13 20:00
Received: 21-May-13
Sampled By: DC

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Classical Chemistry Parameters										
EPA 335.4	**Cyanide (total)**	68.2	mg/L	2.00	0.400	200	W321117	IIT	05/21/13 12:09	D2
SM 4500-CN-I	**Cyanide (WAD)**	0.119	mg/L	0.0100	0.0017		W321118	IIT	05/21/13 13:39	N6

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / Phase I
Work Order: **W3E0461**
Reported: 22-May-13 15:44

Client Sample ID: **TEST #10**
SVL Sample ID: **W3E0461-10 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 20-May-13 20:00
Received: 21-May-13
Sampled By: DC

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Classical Chemistry Parameters										
EPA 335.4	**Cyanide (total)**	63.9	mg/L	2.00	0.400	200	W321117	IIT	05/21/13 12:11	D2
SM 4500-CN-I	**Cyanide (WAD)**	0.107	mg/L	0.0100	0.0017		W321118	IIT	05/21/13 13:47	N6

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

SVL holds the following certifications:
AZ:0538, **CA**:2080, **FL**(**NELAC**):E87993, **ID**:ID00019 & ID00965 (Microbiology), **NV**:ID000192007A, **WA**:C573

Hydrometrics Inc. - CDA	**Project Name: Kaiser In-Lab Treatability Study 2013 / Phase I**
2736 White PIne Drive	Work Order: **W3E0461**
Coeur d Alene, ID 83815	Reported: 22-May-13 15:44

Client Sample ID: **TEST #11**
SVL Sample ID: **W3E0461-11 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 20-May-13 20:00
Received: 21-May-13
Sampled By: DC

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Classical Chemistry Parameters										
EPA 335.4	**Cyanide (total)**	67.0	mg/L	2.00	0.400	200	W321117	IIT	05/21/13 12:13	D2
SM 4500-CN-I	**Cyanide (WAD)**	0.113	mg/L	0.0100	0.0017		W321118	IIT	05/21/13 13:56	N6

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / Phase I
Work Order: **W3E0461**
Reported: 22-May-13 15:44

Client Sample ID: **TEST #12**
SVL Sample ID: **W3E0461-12 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 20-May-13 20:00
Received: 21-May-13
Sampled By: DC

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Classical Chemistry Parameters										
EPA 335.4	**Cyanide (total)**	83.0	mg/L	2.00	0.400	200	W321117	IIT	05/21/13 12:15	D2
SM 4500-CN-I	**Cyanide (WAD)**	0.104	mg/L	0.0100	0.0017		W321118	IIT	05/21/13 13:58	N6

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

SVL holds the following certifications:
AZ:0538, **CA**:2080, **FL**(**NELAC**):E87993, **ID**:ID00019 & ID00965 (Microbiology), **NV**:ID000192007A, **WA**:C573

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / Phase I
Work Order: **W3E0461**
Reported: 22-May-13 15:44

Client Sample ID: **TEST A**
SVL Sample ID: **W3E0461-13 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 20-May-13 20:00
Received: 21-May-13
Sampled By: DC

Anions by Ion Chromatography

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 300.0	**Fluoride**	44.3	mg/L	2.50	0.42	25	W321119	AEW	05/21/13 10:11	

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / Phase I
Work Order: **W3E0461**
Reported: 22-May-13 15:44

Client Sample ID: **TEST B**
SVL Sample ID: **W3E0461-14 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 20-May-13 20:00
Received: 21-May-13
Sampled By: DC

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Anions by Ion Chromatography										
EPA 300.0	**Fluoride**	57.6	mg/L	2.50	0.42	25	W321119	AEW	05/21/13 10:22	

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / Phase I
Work Order: **W3E0461**
Reported: 22-May-13 15:44

Client Sample ID: **TEST C**
SVL Sample ID: **W3E0461-15 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 20-May-13 20:00
Received: 21-May-13
Sampled By: DC

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Anions by Ion Chromatography										
EPA 300.0	**Fluoride**	20.1	mg/L	2.50	0.42	25	W321119	AEW	05/21/13 10:33	

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / Phase I
Work Order: **W3E0461**
Reported: 22-May-13 15:44

Client Sample ID: **TEST D**
SVL Sample ID: **W3E0461-16 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 20-May-13 20:00
Received: 21-May-13
Sampled By: DC

Anions by Ion Chromatography

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 300.0	**Fluoride**	36.7	mg/L	2.50	0.42	25	W321119	AEW	05/21/13 10:44	

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

SVL holds the following certifications:
AZ:0538, **CA**:2080, **FL**(**NELAC**):E87993, **ID**:ID00019 & ID00965 (Microbiology), **NV**:ID000192007A, **WA**:C573

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / Phase I
Work Order: **W3E0461**
Reported: 22-May-13 15:44

Client Sample ID: **TEST E**
SVL Sample ID: **W3E0461-17 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 21-May-13 10:30
Received: 21-May-13
Sampled By: DC

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Anions by Ion Chromatography										
EPA 300.0	**Fluoride**	39.6	mg/L	2.50	0.42	25	W321119	AEW	05/21/13 11:38	

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / Phase I
Work Order: **W3E0461**
Reported: 22-May-13 15:44

Client Sample ID: **TEST F**
SVL Sample ID: **W3E0461-18 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 21-May-13 10:30
Received: 21-May-13
Sampled By: DC

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Anions by Ion Chromatography										
EPA 300.0	**Fluoride**	20.2	mg/L	2.50	0.42	25	W321119	AEW	05/21/13 11:49	

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / Phase I
Work Order: **W3E0461**
Reported: 22-May-13 15:44

Client Sample ID: **TEST G**
SVL Sample ID: **W3E0461-19 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 21-May-13 10:30
Received: 21-May-13
Sampled By: DC

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Anions by Ion Chromatography										
EPA 300.0	**Fluoride**	30.2	mg/L	2.50	0.42	25	W321119	AEW	05/21/13 12:00	

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

Hydrometrics Inc. - CDA	**Project Name: Kaiser In-Lab Treatability Study 2013 / Phase I**
2736 White PIne Drive	Work Order: **W3E0461**
Coeur d Alene, ID 83815	Reported: 22-May-13 15:44

Client Sample ID: **TEST H**
SVL Sample ID: **W3E0461-20 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 21-May-13 10:30
Received: 21-May-13
Sampled By: DC

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Anions by Ion Chromatography										
EPA 300.0	**Fluoride**	41.2	mg/L	2.50	0.42	25	W321119	AEW	05/21/13 12:11	

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / Phase I
Work Order: **W3E0461**
Reported: 22-May-13 15:44

Quality Control - BLANK Data

Method	Analyte	Units	Result	MDL	MRL	Batch ID	Analyzed	Notes
Classical Chemistry Parameters								
EPA 335.4	Cyanide (total)	mg/L	<0.0100	0.0020	0.0100	W321117	21-May-13	
SM 4500-CN-I	Cyanide (WAD)	mg/L	<0.0100	0.0017	0.0100	W321118	21-May-13	
Anions by Ion Chromatography								
EPA 300.0	Fluoride	mg/L	<0.10	0.02	0.10	W321119	21-May-13	

Quality Control - LABORATORY CONTROL SAMPLE Data

Method	Analyte	Units	LCS Result	LCS True	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
Classical Chemistry Parameters									
EPA 335.4	Cyanide (total)	mg/L	0.159	0.150	106	90 - 110	W321117	21-May-13	
SM 4500-CN-I	Cyanide (WAD)	mg/L	0.144	0.150	96.0	90 - 110	W321118	21-May-13	
Anions by Ion Chromatography									
EPA 300.0	Fluoride	mg/L	1.86	2.00	93.0	90 - 110	W321119	21-May-13	

Quality Control - MATRIX SPIKE Data

Method	Analyte	Units	Spike Result	Sample Result (R)	Spike Level (S)	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
Anions by Ion Chromatography										
EPA 300.0	Fluoride	mg/L	2.08	0.17	2.00	95.6	90 - 110	W321119	21-May-13	
EPA 300.0	Fluoride	mg/L	2.11	0.23	2.00	93.8	90 - 110	W321119	21-May-13	

Quality Control - MATRIX SPIKE DUPLICATE Data

Method	Analyte	Units	MSD Result	Spike Result	Spike Level	RPD	RPD Limit	Batch ID	Analyzed	Notes
Anions by Ion Chromatography										
EPA 300.0	Fluoride	mg/L	2.09	2.08	2.00	0.6	20	W321119	21-May-13	

Notes and Definitions

D2	Sample required dilution due to high concentration of target analyte.
N6	Data suspect due to quality control failure, reported per data user's request.
LCS	Laboratory Control Sample (Blank Spike)
RPD	Relative Percent Difference
UDL	A result is less than the detection limit
R > 4S	% recovery not applicable, sample concentration more than four times greater than spike level
<RL	A result is less than the reporting limit
MRL	Method Reporting Limit
MDL	Method Detection Limit
N/A	Not Applicable

Hydrometrics Inc. - CDA	**Project Name: Kaiser In-Lab Treatability Study 2013**
2736 White PIne Drive	Work Order: **W3E0489**
Coeur d Alene, ID 83815	Reported: 22-May-13 15:45

ANALYTICAL REPORT FOR SAMPLES

Sample ID	Laboratory ID	Matrix	Date Sampled	Sampled By	Date Received
TEST I	W3E0489-01	Ground Water	21-May-13 11:40	DC	21-May-2013
TEST II	W3E0489-02	Ground Water	21-May-13 13:30	DC	21-May-2013
TEST 13	W3E0489-03	Ground Water	21-May-13 14:20	DC	21-May-2013
TEST 14	W3E0489-04	Ground Water	21-May-13 14:20	DC	21-May-2013
TEST J	W3E0489-05	Ground Water	21-May-13 14:20	DC	21-May-2013
TEST K	W3E0489-06	Ground Water	21-May-13 14:20	DC	21-May-2013
TEST 14A	W3E0489-07	Ground Water	21-May-13 14:20	DC	21-May-2013

Solid samples are analyzed on an as-received, wet-weight basis, unless otherwise requested.
Sample preparation is defined by the client as per their Data Quality Objectives.
This report supercedes any previous reports for this Work Order. The complete report includes pages for each sample, a full QC report, and a notes section.
The results presented in this report relate only to the samples, and meet all requirements of the NELAC Standards unless otherwise noted.

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3E0489**
Reported: 22-May-13 15:45

Client Sample ID: **TEST I**
SVL Sample ID: **W3E0489-01 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 21-May-13 11:40
Received: 21-May-13
Sampled By: DC

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Anions by Ion Chromatography										
EPA 300.0	**Fluoride**	15.8	mg/L	2.50	0.42	25	W321119	AEW	05/21/13 15:03	

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3E0489**
Reported: 22-May-13 15:45

Client Sample ID: **TEST II**
SVL Sample ID: **W3E0489-02 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 21-May-13 13:30
Received: 21-May-13
Sampled By: DC

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Classical Chemistry Parameters										
EPA 335.4	**Cyanide (total)**	62.4	mg/L	2.00	0.400	200	W321150	IIT	05/21/13 16:29	D2
SM 4500-CN-I	**Cyanide (WAD)**	0.287	mg/L	0.0100	0.0017		W321151	IIT	05/21/13 16:41	
Anions by Ion Chromatography										
EPA 300.0	**Fluoride**	16.8	mg/L	2.50	0.42	25	W321119	AEW	05/21/13 15:14	

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3E0489**
Reported: 22-May-13 15:45

Client Sample ID: **TEST 13**
SVL Sample ID: **W3E0489-03 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 21-May-13 14:20
Received: 21-May-13
Sampled By: DC

Classical Chemistry Parameters

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 335.4	**Cyanide (total)**	0.956	mg/L	0.0500	0.0100	5	W321150	IIT	05/21/13 16:59	D2
SM 4500-CN-I	**Cyanide (WAD)**	0.163	mg/L	0.0100	0.0017		W321151	IIT	05/21/13 16:43	

Anions by Ion Chromatography

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 300.0	**Fluoride**	36.9	mg/L	2.50	0.42	25	W321119	AEW	05/21/13 15:25	

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3E0489**
Reported: 22-May-13 15:45

Client Sample ID: **TEST 14**
SVL Sample ID: **W3E0489-04 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 21-May-13 14:20
Received: 21-May-13
Sampled By: DC

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Classical Chemistry Parameters										
EPA 335.4	**Cyanide (total)**	0.573	mg/L	0.0500	0.0100	5	W321150	IIT	05/21/13 17:01	D2
SM 4500-CN-I	**Cyanide (WAD)**	0.338	mg/L	0.0100	0.0017		W321151	IIT	05/21/13 16:51	
Anions by Ion Chromatography										
EPA 300.0	**Fluoride**	30.1	mg/L	2.50	0.42	25	W321119	AEW	05/21/13 15:36	

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3E0489**
Reported: 22-May-13 15:45

Client Sample ID: **TEST J**
SVL Sample ID: **W3E0489-05 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 21-May-13 14:20
Received: 21-May-13
Sampled By: DC

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Anions by Ion Chromatography										
EPA 300.0	**Fluoride**	9.01	mg/L	2.50	0.42	25	W321119	AEW	05/21/13 15:47	

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

Hydrometrics Inc. - CDA
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Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3E0489**
Reported: 22-May-13 15:45

Client Sample ID: **TEST K**
SVL Sample ID: **W3E0489-06 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 21-May-13 14:20
Received: 21-May-13
Sampled By: DC

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Anions by Ion Chromatography										
EPA 300.0	**Fluoride**	8.33	mg/L	2.50	0.42	25	W321119	AEW	05/21/13 15:58	

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

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Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3E0489**
Reported: 22-May-13 15:45

Client Sample ID: **TEST 14A**
SVL Sample ID: **W3E0489-07 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 21-May-13 14:20
Received: 21-May-13
Sampled By: DC

Classical Chemistry Parameters

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 335.4	**Cyanide (total)**	0.282	mg/L	0.0100	0.0020		W321150	IIT	05/21/13 17:26	
SM 4500-CN-I	**Cyanide (WAD)**	0.484	mg/L	0.0100	0.0017		W321151	IIT	05/21/13 16:53	

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

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Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3E0489**
Reported: 22-May-13 15:45

Quality Control - BLANK Data

Method	Analyte	Units	Result	MDL	MRL	Batch ID	Analyzed	Notes
Classical Chemistry Parameters								
EPA 335.4	Cyanide (total)	mg/L	<0.0100	0.0020	0.0100	W321150	21-May-13	
SM 4500-CN-I	Cyanide (WAD)	mg/L	<0.0100	0.0017	0.0100	W321151	21-May-13	
Anions by Ion Chromatography								
EPA 300.0	Fluoride	mg/L	<0.10	0.02	0.10	W321119	21-May-13	

Quality Control - LABORATORY CONTROL SAMPLE Data

Method	Analyte	Units	LCS Result	LCS True	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
Classical Chemistry Parameters									
EPA 335.4	Cyanide (total)	mg/L	0.160	0.150	107	90 - 110	W321150	21-May-13	
SM 4500-CN-I	Cyanide (WAD)	mg/L	0.154	0.150	103	90 - 110	W321151	21-May-13	
Anions by Ion Chromatography									
EPA 300.0	Fluoride	mg/L	1.86	2.00	93.0	90 - 110	W321119	21-May-13	

Quality Control - MATRIX SPIKE Data

Method	Analyte	Units	Spike Result	Sample Result (R)	Spike Level (S)	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
Anions by Ion Chromatography										
EPA 300.0	Fluoride	mg/L	2.08	0.17	2.00	95.6	90 - 110	W321119	21-May-13	
EPA 300.0	Fluoride	mg/L	2.11	0.23	2.00	93.8	90 - 110	W321119	21-May-13	

Quality Control - MATRIX SPIKE DUPLICATE Data

Method	Analyte	Units	MSD Result	Spike Result	Spike Level	RPD	RPD Limit	Batch ID	Analyzed	Notes
Anions by Ion Chromatography										
EPA 300.0	Fluoride	mg/L	2.09	2.08	2.00	0.6	20	W321119	21-May-13	

Notes and Definitions

D2	Sample required dilution due to high concentration of target analyte.
LCS	Laboratory Control Sample (Blank Spike)
RPD	Relative Percent Difference
UDL	A result is less than the detection limit
R > 4S	% recovery not applicable, sample concentration more than four times greater than spike level
<RL	A result is less than the reporting limit
MRL	Method Reporting Limit
MDL	Method Detection Limit
N/A	Not Applicable

Hydrometrics Inc. - CDA
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Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3E0497**
Reported: 22-May-13 15:47

ANALYTICAL REPORT FOR SAMPLES

Sample ID	Laboratory ID	Matrix	Date Sampled	Sampled By	Date Received
TEST III	W3E0497-01	Ground Water	21-May-13 16:00	DC	22-May-2013
TEST 18	W3E0497-02	Ground Water	21-May-13 20:00	DC	22-May-2013
IX POLISH	W3E0497-03	Ground Water	22-May-13 08:00	DC	22-May-2013
ALUMINA POLISH	W3E0497-04	Ground Water	22-May-13 09:00	DC	22-May-2013
SORBSTER F POLISH	W3E0497-05	Ground Water	22-May-13 09:30	DC	22-May-2013

Solid samples are analyzed on an as-received, wet-weight basis, unless otherwise requested.
Sample preparation is defined by the client as per their Data Quality Objectives.
This report supercedes any previous reports for this Work Order. The complete report includes pages for each sample, a full QC report, and a notes section.
The results presented in this report relate only to the samples, and meet all requirements of the NELAC Standards unless otherwise noted.

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Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3E0497**
Reported: 22-May-13 15:47

Client Sample ID: **TEST III**
SVL Sample ID: **W3E0497-01 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 21-May-13 16:00
Received: 22-May-13
Sampled By: DC

Classical Chemistry Parameters

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 335.4	**Cyanide (total)**	58.6	mg/L	2.00	0.400	200	W321222	IIT	05/22/13 12:22	D2
SM 4500-CN-I	**Cyanide (WAD)**	0.340	mg/L	0.0100	0.0017		W321223	IIT	05/22/13 11:58	

Anions by Ion Chromatography

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 300.0	**Fluoride**	16.8	mg/L	2.50	0.42	25	W321220	AEW	05/22/13 10:17	

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

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Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3E0497**
Reported: 22-May-13 15:47

Client Sample ID: **TEST 18**
SVL Sample ID: **W3E0497-02 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 21-May-13 20:00
Received: 22-May-13
Sampled By: DC

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Classical Chemistry Parameters										
EPA 335.4	**Cyanide (total)**	0.474	mg/L	0.0100	0.0020		W321222	IIT	05/22/13 12:24	
SM 4500-CN-I	**Cyanide (WAD)**	0.369	mg/L	0.0100	0.0017		W321223	IIT	05/22/13 12:06	
Anions by Ion Chromatography										
EPA 300.0	**Fluoride**	5.00	mg/L	2.50	0.42	25	W321220	AEW	05/22/13 10:27	

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

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Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3E0497**
Reported: 22-May-13 15:47

Client Sample ID: **IX POLISH**
SVL Sample ID: **W3E0497-03 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 22-May-13 08:00
Received: 22-May-13
Sampled By: DC

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Classical Chemistry Parameters										
EPA 335.4	**Cyanide (total)**	0.0830	mg/L	0.0100	0.0020		W321222	IIT	05/22/13 12:26	
SM 4500-CN-I	**Cyanide (WAD)**	0.0140	mg/L	0.0100	0.0017		W321223	IIT	05/22/13 12:08	
Anions by Ion Chromatography										
EPA 300.0	Fluoride	< 1.00	mg/L	1.00	0.17	10	W321220	AEW	05/22/13 11:11	

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

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Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3E0497**
Reported: 22-May-13 15:47

Client Sample ID: **ALUMINA POLISH**
SVL Sample ID: **W3E0497-04 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 22-May-13 09:00
Received: 22-May-13
Sampled By: DC

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Classical Chemistry Parameters										
EPA 335.4	**Cyanide (total)**	2.35	mg/L	0.100	0.0200	10	W321222	IIT	05/22/13 11:50	D2
SM 4500-CN-I	**Cyanide (WAD)**	0.319	mg/L	0.0100	0.0017		W321223	IIT	05/22/13 12:10	
Anions by Ion Chromatography										
EPA 300.0	**Fluoride**	7.07	mg/L	2.50	0.42	25	W321220	AEW	05/22/13 10:49	

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

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Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3E0497**
Reported: 22-May-13 15:47

Client Sample ID: **SORBSTER F POLISH**
SVL Sample ID: **W3E0497-05 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 22-May-13 09:30
Received: 22-May-13
Sampled By: DC

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Classical Chemistry Parameters										
EPA 335.4	**Cyanide (total)**	2.10	mg/L	0.100	0.0200	10	W321222	IIT	05/22/13 11:52	D2
SM 4500-CN-I	**Cyanide (WAD)**	0.226	mg/L	0.0100	0.0017		W321223	IIT	05/22/13 12:12	
Anions by Ion Chromatography										
EPA 300.0	**Fluoride**	4.70	mg/L	2.50	0.42	25	W321220	AEW	05/22/13 11:00	

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

Quality Control - BLANK Data

Classical Chemistry Parameters

Method	Analyte	Units	Result	MDL	MRL	Batch ID	Analyzed	Notes
EPA 335.4	Cyanide (total)	mg/L	<0.0100	0.0020	0.0100	W321222	22-May-13	
SM 4500-CN-I	Cyanide (WAD)	mg/L	<0.0100	0.0017	0.0100	W321223	22-May-13	

Quality Control - LABORATORY CONTROL SAMPLE Data

Classical Chemistry Parameters

Method	Analyte	Units	LCS Result	LCS True	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
EPA 335.4	Cyanide (total)	mg/L	0.156	0.150	104	90 - 110	W321222	22-May-13	
SM 4500-CN-I	Cyanide (WAD)	mg/L	0.146	0.150	97.3	90 - 110	W321223	22-May-13	

Notes and Definitions

D2	Sample required dilution due to high concentration of target analyte.
LCS	Laboratory Control Sample (Blank Spike)
RPD	Relative Percent Difference
UDL	A result is less than the detection limit
R > 4S	% recovery not applicable, sample concentration more than four times greater than spike level
<RL	A result is less than the reporting limit
MRL	Method Reporting Limit
MDL	Method Detection Limit
N/A	Not Applicable

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3E0608**
Reported: 11-Jun-13 08:34

ANALYTICAL REPORT FOR SAMPLES

Sample ID	Laboratory ID	Matrix	Date Sampled	Sampled By	Date Received
TEST 15	W3E0608-01	Ground Water	22-May-13 16:45	DC	23-May-2013
RO POLISH	W3E0608-02	Ground Water	22-May-13 14:30	DC	23-May-2013
FINAL PROCESS	W3E0608-03	Ground Water	22-May-13 17:00	DC	23-May-2013
2ND STEP F SLUDGE	W3E0608-04	Sludge	22-May-13 17:00	DC	23-May-2013
1ST STEP CN SLUDGE	W3E0608-05	Sludge	22-May-13 17:00	DC	23-May-2013

Solid samples are analyzed on an as-received, wet-weight basis, unless otherwise requested.
Sample preparation is defined by the client as per their Data Quality Objectives.
This report supercedes any previous reports for this Work Order. The complete report includes pages for each sample, a full QC report, and a notes section.
The results presented in this report relate only to the samples, and meet all requirements of the NELAC Standards unless otherwise noted.

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Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3E0608**
Reported: 11-Jun-13 08:34

Client Sample ID: **TEST 15**
SVL Sample ID: **W3E0608-01 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 22-May-13 16:45
Received: 23-May-13
Sampled By: DC

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Classical Chemistry Parameters										
EPA 335.4	**Cyanide (total)**	58.1	mg/L	2.00	0.400	200	W323039	IIT	06/03/13 15:05	D2
SM 4500-CN-I	**Cyanide (WAD)**	0.966	mg/L	0.0200	0.0034	2	W323095	IIT	06/04/13 15:00	D2

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Nan Wilson
Deputy Technical Director

Hydrometrics Inc. - CDA
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Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3E0608**
Reported: 11-Jun-13 08:34

Client Sample ID: **RO POLISH**
SVL Sample ID: **W3E0608-02 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 22-May-13 14:30
Received: 23-May-13
Sampled By: DC

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Classical Chemistry Parameters										
EPA 335.4	Cyanide (total)	< 0.0100	mg/L	0.0100	0.0020		W323039	IIT	06/03/13 15:07	
SM 4500-CN-I	Cyanide (WAD)	< 0.0100	mg/L	0.0100	0.0017		W323095	IIT	06/04/13 13:49	
Anions by Ion Chromatography										
EPA 300.0	**Fluoride**	0.15	mg/L	0.10	0.02		W323220	AEW	06/06/13 11:33	

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Nan Wilson
Deputy Technical Director

Hydrometrics Inc. - CDA
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Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3E0608**
Reported: 11-Jun-13 08:34

Client Sample ID: **FINAL PROCESS**
SVL Sample ID: **W3E0608-03 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 22-May-13 17:00
Received: 23-May-13
Sampled By: DC

Metals (Dissolved)

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 200.7	**Calcium**	3.12	mg/L	0.040	0.015		W322019	AS	06/04/13 16:18	
EPA 200.7	**Iron**	0.782	mg/L	0.060	0.019		W322019	AS	06/04/13 16:18	
EPA 200.7	**Magnesium**	1.97	mg/L	0.060	0.019		W322019	AS	06/04/13 16:18	
EPA 200.7	**Silica (SiO2)**	2.29	mg/L	0.17	0.05		W322019	AS	06/04/13 16:18	
EPA 200.7	**Sodium**	1700	mg/L	5.00	1.10	10	W322019	AS	06/04/13 16:54	D2
SM 2340B	**Hardness (as CaCO3)**	15.9	mg/L	0.347	0.116		N/A		06/04/13 16:18	

Classical Chemistry Parameters

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 335.4	**Cyanide (total)**	0.339	mg/L	0.0100	0.0020		W323039	IIT	06/03/13 15:09	Q5
EPA 351.2	**TKN**	16.1	mg/L	0.50	0.09		W323047	NCS	06/07/13 11:10	Q5
EPA 353.2	**Nitrate/Nitrite as N**	57.9	mg/L	10.0	3.80	200	W322189	NCS	05/30/13 18:29	D2,Q5
EPA 410.4	**Chemical Oxygen Demand**	24.8	mg/L	5.0	2.5		W322137	SM	05/30/13 11:56	Q5
SM 2320B/2310B	Bicarbonate	< 1.0	mg/L as CaCO3	1.0			W322187	DKS	05/30/13 08:36	
SM 2320B/2310B	Carbonate	< 1.0	mg/L as CaCO3	1.0			W322187	DKS	05/30/13 08:36	
SM 2320B/2310B	Hydroxide	< 1.0	mg/L as CaCO3	1.0			W322187	DKS	05/30/13 08:36	
SM 2320B/2310B	Total Alkalinity	< 1.0	mg/L as CaCO3	1.0			W322187	DKS	05/30/13 08:36	
SM 2540 C	**Total Diss. Solids**	5380	mg/L	100			W322078	KCM/R	05/29/13 10:25	
SM 2580B	**Eh**	514	mV	2.50			W322291	DKS	06/05/13 12:04	
SM 4500 H B	**pH @20.0°C**	3.28	pH Units				W322187	DKS	05/30/13 08:36	H5
SM 4500-CN-I	**Cyanide (WAD)**	0.235	mg/L	0.0100	0.0017		W323095	IIT	06/04/13 13:51	Q5
SM 5310B	**Total Organic Carbon**	7.54	mg/L	1.00	0.20		W323061	NCS	06/03/13 16:53	Q5

Anions by Ion Chromatography

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 300.0	**Chloride**	579	mg/L	20.0	6.10	100	W323220	AEW	06/06/13 11:44	D2
EPA 300.0	Fluoride	< 1.00	mg/L	1.00	0.17	10	W323220	AEW	06/05/13 19:39	D1
EPA 300.0	**Sulfate as SO4**	3180	mg/L	30.0	6.60	100	W323220	AEW	06/06/13 11:44	D2

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Nan Wilson
Deputy Technical Director

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Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3E0608**
Reported: 11-Jun-13 08:34

Client Sample ID: **2ND STEP F SLUDGE**
SVL Sample ID: **W3E0608-04 (Sludge)**

Sample Report Page 1 of 1

Sampled: 22-May-13 17:00
Received: 23-May-13
Sampled By: DC

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Classical Chemistry Parameters										
EPA 9045D	**pH @22.6°C**	6.26	pH Units				W322200	MCE	06/04/13 13:32	
SW846 9012B	**Cyanide (total)**	7.90	mg/kg	0.50	0.10		W323091	IIT	06/05/13 09:56	B7
Anions by Ion Chromatography										
EPA 300.0	**Fluoride**	13.9	mg/kg	10.0	1.6	10	W323360	AEW	06/07/13 11:56	D1
TCLP Extraction Parameters										
EPA 1311	**% Dry Solids**	14.6	%				W322073	ESB	05/31/13 11:30	
EPA 1311	**Final pH**	5.60	pH Units				W322073	ESB	05/31/13 11:30	
TCLP Leachates (Metals) Extracted: 05/30/13 13:30										
EPA 6010B	Arsenic	< 0.250	mg/L Extract	0.250	0.082	10	W323133	TJK	06/07/13 13:36	D1
EPA 6010B	Barium	< 2.00	mg/L Extract	2.00	0.0057	10	W323133	TJK	06/07/13 13:36	D1,M2
EPA 6010B	Cadmium	< 0.0200	mg/L Extract	0.0200	0.0070	10	W323133	TJK	06/07/13 13:36	D1
EPA 6010B	Chromium	< 0.0600	mg/L Extract	0.0600	0.0077	10	W323133	TJK	06/07/13 13:36	D1
EPA 6010B	**Lead**	0.239	mg/L Extract	0.0750	0.0340	10	W323133	TJK	06/07/13 13:36	D1
EPA 6010B	Selenium	< 0.400	mg/L Extract	0.400	0.089	10	W323133	TJK	06/07/13 13:36	D1,M2
EPA 6010B	**Silver**	0.150	mg/L Extract	0.0500	0.0160	10	W323133	AS	06/09/13 13:05	D1
EPA 7470A	Mercury	< 0.00020	mg/L Extract	0.00020	0.000045		W323229	STA	06/07/13 11:32	

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

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2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3E0608**
Reported: 11-Jun-13 08:34

Client Sample ID: **1ST STEP CN SLUDGE**
SVL Sample ID: **W3E0608-05 (Sludge)**

Sample Report Page 1 of 1

Sampled: 22-May-13 17:00
Received: 23-May-13
Sampled By: DC

Classical Chemistry Parameters

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 9045D	**pH @22.5°C**	6.38	pH Units				W322200	MCE	06/04/13 13:32	
SW846 9012B	**Cyanide (total)**	210	mg/kg	5.00	1.00	10	W323091	IIT	06/05/13 09:58	B7,D2

Anions by Ion Chromatography

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 300.0	**Fluoride**	35.2	mg/kg	10.0	1.6	10	W323360	AEW	06/07/13 12:08	D1

TCLP Extraction Parameters

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 1311	**% Dry Solids**	13.4	%				W322073	ESB	05/31/13 11:30	
EPA 1311	**Final pH**	5.18	pH Units				W322073	ESB	05/31/13 11:30	

TCLP Leachates (Metals) Extracted: 05/30/13 13:30

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 6010B	Arsenic	< 0.050	mg/L Extract	0.050	0.008		W323133	TJK	06/07/13 13:29	
EPA 6010B	Barium	< 1.00	mg/L Extract	1.00	0.0006		W323133	TJK	06/07/13 13:29	
EPA 6010B	Cadmium	< 0.0100	mg/L Extract	0.0100	0.0007		W323133	TJK	06/07/13 13:29	
EPA 6010B	Chromium	< 0.0500	mg/L Extract	0.0500	0.0008		W323133	TJK	06/07/13 13:29	
EPA 6010B	Lead	< 0.0500	mg/L Extract	0.0500	0.0034		W323133	TJK	06/07/13 13:29	
EPA 6010B	Selenium	< 0.050	mg/L Extract	0.050	0.009		W323133	TJK	06/07/13 13:29	
EPA 6010B	Silver	< 0.0500	mg/L Extract	0.0500	0.0016		W323133	AS	06/09/13 13:24	
EPA 7470A	Mercury	< 0.00020	mg/L Extract	0.00020	0.000045		W323229	STA	06/07/13 11:33	

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Nan Wilson
Deputy Technical Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3E0608**
Reported: 11-Jun-13 08:34

Quality Control - BLANK Data

Metals (Dissolved)

Method	Analyte	Units	Result	MDL	MRL	Batch ID	Analyzed	Notes
EPA 200.7	Calcium	mg/L	<0.040	0.015	0.040	W322019	04-Jun-13	
EPA 200.7	Iron	mg/L	<0.060	0.019	0.060	W322019	04-Jun-13	
EPA 200.7	Magnesium	mg/L	<0.060	0.019	0.060	W322019	04-Jun-13	
EPA 200.7	Silica (SiO2)	mg/L	<0.17	0.05	0.17	W322019	04-Jun-13	
EPA 200.7	Sodium	mg/L	<0.50	0.11	0.50	W322019	04-Jun-13	

Classical Chemistry Parameters

Method	Analyte	Units	Result	MDL	MRL	Batch ID	Analyzed	Notes
EPA 335.4	Cyanide (total)	mg/L	<0.0100	0.0020	0.0100	W323039	03-Jun-13	
EPA 351.2	TKN	mg/L	<0.50	0.09	0.50	W323047	07-Jun-13	
EPA 353.2	Nitrate/Nitrite as N	mg/L	<0.050	0.019	0.050	W322189	30-May-13	
EPA 410.4	Chemical Oxygen Demand	mg/L	<5.0	2.5	5.0	W322137	30-May-13	
SM 2320B/2310B	Total Alkalinity	mg/L as CaCO3	<1.0		1.0	W322187	30-May-13	
SM 2320B/2310B	Bicarbonate	mg/L as CaCO3	<1.0		1.0	W322187	30-May-13	
SM 2320B/2310B	Carbonate	mg/L as CaCO3	<1.0		1.0	W322187	30-May-13	
SM 2320B/2310B	Hydroxide	mg/L as CaCO3	<1.0		1.0	W322187	30-May-13	
SM 2540 C	Total Diss. Solids	mg/L	<10		10	W322078	29-May-13	
SM 4500-CN-I	Cyanide (WAD)	mg/L	<0.0100	0.0017	0.0100	W323095	04-Jun-13	
SM 5310B	Total Organic Carbon	mg/L	<1.00	0.20	1.00	W323061	03-Jun-13	
SW846 9012B	Cyanide (total)	mg/kg	0.70	0.10	0.50	W323091	05-Jun-13	B7

Anions by Ion Chromatography

Method	Analyte	Units	Result	MDL	MRL	Batch ID	Analyzed	Notes
EPA 300.0	Fluoride	mg/kg	<1.0	0.2	1.0	W323360	07-Jun-13	
EPA 300.0	Fluoride	mg/L	<0.10	0.02	0.10	W323220	05-Jun-13	
EPA 300.0	Chloride	mg/L	<0.20	0.06	0.20	W323220	05-Jun-13	
EPA 300.0	Sulfate as SO4	mg/L	<0.30	0.07	0.30	W323220	05-Jun-13	

Quality Control - EXTRACTION BLANK Data

TCLP Leachates (Metals) Extracted: 05/30/13 13:30

Method	Analyte	Units	Result	MDL	MRL	Batch ID	Analyzed	Notes
EPA 6010B	Arsenic	mg/L Extract	<0.050	0.008	0.050	W323133	07-Jun-13	
EPA 6010B	Barium	mg/L Extract	<1.00	0.0006	1.00	W323133	07-Jun-13	
EPA 6010B	Cadmium	mg/L Extract	<0.0100	0.0007	0.0100	W323133	07-Jun-13	
EPA 6010B	Chromium	mg/L Extract	<0.0500	0.0008	0.0500	W323133	07-Jun-13	
EPA 6010B	Lead	mg/L Extract	<0.0500	0.0034	0.0500	W323133	07-Jun-13	
EPA 6010B	Selenium	mg/L Extract	<0.050	0.009	0.050	W323133	07-Jun-13	
EPA 6010B	Silver	mg/L Extract	<0.0500	0.0016	0.0500	W323133	09-Jun-13	

Quality Control - LABORATORY CONTROL SAMPLE Data

Metals (Dissolved)

Method	Analyte	Units	LCS Result	LCS True	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
EPA 200.7	Calcium	mg/L	19.5	20.0	97.7	85 - 115	W322019	04-Jun-13	
EPA 200.7	Iron	mg/L	10.0	10.0	100	85 - 115	W322019	04-Jun-13	
EPA 200.7	Magnesium	mg/L	20.4	20.0	102	85 - 115	W322019	04-Jun-13	
EPA 200.7	Silica (SiO2)	mg/L	10.0	10.7	93.8	85 - 115	W322019	04-Jun-13	
EPA 200.7	Sodium	mg/L	19.0	19.0	99.7	85 - 115	W322019	04-Jun-13	

Classical Chemistry Parameters

Method	Analyte	Units	LCS Result	LCS True	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
EPA 335.4	Cyanide (total)	mg/L	0.156	0.150	104	90 - 110	W323039	03-Jun-13	
EPA 351.2	TKN	mg/L	9.67	10.0	96.7	90 - 110	W323047	07-Jun-13	

Quality Control - LABORATORY CONTROL SAMPLE Data (Continued)

Classical Chemistry Parameters (Continued)

Method	Analyte	Units	LCS Result	LCS True	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
EPA 353.2	Nitrate/Nitrite as N	mg/L	1.94	2.00	97.0	90 - 110	W322189	30-May-13	
EPA 410.4	Chemical Oxygen Demand	mg/L	109	114	95.3	90 - 110	W322137	30-May-13	
EPA 9045D	pH	pH Units	7.76	8.15	95.2	94 - 106	W322200	04-Jun-13	
SM 2320B/2310B	Total Alkalinity	mg/L as CaCO3	92.4	97.2	95.1	85 - 115	W322187	30-May-13	
SM 2320B/2310B	Bicarbonate	mg/L as CaCO3	92.4	97.2	95.1	85 - 115	W322187	30-May-13	
SM 2580B	Eh	mV	222	220	101	90 - 110	W322291	05-Jun-13	
SM 4500-CN-I	Cyanide (WAD)	mg/L	0.153	0.150	102	90 - 110	W323095	04-Jun-13	
SM 5310B	Total Organic Carbon	mg/L	33.6	34.3	97.9	80 - 120	W323061	03-Jun-13	
SW846 9012B	Cyanide (total)	mg/L	0.28	0.248	114	80 - 120	W323091	05-Jun-13	

Anions by Ion Chromatography

Method	Analyte	Units	LCS Result	LCS True	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
EPA 300.0	Fluoride	mg/kg	151	119	127	50 - 150	W323360	07-Jun-13	
EPA 300.0	Fluoride	mg/L	1.90	2.00	95.0	90 - 110	W323220	05-Jun-13	
EPA 300.0	Chloride	mg/L	2.82	3.00	93.8	90 - 110	W323220	05-Jun-13	
EPA 300.0	Sulfate as SO4	mg/L	9.84	10.0	98.4	90 - 110	W323220	05-Jun-13	

TCLP Leachates (Metals)

Method	Analyte	Units	LCS Result	LCS True	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
EPA 6010B	Arsenic	mg/L Extract	0.987	1.00	98.7	80 - 120	W323133	07-Jun-13	
EPA 6010B	Barium	mg/L Extract	18.2	20.0	90.8	80 - 120	W323133	07-Jun-13	
EPA 6010B	Cadmium	mg/L Extract	0.192	0.200	96.1	80 - 120	W323133	07-Jun-13	
EPA 6010B	Chromium	mg/L Extract	0.923	1.00	92.3	80 - 120	W323133	07-Jun-13	
EPA 6010B	Lead	mg/L Extract	0.903	1.00	90.3	80 - 120	W323133	07-Jun-13	
EPA 6010B	Selenium	mg/L Extract	0.193	0.200	96.4	80 - 120	W323133	07-Jun-13	
EPA 6010B	Silver	mg/L Extract	0.964	1.00	96.4	80 - 120	W323133	09-Jun-13	
EPA 7470A	Mercury	mg/L Extract	0.00502	0.00500	100	80 - 120	W323229	07-Jun-13	

Quality Control - DUPLICATE Data

Classical Chemistry Parameters

Method	Analyte	Units	Duplicate Result	Sample Result	RPD	RPD Limit	Batch ID	Analyzed	Notes
EPA 351.2	TKN	mg/L	4.21	4.36	3.5	20	W323047	07-Jun-13	
EPA 9045D	pH	pH Units	6.24	6.38	2.2	20	W322200	04-Jun-13	
SM 2320B/2310B	Total Alkalinity	mg/L as CaCO3	<1.0	<1.0	UDL	20	W322187	30-May-13	
SM 2320B/2310B	Bicarbonate	mg/L as CaCO3	<1.0	<1.0	UDL	20	W322187	30-May-13	
SM 2320B/2310B	Carbonate	mg/L as CaCO3	<1.0	<1.0	UDL	20	W322187	30-May-13	
SM 2320B/2310B	Hydroxide	mg/L as CaCO3	<1.0	<1.0	UDL	20	W322187	30-May-13	
SM 2540 C	Total Diss. Solids	mg/L	1570	1550	1.1	10	W322078	29-May-13	
SM 2540 C	Total Diss. Solids	mg/L	364	360	1.1	10	W322078	29-May-13	
SM 2580B	Eh	mV	510	514	0.8	20	W322291	05-Jun-13	
SM 4500 H B	pH	pH Units	3.27	3.28	0.3	20	W322187	30-May-13	
SM 5310B	Total Organic Carbon	mg/L	1.18	1.44	20.3	20	W323061	03-Jun-13	R2B

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Quality Control - MATRIX SPIKE Data

Metals (Dissolved)

Method	Analyte	Units	Spike Result	Sample Result (R)	Spike Level (S)	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
EPA 200.7	Calcium	mg/L	24.5	5.22	20.0	96.2	70 - 130	W322019	04-Jun-13	
EPA 200.7	Iron	mg/L	9.46	<0.060	10.0	94.3	70 - 130	W322019	04-Jun-13	
EPA 200.7	Magnesium	mg/L	21.6	1.68	20.0	99.7	70 - 130	W322019	04-Jun-13	
EPA 200.7	Silica (SiO2)	mg/L	21.8	11.2	10.7	99.2	70 - 130	W322019	04-Jun-13	
EPA 200.7	Sodium	mg/L	20.3	1.86	19.0	97.3	70 - 130	W322019	04-Jun-13	

Classical Chemistry Parameters

Method	Analyte	Units	Spike Result	Sample Result (R)	Spike Level (S)	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
EPA 335.4	Cyanide (total)	mg/L	0.108	<0.0100	0.100	104	90 - 110	W323039	03-Jun-13	
EPA 351.2	TKN	mg/L	11.9	4.36	8.00	93.7	90 - 110	W323047	07-Jun-13	
EPA 351.2	TKN	mg/L	8.66	0.82	8.00	98.1	90 - 110	W323047	07-Jun-13	
EPA 353.2	Nitrate/Nitrite as N	mg/L	1.04	<0.050	1.00	101	90 - 110	W322189	30-May-13	
EPA 353.2	Nitrate/Nitrite as N	mg/L	4.14	3.17	1.00	96.7	90 - 110	W322189	30-May-13	
EPA 410.4	Chemical Oxygen Demand	mg/L	51.0	<5.0	50.0	95.5	90 - 110	W322137	30-May-13	
EPA 410.4	Chemical Oxygen Demand	mg/L	57.3	7.0	50.0	101	90 - 110	W322137	30-May-13	
SM 4500-CN-I	Cyanide (WAD)	mg/L	0.102	<0.0100	0.100	102	75 - 125	W323095	04-Jun-13	
SM 5310B	Total Organic Carbon	mg/L	48.6	1.44	50.0	94.2	75 - 125	W323061	03-Jun-13	
SW846 9012B	Cyanide (total)	mg/kg	6.45	7.90	5.00	-29.0	75 - 125	W323091	05-Jun-13	M2

Anions by Ion Chromatography

Method	Analyte	Units	Spike Result	Sample Result (R)	Spike Level (S)	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
EPA 300.0	Fluoride	mg/kg	<25.0	<25.0	20.0	17.6	75 - 125	W323360	07-Jun-13	D1,M4
EPA 300.0	Fluoride	mg/L	1.94	<0.10	2.00	94.0	90 - 110	W323220	05-Jun-13	
EPA 300.0	Fluoride	mg/L	2.45	0.39	2.00	103	90 - 110	W323220	06-Jun-13	
EPA 300.0	Chloride	mg/L	4.05	1.05	3.00	100	90 - 110	W323220	05-Jun-13	
EPA 300.0	Chloride	mg/L	5.92	2.77	3.00	105	90 - 110	W323220	06-Jun-13	
EPA 300.0	Sulfate as SO4	mg/L	29.9	19.0	10.0	109	90 - 110	W323220	05-Jun-13	
EPA 300.0	Sulfate as SO4	mg/L	20.8	8.59	10.0	122	90 - 110	W323220	06-Jun-13	M1

TCLP Leachates (Metals)

Method	Analyte	Units	Spike Result	Sample Result (R)	Spike Level (S)	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
EPA 6010B	Arsenic	mg/L Extract	0.818	<0.250	1.00	81.8	75 - 125	W323133	07-Jun-13	D1
EPA 6010B	Barium	mg/L Extract	3.73	<2.00	20.0	18.2	75 - 125	W323133	07-Jun-13	D1,M2
EPA 6010B	Cadmium	mg/L Extract	0.157	<0.0200	0.200	78.3	75 - 125	W323133	07-Jun-13	D1
EPA 6010B	Chromium	mg/L Extract	0.788	<0.0600	1.00	78.8	75 - 125	W323133	07-Jun-13	D1
EPA 6010B	Lead	mg/L Extract	1.04	0.239	1.00	80.0	75 - 125	W323133	07-Jun-13	D1
EPA 6010B	Selenium	mg/L Extract	0.513	<0.400	0.200	69.5	75 - 125	W323133	07-Jun-13	D1,M2
EPA 6010B	Silver	mg/L Extract	1.09	0.150	1.00	93.5	75 - 125	W323133	09-Jun-13	D1
EPA 7470A	Mercury	mg/L Extract	0.00104	<0.00020	0.00100	98.0	70 - 130	W323229	07-Jun-13	

Quality Control - MATRIX SPIKE DUPLICATE Data

Metals (Dissolved)

Method	Analyte	Units	MSD Result	Spike Result	Spike Level	RPD	RPD Limit	Batch ID	Analyzed	Notes
EPA 200.7	Calcium	mg/L	24.2	24.5	20.0	1.0	20	W322019	04-Jun-13	
EPA 200.7	Iron	mg/L	9.31	9.46	10.0	1.6	20	W322019	04-Jun-13	
EPA 200.7	Magnesium	mg/L	21.5	21.6	20.0	0.4	20	W322019	04-Jun-13	
EPA 200.7	Silica (SiO2)	mg/L	21.6	21.8	10.7	0.9	20	W322019	04-Jun-13	
EPA 200.7	Sodium	mg/L	20.2	20.3	19.0	0.7	20	W322019	04-Jun-13	

Classical Chemistry Parameters

Method	Analyte	Units	MSD Result	Spike Result	Spike Level	RPD	RPD Limit	Batch ID	Analyzed	Notes
EPA 335.4	Cyanide (total)	mg/L	0.104	0.108	0.100	3.8	20	W323039	03-Jun-13	
EPA 353.2	Nitrate/Nitrite as N	mg/L	1.06	1.04	1.00	1.8	20	W322189	30-May-13	

Quality Control - MATRIX SPIKE DUPLICATE Data (Continued)

Classical Chemistry Parameters (Continued)

Method	Analyte	Units	MSD Result	Spike Result	Spike Level	RPD	RPD Limit	Batch ID	Analyzed	Notes
EPA 410.4	Chemical Oxygen Demand	mg/L	52.0	51.0	50.0	1.9	20	W322137	30-May-13	
SM 4500-CN-I	Cyanide (WAD)	mg/L	0.103	0.102	0.100	1.0	20	W323095	04-Jun-13	
SM 5310B	Total Organic Carbon	mg/L	47.1	48.6	50.0	3.0	20	W323061	03-Jun-13	
SW846 9012B	Cyanide (total)	mg/kg	11.8	6.45	5.00	58.2	20	W323091	05-Jun-13	R2B

Anions by Ion Chromatography

Method	Analyte	Units	MSD Result	Spike Result	Spike Level	RPD	RPD Limit	Batch ID	Analyzed	Notes
EPA 300.0	Fluoride	mg/kg	21.7	21.9	20.0	0.6	20	W323360	07-Jun-13	D1,M4
EPA 300.0	Fluoride	mg/L	1.94	1.94	2.00	0.3	20	W323220	05-Jun-13	
EPA 300.0	Chloride	mg/L	4.05	4.05	3.00	0.2	20	W323220	05-Jun-13	
EPA 300.0	Sulfate as SO4	mg/L	29.9	29.9	10.0	0.1	20	W323220	05-Jun-13	

TCLP Leachates (Metals)

Method	Analyte	Units	MSD Result	Spike Result	Spike Level	RPD	RPD Limit	Batch ID	Analyzed	Notes
EPA 6010B	Arsenic	mg/L Extract	0.791	0.818	1.00	3.4	20	W323133	07-Jun-13	D1
EPA 6010B	Barium	mg/L Extract	5.28	3.73	20.0	34.3	20	W323133	07-Jun-13	D1,M2
EPA 6010B	Cadmium	mg/L Extract	0.156	0.157	0.200	0.2	20	W323133	07-Jun-13	D1
EPA 6010B	Chromium	mg/L Extract	0.789	0.788	1.00	0.0	20	W323133	07-Jun-13	D1
EPA 6010B	Lead	mg/L Extract	1.06	1.04	1.00	2.0	20	W323133	07-Jun-13	D1
EPA 6010B	Selenium	mg/L Extract	0.560	0.513	0.200	8.8	20	W323133	07-Jun-13	D1
EPA 6010B	Silver	mg/L Extract	1.08	1.09	1.00	0.6	20	W323133	09-Jun-13	D1
EPA 7470A	Mercury	mg/L Extract	0.00106	0.00104	0.00100	1.9	20	W323229	07-Jun-13	

Quality Control - POST DIGESTION SPIKE Data

TCLP Leachates (Metals)

Method	Analyte	Units	Spike Result	Sample Result (R)	Spike Level (S)	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
EPA 6010B	Barium	mg/L Extract	185	<2.0000	200	92.3	75 - 125	W323133	09-Jun-13	D1
EPA 6010B	Selenium	mg/L Extract	2.21	<0.400	2.00	91.8	75 - 125	W323133	09-Jun-13	D1

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Project Name: Kaiser In-Lab Treatability Study 2013
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Notes and Definitions

B7	Target analyte detected in method blank exceeded method QC limits, but concentrations in the samples are at least 10x the blank concentration.
D1	Sample required dilution due to matrix.
D2	Sample required dilution due to high concentration of target analyte.
H5	This test is specified to be performed in the field within 15 minutes of sampling; sample was received and analyzed past the regulatory holding time.
M1	Matrix spike recovery was high, but the LCS recovery was acceptable.
M2	Matrix spike recovery was low, but the LCS recovery was acceptable.
M4	The analysis of the spiked sample required a dilution such that the spike recovery calculation does not provide useful information. The LCS recovery was acceptable.
Q5	Sample was received with inadequate preservation, but preserved by the laboratory.
R2B	RPD exceeded the laboratory acceptance limit.
LCS	Laboratory Control Sample (Blank Spike)
RPD	Relative Percent Difference
UDL	A result is less than the detection limit
R > 4S	% recovery not applicable, sample concentration more than four times greater than spike level
<RL	A result is less than the reporting limit
MRL	Method Reporting Limit
MDL	Method Detection Limit
N/A	Not Applicable

APPENDIX B

TREATED WATER AND GROUNDWATER MIXING TESTS AND SEDIMENT LEACHING TEST RESULTS

Results of Treated Water:Groundwater Mixing Tests and Sediment Leaching Tests

Test Description	Sample Name	Analyte		Results				
			Units	5/17/2013	5/22/2013	6/6/2013	7/8/2013	7/29/2013
Test 18 + Sediment	#1 COMPLETE + SEDIMENT	Fluoride	mg/L		5	4.38	4.64	6.47
		Eh	mV			163	140	165
		pH	pH Units			8.81	8.87	8.87
		Cyanide (WAD)	mg/L		0.235	0.057	0.055	0.074
		Cyanide (total)	mg/L		0.339	5.14	5.52	5.38
Test 18 + Groundwater +Sediment	#2 COMPLETE + GW + SEDIMENT	Fluoride	mg/L		30.55	30.1	29.5	31.9
		Eh	mV			108	234	234
		pH	pH Units			9.63	9.68	9.7
		Cyanide (WAD)	mg/L		0.4505	0.093	0.154	0.161
		Cyanide (total)	mg/L		33.687	18.9	19.1	16.7
Test 15 + Sediment	#3 PEROXIDE + SEDIMENT	Fluoride	mg/L			59.9	57	
		Eh	mV			138	125	
		pH	pH Units			8.96	8.65	
		Cyanide (WAD)	mg/L		0.532	0.203	0.18	
		Cyanide (total)	mg/L		66.9	21.2	26.5	
Test 15 + Groundwater + Sediment	#4 PEROXIDE + GW+SEDIMENT	Fluoride	mg/L			58.6	55.9	
		Eh	mV			128	90.1	
		pH	pH Units			9.46	9.36	
		Cyanide (WAD)	mg/L		0.749	0.356	0.232	
		Cyanide (total)	mg/L		62.5	27.2	21.4	
Test 18	#5 COMPLETE	Fluoride	mg/L		5	2.5	2.5	2.5
		Eh	mV			469	504	516
		pH	pH Units			3.42	3.45	3.44
		Cyanide (WAD)	mg/L		0.235	0.281	0.279	0.326
		Cyanide (total)	mg/L		0.339	0.449	0.47	0.463
Test 15	#6 PEROXIDE	Fluoride	mg/L			60.8	57.3	
		Eh	mV			191	170	
		pH	pH Units			8.86	8.47	
		Cyanide (WAD)	mg/L		0.966	0.146	0.253	
		Cyanide (total)	mg/L		58.1	58.5	63	
Test 18 + Groundwater (1:1 ratio)	#7 1:1 COMP:GW	Fluoride	mg/L		30.55	28.6	27.7	29.6
		Eh	mV			182	256	265
		pH	pH Units			9.72	9.83	9.71
		Cyanide (WAD)	mg/L		0.3835	0.531	0.376	0.307
		Cyanide (total)	mg/L		33.6195	31	32.4	32.3
Test 15 + Groundwater (1:1 ratio)	#8 1:1 PEROXIDE:GROUNDWATER	Fluoride	mg/L			58.2	54.8	
		Eh	mV			181	177	
		pH	pH Units			9.49	9.52	
		Cyanide (WAD)	mg/L		0.749	0.204	0.262	
		Cyanide (total)	mg/L		62.5	60.6	63.3	
Raw Groundwater	#9 GROUNDWATER	Fluoride	mg/L	56.1	56.1	55.8	52.8	55.3
		Eh	mV	202		172	152	114
		pH	pH Units	9.96		9.87	9.96	9.78
		Cyanide (WAD)	mg/L	0.532	0.532	0.368	0.213	0.112
		Cyanide (total)	mg/L	66.9	66.9	59.3	63.1	59.5
Test 18 + Groundwater (1:4.63 ratio)	#10 1:4.63 COMP:GW	Fluoride	mg/L		47.02362345	45.5	43.1	46
		Eh	mV			169	167	135
		pH	pH Units			9.84	9.91	9.7
		Cyanide (WAD)	mg/L		0.479246892	0.398	0.21	0.195
		Cyanide (total)	mg/L		55.07744227	50.6	51.4	48.7
Test 18 + Groundwater (4.71:1 ratio)	#11 4.71:1 COMP:GW	Fluoride	mg/L		14.14742451	10.4	11.1	10.7
		Eh	mV			255	274	280
		pH	pH Units			9.24	9.23	8.95
		Cyanide (WAD)	mg/L		0.291092362	0.418	0.249	0.317
		Cyanide (total)	mg/L		12.16637478	10.9	11.8	11.4

Hydrometrics Inc. - CDA	**Project Name: Kaiser In-Lab Treatability Study 2013 / Phase I**
2736 White PIne Drive	Work Order: **W3E0430**
Coeur d Alene, ID 83815	Reported: 21-May-13 13:20

ANALYTICAL REPORT FOR SAMPLES

Sample ID	Laboratory ID	Matrix	Date Sampled	Sampled By	Date Received
KM-2 BULK WATER	W3E0430-01	Water	17-May-13 00:00	TU	17-May-2013

Solid samples are analyzed on an as-received, wet-weight basis, unless otherwise requested.
Sample preparation is defined by the client as per their Data Quality Objectives.
This report supercedes any previous reports for this Work Order. The complete report includes pages for each sample, a full QC report, and a notes section.
The results presented in this report relate only to the samples, and meet all requirements of the NELAC Standards unless otherwise noted.

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / Phase I
Work Order: **W3E0430**
Reported: 21-May-13 13:20

Client Sample ID: **KM-2 BULK WATER**
SVL Sample ID: **W3E0430-01 (Water)**

Sample Report Page 1 of 1

Sampled: 17-May-13 00:00
Received: 17-May-13
Sampled By: TU

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Metals (Dissolved)										
EPA 200.7	**Calcium**	0.529	mg/L	0.040	0.015		W321001	AS	05/19/13 11:57	
EPA 200.7	**Iron**	24.8	mg/L	0.060	0.019		W321001	AS	05/19/13 11:57	
EPA 200.7	**Magnesium**	1.75	mg/L	0.060	0.019		W321001	AS	05/19/13 11:57	
EPA 200.7	**Silica (SiO2)**	11.9	mg/L	0.17	0.05		W321001	AS	05/19/13 11:57	
EPA 200.7	**Sodium**	1440	mg/L	10.0	2.20	20	W321001	TJK	05/20/13 12:40	D2
SM 2340B	**Hardness (as CaCO3)**	8.55	mg/L	0.347	0.116		N/A		05/19/13 11:57	
Classical Chemistry Parameters										
EPA 335.4	**Cyanide (total)**	66.9	mg/L	2.00	0.400	200	W321040	IIT	05/20/13 13:47	D2,Q5
EPA 351.2	**TKN**	47.7	mg/L	2.00	0.37	4	W321028	NCS	05/20/13 11:58	D2,Q5
EPA 353.2	**Nitrate/Nitrite as N**	74.7	mg/L	1.00	0.380	20	W321039	RHW	05/20/13 11:57	D2,M3,Q5
EPA 410.4	**Chemical Oxygen Demand**	63.4	mg/L	5.0	2.5		W321065	SM	05/21/13 08:59	
SM 2320B/2310B	**Bicarbonate**	964	mg/L as CaCO3	1.0			W321024	AGF	05/20/13 08:54	
SM 2320B/2310B	**Carbonate**	1510	mg/L as CaCO3	1.0			W321024	AGF	05/20/13 08:54	
SM 2320B/2310B	Hydroxide	< 1.0	mg/L as CaCO3	1.0			W321024	AGF	05/20/13 08:54	
SM 2320B/2310B	**Total Alkalinity**	2470	mg/L as CaCO3	1.0			W321024	AGF	05/20/13 08:54	
SM 2540 C	**Total Diss. Solids**	3650	mg/L	40			W320427	JMS	05/17/13 16:41	
SM 2580B	**Eh**	202	mV	2.50			W321025	DKS	05/20/13 08:59	
SM 4500 H B	**pH @19.0°C**	9.96	pH Units				W321024	AGF	05/20/13 08:54	H5
SM 4500-CN-I	**Cyanide (WAD)**	0.532	mg/L	0.0500	0.0085	5	W321042	IIT	05/20/13 14:49	D2,Q5
SM 5310B	**Total Organic Carbon**	36.7	mg/L	1.00	0.20		W321063	SM	05/20/13 15:55	Q5
Anions by Ion Chromatography										
EPA 300.0	**Chloride**	34.3	mg/L	5.00	1.52	25	W321051	AEW	05/20/13 12:49	D2
EPA 300.0	**Fluoride**	56.1	mg/L	2.50	0.42	25	W321051	AEW	05/20/13 12:49	D2
EPA 300.0	**Sulfate as SO4**	323	mg/L	7.50	1.65	25	W321051	AEW	05/20/13 12:49	D2

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

John Kern

John Kern
Laboratory Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / Phase I
Work Order: **W3E0430**
Reported: 21-May-13 13:20

Quality Control - BLANK Data

Metals (Dissolved)

Method	Analyte	Units	Result	MDL	MRL	Batch ID	Analyzed	Notes
EPA 200.7	Calcium	mg/L	<0.040	0.015	0.040	W321001	19-May-13	
EPA 200.7	Iron	mg/L	<0.060	0.019	0.060	W321001	19-May-13	
EPA 200.7	Magnesium	mg/L	<0.060	0.019	0.060	W321001	19-May-13	
EPA 200.7	Silica (SiO2)	mg/L	<0.17	0.05	0.17	W321001	19-May-13	
EPA 200.7	Sodium	mg/L	<0.50	0.11	0.50	W321001	19-May-13	

Classical Chemistry Parameters

Method	Analyte	Units	Result	MDL	MRL	Batch ID	Analyzed	Notes
EPA 335.4	Cyanide (total)	mg/L	<0.0100	0.0020	0.0100	W321040	20-May-13	
EPA 351.2	TKN	mg/L	<0.50	0.09	0.50	W321028	20-May-13	
EPA 353.2	Nitrate/Nitrite as N	mg/L	<0.050	0.019	0.050	W321039	20-May-13	
EPA 410.4	Chemical Oxygen Demand	mg/L	<5.0	2.5	5.0	W321065	21-May-13	
SM 2320B/2310B	Total Alkalinity	mg/L as CaCO3	<1.0		1.0	W321024	20-May-13	
SM 2320B/2310B	Bicarbonate	mg/L as CaCO3	<1.0		1.0	W321024	20-May-13	
SM 2320B/2310B	Carbonate	mg/L as CaCO3	<1.0		1.0	W321024	20-May-13	
SM 2320B/2310B	Hydroxide	mg/L as CaCO3	<1.0		1.0	W321024	20-May-13	
SM 2540 C	Total Diss. Solids	mg/L	<10		10	W320427	17-May-13	
SM 4500-CN-I	Cyanide (WAD)	mg/L	<0.0100	0.0017	0.0100	W321042	20-May-13	
SM 5310B	Total Organic Carbon	mg/L	<1.00	0.20	1.00	W321063	20-May-13	

Anions by Ion Chromatography

Method	Analyte	Units	Result	MDL	MRL	Batch ID	Analyzed	Notes
EPA 300.0	Fluoride	mg/L	<0.10	0.02	0.10	W321051	20-May-13	
EPA 300.0	Chloride	mg/L	<0.20	0.06	0.20	W321051	20-May-13	
EPA 300.0	Sulfate as SO4	mg/L	<0.30	0.07	0.30	W321051	20-May-13	

Quality Control - LABORATORY CONTROL SAMPLE Data

Metals (Dissolved)

Method	Analyte	Units	LCS Result	LCS True	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
EPA 200.7	Calcium	mg/L	20.2	20.0	101	85 - 115	W321001	19-May-13	
EPA 200.7	Iron	mg/L	10.1	10.0	101	85 - 115	W321001	19-May-13	
EPA 200.7	Magnesium	mg/L	20.7	20.0	103	85 - 115	W321001	19-May-13	
EPA 200.7	Silica (SiO2)	mg/L	11.3	10.7	105	85 - 115	W321001	19-May-13	
EPA 200.7	Sodium	mg/L	18.5	19.0	97.2	85 - 115	W321001	19-May-13	

Classical Chemistry Parameters

Method	Analyte	Units	LCS Result	LCS True	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
EPA 335.4	Cyanide (total)	mg/L	0.159	0.150	106	90 - 110	W321040	20-May-13	
EPA 351.2	TKN	mg/L	9.38	10.0	93.8	90 - 110	W321028	20-May-13	
EPA 353.2	Nitrate/Nitrite as N	mg/L	2.01	2.00	101	90 - 110	W321039	20-May-13	
EPA 410.4	Chemical Oxygen Demand	mg/L	115	114	101	90 - 110	W321065	21-May-13	
SM 2320B/2310B	Total Alkalinity	mg/L as CaCO3	96.5	97.2	99.3	85 - 115	W321024	20-May-13	
SM 2320B/2310B	Bicarbonate	mg/L as CaCO3	96.5	97.2	99.3	85 - 115	W321024	20-May-13	
SM 2580B	Eh	mV	222	220	101	90 - 110	W321025	20-May-13	
SM 4500-CN-I	Cyanide (WAD)	mg/L	0.150	0.150	100	90 - 110	W321042	20-May-13	
SM 5310B	Total Organic Carbon	mg/L	34.7	34.3	101	80 - 120	W321063	20-May-13	

Anions by Ion Chromatography

Method	Analyte	Units	LCS Result	LCS True	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
EPA 300.0	Fluoride	mg/L	1.88	2.00	93.9	90 - 110	W321051	20-May-13	
EPA 300.0	Chloride	mg/L	2.79	3.00	93.1	90 - 110	W321051	20-May-13	
EPA 300.0	Sulfate as SO4	mg/L	9.89	10.0	98.9	90 - 110	W321051	20-May-13	

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / Phase I
Work Order: **W3E0430**
Reported: 21-May-13 13:20

Quality Control - DUPLICATE Data

Classical Chemistry Parameters

Method	Analyte	Units	Duplicate Result	Sample Result	RPD	RPD Limit	Batch ID	Analyzed	Notes
EPA 351.2	TKN	mg/L	3.22	3.42	6.1	20	W321028	20-May-13	
SM 2320B/2310B	Total Alkalinity	mg/L as CaCO3	2480	2470	0.3	20	W321024	20-May-13	
SM 2320B/2310B	Bicarbonate	mg/L as CaCO3	964	964	0.0	20	W321024	20-May-13	
SM 2320B/2310B	Carbonate	mg/L as CaCO3	1520	1510	0.4	20	W321024	20-May-13	
SM 2320B/2310B	Hydroxide	mg/L as CaCO3	<1.0	<1.0	UDL	20	W321024	20-May-13	
SM 2540 C	Total Diss. Solids	mg/L	3650	3650	0.1	10	W320427	17-May-13	
SM 2580B	Eh	mV	205	202	1.5	20	W321025	20-May-13	
SM 4500 H B	pH	pH Units	9.97	9.96	0.1	20	W321024	20-May-13	

Quality Control - MATRIX SPIKE Data

Metals (Dissolved)

Method	Analyte	Units	Spike Result	Sample Result (R)	Spike Level (S)	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
EPA 200.7	Calcium	mg/L	21.7	0.529	20.0	106	70 - 130	W321001	19-May-13	
EPA 200.7	Iron	mg/L	29.4	24.8	10.0	46.4	70 - 130	W321001	19-May-13	M2
EPA 200.7	Magnesium	mg/L	23.4	1.75	20.0	108	70 - 130	W321001	19-May-13	
EPA 200.7	Silica (SiO2)	mg/L	23.1	11.9	10.7	105	70 - 130	W321001	19-May-13	
EPA 200.7	Sodium	mg/L	1450	1440	19.0	R > 4S	70 - 130	W321001	20-May-13	D2,M3

Classical Chemistry Parameters

Method	Analyte	Units	Spike Result	Sample Result (R)	Spike Level (S)	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
EPA 335.4	Cyanide (total)	mg/L	0.108	<0.0100	0.100	108	90 - 110	W321040	20-May-13	
EPA 335.4	Cyanide (total)	mg/L	0.108	<0.0100	0.100	108	90 - 110	W321040	20-May-13	
EPA 351.2	TKN	mg/L	11.9	3.42	8.00	106	90 - 110	W321028	20-May-13	
EPA 353.2	Nitrate/Nitrite as N	mg/L	73.5	74.7	1.00	R > 4S	90 - 110	W321039	20-May-13	D2,M3
EPA 410.4	Chemical Oxygen Demand	mg/L	51.0	<5.0	50.0	102	90 - 110	W321065	21-May-13	
SM 4500-CN-I	Cyanide (WAD)	mg/L	0.0970	<0.0100	0.100	97.0	75 - 125	W321042	20-May-13	
SM 5310B	Total Organic Carbon	mg/L	51.6	1.23	50.0	101	75 - 125	W321063	20-May-13	

Anions by Ion Chromatography

Method	Analyte	Units	Spike Result	Sample Result (R)	Spike Level (S)	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
EPA 300.0	Fluoride	mg/L	1.98	<0.10	2.00	96.9	90 - 110	W321051	20-May-13	
EPA 300.0	Chloride	mg/L	3.59	0.76	3.00	94.4	90 - 110	W321051	20-May-13	
EPA 300.0	Sulfate as SO4	mg/L	23.3	12.2	10.0	111	90 - 110	W321051	20-May-13	M1

Quality Control - MATRIX SPIKE DUPLICATE Data

Metals (Dissolved)

Method	Analyte	Units	MSD Result	Spike Result	Spike Level	RPD	RPD Limit	Batch ID	Analyzed	Notes
EPA 200.7	Calcium	mg/L	21.9	21.7	20.0	1.1	20	W321001	19-May-13	
EPA 200.7	Iron	mg/L	31.2	29.4	10.0	6.0	20	W321001	19-May-13	M2
EPA 200.7	Magnesium	mg/L	23.9	23.4	20.0	2.5	20	W321001	19-May-13	
EPA 200.7	Silica (SiO2)	mg/L	23.5	23.1	10.7	1.7	20	W321001	19-May-13	
EPA 200.7	Sodium	mg/L	1420	1450	19.0	2.4	20	W321001	20-May-13	D2,M3

Classical Chemistry Parameters

Method	Analyte	Units	MSD Result	Spike Result	Spike Level	RPD	RPD Limit	Batch ID	Analyzed	Notes
EPA 335.4	Cyanide (total)	mg/L	0.107	0.108	0.100	0.9	20	W321040	20-May-13	
EPA 353.2	Nitrate/Nitrite as N	mg/L	74.0	73.5	1.00	0.7	20	W321039	20-May-13	D2,M3
EPA 410.4	Chemical Oxygen Demand	mg/L	51.0	51.0	50.0	0.1	20	W321065	21-May-13	

Quality Control - MATRIX SPIKE DUPLICATE Data (Continued)

Method	Analyte	Units	MSD Result	Spike Result	Spike Level	RPD	RPD Limit	Batch ID	Analyzed	Notes
Classical Chemistry Parameters (Continued)										
SM 4500-CN-I	Cyanide (WAD)	mg/L	0.104	0.0970	0.100	7.0	20	W321042	20-May-13	
SM 5310B	Total Organic Carbon	mg/L	51.3	51.6	50.0	0.7	20	W321063	20-May-13	
Anions by Ion Chromatography										
EPA 300.0	Fluoride	mg/L	1.99	1.98	2.00	0.6	20	W321051	20-May-13	
EPA 300.0	Chloride	mg/L	3.62	3.59	3.00	1.0	20	W321051	20-May-13	
EPA 300.0	Sulfate as SO4	mg/L	22.7	23.3	10.0	2.8	20	W321051	20-May-13	

Notes and Definitions

D2	Sample required dilution due to high concentration of target analyte.
H5	This test is specified to be performed in the field within 15 minutes of sampling; sample was received and analyzed past the regulatory holding time.
M1	Matrix spike recovery was high, but the LCS recovery was acceptable.
M2	Matrix spike recovery was low, but the LCS recovery was acceptable.
M3	The spike recovery value is unusable since the analyte concentration in the sample is disproportionate to spike level. The LCS was acceptable.
Q5	Sample was received with inadequate preservation, but preserved by the laboratory.
LCS	Laboratory Control Sample (Blank Spike)
RPD	Relative Percent Difference
UDL	A result is less than the detection limit
R > 4S	% recovery not applicable, sample concentration more than four times greater than spike level
<RL	A result is less than the reporting limit
MRL	Method Reporting Limit
MDL	Method Detection Limit
N/A	Not Applicable

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3E0562**
Reported: 13-Jun-13 08:44

ANALYTICAL REPORT FOR SAMPLES

Sample ID	Laboratory ID	Matrix	Date Sampled	Date Received
#1 COMPLETE	W3E0562-01	Ground Water	06-Jun-13 10:00	23-May-2013
#2 COMPLETE + GW	W3E0562-02	Ground Water	06-Jun-13 10:00	23-May-2013
#3 PEROXIDE	W3E0562-03	Ground Water	06-Jun-13 10:00	23-May-2013
#4 PEROXIDE + GW	W3E0562-04	Ground Water	06-Jun-13 10:00	23-May-2013
#5 COMPLETE	W3E0562-05	Ground Water	06-Jun-13 10:00	23-May-2013
#6 PEROXIDE	W3E0562-06	Ground Water	06-Jun-13 10:00	23-May-2013
#7 1:1 COMP:GW	W3E0562-07	Ground Water	06-Jun-13 10:00	23-May-2013
#8 1:1 PEROX:GW	W3E0562-08	Ground Water	06-Jun-13 10:00	23-May-2013
#9 GW	W3E0562-09	Ground Water	06-Jun-13 10:00	23-May-2013
#10 1:4.63 COMP:GW	W3E0562-10	Ground Water	06-Jun-13 10:00	23-May-2013
#11 4.71:1 COMP:GW	W3E0562-11	Ground Water	06-Jun-13 10:00	23-May-2013

Solid samples are analyzed on an as-received, wet-weight basis, unless otherwise requested.
Sample preparation is defined by the client as per their Data Quality Objectives.
This report supercedes any previous reports for this Work Order. The complete report includes pages for each sample, a full QC report, and a notes section.
The results presented in this report relate only to the samples, and meet all requirements of the NELAC Standards unless otherwise noted.

Hydrometrics Inc. - CDA	**Project Name: Kaiser In-Lab Treatability Study 2013**
2736 White PIne Drive	Work Order: **W3E0562**
Coeur d Alene, ID 83815	Reported: 13-Jun-13 08:44

Client Sample ID: **#1 COMPLETE**
SVL Sample ID: **W3E0562-01 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 06-Jun-13 10:00
Received: 23-May-13
Sampled By:

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Classical Chemistry Parameters										
EPA 335.4	**Cyanide (total)**	5.14	mg/L	0.500	0.100	50	W324061	IIT	06/11/13 11:25	D2
SM 2580B	**Eh**	163	mV	2.50			W323316	DKS	06/06/13 13:49	
SM 4500 H B	**pH @24.1°C**	8.81	pH Units				W323318	DKS	06/06/13 12:12	
SM 4500-CN-I	**Cyanide (WAD)**	0.0570	mg/L	0.0100	0.0017		W324023	IIT	06/10/13 12:42	
Anions by Ion Chromatography										
EPA 300.0	**Fluoride**	4.38	mg/L	1.00	0.17	10	W323329	AEW	06/06/13 21:02	D1

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

John Kern

John Kern
Laboratory Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3E0562**
Reported: 13-Jun-13 08:44

Client Sample ID: **#2 COMPLETE + GW**
SVL Sample ID: **W3E0562-02 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 06-Jun-13 10:00
Received: 23-May-13
Sampled By:

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Classical Chemistry Parameters										
EPA 335.4	**Cyanide (total)**	18.9	mg/L	0.500	0.100	50	W324061	IIT	06/11/13 11:27	D2
SM 2580B	**Eh**	108	mV	2.50			W323316	DKS	06/06/13 13:49	
SM 4500 H B	**pH @24.9°C**	9.63	pH Units				W323318	DKS	06/06/13 12:12	
SM 4500-CN-I	**Cyanide (WAD)**	0.0930	mg/L	0.0100	0.0017		W324023	IIT	06/10/13 12:44	
Anions by Ion Chromatography										
EPA 300.0	**Fluoride**	30.1	mg/L	1.00	0.17	10	W323329	AEW	06/06/13 21:14	D2

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

John Kern

John Kern
Laboratory Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3E0562**
Reported: 13-Jun-13 08:44

Client Sample ID: **#3 PEROXIDE**
SVL Sample ID: **W3E0562-03 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 06-Jun-13 10:00
Received: 23-May-13
Sampled By:

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Classical Chemistry Parameters										
EPA 335.4	**Cyanide (total)**	21.2	mg/L	0.500	0.100	50	W324061	IIT	06/11/13 11:29	D2
SM 2580B	**Eh**	138	mV	2.50			W323316	DKS	06/06/13 13:49	
SM 4500 H B	**pH @25.4°C**	8.96	pH Units				W323318	DKS	06/06/13 12:12	
SM 4500-CN-I	**Cyanide (WAD)**	0.203	mg/L	0.0100	0.0017		W324023	IIT	06/10/13 12:46	
Anions by Ion Chromatography										
EPA 300.0	**Fluoride**	59.9	mg/L	1.00	0.17	10	W323329	AEW	06/06/13 21:26	D2

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

John Kern

John Kern
Laboratory Director

SVL holds the following certifications:
AZ:0538, **CA**:2080, **FL**(**NELAC**):E87993, **ID**:ID00019 & ID00965 (Microbiology), **NV**:ID000192007A, **WA**:C573

Hydrometrics Inc. - CDA	**Project Name: Kaiser In-Lab Treatability Study 2013**
2736 White PIne Drive	Work Order: **W3E0562**
Coeur d Alene, ID 83815	Reported: 13-Jun-13 08:44

Client Sample ID: **#4 PEROXIDE + GW**
SVL Sample ID: **W3E0562-04 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 06-Jun-13 10:00
Received: 23-May-13
Sampled By:

Classical Chemistry Parameters

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 335.4	**Cyanide (total)**	27.2	mg/L	1.00	0.200	100	W324061	IIT	06/11/13 14:21	D2
SM 2580B	**Eh**	128	mV	2.50			W323316	DKS	06/06/13 13:49	
SM 4500 H B	**pH @25.2°C**	9.46	pH Units				W323318	DKS	06/06/13 12:12	
SM 4500-CN-I	**Cyanide (WAD)**	0.356	mg/L	0.0100	0.0017		W324023	IIT	06/10/13 12:48	

Anions by Ion Chromatography

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 300.0	**Fluoride**	58.6	mg/L	1.00	0.17	10	W323329	AEW	06/06/13 21:38	D2

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

John Kern

John Kern
Laboratory Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3E0562**
Reported: 13-Jun-13 08:44

Client Sample ID: **#5 COMPLETE**
SVL Sample ID: **W3E0562-05 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 06-Jun-13 10:00
Received: 23-May-13
Sampled By:

Classical Chemistry Parameters

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 335.4	**Cyanide (total)**	0.449	mg/L	0.0100	0.0020		W324061	IIT	06/11/13 14:23	
SM 2580B	**Eh**	469	mV	2.50			W323316	DKS	06/06/13 13:49	
SM 4500 H B	**pH @22.3°C**	3.42	pH Units				W323318	DKS	06/06/13 12:12	
SM 4500-CN-I	**Cyanide (WAD)**	0.281	mg/L	0.0100	0.0017		W324023	IIT	06/10/13 12:50	

Anions by Ion Chromatography

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 300.0	Fluoride	< 1.00	mg/L	1.00	0.17	10	W323329	AEW	06/06/13 21:50	D1

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

John Kern

John Kern
Laboratory Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3E0562**
Reported: 13-Jun-13 08:44

Client Sample ID: **#6 PEROXIDE**
SVL Sample ID: **W3E0562-06 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 06-Jun-13 10:00
Received: 23-May-13
Sampled By:

Classical Chemistry Parameters

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 335.4	**Cyanide (total)**	58.5	mg/L	2.00	0.400	200	W324061	IIT	06/11/13 14:25	D2
SM 2580B	**Eh**	191	mV	2.50			W323316	DKS	06/06/13 13:49	
SM 4500 H B	**pH @21.5°C**	8.86	pH Units				W323318	DKS	06/06/13 12:12	
SM 4500-CN-I	**Cyanide (WAD)**	0.146	mg/L	0.0100	0.0017		W324023	IIT	06/10/13 12:52	

Anions by Ion Chromatography

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 300.0	**Fluoride**	60.8	mg/L	1.00	0.17	10	W323329	AEW	06/06/13 22:02	D2

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

John Kern

John Kern
Laboratory Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3E0562**
Reported: 13-Jun-13 08:44

Client Sample ID: **#7 1:1 COMP:GW**
SVL Sample ID: **W3E0562-07 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 06-Jun-13 10:00
Received: 23-May-13
Sampled By:

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Classical Chemistry Parameters										
EPA 335.4	**Cyanide (total)**	31.0	mg/L	1.00	0.200	100	W324061	IIT	06/11/13 14:27	D2
SM 2580B	**Eh**	182	mV	2.50			W323316	DKS	06/06/13 13:49	
SM 4500 H B	**pH @21.7°C**	9.72	pH Units				W323318	DKS	06/06/13 12:12	
SM 4500-CN-I	**Cyanide (WAD)**	0.531	mg/L	0.0200	0.0034	2	W324023	IIT	06/10/13 12:54	D2
Anions by Ion Chromatography										
EPA 300.0	**Fluoride**	28.6	mg/L	1.00	0.17	10	W323329	AEW	06/06/13 22:14	D2

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

John Kern

John Kern
Laboratory Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3E0562**
Reported: 13-Jun-13 08:44

Client Sample ID: **#8 1:1 PEROX:GW**
SVL Sample ID: **W3E0562-08 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 06-Jun-13 10:00
Received: 23-May-13
Sampled By:

Classical Chemistry Parameters

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 335.4	**Cyanide (total)**	60.6	mg/L	2.00	0.400	200	W324061	IIT	06/11/13 14:29	D2
SM 2580B	**Eh**	181	mV	2.50			W323316	DKS	06/06/13 13:49	
SM 4500 H B	**pH @22.3°C**	9.49	pH Units				W323318	DKS	06/06/13 12:12	
SM 4500-CN-I	**Cyanide (WAD)**	0.204	mg/L	0.0100	0.0017		W324023	IIT	06/10/13 12:56	

Anions by Ion Chromatography

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 300.0	**Fluoride**	58.2	mg/L	1.00	0.17	10	W323329	AEW	06/06/13 22:26	D2

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

John Kern

John Kern
Laboratory Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3E0562**
Reported: 13-Jun-13 08:44

Client Sample ID: **#9 GW**
SVL Sample ID: **W3E0562-09 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 06-Jun-13 10:00
Received: 23-May-13
Sampled By:

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Classical Chemistry Parameters										
EPA 335.4	**Cyanide (total)**	59.3	mg/L	2.00	0.400	200	W324061	IIT	06/11/13 14:31	D2
SM 2580B	**Eh**	172	mV	2.50			W323316	DKS	06/06/13 13:49	
SM 4500 H B	**pH @21.9°C**	9.87	pH Units				W323318	DKS	06/06/13 12:12	
SM 4500-CN-I	**Cyanide (WAD)**	0.368	mg/L	0.0100	0.0017		W324023	IIT	06/10/13 12:58	
Anions by Ion Chromatography										
EPA 300.0	**Fluoride**	55.8	mg/L	1.00	0.17	10	W323329	AEW	06/06/13 23:02	D2

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

John Kern

John Kern
Laboratory Director

Hydrometrics Inc. - CDA	**Project Name: Kaiser In-Lab Treatability Study 2013**
2736 White PIne Drive	Work Order: **W3E0562**
Coeur d Alene, ID 83815	Reported: 13-Jun-13 08:44

Client Sample ID: **#10 1:4.63 COMP:GW**

SVL Sample ID: **W3E0562-10 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 06-Jun-13 10:00
Received: 23-May-13
Sampled By:

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Classical Chemistry Parameters										
EPA 335.4	**Cyanide (total)**	50.6	mg/L	2.00	0.400	200	W324061	IIT	06/11/13 14:33	D2
SM 2580B	**Eh**	169	mV	2.50			W323316	DKS	06/06/13 13:49	
SM 4500 H B	**pH @22.7°C**	9.84	pH Units				W323318	DKS	06/06/13 12:12	
SM 4500-CN-I	**Cyanide (WAD)**	0.398	mg/L	0.0100	0.0017		W324023	IIT	06/10/13 13:00	
Anions by Ion Chromatography										
EPA 300.0	**Fluoride**	45.5	mg/L	1.00	0.17	10	W323329	AEW	06/06/13 23:14	D2

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

John Kern

John Kern
Laboratory Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3E0562**
Reported: 13-Jun-13 08:44

Client Sample ID: **#11 4.71:1 COMP:GW**
SVL Sample ID: **W3E0562-11 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 06-Jun-13 10:00
Received: 23-May-13
Sampled By:

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Classical Chemistry Parameters										
EPA 335.4	**Cyanide (total)**	10.9	mg/L	0.500	0.100	50	W324061	IIT	06/11/13 11:51	D2
SM 2580B	**Eh**	255	mV	2.50			W323316	DKS	06/06/13 13:49	
SM 4500 H B	**pH @22.2°C**	9.24	pH Units				W323318	DKS	06/06/13 12:12	
SM 4500-CN-I	**Cyanide (WAD)**	0.418	mg/L	0.0100	0.0017		W324023	IIT	06/10/13 13:08	
Anions by Ion Chromatography										
EPA 300.0	**Fluoride**	10.4	mg/L	1.00	0.17	10	W323329	AEW	06/06/13 23:26	D2

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

John Kern

John Kern
Laboratory Director

SVL holds the following certifications:
AZ:0538, **CA**:2080, **FL**(**NELAC**):E87993, **ID**:ID00019 & ID00965 (Microbiology), **NV**:ID000192007A, **WA**:C573

Quality Control - BLANK Data

Method	Analyte	Units	Result	MDL	MRL	Batch ID	Analyzed	Notes
Classical Chemistry Parameters								
EPA 335.4	Cyanide (total)	mg/L	<0.0100	0.0020	0.0100	W324061	11-Jun-13	
SM 4500-CN-I	Cyanide (WAD)	mg/L	<0.0100	0.0017	0.0100	W324023	10-Jun-13	
Anions by Ion Chromatography								
EPA 300.0	Fluoride	mg/L	<0.10	0.02	0.10	W323329	06-Jun-13	

Quality Control - LABORATORY CONTROL SAMPLE Data

Method	Analyte	Units	LCS Result	LCS True	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
Classical Chemistry Parameters									
EPA 335.4	Cyanide (total)	mg/L	0.157	0.150	105	90 - 110	W324061	11-Jun-13	
SM 2580B	Eh	mV	217	220	98.6	98.59 - 101.4	W323316	06-Jun-13	
SM 4500 H B	pH	pH Units	8.35	8.41	99.3	85 - 115	W323318	06-Jun-13	
SM 4500-CN-I	Cyanide (WAD)	mg/L	0.154	0.150	103	90 - 110	W324023	10-Jun-13	
Anions by Ion Chromatography									
EPA 300.0	Fluoride	mg/L	1.90	2.00	95.0	90 - 110	W323329	06-Jun-13	

Quality Control - DUPLICATE Data

Method	Analyte	Units	Duplicate Result	Sample Result	RPD	RPD Limit	Batch ID	Analyzed	Notes
Classical Chemistry Parameters									
SM 2580B	Eh	mV	143	163	13.1	20	W323316	06-Jun-13	
SM 4500 H B	pH	pH Units	8.82	8.81	0.1	20	W323318	06-Jun-13	

Quality Control - MATRIX SPIKE Data

Method	Analyte	Units	Spike Result	Sample Result (R)	Spike Level (S)	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
Classical Chemistry Parameters										
EPA 335.4	Cyanide (total)	mg/L	0.101	<0.0100	0.100	101	90 - 110	W324061	11-Jun-13	
EPA 335.4	Cyanide (total)	mg/L	0.103	<0.0100	0.100	99.0	90 - 110	W324061	11-Jun-13	
SM 4500-CN-I	Cyanide (WAD)	mg/L	0.115	0.0100	0.100	105	75 - 125	W324023	10-Jun-13	
Anions by Ion Chromatography										
EPA 300.0	Fluoride	mg/L	2.36	0.32	2.00	102	90 - 110	W323329	06-Jun-13	
EPA 300.0	Fluoride	mg/L	1.93	0.17	2.00	87.9	90 - 110	W323329	07-Jun-13	M2

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3E0562**
Reported: 13-Jun-13 08:44

Quality Control - MATRIX SPIKE DUPLICATE Data

Method	Analyte	Units	MSD Result	Spike Result	Spike Level	RPD	RPD Limit	Batch ID	Analyzed	Notes
Classical Chemistry Parameters										
EPA 335.4	Cyanide (total)	mg/L	0.103	0.101	0.100	2.0	20	W324061	11-Jun-13	
SM 4500-CN-I	Cyanide (WAD)	mg/L	0.115	0.115	0.100	0.0	20	W324023	10-Jun-13	
Anions by Ion Chromatography										
EPA 300.0	Fluoride	mg/L	1.98	1.93	2.00	2.6	20	W323329	07-Jun-13	

Notes and Definitions

D1	Sample required dilution due to matrix.
D2	Sample required dilution due to high concentration of target analyte.
M2	Matrix spike recovery was low, but the LCS recovery was acceptable.
LCS	Laboratory Control Sample (Blank Spike)
RPD	Relative Percent Difference
UDL	A result is less than the detection limit
R > 4S	% recovery not applicable, sample concentration more than four times greater than spike level
<RL	A result is less than the reporting limit
MRL	Method Reporting Limit
MDL	Method Detection Limit
N/A	Not Applicable

One Government Gulch - PO Box 929 Kellogg ID 83837-0929 (208) 784-1258 Fax (208) 783-0891

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3G0128**
Reported: 23-Jul-13 14:00

ANALYTICAL REPORT FOR SAMPLES

Sample ID	Laboratory ID	Matrix	Date Sampled	Date Received
#1 COMPLETE	W3G0128-01	Ground Water	08-Jul-13 11:32	08-Jul-2013
#2 COMPLETE + GW	W3G0128-02	Ground Water	08-Jul-13 11:32	08-Jul-2013
#3 PEROXIDE	W3G0128-03	Ground Water	08-Jul-13 11:32	08-Jul-2013
#4 PEROXIDE + GW	W3G0128-04	Ground Water	08-Jul-13 11:32	08-Jul-2013
#5 COMPLETE	W3G0128-05	Ground Water	08-Jul-13 11:32	08-Jul-2013
#6 PEROXIDE	W3G0128-06	Ground Water	08-Jul-13 11:32	08-Jul-2013
#7 1:1 COMP:GW	W3G0128-07	Ground Water	08-Jul-13 11:32	08-Jul-2013
#8 1:1 PEROX:GW	W3G0128-08	Ground Water	08-Jul-13 11:32	08-Jul-2013
#9 GW	W3G0128-09	Ground Water	08-Jul-13 11:32	08-Jul-2013
#10 1:4.63 COMP:GW	W3G0128-10	Ground Water	08-Jul-13 11:32	08-Jul-2013
#11 4.71:1 COMP:GW	W3G0128-11	Ground Water	08-Jul-13 11:32	08-Jul-2013

Solid samples are analyzed on an as-received, wet-weight basis, unless otherwise requested.
Sample preparation is defined by the client as per their Data Quality Objectives.
This report supercedes any previous reports for this Work Order. The complete report includes pages for each sample, a full QC report, and a notes section.
The results presented in this report relate only to the samples, and meet all requirements of the NELAC Standards unless otherwise noted.

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3G0128**
Reported: 23-Jul-13 14:00

Client Sample ID: **#1 COMPLETE**
SVL Sample ID: **W3G0128-01 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 08-Jul-13 11:32
Received: 08-Jul-13
Sampled By:

Classical Chemistry Parameters

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 335.4	**Cyanide (total)**	5.52	mg/L	0.200	0.0400	20	W329136	IIT	07/17/13 12:21	D2
SM 2580B	**Eh**	140	mV	2.50			W328035	DKS	07/08/13 12:45	
SM 4500 H B	**pH @25.8°C**	8.87	pH Units				W328034	DKS	07/08/13 12:45	H5
SM 4500-CN-I	**Cyanide (WAD)**	0.0550	mg/L	0.0100	0.0017		W329131	IIT	07/16/13 11:44	

Anions by Ion Chromatography

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 300.0	**Fluoride**	4.64	mg/L	2.50	0.42	25	W328071	AEW	07/08/13 21:12	D1,M2

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

John Kern

John Kern
Laboratory Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3G0128**
Reported: 23-Jul-13 14:00

Client Sample ID: **#2 COMPLETE + GW**
SVL Sample ID: **W3G0128-02 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 08-Jul-13 11:32
Received: 08-Jul-13
Sampled By:

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Classical Chemistry Parameters										
EPA 335.4	**Cyanide (total)**	19.1	mg/L	0.500	0.100	50	W329136	IIT	07/17/13 12:23	D2
SM 2580B	**Eh**	234	mV	2.50			W328035	DKS	07/08/13 12:45	
SM 4500 H B	**pH @25.3°C**	9.68	pH Units				W328034	DKS	07/08/13 12:45	H5
SM 4500-CN-I	**Cyanide (WAD)**	0.154	mg/L	0.0100	0.0017		W329131	IIT	07/16/13 11:46	
Anions by Ion Chromatography										
EPA 300.0	**Fluoride**	29.5	mg/L	2.50	0.42	25	W328071	AEW	07/08/13 21:45	D2

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

John Kern

John Kern
Laboratory Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3G0128**
Reported: 23-Jul-13 14:00

Client Sample ID: **#3 PEROXIDE**
SVL Sample ID: **W3G0128-03 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 08-Jul-13 11:32
Received: 08-Jul-13
Sampled By:

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Classical Chemistry Parameters										
EPA 335.4	**Cyanide (total)**	26.5	mg/L	1.00	0.200	100	W329136	IIT	07/17/13 14:12	D2
SM 2580B	**Eh**	125	mV	2.50			W328035	DKS	07/08/13 12:45	
SM 4500 H B	**pH @25.9°C**	8.65	pH Units				W328034	DKS	07/08/13 12:45	H5
SM 4500-CN-I	**Cyanide (WAD)**	0.180	mg/L	0.0100	0.0017		W329131	IIT	07/16/13 11:48	
Anions by Ion Chromatography										
EPA 300.0	**Fluoride**	57.0	mg/L	2.50	0.42	25	W328071	AEW	07/08/13 21:56	D2

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

John Kern

John Kern
Laboratory Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3G0128**
Reported: 23-Jul-13 14:00

Client Sample ID: **#4 PEROXIDE + GW**
SVL Sample ID: **W3G0128-04 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 08-Jul-13 11:32
Received: 08-Jul-13
Sampled By:

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Classical Chemistry Parameters										
EPA 335.4	**Cyanide (total)**	21.4	mg/L	1.00	0.200	100	W329136	IIT	07/17/13 12:33	D2
SM 2580B	**Eh**	90.1	mV	2.50			W328035	DKS	07/08/13 12:45	
SM 4500 H B	**pH @25.5°C**	9.36	pH Units				W328034	DKS	07/08/13 12:45	H5
SM 4500-CN-I	**Cyanide (WAD)**	0.232	mg/L	0.0100	0.0017		W329131	IIT	07/16/13 11:50	
Anions by Ion Chromatography										
EPA 300.0	**Fluoride**	55.9	mg/L	2.50	0.42	25	W328071	AEW	07/08/13 22:07	D2

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

John Kern

John Kern
Laboratory Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3G0128**
Reported: 23-Jul-13 14:00

Client Sample ID: **#5 COMPLETE**
SVL Sample ID: **W3G0128-05 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 08-Jul-13 11:32
Received: 08-Jul-13
Sampled By:

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Classical Chemistry Parameters										
EPA 335.4	**Cyanide (total)**	0.470	mg/L	0.0200	0.0040	2	W329136	IIT	07/17/13 14:20	D2
SM 2580B	**Eh**	504	mV	2.50			W328035	DKS	07/08/13 12:45	
SM 4500 H B	**pH @22.8°C**	3.45	pH Units				W328034	DKS	07/08/13 12:45	H5
SM 4500-CN-I	**Cyanide (WAD)**	0.279	mg/L	0.0100	0.0017		W329131	IIT	07/16/13 11:52	
Anions by Ion Chromatography										
EPA 300.0	Fluoride	< 2.50	mg/L	2.50	0.42	25	W328071	AEW	07/08/13 22:18	D1

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

John Kern

John Kern
Laboratory Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3G0128**
Reported: 23-Jul-13 14:00

Client Sample ID: **#6 PEROXIDE**
SVL Sample ID: **W3G0128-06 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 08-Jul-13 11:32
Received: 08-Jul-13
Sampled By:

Classical Chemistry Parameters

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 335.4	**Cyanide (total)**	63.0	mg/L	2.00	0.400	200	W329136	IIT	07/17/13 12:37	D2
SM 2580B	**Eh**	170	mV	2.50			W328035	DKS	07/08/13 12:45	
SM 4500 H B	**pH @22.5°C**	8.47	pH Units				W328034	DKS	07/08/13 12:45	H5
SM 4500-CN-I	**Cyanide (WAD)**	0.253	mg/L	0.0100	0.0017		W329131	IIT	07/16/13 11:54	

Anions by Ion Chromatography

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 300.0	**Fluoride**	57.3	mg/L	2.50	0.42	25	W328071	AEW	07/08/13 22:28	D2

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

John Kern

John Kern
Laboratory Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3G0128**
Reported: 23-Jul-13 14:00

Client Sample ID: **#7 1:1 COMP:GW**
SVL Sample ID: **W3G0128-07 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 08-Jul-13 11:32
Received: 08-Jul-13
Sampled By:

Classical Chemistry Parameters

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 335.4	**Cyanide (total)**	32.4	mg/L	1.00	0.200	100	W329136	IIT	07/17/13 12:39	D2
SM 2580B	**Eh**	256	mV	2.50			W328035	DKS	07/08/13 12:45	
SM 4500 H B	**pH @22.3°C**	9.83	pH Units				W328034	DKS	07/08/13 12:45	H5
SM 4500-CN-I	**Cyanide (WAD)**	0.376	mg/L	0.0100	0.0017		W329131	IIT	07/16/13 11:56	

Anions by Ion Chromatography

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 300.0	**Fluoride**	27.7	mg/L	2.50	0.42	25	W328071	AEW	07/08/13 19:01	D2

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

John Kern

John Kern
Laboratory Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3G0128**
Reported: 23-Jul-13 14:00

Client Sample ID: **#8 1:1 PEROX:GW**
SVL Sample ID: **W3G0128-08 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 08-Jul-13 11:32
Received: 08-Jul-13
Sampled By:

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Classical Chemistry Parameters										
EPA 335.4	**Cyanide (total)**	63.3	mg/L	2.00	0.400	200	W329136	IIT	07/17/13 12:41	D2
SM 2580B	**Eh**	177	mV	2.50			W328035	DKS	07/08/13 12:45	
SM 4500 H B	**pH @22.4°C**	9.52	pH Units				W328034	DKS	07/08/13 12:45	H5
SM 4500-CN-I	**Cyanide (WAD)**	0.262	mg/L	0.0100	0.0017		W329131	IIT	07/16/13 11:58	
Anions by Ion Chromatography										
EPA 300.0	**Fluoride**	54.8	mg/L	2.50	0.42	25	W328071	AEW	07/08/13 19:12	D2

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

John Kern

John Kern
Laboratory Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3G0128**
Reported: 23-Jul-13 14:00

Client Sample ID: **#9 GW**
SVL Sample ID: **W3G0128-09 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 08-Jul-13 11:32
Received: 08-Jul-13
Sampled By:

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Classical Chemistry Parameters										
EPA 335.4	**Cyanide (total)**	63.1	mg/L	2.00	0.400	200	W329136	IIT	07/17/13 12:43	D2
SM 2580B	**Eh**	152	mV	2.50			W328035	DKS	07/08/13 12:45	
SM 4500 H B	**pH @22.2°C**	9.96	pH Units				W328034	DKS	07/08/13 12:45	H5
SM 4500-CN-I	**Cyanide (WAD)**	0.213	mg/L	0.0100	0.0017		W329131	IIT	07/16/13 12:06	
Anions by Ion Chromatography										
EPA 300.0	**Fluoride**	52.8	mg/L	2.50	0.42	25	W328071	AEW	07/08/13 19:23	D2

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

John Kern

John Kern
Laboratory Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3G0128**
Reported: 23-Jul-13 14:00

Client Sample ID: **#10 1:4.63 COMP:GW**
SVL Sample ID: **W3G0128-10 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 08-Jul-13 11:32
Received: 08-Jul-13
Sampled By:

Classical Chemistry Parameters

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 335.4	**Cyanide (total)**	51.4	mg/L	2.00	0.400	200	W329136	IIT	07/17/13 12:45	D2
SM 2580B	**Eh**	167	mV	2.50			W328035	DKS	07/08/13 12:45	
SM 4500 H B	**pH @22.1°C**	9.91	pH Units				W328034	DKS	07/08/13 12:45	H5
SM 4500-CN-I	**Cyanide (WAD)**	0.210	mg/L	0.0100	0.0017		W329131	IIT	07/16/13 12:08	

Anions by Ion Chromatography

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 300.0	**Fluoride**	43.1	mg/L	2.50	0.42	25	W328071	AEW	07/08/13 19:34	D2

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

John Kern

John Kern
Laboratory Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3G0128**
Reported: 23-Jul-13 14:00

Client Sample ID: **#11 4.71:1 COMP:GW**
SVL Sample ID: **W3G0128-11 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 08-Jul-13 11:32
Received: 08-Jul-13
Sampled By:

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Classical Chemistry Parameters										
EPA 335.4	**Cyanide (total)**	11.8	mg/L	0.500	0.100	50	W329136	IIT	07/17/13 12:47	D2
SM 2580B	**Eh**	274	mV	2.50			W328035	DKS	07/08/13 12:45	
SM 4500 H B	**pH @22.3°C**	9.23	pH Units				W328034	DKS	07/08/13 12:45	H5
SM 4500-CN-I	**Cyanide (WAD)**	0.249	mg/L	0.0100	0.0017		W329131	IIT	07/16/13 12:10	
Anions by Ion Chromatography										
EPA 300.0	**Fluoride**	11.1	mg/L	2.50	0.42	25	W328071	AEW	07/08/13 19:45	D2,M3

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

John Kern

John Kern
Laboratory Director

Quality Control - BLANK Data

Method	Analyte	Units	Result	MDL	MRL	Batch ID	Analyzed	Notes
Classical Chemistry Parameters								
EPA 335.4	Cyanide (total)	mg/L	<0.0100	0.0020	0.0100	W329136	17-Jul-13	
SM 4500-CN-I	Cyanide (WAD)	mg/L	<0.0100	0.0017	0.0100	W329131	16-Jul-13	
Anions by Ion Chromatography								
EPA 300.0	Fluoride	mg/L	<0.10	0.02	0.10	W328071	08-Jul-13	

Quality Control - LABORATORY CONTROL SAMPLE Data

Method	Analyte	Units	LCS Result	LCS True	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
Classical Chemistry Parameters									
EPA 335.4	Cyanide (total)	mg/L	0.147	0.150	98.0	90 - 110	W329136	17-Jul-13	
SM 2580B	Eh	mV	223	220	101	98.59 - 101.4	W328035	08-Jul-13	
SM 4500-CN-I	Cyanide (WAD)	mg/L	0.147	0.150	98.0	90 - 110	W329131	16-Jul-13	
Anions by Ion Chromatography									
EPA 300.0	Fluoride	mg/L	1.95	2.00	97.4	90 - 110	W328071	08-Jul-13	

Quality Control - DUPLICATE Data

Method	Analyte	Units	Duplicate Result	Sample Result	RPD	RPD Limit	Batch ID	Analyzed	Notes
Classical Chemistry Parameters									
SM 2580B	Eh	mV	151	140	8.0	20	W328035	08-Jul-13	
SM 4500 H B	pH	pH Units	8.85	8.87	0.2	20	W328034	08-Jul-13	

Quality Control - MATRIX SPIKE Data

Method	Analyte	Units	Spike Result	Sample Result (R)	Spike Level (S)	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
Classical Chemistry Parameters										
EPA 335.4	Cyanide (total)	mg/L	0.206	0.0770	0.100	129	90 - 110	W329136	17-Jul-13	M1
EPA 335.4	Cyanide (total)	mg/L	0.0990	<0.0100	0.100	99.0	90 - 110	W329136	17-Jul-13	
SM 4500-CN-I	Cyanide (WAD)	mg/L	0.109	<0.0100	0.100	101	75 - 125	W329131	16-Jul-13	
Anions by Ion Chromatography										
EPA 300.0	Fluoride	mg/L	13.0	11.1	2.00	94.5	90 - 110	W328071	08-Jul-13	D2,M3
EPA 300.0	Fluoride	mg/L	6.40	4.64	2.00	88.1	90 - 110	W328071	08-Jul-13	D1,M2

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3G0128**
Reported: 23-Jul-13 14:00

Quality Control - MATRIX SPIKE DUPLICATE Data

Method	Analyte	Units	MSD Result	Spike Result	Spike Level	RPD	RPD Limit	Batch ID	Analyzed	Notes
Classical Chemistry Parameters										
EPA 335.4	Cyanide (total)	mg/L	0.183	0.206	0.100	11.8	20	W329136	17-Jul-13	
SM 4500-CN-I	Cyanide (WAD)	mg/L	0.110	0.109	0.100	0.9	20	W329131	16-Jul-13	
Anions by Ion Chromatography										
EPA 300.0	Fluoride	mg/L	6.38	6.40	2.00	0.3	20	W328071	08-Jul-13	D1,M2

Notes and Definitions

D1	Sample required dilution due to matrix.
D2	Sample required dilution due to high concentration of target analyte.
H5	This test is specified to be performed in the field within 15 minutes of sampling; sample was received and analyzed past the regulatory holding time.
M1	Matrix spike recovery was high, but the LCS recovery was acceptable.
M2	Matrix spike recovery was low, but the LCS recovery was acceptable.
M3	The spike recovery value is unusable since the analyte concentration in the sample is disproportionate to spike level. The LCS was acceptable.
LCS	Laboratory Control Sample (Blank Spike)
RPD	Relative Percent Difference
UDL	A result is less than the detection limit
R > 4S	% recovery not applicable, sample concentration more than four times greater than spike level
<RL	A result is less than the reporting limit
MRL	Method Reporting Limit
MDL	Method Detection Limit
N/A	Not Applicable

Hydrometrics Inc. - CDA	**Project Name: Kaiser In-Lab Treatability Study 2013**
2736 White PIne Drive	Work Order: **W3G0698**
Coeur d Alene, ID 83815	Reported: 14-Aug-13 12:38

ANALYTICAL REPORT FOR SAMPLES

Sample ID	Laboratory ID	Matrix	Date Sampled	Date Received
#1 COMPLETE	W3G0698-01	Ground Water	29-Jul-13 11:00	23-May-2013
#2 COMPLETE + GW	W3G0698-02	Ground Water	29-Jul-13 11:00	23-May-2013
#5 COMPLETE	W3G0698-03	Ground Water	29-Jul-13 11:00	23-May-2013
#7 1:1 COMP:GW	W3G0698-04	Ground Water	29-Jul-13 11:00	23-May-2013
#9 GW	W3G0698-05	Ground Water	29-Jul-13 11:00	23-May-2013
#10 1:4.63 COMP:GW	W3G0698-06	Ground Water	29-Jul-13 11:00	23-May-2013
#11 4.71:1 COMP:GW	W3G0698-07	Ground Water	29-Jul-13 11:00	23-May-2013

Solid samples are analyzed on an as-received, wet-weight basis, unless otherwise requested.
Sample preparation is defined by the client as per their Data Quality Objectives.
This report supercedes any previous reports for this Work Order. The complete report includes pages for each sample, a full QC report, and a notes section.
The results presented in this report relate only to the samples, and meet all requirements of the NELAC Standards unless otherwise noted.

One Government Gulch - PO Box 929 Kellogg ID 83837-0929 (208) 784-1258 Fax (208) 783-0891

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3G0698**
Reported: 14-Aug-13 12:38

Client Sample ID: **#1 COMPLETE**
SVL Sample ID: **W3G0698-01 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 29-Jul-13 11:00
Received: 23-May-13
Sampled By:

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Metals (Dissolved)										
EPA 200.7	**Calcium**	22.3	mg/L	0.040	0.015		W331105	TJK	08/09/13 09:19	
EPA 200.7	**Iron**	1.95	mg/L	0.060	0.019		W331105	TJK	08/09/13 09:19	
EPA 200.7	**Magnesium**	9.81	mg/L	0.060	0.039		W331105	TJK	08/09/13 09:19	
EPA 200.7	**Silica (SiO2)**	7.76	mg/L	0.17	0.05		W331105	TJK	08/09/13 09:19	
EPA 200.7	**Sodium**	1540	mg/L	5.00	1.10	10	W331105	TJK	08/09/13 09:48	D2
SM 2340B	**Hardness (as CaCO3)**	96.0	mg/L	0.347	0.198		N/A		08/09/13 09:19	
Classical Chemistry Parameters										
EPA 335.4	**Cyanide (total)**	5.38	mg/L	0.200	0.0380	20	W332190	IIT	08/08/13 11:30	D2
EPA 351.2	**TKN**	21.6	mg/L	1.00	0.18	2	W332014	NCS	08/09/13 10:20	D2
EPA 353.2	**Nitrate/Nitrite as N**	63.7	mg/L	1.00	0.200	20	W332127	RHW	08/07/13 10:20	D2
EPA 410.4	**Chemical Oxygen Demand**	20.1	mg/L	5.0	2.5		W332276	SM	08/09/13 10:12	
SM 2320B/2310B	**Bicarbonate**	179	mg/L as CaCO3	1.0			W331126	CFP	07/30/13 12:05	
SM 2320B/2310B	**Carbonate**	43.4	mg/L as CaCO3	1.0			W331126	CFP	07/30/13 12:05	
SM 2320B/2310B	Hydroxide	< 1.0	mg/L as CaCO3	1.0			W331126	CFP	07/30/13 12:05	
SM 2320B/2310B	**Total Alkalinity**	222	mg/L as CaCO3	1.0			W331126	CFP	07/30/13 12:05	
SM 2540 C	**Total Diss. Solids**	5550	mg/L	100			W331131	JDM	07/30/13 13:30	D1
SM 2580B	**Eh**	165	mV	2.50			W331077	AGF	07/29/13 13:10	
SM 4500 H B	**pH @21.0°C**	8.87	pH Units				W331126	CFP	07/30/13 12:05	H5
SM 4500-CN-I	**Cyanide (WAD)**	0.0740	mg/L	0.0100	0.0017		W332189	IIT	08/07/13 15:22	
SM 5310B	**Total Organic Carbon**	7.57	mg/L	1.00	0.20		W332274	SM	08/08/13 12:14	
Anions by Ion Chromatography										
EPA 300.0	**Chloride**	537	mg/L	50.0	15.2	250	W332114	AEW	08/06/13 19:42	D2
EPA 300.0	**Fluoride**	6.47	mg/L	2.50	0.42	25	W332114	AEW	08/06/13 19:31	D1
EPA 300.0	**Sulfate as SO4**	3030	mg/L	75.0	16.5	250	W332114	AEW	08/06/13 19:42	D2

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

John Kern

John Kern
Laboratory Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3G0698**
Reported: 14-Aug-13 12:38

Client Sample ID: **#2 COMPLETE + GW**
SVL Sample ID: **W3G0698-02 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 29-Jul-13 11:00
Received: 23-May-13
Sampled By:

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Metals (Dissolved)										
EPA 200.7	**Calcium**	2.02	mg/L	0.040	0.015		W331105	TJK	08/09/13 09:25	
EPA 200.7	**Iron**	13.0	mg/L	0.060	0.019		W331105	TJK	08/09/13 09:25	
EPA 200.7	**Magnesium**	1.58	mg/L	0.060	0.039		W331105	TJK	08/09/13 09:25	
EPA 200.7	**Silica (SiO2)**	7.85	mg/L	0.17	0.05		W331105	TJK	08/09/13 09:25	
EPA 200.7	**Sodium**	1420	mg/L	5.00	1.10	10	W331105	TJK	08/09/13 09:55	D2
SM 2340B	**Hardness (as CaCO3)**	11.5	mg/L	0.347	0.198		N/A		08/09/13 09:25	
Classical Chemistry Parameters										
EPA 335.4	**Cyanide (total)**	16.7	mg/L	0.500	0.0950	50	W332190	IIT	08/08/13 13:40	D2
EPA 351.2	**TKN**	46.8	mg/L	2.50	0.46	5	W332014	NCS	08/09/13 09:56	D2
EPA 353.2	**Nitrate/Nitrite as N**	68.0	mg/L	1.00	0.200	20	W332127	RHW	08/07/13 10:22	D2
EPA 410.4	**Chemical Oxygen Demand**	53.9	mg/L	5.0	2.5		W332276	SM	08/09/13 10:12	
SM 2320B/2310B	**Bicarbonate**	738	mg/L as CaCO3	1.0			W331250	DKS	08/01/13 09:37	
SM 2320B/2310B	**Carbonate**	672	mg/L as CaCO3	1.0			W331250	DKS	08/01/13 09:37	
SM 2320B/2310B	Hydroxide	< 1.0	mg/L as CaCO3	1.0			W331250	DKS	08/01/13 09:37	
SM 2320B/2310B	**Total Alkalinity**	1410	mg/L as CaCO3	1.0			W331250	DKS	08/01/13 09:37	
SM 2540 C	**Total Diss. Solids**	4470	mg/L	100			W331131	JDM	07/30/13 13:30	D1
SM 2580B	**Eh**	234	mV	2.50			W331077	AGF	07/29/13 13:10	
SM 4500 H B	**pH @18.0°C**	9.70	pH Units				W331250	DKS	08/01/13 09:37	H5
SM 4500-CN-I	**Cyanide (WAD)**	0.161	mg/L	0.0100	0.0017		W332189	IIT	08/07/13 15:24	
SM 5310B	**Total Organic Carbon**	17.2	mg/L	1.00	0.20		W332274	SM	08/08/13 12:27	
Anions by Ion Chromatography										
EPA 300.0	**Chloride**	289	mg/L	50.0	15.2	250	W332114	AEW	08/06/13 20:03	D2
EPA 300.0	**Fluoride**	31.9	mg/L	2.50	0.42	25	W332114	AEW	08/06/13 19:52	D2
EPA 300.0	**Sulfate as SO4**	1700	mg/L	75.0	16.5	250	W332114	AEW	08/06/13 20:03	D2

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

John Kern

John Kern
Laboratory Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3G0698**
Reported: 14-Aug-13 12:38

Client Sample ID: **#5 COMPLETE**
SVL Sample ID: **W3G0698-03 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 29-Jul-13 11:00
Received: 23-May-13
Sampled By:

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Metals (Dissolved)										
EPA 200.7	**Calcium**	3.21	mg/L	0.040	0.015		W331105	TJK	08/09/13 09:31	
EPA 200.7	**Iron**	1.26	mg/L	0.060	0.019		W331105	TJK	08/09/13 09:31	
EPA 200.7	**Magnesium**	1.91	mg/L	0.060	0.039		W331105	TJK	08/09/13 09:31	
EPA 200.7	**Silica (SiO2)**	2.39	mg/L	0.17	0.05		W331105	TJK	08/09/13 09:31	
EPA 200.7	**Sodium**	1540	mg/L	5.00	1.10	10	W331105	TJK	08/09/13 10:56	D2
SM 2340B	**Hardness (as CaCO3)**	15.9	mg/L	0.347	0.198		N/A		08/09/13 09:31	
Classical Chemistry Parameters										
EPA 335.4	**Cyanide (total)**	0.463	mg/L	0.0100	0.0019		W332190	IIT	08/08/13 11:34	M1
EPA 351.2	**TKN**	14.9	mg/L	0.50	0.09		W332014	NCS	08/09/13 09:58	
EPA 353.2	**Nitrate/Nitrite as N**	64.3	mg/L	2.50	0.500	50	W332060	ARP	08/06/13 14:17	D2
EPA 410.4	**Chemical Oxygen Demand**	22.6	mg/L	5.0	2.5		W332276	SM	08/09/13 10:12	
SM 2320B/2310B	Bicarbonate	< 1.0	mg/L as CaCO3	1.0			W331126	CFP	07/30/13 12:36	
SM 2320B/2310B	Carbonate	< 1.0	mg/L as CaCO3	1.0			W331126	CFP	07/30/13 12:36	
SM 2320B/2310B	Hydroxide	< 1.0	mg/L as CaCO3	1.0			W331126	CFP	07/30/13 12:36	
SM 2320B/2310B	Total Alkalinity	< 1.0	mg/L as CaCO3	1.0			W331126	CFP	07/30/13 12:36	
SM 2540 C	**Total Diss. Solids**	5250	mg/L	100			W331131	JDM	07/30/13 13:30	D1
SM 2580B	**Eh**	516	mV	2.50			W331077	AGF	07/29/13 13:10	
SM 4500 H B	**pH @20.0°C**	3.44	pH Units				W331126	CFP	07/30/13 12:36	H5
SM 4500-CN-I	**Cyanide (WAD)**	0.326	mg/L	0.0100	0.0017		W332189	IIT	08/07/13 15:26	
SM 5310B	**Total Organic Carbon**	8.00	mg/L	1.00	0.20		W332274	SM	08/08/13 12:40	
Anions by Ion Chromatography										
EPA 300.0	**Chloride**	557	mg/L	50.0	15.2	250	W332114	AEW	08/06/13 20:24	D2
EPA 300.0	Fluoride	< 2.50	mg/L	2.50	0.42	25	W332114	AEW	08/06/13 20:13	D1
EPA 300.0	**Sulfate as SO4**	3100	mg/L	75.0	16.5	250	W332114	AEW	08/06/13 20:24	D2

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

John Kern

John Kern
Laboratory Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3G0698**
Reported: 14-Aug-13 12:38

Client Sample ID: **#7 1:1 COMP:GW**
SVL Sample ID: **W3G0698-04 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 29-Jul-13 11:00
Received: 23-May-13
Sampled By:

Metals (Dissolved)

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 200.7	**Calcium**	1.87	mg/L	0.040	0.015		W331105	TJK	08/09/13 09:37	
EPA 200.7	**Iron**	11.0	mg/L	0.060	0.019		W331105	TJK	08/09/13 09:37	
EPA 200.7	**Magnesium**	1.63	mg/L	0.060	0.039		W331105	TJK	08/09/13 09:37	
EPA 200.7	**Silica (SiO2)**	6.28	mg/L	0.17	0.05		W331105	TJK	08/09/13 09:37	
EPA 200.7	**Sodium**	1360	mg/L	5.00	1.10	10	W331105	TJK	08/09/13 11:02	D2
SM 2340B	**Hardness (as CaCO3)**	11.4	mg/L	0.347	0.198		N/A		08/09/13 09:37	

Classical Chemistry Parameters

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 335.4	**Cyanide (total)**	32.3	mg/L	1.00	0.190	100	W332190	IIT	08/08/13 11:36	D2
EPA 351.2	**TKN**	32.7	mg/L	2.50	0.46	5	W332014	NCS	08/09/13 10:22	D2
EPA 353.2	**Nitrate/Nitrite as N**	70.3	mg/L	2.50	0.500	50	W332060	ARP	08/06/13 14:00	D2
EPA 410.4	**Chemical Oxygen Demand**	42.0	mg/L	5.0	2.5		W332276	SM	08/09/13 10:12	
SM 2320B/2310B	**Bicarbonate**	547	mg/L as CaCO3	1.0			W331250	DKS	08/01/13 09:48	
SM 2320B/2310B	**Carbonate**	617	mg/L as CaCO3	1.0			W331250	DKS	08/01/13 09:48	
SM 2320B/2310B	Hydroxide	< 1.0	mg/L as CaCO3	1.0			W331250	DKS	08/01/13 09:48	
SM 2320B/2310B	**Total Alkalinity**	1160	mg/L as CaCO3	1.0			W331250	DKS	08/01/13 09:48	
SM 2540 C	**Total Diss. Solids**	4400	mg/L	100			W331131	JDM	07/30/13 13:30	D1
SM 2580B	**Eh**	265	mV	2.50			W331077	AGF	07/29/13 13:10	
SM 4500 H B	**pH @19.0°C**	9.71	pH Units				W331250	DKS	08/01/13 09:48	H5
SM 4500-CN-I	**Cyanide (WAD)**	0.307	mg/L	0.0100	0.0017		W332189	IIT	08/07/13 15:28	
SM 5310B	**Total Organic Carbon**	21.4	mg/L	1.00	0.20		W332274	SM	08/08/13 12:53	

Anions by Ion Chromatography

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 300.0	**Chloride**	289	mg/L	50.0	15.2	250	W332114	AEW	08/06/13 20:44	D2
EPA 300.0	**Fluoride**	29.6	mg/L	2.50	0.42	25	W332114	AEW	08/06/13 20:34	D2
EPA 300.0	**Sulfate as SO4**	1690	mg/L	75.0	16.5	250	W332114	AEW	08/06/13 20:44	D2

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

John Kern

John Kern
Laboratory Director

Hydrometrics Inc. - CDA	**Project Name: Kaiser In-Lab Treatability Study 2013**
2736 White PIne Drive	Work Order: **W3G0698**
Coeur d Alene, ID 83815	Reported: 14-Aug-13 12:38

Client Sample ID: **#9 GW**
SVL Sample ID: **W3G0698-05 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 29-Jul-13 11:00
Received: 23-May-13
Sampled By:

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Metals (Dissolved)										
EPA 200.7	**Calcium**	0.607	mg/L	0.040	0.015		W331105	TJK	08/09/13 09:43	
EPA 200.7	**Iron**	22.5	mg/L	0.060	0.019		W331105	TJK	08/09/13 09:43	
EPA 200.7	**Magnesium**	1.42	mg/L	0.060	0.039		W331105	TJK	08/09/13 09:43	
EPA 200.7	**Silica (SiO2)**	11.1	mg/L	0.17	0.05		W331105	TJK	08/09/13 09:43	
EPA 200.7	**Sodium**	1240	mg/L	5.00	1.10	10	W331105	TJK	08/09/13 11:08	D2
SM 2340B	**Hardness (as CaCO3)**	7.36	mg/L	0.347	0.198		N/A		08/09/13 09:43	
Classical Chemistry Parameters										
EPA 335.4	**Cyanide (total)**	59.5	mg/L	2.00	0.380	200	W332190	IIT	08/08/13 11:38	D2
EPA 351.2	**TKN**	27.5	mg/L	2.50	0.46	5	W332014	NCS	08/09/13 10:23	D2
EPA 353.2	**Nitrate/Nitrite as N**	91.6	mg/L	5.00	1.00	100	W332060	ARP	08/06/13 13:46	D2
EPA 410.4	**Chemical Oxygen Demand**	67.0	mg/L	5.0	2.5		W332276	SM	08/09/13 10:12	
SM 2320B/2310B	**Bicarbonate**	1060	mg/L as CaCO3	1.0			W331250	DKS	08/01/13 09:58	
SM 2320B/2310B	**Carbonate**	1150	mg/L as CaCO3	1.0			W331250	DKS	08/01/13 09:58	
SM 2320B/2310B	Hydroxide	< 1.0	mg/L as CaCO3	1.0			W331250	DKS	08/01/13 09:58	
SM 2320B/2310B	**Total Alkalinity**	2210	mg/L as CaCO3	1.0			W331250	DKS	08/01/13 09:58	
SM 2540 C	**Total Diss. Solids**	3600	mg/L	40			W331131	JDM	07/30/13 13:30	D1
SM 2580B	**Eh**	114	mV	2.50			W331077	AGF	07/29/13 13:10	
SM 4500 H B	**pH @19.0°C**	9.78	pH Units				W331250	DKS	08/01/13 09:58	H5
SM 4500-CN-I	**Cyanide (WAD)**	0.112	mg/L	0.0100	0.0017		W332189	IIT	08/07/13 15:30	
SM 5310B	**Total Organic Carbon**	37.8	mg/L	1.00	0.20		W332274	SM	08/08/13 13:06	
Anions by Ion Chromatography										
EPA 300.0	**Chloride**	36.6	mg/L	5.00	1.52	25	W332114	AEW	08/06/13 21:16	D2
EPA 300.0	**Fluoride**	55.3	mg/L	2.50	0.42	25	W332114	AEW	08/06/13 21:16	D2
EPA 300.0	**Sulfate as SO4**	340	mg/L	7.50	1.65	25	W332114	AEW	08/06/13 21:16	D2

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

John Kern

John Kern
Laboratory Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3G0698**
Reported: 14-Aug-13 12:38

Client Sample ID: **#10 1:4.63 COMP:GW**
SVL Sample ID: **W3G0698-06 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 29-Jul-13 11:00
Received: 23-May-13
Sampled By:

Metals (Dissolved)

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 200.7	**Calcium**	1.07	mg/L	0.040	0.015		W331105	TJK	08/09/13 10:13	
EPA 200.7	**Iron**	18.6	mg/L	0.060	0.019		W331105	TJK	08/09/13 10:13	
EPA 200.7	**Magnesium**	1.48	mg/L	0.060	0.039		W331105	TJK	08/09/13 10:13	
EPA 200.7	**Silica (SiO2)**	9.41	mg/L	0.17	0.05		W331105	TJK	08/09/13 10:13	
EPA 200.7	**Sodium**	1320	mg/L	5.00	1.10	10	W331105	TJK	08/09/13 11:26	D2
SM 2340B	**Hardness (as CaCO3)**	8.74	mg/L	0.347	0.198		N/A		08/09/13 10:13	

Classical Chemistry Parameters

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 335.4	**Cyanide (total)**	48.7	mg/L	2.00	0.380	200	W332190	IIT	08/08/13 11:40	D2
EPA 351.2	**TKN**	25.5	mg/L	2.50	0.46	5	W332014	NCS	08/09/13 10:24	D2
EPA 353.2	**Nitrate/Nitrite as N**	89.9	mg/L	5.00	1.00	100	W332060	ARP	08/06/13 13:47	D2
EPA 410.4	**Chemical Oxygen Demand**	56.8	mg/L	5.0	2.5		W332276	SM	08/09/13 10:12	
SM 2320B/2310B	**Bicarbonate**	922	mg/L as CaCO3	1.0			W331250	DKS	08/01/13 10:13	
SM 2320B/2310B	**Carbonate**	867	mg/L as CaCO3	1.0			W331250	DKS	08/01/13 10:13	
SM 2320B/2310B	Hydroxide	< 1.0	mg/L as CaCO3	1.0			W331250	DKS	08/01/13 10:13	
SM 2320B/2310B	**Total Alkalinity**	1790	mg/L as CaCO3	1.0			W331250	DKS	08/01/13 10:13	
SM 2540 C	**Total Diss. Solids**	3920	mg/L	40			W331131	JDM	07/30/13 13:30	D1
SM 2580B	**Eh**	135	mV	2.50			W331077	AGF	07/29/13 13:10	
SM 4500 H B	**pH @19.0°C**	9.70	pH Units				W331250	DKS	08/01/13 10:13	H5
SM 4500-CN-I	**Cyanide (WAD)**	0.195	mg/L	0.0100	0.0017		W332189	IIT	08/08/13 10:12	
SM 5310B	**Total Organic Carbon**	32.6	mg/L	1.00	0.20		W332274	SM	08/08/13 13:19	

Anions by Ion Chromatography

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 300.0	**Chloride**	133	mg/L	5.00	1.52	25	W332114	AEW	08/06/13 21:36	D2
EPA 300.0	**Fluoride**	46.0	mg/L	2.50	0.42	25	W332114	AEW	08/06/13 21:36	D2
EPA 300.0	**Sulfate as SO4**	849	mg/L	7.50	1.65	25	W332114	AEW	08/06/13 21:36	D2

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

John Kern

John Kern
Laboratory Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3G0698**
Reported: 14-Aug-13 12:38

Client Sample ID: **#11 4.71:1 COMP:GW**
SVL Sample ID: **W3G0698-07 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 29-Jul-13 11:00
Received: 23-May-13
Sampled By:

Metals (Dissolved)

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 200.7	**Calcium**	2.68	mg/L	0.040	0.015		W331105	TJK	08/09/13 10:19	
EPA 200.7	**Iron**	3.60	mg/L	0.060	0.019		W331105	TJK	08/09/13 10:19	
EPA 200.7	**Magnesium**	1.77	mg/L	0.060	0.039		W331105	TJK	08/09/13 10:19	
EPA 200.7	**Silica (SiO2)**	3.44	mg/L	0.17	0.05		W331105	TJK	08/09/13 10:19	
EPA 200.7	**Sodium**	1520	mg/L	5.00	1.10	10	W331105	TJK	08/09/13 11:33	D2
SM 2340B	**Hardness (as CaCO3)**	14.0	mg/L	0.347	0.198		N/A		08/09/13 10:19	

Classical Chemistry Parameters

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 335.4	**Cyanide (total)**	11.4	mg/L	0.500	0.0950	50	W332190	IIT	08/08/13 11:48	D2
EPA 351.2	**TKN**	17.9	mg/L	0.50	0.09		W332014	NCS	08/09/13 10:03	
EPA 353.2	**Nitrate/Nitrite as N**	67.3	mg/L	2.50	0.500	50	W332060	ARP	08/06/13 14:01	D2
EPA 410.4	**Chemical Oxygen Demand**	24.4	mg/L	5.0	2.5		W332276	SM	08/09/13 10:12	
SM 2320B/2310B	**Bicarbonate**	302	mg/L as CaCO3	1.0			W331126	CFP	07/30/13 13:50	
SM 2320B/2310B	**Carbonate**	64.4	mg/L as CaCO3	1.0			W331126	CFP	07/30/13 13:50	
SM 2320B/2310B	Hydroxide	< 1.0	mg/L as CaCO3	1.0			W331126	CFP	07/30/13 13:50	
SM 2320B/2310B	**Total Alkalinity**	366	mg/L as CaCO3	1.0			W331126	CFP	07/30/13 13:50	
SM 2540 C	**Total Diss. Solids**	12200	mg/L	100			W331131	JDM	07/30/13 13:30	D1
SM 2580B	**Eh**	280	mV	2.50			W331077	AGF	07/29/13 13:10	
SM 4500 H B	**pH @21.0°C**	8.95	pH Units				W331126	CFP	07/30/13 13:50	H5
SM 4500-CN-I	**Cyanide (WAD)**	0.317	mg/L	0.0100	0.0017		W332189	IIT	08/07/13 15:32	
SM 5310B	**Total Organic Carbon**	11.2	mg/L	1.00	0.20		W332274	SM	08/08/13 13:32	

Anions by Ion Chromatography

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 300.0	**Chloride**	461	mg/L	50.0	15.2	250	W332114	AEW	08/06/13 22:08	D2
EPA 300.0	**Fluoride**	10.7	mg/L	2.50	0.42	25	W332114	AEW	08/06/13 21:57	D2
EPA 300.0	**Sulfate as SO4**	2630	mg/L	75.0	16.5	250	W332114	AEW	08/06/13 22:08	D2

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

John Kern

John Kern
Laboratory Director

Quality Control - BLANK Data

Metals (Dissolved)

Method	Analyte	Units	Result	MDL	MRL	Batch ID	Analyzed	Notes
EPA 200.7	Calcium	mg/L	<0.040	0.015	0.040	W331105	09-Aug-13	
EPA 200.7	Iron	mg/L	<0.060	0.019	0.060	W331105	09-Aug-13	
EPA 200.7	Magnesium	mg/L	<0.060	0.039	0.060	W331105	09-Aug-13	
EPA 200.7	Silica (SiO2)	mg/L	<0.17	0.05	0.17	W331105	09-Aug-13	
EPA 200.7	Sodium	mg/L	<0.50	0.11	0.50	W331105	09-Aug-13	

Classical Chemistry Parameters

Method	Analyte	Units	Result	MDL	MRL	Batch ID	Analyzed	Notes
EPA 335.4	Cyanide (total)	mg/L	<0.0100	0.0019	0.0100	W332190	08-Aug-13	
EPA 351.2	TKN	mg/L	<0.50	0.09	0.50	W332014	09-Aug-13	
EPA 353.2	Nitrate/Nitrite as N	mg/L	<0.050	0.010	0.050	W332060	06-Aug-13	
EPA 353.2	Nitrate/Nitrite as N	mg/L	<0.050	0.010	0.050	W332127	07-Aug-13	
EPA 410.4	Chemical Oxygen Demand	mg/L	<5.0	2.5	5.0	W332276	09-Aug-13	
SM 2320B/2310B	Total Alkalinity	mg/L as CaCO3	<1.0		1.0	W331126	30-Jul-13	
SM 2320B/2310B	Total Alkalinity	mg/L as CaCO3	<1.0		1.0	W331250	01-Aug-13	
SM 2320B/2310B	Bicarbonate	mg/L as CaCO3	<1.0		1.0	W331126	30-Jul-13	
SM 2320B/2310B	Bicarbonate	mg/L as CaCO3	<1.0		1.0	W331250	01-Aug-13	
SM 2320B/2310B	Carbonate	mg/L as CaCO3	<1.0		1.0	W331126	30-Jul-13	
SM 2320B/2310B	Carbonate	mg/L as CaCO3	<1.0		1.0	W331250	01-Aug-13	
SM 2320B/2310B	Hydroxide	mg/L as CaCO3	<1.0		1.0	W331126	30-Jul-13	
SM 2320B/2310B	Hydroxide	mg/L as CaCO3	<1.0		1.0	W331250	01-Aug-13	
SM 2540 C	Total Diss. Solids	mg/L	<10		10	W331131	30-Jul-13	
SM 4500-CN-I	Cyanide (WAD)	mg/L	<0.0100	0.0017	0.0100	W332189	07-Aug-13	
SM 5310B	Total Organic Carbon	mg/L	<1.00	0.20	1.00	W332274	08-Aug-13	

Anions by Ion Chromatography

Method	Analyte	Units	Result	MDL	MRL	Batch ID	Analyzed	Notes
EPA 300.0	Fluoride	mg/L	<0.10	0.02	0.10	W332114	06-Aug-13	
EPA 300.0	Chloride	mg/L	<0.20	0.06	0.20	W332114	06-Aug-13	
EPA 300.0	Sulfate as SO4	mg/L	<0.30	0.07	0.30	W332114	06-Aug-13	

Quality Control - LABORATORY CONTROL SAMPLE Data

Metals (Dissolved)

Method	Analyte	Units	LCS Result	LCS True	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
EPA 200.7	Calcium	mg/L	18.4	20.0	91.9	85 - 115	W331105	09-Aug-13	
EPA 200.7	Iron	mg/L	9.25	10.0	92.5	85 - 115	W331105	09-Aug-13	
EPA 200.7	Magnesium	mg/L	18.5	20.0	92.6	85 - 115	W331105	09-Aug-13	
EPA 200.7	Silica (SiO2)	mg/L	10.6	10.7	99.3	85 - 115	W331105	09-Aug-13	
EPA 200.7	Sodium	mg/L	18.1	19.0	95.0	85 - 115	W331105	09-Aug-13	

Classical Chemistry Parameters

Method	Analyte	Units	LCS Result	LCS True	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
EPA 335.4	Cyanide (total)	mg/L	0.154	0.150	103	90 - 110	W332190	08-Aug-13	
EPA 351.2	TKN	mg/L	8.42	8.00	105	90 - 110	W332014	09-Aug-13	
EPA 353.2	Nitrate/Nitrite as N	mg/L	1.96	2.00	97.8	90 - 110	W332060	06-Aug-13	
EPA 353.2	Nitrate/Nitrite as N	mg/L	1.99	2.00	99.3	90 - 110	W332127	07-Aug-13	
EPA 410.4	Chemical Oxygen Demand	mg/L	110	114	96.2	90 - 110	W332276	09-Aug-13	
SM 2320B/2310B	Total Alkalinity	mg/L as CaCO3	102	97.2	105	85 - 115	W331250	01-Aug-13	
SM 2320B/2310B	Total Alkalinity	mg/L as CaCO3	95.4	97.2	98.2	85 - 115	W331126	30-Jul-13	
SM 2320B/2310B	Bicarbonate	mg/L as CaCO3	88.3	97.2	90.9	85 - 115	W331250	01-Aug-13	
SM 2320B/2310B	Bicarbonate	mg/L as CaCO3	94.6	97.2	97.3	85 - 115	W331126	30-Jul-13	
SM 2580B	Eh	mV	221	220	100	98.59 - 101.4	W331077	29-Jul-13	
SM 4500-CN-I	Cyanide (WAD)	mg/L	0.152	0.150	101	90 - 110	W332189	07-Aug-13	

Quality Control - LABORATORY CONTROL SAMPLE Data (Continued)

Method	Analyte	Units	LCS Result	LCS True	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
Classical Chemistry Parameters (Continued)									
SM 5310B	Total Organic Carbon	mg/L	36.4	34.3	106	80 - 120	W332274	08-Aug-13	
Anions by Ion Chromatography									
EPA 300.0	Fluoride	mg/L	2.00	2.00	100	90 - 110	W332114	06-Aug-13	
EPA 300.0	Chloride	mg/L	3.02	3.00	101	90 - 110	W332114	06-Aug-13	
EPA 300.0	Sulfate as SO4	mg/L	10.7	10.0	107	90 - 110	W332114	06-Aug-13	

Quality Control - DUPLICATE Data

Method	Analyte	Units	Duplicate Result	Sample Result	RPD	RPD Limit	Batch ID	Analyzed	Notes
Classical Chemistry Parameters									
SM 2320B/2310B	Total Alkalinity	mg/L as CaCO3	1430	1410	1.3	20	W331250	01-Aug-13	
SM 2320B/2310B	Total Alkalinity	mg/L as CaCO3	223	222	0.2	20	W331126	30-Jul-13	
SM 2320B/2310B	Bicarbonate	mg/L as CaCO3	178	179	0.3	20	W331126	30-Jul-13	
SM 2320B/2310B	Bicarbonate	mg/L as CaCO3	748	738	1.3	20	W331250	01-Aug-13	
SM 2320B/2310B	Carbonate	mg/L as CaCO3	44.5	43.4	2.4	20	W331126	30-Jul-13	
SM 2320B/2310B	Carbonate	mg/L as CaCO3	681	672	1.4	20	W331250	01-Aug-13	
SM 2320B/2310B	Hydroxide	mg/L as CaCO3	<1.0	<1.0	UDL	20	W331126	30-Jul-13	
SM 2320B/2310B	Hydroxide	mg/L as CaCO3	<1.0	<1.0	UDL	20	W331250	01-Aug-13	
SM 2540 C	Total Diss. Solids	mg/L	348	353	1.4	10	W331131	30-Jul-13	
SM 2540 C	Total Diss. Solids	mg/L	618	617	0.2	10	W331131	30-Jul-13	
SM 2580B	Eh	mV	166	165	0.6	20	W331077	29-Jul-13	
SM 4500 H B	pH	pH Units	8.88	8.87	0.1	20	W331126	30-Jul-13	
SM 4500 H B	pH	pH Units	9.70	9.70	0.0	20	W331250	01-Aug-13	

Quality Control - MATRIX SPIKE Data

Method	Analyte	Units	Spike Result	Sample Result (R)	Spike Level (S)	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
Metals (Dissolved)										
EPA 200.7	Calcium	mg/L	625	592	20.0	R > 4S	70 - 130	W331105	09-Aug-13	M3
EPA 200.7	Iron	mg/L	9.16	<0.060	10.0	91.6	70 - 130	W331105	09-Aug-13	
EPA 200.7	Magnesium	mg/L	185	163	20.0	109	70 - 130	W331105	09-Aug-13	M3
EPA 200.7	Silica (SiO2)	mg/L	42.4	31.4	10.7	103	70 - 130	W331105	09-Aug-13	
EPA 200.7	Sodium	mg/L	69.9	50.4	19.0	103	70 - 130	W331105	09-Aug-13	
Classical Chemistry Parameters										
EPA 335.4	Cyanide (total)	mg/L	0.575	0.463	0.100	R > 4S	90 - 110	W332190	08-Aug-13	D2,M1
EPA 335.4	Cyanide (total)	mg/L	20.2	20.0	0.100	R > 4S	90 - 110	W332190	08-Aug-13	D2,M4
EPA 351.2	TKN	mg/L	8.09	<0.50	8.00	99.2	90 - 110	W332014	09-Aug-13	
EPA 351.2	TKN	mg/L	13.7	5.78	8.00	99.0	90 - 110	W332014	09-Aug-13	
EPA 353.2	Nitrate/Nitrite as N	mg/L	2.18	0.924	1.00	126	90 - 110	W332060	06-Aug-13	M1
EPA 353.2	Nitrate/Nitrite as N	mg/L	91.2	99.3	1.00	R > 4S	90 - 110	W332060	06-Aug-13	D2,M3
EPA 353.2	Nitrate/Nitrite as N	mg/L	1.39	0.370	1.00	102	90 - 110	W332127	07-Aug-13	
EPA 353.2	Nitrate/Nitrite as N	mg/L	1.35	0.301	1.00	104	90 - 110	W332127	07-Aug-13	
EPA 410.4	Chemical Oxygen Demand	mg/L	51.1	5.1	50.0	92.1	90 - 110	W332276	09-Aug-13	
SM 4500-CN-I	Cyanide (WAD)	mg/L	0.0940	<0.0100	0.100	94.0	75 - 125	W332189	07-Aug-13	
SM 5310B	Total Organic Carbon	mg/L	50.7	2.20	50.0	97.0	75 - 125	W332274	08-Aug-13	

Quality Control - MATRIX SPIKE Data (Continued)

Anions by Ion Chromatography

Method	Analyte	Units	Spike Result	Sample Result (R)	Spike Level (S)	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
EPA 300.0	Fluoride	mg/L	2.42	0.37	2.00	103	90 - 110	W332114	06-Aug-13	
EPA 300.0	Fluoride	mg/L	3.14	1.20	2.00	97.4	90 - 110	W332114	06-Aug-13	D1
EPA 300.0	Chloride	mg/L	104	102	3.00	R > 4S	90 - 110	W332114	06-Aug-13	D2,M3
EPA 300.0	Chloride	mg/L	17.7	15.0	3.00	91.5	90 - 110	W332114	06-Aug-13	D2,M3
EPA 300.0	Sulfate as SO4	mg/L	29.1	17.8	10.0	113	90 - 110	W332114	06-Aug-13	M1
EPA 300.0	Sulfate as SO4	mg/L	1320	1320	10.0	R > 4S	90 - 110	W332114	06-Aug-13	D2,M3

Quality Control - MATRIX SPIKE DUPLICATE Data

Metals (Dissolved)

Method	Analyte	Units	MSD Result	Spike Result	Spike Level	RPD	RPD Limit	Batch ID	Analyzed	Notes
EPA 200.7	Calcium	mg/L	635	625	20.0	1.6	20	W331105	09-Aug-13	M3
EPA 200.7	Iron	mg/L	9.26	9.16	10.0	1.1	20	W331105	09-Aug-13	
EPA 200.7	Magnesium	mg/L	186	185	20.0	0.5	20	W331105	09-Aug-13	M3
EPA 200.7	Silica (SiO2)	mg/L	42.7	42.4	10.7	0.5	20	W331105	09-Aug-13	
EPA 200.7	Sodium	mg/L	70.7	69.9	19.0	1.1	20	W331105	09-Aug-13	

Classical Chemistry Parameters

Method	Analyte	Units	MSD Result	Spike Result	Spike Level	RPD	RPD Limit	Batch ID	Analyzed	Notes
EPA 335.4	Cyanide (total)	mg/L	0.588	0.575	0.100	2.2	20	W332190	08-Aug-13	D2,M1
EPA 351.2	TKN	mg/L	7.93	8.09	8.00	2.0	20	W332014	09-Aug-13	
EPA 353.2	Nitrate/Nitrite as N	mg/L	2.20	2.18	1.00	0.9	20	W332060	06-Aug-13	M1
EPA 353.2	Nitrate/Nitrite as N	mg/L	1.38	1.39	1.00	0.2	20	W332127	07-Aug-13	
EPA 410.4	Chemical Oxygen Demand	mg/L	52.4	51.1	50.0	2.5	20	W332276	09-Aug-13	
SM 4500-CN-I	Cyanide (WAD)	mg/L	0.100	0.0940	0.100	6.2	20	W332189	07-Aug-13	
SM 5310B	Total Organic Carbon	mg/L	52.7	50.7	50.0	3.9	20	W332274	08-Aug-13	

Anions by Ion Chromatography

Method	Analyte	Units	MSD Result	Spike Result	Spike Level	RPD	RPD Limit	Batch ID	Analyzed	Notes
EPA 300.0	Fluoride	mg/L	2.44	2.42	2.00	0.7	20	W332114	06-Aug-13	
EPA 300.0	Chloride	mg/L	17.7	17.7	3.00	0.1	20	W332114	07-Aug-13	D2,M3
EPA 300.0	Sulfate as SO4	mg/L	29.4	29.1	10.0	1.1	20	W332114	06-Aug-13	M1

Notes and Definitions

D1	Sample required dilution due to matrix.
D2	Sample required dilution due to high concentration of target analyte.
H5	This test is specified to be performed in the field within 15 minutes of sampling; sample was received and analyzed past the regulatory holding time.
M1	Matrix spike recovery was high, but the LCS recovery was acceptable.
M3	The spike recovery value is unusable since the analyte concentration in the sample is disproportionate to spike level. The LCS was acceptable.
M4	The analysis of the spiked sample required a dilution such that the spike recovery calculation does not provide useful information. The LCS recovery was acceptable.
LCS	Laboratory Control Sample (Blank Spike)
RPD	Relative Percent Difference
UDL	A result is less than the detection limit
R > 4S	% recovery not applicable, sample concentration more than four times greater than spike level
<RL	A result is less than the reporting limit
MRL	Method Reporting Limit
MDL	Method Detection Limit
N/A	Not Applicable

APPENDIX C

WETLAND EX SITU TREATMENT REPORT

(ARCONIC, 2017)

DRAFT FINAL REPORT FOR EX SITU TREATABILITY STUDY 2016 ACTIVITIES
FOR KAISER MEAD NPL SITE

Prepared for:

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February 2017

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

DRAFT FINAL REPORT FOR EX SITU TREATABILITY STUDY 2016 ACTIVITIES
FOR KAISER MEAD NPL SITE

1.0 INTRODUCTION

This Draft Final Report has been prepared to comply with the request by the Washington Department of Ecology (Ecology, 2014) to Mead Custodial Trust dated December 8, 2014, to proceed with certain actions as a continuation of the Supplemental Feasibility Study (SFS) for the Kaiser Mead NPL site (Kaiser Mead). This report describes the results of laboratory-scale testing of wetland and electro-coagulation treatment systems in accordance with the March 2016 Work Plan for Ex Situ Treatability Study 2016 Activities (Hydrometrics, 2016).

The purpose of the SFS is to develop and evaluate cleanup action alternatives for the contaminated groundwater at Kaiser Mead and to recommend a remedial alternative to be implemented to achieve compliance with groundwater cleanup requirements established for this site. The purpose of the activities described in this Final Report is to provide sufficient information to support the selection of a preferred remedy in the SFS. The Final Report includes the results and analysis from a 9-month study of a laboratory scale pilot free surface wetland system with post polishing using electro-coagulation technology for treatment of cyanide and fluoride from the impacted groundwater.

During 2016 ex situ treatability study activities, three different site water samples ranging from low cyanide and fluoride levels to very high cyanide and fluoride levels were subjected to wetland and electrocoagulation treatment under various laboratory conditions representative of field conditions in the Kaiser Mead area. The wetland system seems to respond positively with respect to removal of cyanide from these waters without any deleterious effects on flora and fauna. In particular, browning of shoots and visible root exudates, typical for an unhealthy wetland, were not observable during the course of wetland exposure to different strength cyanide and fluoride levels. In addition, small organisms, such as worms and minnows were seen living in the wetland environment. Under standard conditions of hydraulic residence time (HRT) of 7 days, sunlight intensity of 153 Watt/m2 (average condition for Spokane, WA) and ambient water temperature of 20^{o} C, average total cyanide removals in the wetland ranges from 60% to 75% for influent total cyanide concentrations ranging from 61 mg/L to 10 mg/L and fluoride levels ranging from 45 mg/L to 6 mg/L, respectively.

Further treatment of cyanide and fluoride takes place in the electro-coagulation (EC) system, with final total cyanide and total fluoride levels achieved of <0.5 mg/L and 2.5 mg/L, respectively for low and moderate strength water samples under both standard and winter conditions. Final WAD cyanide concentrations for low and moderate strength waters were 0.04 and 0.1 mg/L, respectively under standard conditions and 0.01 and 0.17 mg/L, respectively under winter conditions.

For the high strength sample, following wetland treatment, the EC system was able to achieve total cyanide, WAD cyanide and total fluoride concentration levels of 1.5 ppm, 0.76 ppm and 2.9 ppm, respectively. Thus, the clean-up goals for both cyanide and fluoride were met for the low and moderate strength waters, while the clean-up goal for only fluoride was met for the high strength water.

1.1 REPORT ORGANIZATION

This report includes the results from the bench-scale ex situ treatment tasks performed as part of the Work Plan submitted in March 2016 (Hydrometrics, 2016). Section 2 presents the goals and objectives of the ex situ activities. Section 3 describes the scope of work and methods for the ex situ activities. Section 4 describes the activities and results from the ex situ treatability tests. Section 5 summarizes test results and provides cost and operating data for performing a field pilot scale test of a wetland and electro-coagulation system.

2.0 GOALS AND OBJECTIVES

The purpose of the wetland and electro-coagulation (EC) testing is to determine the potential effectiveness of these technologies on Site groundwater and the potential size and cost of the wetland and EC systems that would be needed for a full-scale treatment system. This data will allow a better comparison of estimated costs and benefits of the wetland/EC system with other remedial alternatives.

The overall goal of wetland/EC system is the same as for other alternatives which is to achieve, or contribute to achievement of groundwater cleanup goals. Similar to other ex situ and in situ methods tested, the ultimate target for treatability testing is to achieve cleanup levels (0.2 mg/L free cyanide[1] and 4 mg/L fluoride) in effluent. In addition, the groundwater is considered contaminated environmental media by Ecology[2] and the groundwater must meet the "contained-in" requirements for environmental media including the specific numeric standards that must be met to no longer be considered hazardous waste. Once treated to meet the cleanup levels for cyanide and fluoride, it will no longer be considered hazardous waste. Sludge and solids generated from the treatment would be considered hazardous waste per the "derived from" rule.

2.1 EX SITU TREATMENT TESTS OBJECTIVES

The objectives of the tests for ex situ treatment of groundwater for fluoride and cyanide include:

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[1] Free cyanide refers to the sum of HCN and CN ions in a sample and is the most toxic form of cyanide. Weak to moderately strong metal-cyanide complexes are compounds that dissociate and release HCN under mildly acidic conditions. The WAD method was developed to quantify available cyanide, which measures the weak and moderately strong metal cyanide complexes plus free cyanide (Lipps). Task 2 of the 2004 Remedial Action Plan (Attachment E to the 2004 Consent Decree) specified that WAD CN be analyzed in the groundwater monitoring program. Ecology elected to use the WAD CN method at that time as they determined the analytical method for WAD CN provided more consistent results at low levels than free CN methods and its use is consistent with the state clean water act for surface water (WAC 173-201A-240). From 2004 to 2016 WAD cyanide was measured during groundwater monitoring. Due to improvements to the analytical methods for free cyanide, free cyanide analyses were incorporated into routing groundwater monitoring in 2015. In October 2016, Ecology supported the switch from WAD to free cyanide analyses for future monitoring and compliance determinations.

[2]

- Provide data for the evaluation of effectiveness (on site groundwater) of constructed wetland processes to treat relevant cyanide forms in the presence of fluoride;

- Provide data for the evaluation of effectiveness (on site groundwater) of electro-coagulation (EC) processes to treat fluoride following the wetland treatment of cyanide;

- Provide data for design of field pilot-scale and full-scale constructed wetland treatment systems and for determining the configuration of the EC units required for effective treatment of cyanide and fluoride of Site groundwater; and

- Develop full-scale preliminary cost estimates for ex situ cyanide and fluoride treatment systems.

3.0 SCOPE OF WORK

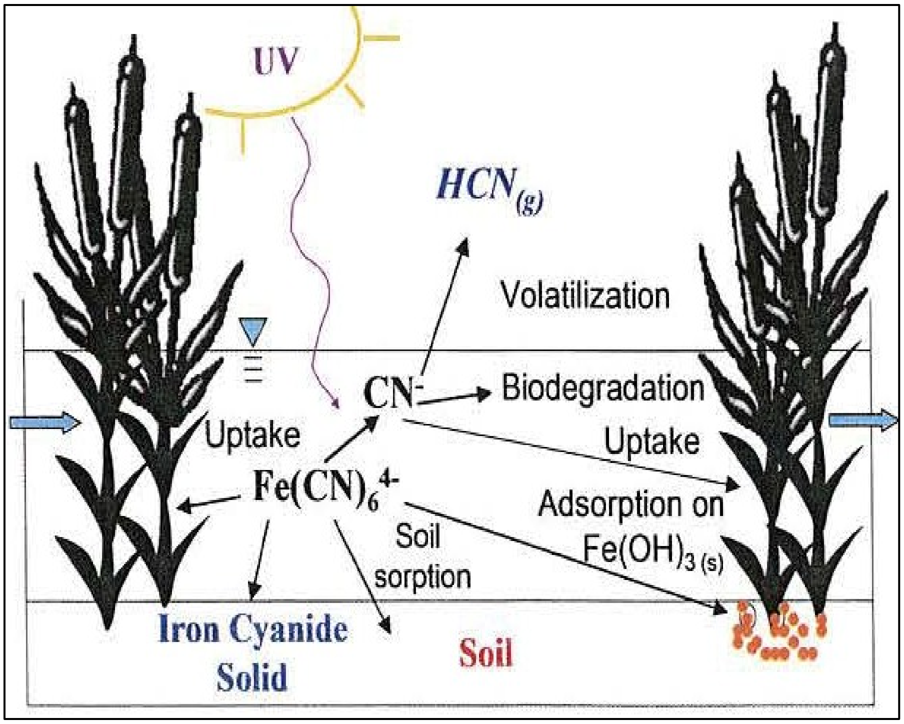
The 2016, tasks of ex situ laboratory scale testing were developed to supplement the previous work in support of the SFS. To perform the testing, Hydrometrics enlisted expertise from Arconic (formerly Alcoa) for the wetland scope and BakerCorp-Kaselco for the electro-coagulation scope. Alcoa is currently utilizing working wetlands for treatment of cyanide impacted waters at a number of their aluminum smelters and Kaselco has implemented electro-coagulation units at other cleanup sites in the northwest. The scope of work is discussed in the following sections.

3.1 EX SITU WETLAND TREATMENT MECHANISMS

The primary mechanisms of wetland treatment utilize the free surface wetland system to allow photo-dissociation of iron cyanide complexes followed by biodegradation of free or weakly complexed cyanide. Figure 3-1 indicates the general schematic of the cyanide destruction in a free surface wetland system.

Based on detailed mass balance analyses from multiple pilot and full-scale cyanide treatment wetlands, it has been demonstrated that the photo-dissociation of iron cyanide to free cyanide followed by the biodegradation of free cyanide are the primary cyanide removal fate processes occurring in the wetland system. It has also been demonstrated that the cyanide removal capacity of the wetland system is a function of hydraulic retention time (HRT) of the wetland system and climatic variations including ambient temperature and solar intensity. Although plant uptake and sediment sorption are not the major cyanide removal processes in the system, they provide suitable conditions for biodegradation by providing degradation sites and organic carbon. In addition, volatilization of free cyanide plays a minor role in influencing the fate of cyanide regardless of the time of the year.

FIGURE 3-1. GENERAL SCHEMATIC OF CYANIDE DESTRUCTION VIA FREE SURFACE WETLAND SYSTEM



Wetlands will maintain a minimum amount of efficiency during the winter freezing conditions. The primary removal mechanism occurs via diffused sunlight initializing the photo-dissociation of iron cyanide. The photo-dissociation process occurs very rapidly and experience at Alcoa's pilot project in Tennessee is that a relatively small open surface area, free of vegetation, is sufficient to make the process effective. At a full-scale operation such as Kaiser Mead it is envisioned that the influent water will be exposed to diffused light at the entrance section of the wetland (Figure 3-2) as the wetland entrance section will be maintained above freezing conditions due to the heat capacity of the groundwater being pumped into the wetland.

Additionally, the absence of vegetation at the wetland entrance maximizes light exposure and consequently photo-dissociation of the iron cyanide. Based on Alcoa Tennessee Operations experience in operating a wetland under freezing conditions, even in presence of few inches

FIGURE 3-2. TYPICAL ENTRANCE TO WETLAND

Photo from a previous test at Alcoa, TN location

of frozen surface, the water underneath flows and cyanide treatment via biodegradation (in the plant root zone) followed by plant root uptake and soil sorption continues to occur at the required efficiencies.

Rhizospehere-mediated biodegradation is the primary form for bio-decay process for cyanide. As such, the root zones of the emergent and submergent species provide the necessary biomass for cyanide degradation, provided a constant source of cyanide is present to propagate the biomass growth and sustain the biomass population. These are ubiquitous processes (as long as soils of sufficient organic content are used for plantation of the submergent species) that are not dependent on geographical location.

The rate of biodegradation is dependent on the temperature and root surface availability which are necessary for optimum biomass growth and sustenance. As shown in Figure 3-3, icy conditions and reduced plant active mass were observed in a previously implemented

FIGURE 3-3. WINTER WETLAND CONDITIONS

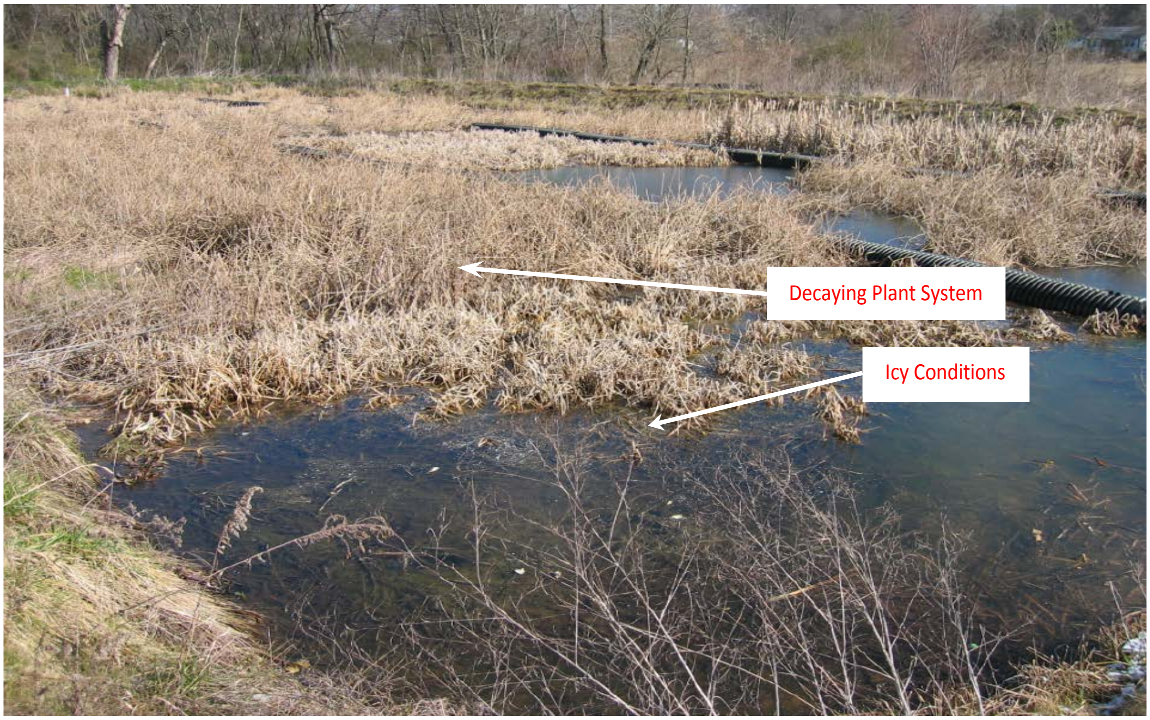


Photo from a previous test at Alcoa, TN location

cyanide treatment wetland study during the winter months compared to warmer months when the presence of full grown plants was evident. Although the measured rate of biodegradation of free cyanide was decreased during the winter months in the treatment wetland (see Table 3-1 showing data from an Alcoa wetland treatment system in Alcoa, TN), the wetland system was still successful in removing over 90% cyanide as shown in Figure 3-4.

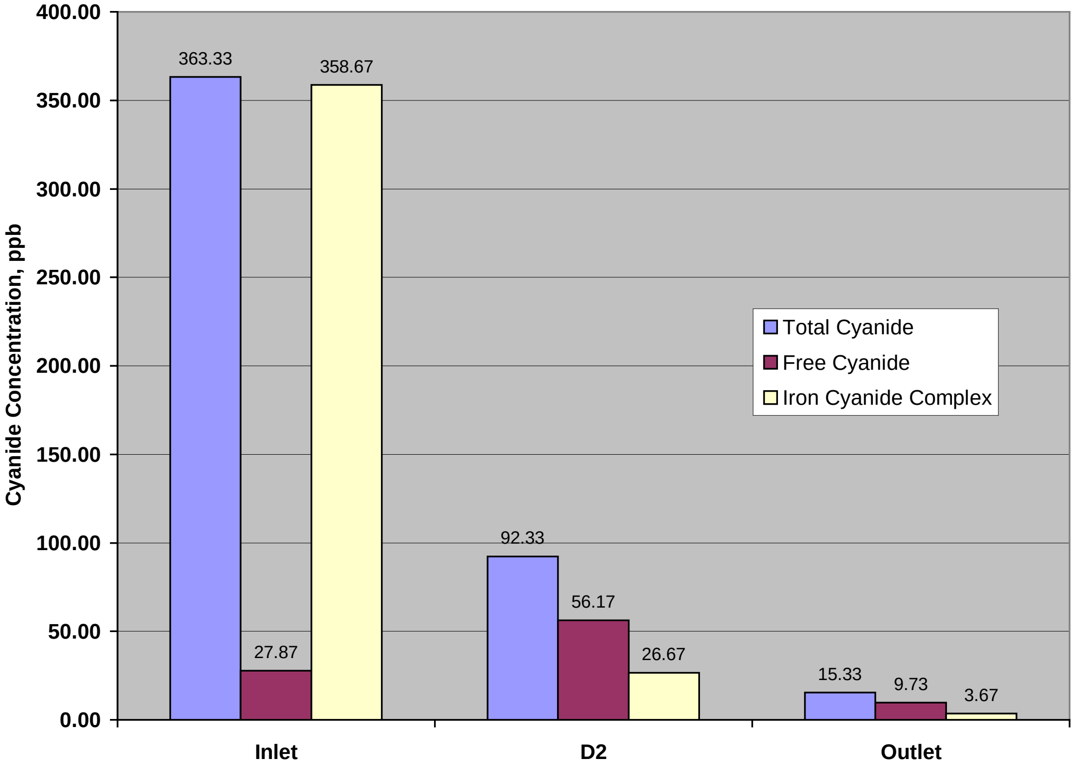
Figure 3-4 shows data cyanide removal efficiency data collected during winter months at a wetland site treating 5-7 gpm of spent potliner (SPL) impacted groundwater in Alcoa, TN near Knoxville, TN. Location D2 on the figure represents a sampling location midway between the inlet and outlet of the pilot-scale wetland. Design of the wetland system to operate during cold periods is an important part of the testing and design process. If the

TABLE 3-1. FIRST ORDER FREE CYANIDE BIODEGRADATION RATES

Monitoring Event	First Order Rate, hrs^{-1}
June-July 2004	0.0546 (@22^{o}C)
Feb-March 2005	0.0376 (@8^{o}C)
August 2005	0.0491 (@20^{o}C)

Data from a previous test at Alcoa, TN location

FIGURE 3-4. WETLAND CYANIDE DESTRUCTION DATA DURING A 21-DAY MONITORING EVENT IN FEB-MAR TIMEFRAME



Data from a previous test at Alcoa, TN location (Location D2 is located mid-way into the wetland)Average Daily Water temperature ranged from 4^{O}C to 10^{o}C during the 21 day monitoring event wetland system is effective on KM site waters under lab testing conditions, further pilot-scale testing in the field under actual Spokane winter conditions would be recommended prior to final design of a full-scale wetland system.

3.2 EX SITU LAB SCALE TREATMENT - CONSTRUCTED WETLAND AND EC TESTS

The ex situ treatment test was conducted by Arconic (formerly Alcoa). The first step in the treatability study involved a lab scale wetland study to determine cyanide (total, WAD and free) treatment effectiveness using actual groundwater from the Kaiser Mead site. Three actual groundwater samples from three active monitoring wells were used during the course of this treatability study in a sequential manner with total cyanide and total fluoride levels increasing progressively in the influent. They were well number TW1B, well number KMCP-4B and well number KM-5, respectively. The location of wells with respect to the cyanide plume is shown in Figure 3-5. Table 3-2 shows the relative cyanide and fluoride concentration levels in the three wells based on analysis of the bulk samples prior to shipping to Arconic.

3.2.1 Constructed Wetland Tests

The lab-scale wetland was constructed at Arconic Technology Center (ATC) in New Kensington, PA. The most critical design parameters were the HRT, depth of the water column and the areal extent of the vegetative cover. Once the optimum HRT was established based on information from previous lab-scale and field pilot scale testing performed at ATC as well as in Alcoa plants in TN and NY, the areal extent of the wetland was then designed to match the required design flow rate for a full-scale operation. The dimensions of the working physical pilot model was approximately 2.5 ft. by 3.5 ft. rectangular wetland cell with 3-4 inches of standing water. Perforated distribution pipe was used at the inlet section to properly distribute water throughout the wetland cell. See Figure 3-6 for schematic and actual picture of the lab-scale wetland.

FIGURE 3-5. LOCATION OF SELECTED WELLS WRT 2015 CYANIDE PLUME

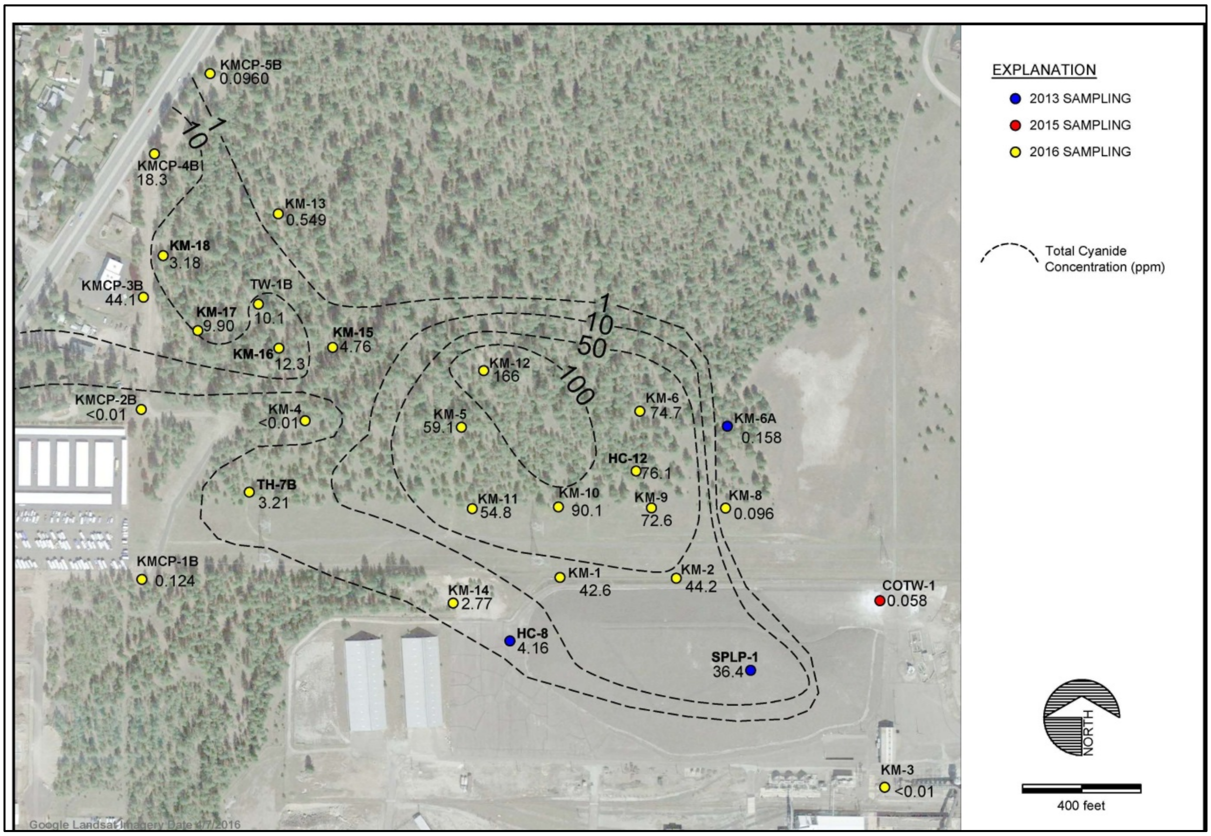
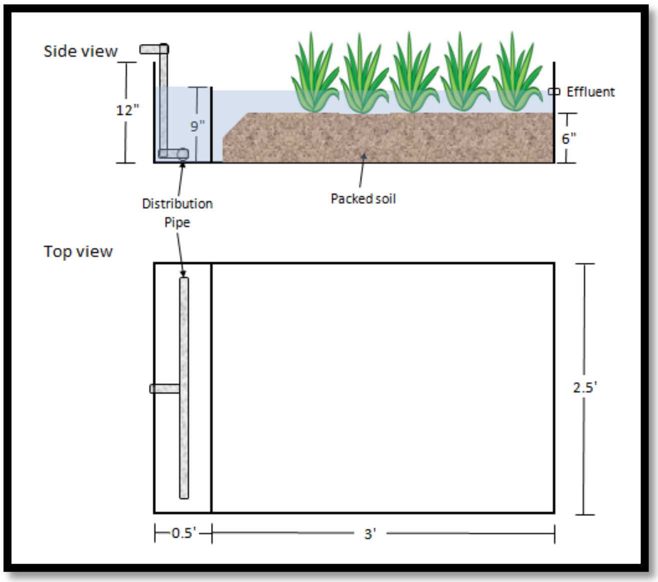
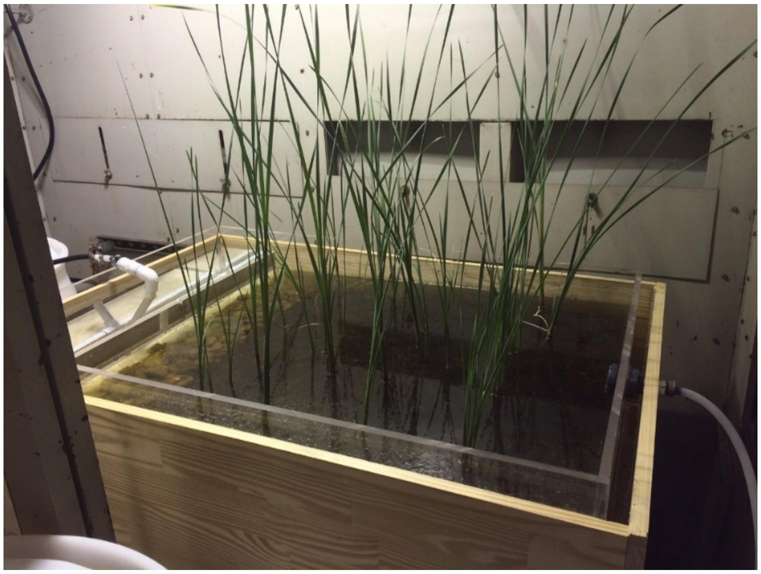


TABLE 3-2. SELECTED WELL MONITORING RESULTS

Well No.	Total CN, mg/L	WAD CN, mg/L	Free CN, mg/L	Total F, mg/L	pH, s.u.
TW-1B	10.1	1.4	1.46	5.14	9
KMCP-4B	18.3	0.952	0.926	15.6	9.3
KM-5	61.5	2.28	1.92	45.2	10

FIGURE 3-6. LAB SCALE WETLAND

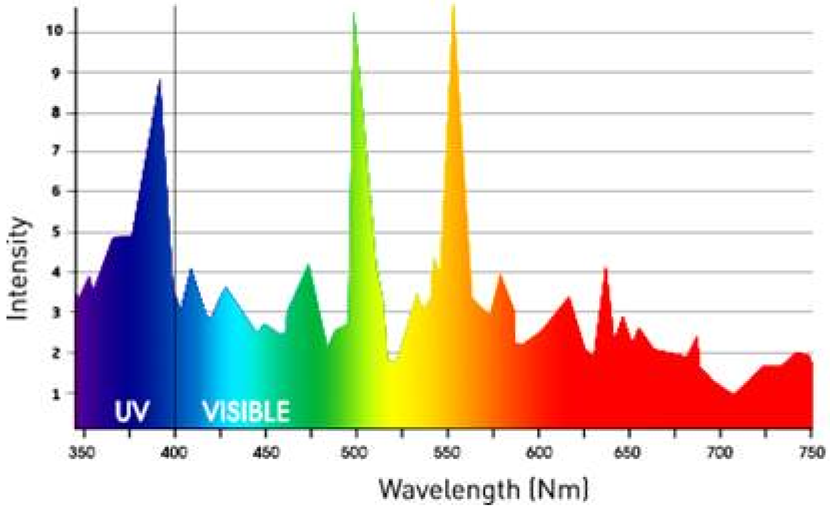




The lamp used for the Kaiser Mead laboratory pilot treatability study was a 1000W metal halide lamp. The lamp features low iron glass for enhanced UV penetration to more closely mimic sunlight, and covers the light spectrum from 350–700 nm. The light source was moved closer or farther away from the intended target to achieve the desired output. A digital ballast controlled the entire lamp assembly for optimal and consistent performance. This lamp simulated the seasonal solar and UV spectrum typical of the Spokane area (Solar

Radiation Intensity between 94 and 153 watt/m^2; UV radiation between 17 and 28 umol/m^2/day). The pertinent UV wavelength is shown in Figure 3-7.

FIGURE 3-7. SOLAR RADIATION SPECTRUM SIMULATED BY THE METAL HALIDE LAMP



Organic-rich soil with total organic carbon (TOC) content close to 4% was used as the principal soil substrate for the wetland. Cyanide and fluoride-tolerant grown cuttings of emergent and submergent plant species common in Washington lakes were used for planting purposes. Emergent species like cattails were planted as plugs, while submergent and floating-leaned species (coontail) were installed as cuttings. One other Washington state emergent species suitable for the Mead climate/ecotone to increase structural and species diversity was included, namely: Pondweed (*Potamogeton gramineus*).

The treatability test wetland was operated with a nominal flow rate of ~12 mL/min to yield approximately 7 days of HRT. This HRT was selected based on multiple lab-scale and pilot-scale studies previously conducted by Alcoa. The HRT takes into account the relative rates of photo-dissociation, biodegradation and plant uptake as a function of temperature, cyanide concentrations and general water chemistry. During the lab-scale wetland evaluation stage, provisions were made to adjust the flowrate to increase the HRT up to 10 days as well as decrease the HRT to 4 days in order to evaluate the total/free/WAD cyanide removal efficiency as a function of HRT.

Following the start-up/commissioning of the wetland pilot, the system was first acclimatized for a period of 2 weeks starting April 15, 2016. Water from monitoring well KM-3 with non-detectable level of total cyanide and fluoride was used to acclimatize the wetland system. Figure 3-6 shows the wetland system during the acclimatization period. Following the acclimatization period, the wetland was exposed to low strength water from TW-1B. Site groundwater from the plume areas upon receipt were analyzed immediately for characterization (total, free and WAD cyanide, fluoride, pH, total suspended solids, total and dissolved iron and chemical oxygen demand). The analytical methods used were consistent with Table 3-3. The water samples were all transported in new clean 55-gallon drums made of plastic. The groundwater from 55-gallon shipping drums were piped directly into the lab-scale wetland system via opaque tubing to prevent any losses of cyanide (via volatilization).

The influent samples were monitored (twice weekly) for characterization and if a reduction in concentration of the influent sample was reported (when compared to the initial sample analysis), then those changes were noted and considered during evaluation of project results.

Table 3-4 provides the final operational conditions that were used to run the pilot wetland operation as well as the selected fluoride removal tests using the EC technology. As shown in Table 3-4, although the wetland system was effectively operated and monitored for 174 days, the system itself operated for about 200 days, including the initial set-up period and final decommissioning period.

As per the work plan, the key parameters that were varied during the treatability study for the wetland system were HRT (flow rate), temperature, and sunlight intensity.

TABLE 3-3. WATER QUALITY ANALYTICAL PARAMETER LIST

Analytes	Proposed Reporting Limit (mg/L unless specified)
Field Parameters	
pH	0.1 su
Temperature	0.1^{o}C
Chemical Oxygen Demand	5.0
Total Suspended Solids	5.0
Specific Conductivity	5 umhos/cm
Major Minerals	
Fluoride (Method 300) Total and Dissolved	10
Iron – Total and Dissolved	0.060
Cyanide Forms	
Total Cyanide (EPA 335.4)	0.01
WAD Cyanide (SM-4500-CN-I)	0.01
Free Cyanide (ASTM D7237 or D4282)	0.01

3.2.2 Electro-Coagulation Tests

The following diagram (Figure 3-8) is a schematic representation of the EC bench-top equipment configuration used in the treatability testing:

The bench-top arrangement yields results that scale well to the full-scale BakerCorp-Kaselco reactor treatment system when operated at prescribed electrical and flow parameters.

For the testing described herein, samples are fed into the bench-scale reactor in 2,200 mL (approximately) batches at the rate of 525 mL/min. Unlike full-scale operations where treatment is accomplished with a single pass of the waste stream through the electro-coagulation reactor, bench testing involves running each sample through the reactor multiple times; this protocol allows the technician to observe treatment status at appropriate intervals

TABLE 3-4. TEST MATRIX FOR THE LAB-SCALE TREATABILITY STUDY

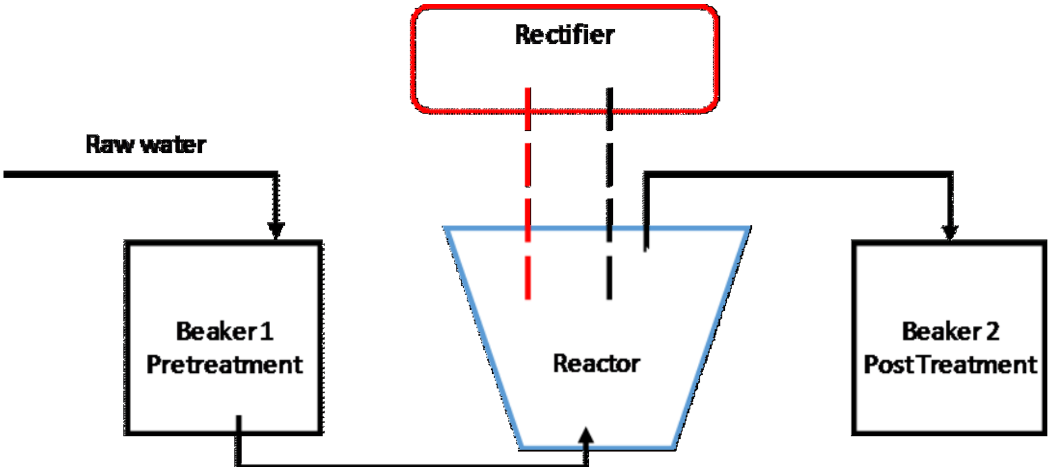
Testing Period	Water Sample Tested	Duration, days	HRT, days	Flow Rate, ml/Min	Solar Intensity, Watt/m^2	Ave pH, s.u.	Ave Water Temp., °C	EC Testing for Fluoride
Acclimization	KM-3	14	7	12	153	8.06	22.1	
Low Strength - Std Conditions	TW-1B	30	7	12	153	8.6	21.6	Yes
Low Strength - High Flow Conditions	TW-1B	7	4	22	153	8.21	22.1	
Low Strength - Low Flow Conditions	TW-1B	14	10	8.5	153	8.54	21.5	
Low Strength - Winter Conditions	TW-1B	7	7	12	94	8.57	5	
Med Strength - Std Conditions	KMCP-4B	10	7	12	153	8.9	22	Yes
Med Strength - Low Flow Conditions	KMCP-4B	27	10	8.5	153	8.94	21.72	
Med Strength - Winter Conditions	KMCP-4B	11	7	12	94	8.9	4	
Med Strength - High Flow Conditions	KMCP-4B	7	4	22	153	9.2	21.4	
Acclimitization	TW-1B	35	7	12	153	8.2	21	
High Strength - Std Conditions	KM-5	11	7	12	153	9.7	20.8	Yes

Note that “low, “medium” and “high” strength are relative terms used to convey the general water quality relative to the overall Kaiser Mead Site. See Table 3-2 for actual contaminant concentrations.

inside the process and to make adjustments to the treatment protocol as necessary to improve efficiency.

For the testing described herein, the rectifier controller was set to maintain constant current; rectifier voltage varied in proportion to the conductivity of the waste stream, up to a maximum of 48 VDC. A series of tests was conducted on the sample waste streams to determine the effects of temperature (°F), standard pH units (Note: all pH values identified in this report are S.U.), and chemical addition on treatment. The raw samples delivered to BakerCorp-Kaselco for testing were split as follows into four (6) brackets (batches) for evaluation:

FIGURE 3-8. SCHEMATIC REPRESENTATION OF THE BENCH TOP EQUIPMENT CONFIGURATION



a. Bracket 1 – Medium Strength Sample, Cold (33 ºF);

b. Bracket 2 – Medium Strength Sample, Ambient Temperature (up to 80 ºF);

c. Bracket 3 – Low Strength Sample, Cold (33 ºF);

d. Bracket 4 – Low Strength Sample, Ambient Temperature (up to 80 ºF);

e. Bracket 5 – Medium Strength Sample for TCLP Testing; and

f. Bracket 6 – High Strength Sample.

Each Bracket was further split to evaluate separately the effects on treatment of hydronium ion concentration (pH), of calcium chloride concentration ($CaCl_2$), and of the addition of an anionic polymer to improve floc formation. No samples were artificially heated prior to testing. A total of 21 individual tests were run to evaluate the efficacy of the treatment process under varying temperatures, pH levels, and calcium chloride concentrations. The following Table 3-5 summarizes the test parameters within each bracket:

TABLE 3-5. SUMMARY TEST MATRIX FOR EC STUDY

BRACKET 1 Medium Strength Sample, Cold (33 ºF)	**TEST 1**	Pretreated to adjust pH to 6.02; added $CaCl_2$
	TEST 2	No Pretreatment
	TEST 3	No Pretreatment
	TEST 4	Pretreated to adjust pH to 6.05; no $CaCl_2$ added
BRACKET 2 Medium Strength Sample, Ambient Temperature (up to 80 ºF)	**TEST 5**	Pretreated to adjust pH to 6.03; added $CaCl_2$
	TEST 6	No Pretreatment
	TEST 7	No Pretreatment
	TEST 8	Pretreated to adjust pH to 6.00; no $CaCl_2$ added
BRACKET 3 Low Strength Sample, Cold (33 ºF)	**TEST 9**	Pretreated to adjust pH to 6.02; added $CaCl_2$
	TEST 10	No Pretreatment
	TEST 11	No Pretreatment
	TEST 12	Pretreated to adjust pH to 6.05; no $CaCl_2$ added
BRACKET 4 Low Strength Sample, Ambient Temperature (up to 80 ºF)	**TEST 13**	Pretreated to adjust pH to 6.03; $CaCl_2$ added
	TEST 14	No Pretreatment
	TEST 15	No Pretreatment
	TEST 16	Pretreated to adjust pH to 6.00; no $CaCl_2$ added
BRACKET 2 – Additional Tests Medium Strength Sample, Ambient Temperature	**TEST 17**	Pretreated to adjust pH to 7.15; added $CaCl_2$
	TEST 18	Pretreated to adjust pH to 7.15; no $CaCl_2$ added
BRACKET 5 Medium Strength Sample for TCLP Analysis	**TEST 19**	Pretreated to adjust pH to 7.2; added $CaCl_2$
BRACKET 6 Additional High Strength Sample, Ambient and Cold Temperature	**TEST 20 (ambient) & TEST 21 (cold)**	Pretreated to adjust pH to 7.1; added $CaCl_2$

When used in individual tests, calcium chloride ($CaCl_2$) was added at the rate of 0.3 g/L. When used in individual tests, stock polymer solution was added at the rate of 1.2 g/L. When used for individual tests, concentrated (95% to 98%) sulfuric acid solution was used, unless otherwise noted. One split sample from each bracket was tested at the pH of the sample when received at the laboratory (“Raw” pH), and the other split sample was tested after its pH was adjusted to 6.0. The pH of the raw low strength sample batch of wetland effluent received by BakerCorp-Kaselco from Arconic was 8.1, the pH of the raw moderate strength sample batch was 8.4, and the pH of the raw high strength sample batch was 9.35.

Data generated throughout the course of the bench-scale evaluation provide information to confirm the conceptual treatment train methodology, and to refine full-scale treatment system component design and operational parameters.

For each set of tests, solids were separated from the water column by gravity filtration, and 3 representative samples were taken and split for third party analysis. The volumes of *pressed solids* posted for each set of test parameters were estimated, based on experience, from the volume of solids settled in the various samples generated under the associated set of parameters. Three treated samples from each bench-scale test were submitted to the third party laboratory, (AnalySys Laboratories) for analysis.

The analyses of raw water and treated water samples derived from the bench top testing described herein show that, when suitably configured, the KASELCO Electro-coagulation Technology was able to reduce the concentrations of the metals present in the waste stream, and reduce the concentrations of cyanide and fluoride to below the limits established for this cleanup.

Laboratory test results generated using the BakerCorp-KASELCO bench-top characteristically correlate well with results seen during full-scale treatment using BakerCorp-KASELCO electro-coagulation systems.

In total, 21 treatability tests using EC technology were conducted for the 3 wetland effluent samples using a number of different treatment protocols to evaluate the effects of varying the following parameters:

- The temperature of the sample being tested;
- The pH of the sample before and after treatment;
- The concentration of calcium chloride added to the raw sample prior to primary treatment;
- The addition of an anionic polymer after primary treatment to enhance floc formation; and
- The configuration and composition of the electro-coagulation reactor electrodes used.

The primary contaminants of concern for these tests included fluoride (treatment standard <4.0 mg/L), and free and weak acid dissociable (WAD) cyanide (treatment standard <0.2 mg/L).

The preferred protocol selected after testing entailed adjusting the pH to approximately 7.2 standard units and adding calcium chloride to the sample prior to primary treatment, processing the sample through a BakerCorp HiFlo® reactor in the 07 configuration with a combination of iron and aluminum plates, aerating the sample after primary treatment, readjusting the pH to 7.2 standard units, and then adding an anionic polymer to enhance flocculate separation and settling.

However, for treating the high strength water effluent from the wetland (KM-5), the combination of iron and aluminum plates needed to be altered from the previous test configuration used for the low and medium strength water tests in order to balance the fluoride and cyanide removal efficiencies and provide the concentration of aluminum ions needed to remediate the fluoride and the iron ions needed to remediate the residual cyanide, such that both fluoride and free/WAD cyanide effluent from the EC reactor were below the respective compliance levels.

3.2.3 Treatment Sample Analysis

During the course of operation, the wetland was primarily sampled for total, free, WAD cyanide, iron as well as fluoride at a frequency of 2 times a week from the influent and effluent sampling points. The analytical methods were consistent with those used for the project groundwater analyses and mentioned in Table 3-6. Other parameters monitored included pH, total suspended solids, chemical oxygen demand and temperature.

Soil and plant tissue material samples were collected from the wetland cell at the end of the test period. Plant tissue samples (a composite of plant tissues from entry, middle and exit areas) were analyzed for cyanide and fluoride uptake per the methodologies outlined in Table 3-7. It is Alcoa’s experience that plants will uptake some fluoride and cyanide, of which cyanide is destroyed within the plant body and fluoride is stored. Similarly, a composite of entry, middle and exit area soils was also collected for quantification of fluoride and cyanide forms. The results from these tests were used to close the mass balance of cyanide and fluoride during the course of 6 months of treatability testing.

TABLE 3-6. ANALYTICAL METHODS USED FOR WETLAND AND WATER ANALYSIS

Analyte	Method	Reporting Limit (mg/L)
Field Parameters		
pH		0.1 su
Temperature		0.1^{o} C
Specific Conductivity		5 umhos/cm
Major Minerals		
Fluoride	EPA 300	0.1
Chemical Oxygen Demand	EPA 420.4	5
Total Suspended Solids	ASTM 2540D	5
Metals		
Iron- Total and Dissolved	EPA 200.7	0.060
Cyanide Forms		
Total Cyanide	EPA 335.4	0.01
WAD Cyanide	SM-4500-CN-I	0.01
Free Cyanide	ASTM D7237 or D4282	0.01

TABLE 3-7. SOIL, SLUDGE AND PLANT TISSUE ANALYTICAL PARAMETERS

Analyte	Method	Reporting Limit (ug/kg)
Major Minerals		
Fluoride	EPA 340	1
Cyanide Forms		
Total Cyanide	EPA 335.4	5
WAD Cyanide	SM-4500-CN-I	1
Free Cyanide	ASTM D7237 or D4282	1

4.0 RESULTS

4.1 TREATMENT OF LOW STRENGTH GROUNDWATER FROM WELL TW-1B

4.1.1 Standard Conditions

Under the standard conditions described in Table 3-4 (HRT = 7 days; Solar intensity = 153 Watt/m2, water temperature = 22^{o}C), the treatment of low strength water from well TW-1B for a period of 30 days resulted in an average total cyanide removal efficiency of 88%, with average concentration of total cyanide, WAD cyanide and free cyanide recorded to be 1.2 mg/l, 0.12 mg/l and 0.1 mg/l, respectively at the wetland effluent. The average fluoride concentration level recorded for this period at the wetland effluent was 4.3 mg/l, which indicated a mere 16% removal of total fluoride in the wetland.

Approximately 10 gallons of water from the wetland effluent during the middle of the 30-day test period was sent to BakerCorp-Kaselco for evaluation of fluoride and cyanide treatment via the Electro-Coagulation (EC) test scheme. BakerCorp-Kaselco performed 8 different tests with this water (Bracket 3 and Bracket 4), 4 tests performed under cold conditions mimicking the winter conditions and 4 tests were performed using ambient water temperature.

Table 4-1 shows the results of the low strength water tests under summer conditions (water temperature = 80^{o}F or 27^{o}C). Note, some difference was observed between the water analyzed by BakerCorp labelled as “Low Strength-Post Wetland” in Table 4-1 and the data reported earlier for cyanide and fluoride levels (i.e., average concentration of total cyanide, WAD cyanide, free cyanide and total fluoride recorded at wetland effluent to be 1.2 mg/l, 0.12 mg/l, 0.1 mg/l and 4.3 mg/l, respectively). This is because, the post wetland data from ATC were average data over the entire course of wetland testing under that specific test condition, while the wetland treated water that was furnished to BakerCorp for EC testing was a grab sample within that test period.

TABLE 4-1. RESULTS FROM EC TESTING OF LOW STRENGTH WATER UNDER SUMMER CONDITIONS (80^{O}F WATER TEMP)

Constituent	Low Strength - Post Wetland, mg/l	Test 14-EC Effluent, mg/l	Test 15-EC effluent, mg/l
Aluminum	0.128	1.87	0.155
Arsenic	<0.02	<0.02	<0.02
Barium	0.0719	<0.02	<0.02
Boron	<0.5	<0.5	<0.5
Cadmium	<0.01	<0.01	<0.01
Calcium	32.9	24.4	27.1
Chromium	<0.02	<0.02	<0.2
Copper	<0.02	0.0378	0.0447
Iron	1.33	<0.2	<0.2
Lead	<0.02	<0.02	<0.02
Magnesium	33.4	17.1	22.5
Manganese	0.173	<0.02	0.0753
Molybdenum	<0.02	<0.02	<0.02
Nickel	<0.02	<0.02	<0.02
Potassium	4.29	5.33	5.56
Selenium	<0.02	<0.02	<0.02
Silicon	<2	<2	<2
Silver	<0.01	<0.01	<0.01
Sodium	159	150	148
Strontium	0.137	0.0848	0.094
Zinc	<0.05	<0.05	<0.05
Cyanide, Total	0.687	**0.117**	**0.116**
Cyanide, WAD	0.0257	**0.0345**	**0.0345**
Fluoride	5.53	**3.36**	**<2.5**

Table 4-2 outlines the results of the solids generation from the EC tests for this condition. This information corresponds to the quantity of sludge generated per gallon of water treated, which is an important parameter related to determining the operating and maintenance costs for the technology. The “Lab Results” reported in Table 4-2 are based on solids that settled under gravity settling condition. For each set of tests, solids were separated from the water column by gravity filtration, and three representative samples were taken and split for third party analysis. The volumes of pressed solids posted for each set of parameters were estimated, based on experience, from the volume of solids settled in the various samples generated under the associated set of parameters.

TABLE 4-2. SOLIDS GENERATION FROM LOW STRENGTH WATER TESTS UNDER SUMMER CONDITIONS

Solids Generation	Test 14	Test 15
Lab Results (g/100mL)	0.059	0.084
Pressed Solids (ft^3/1,000 gallons)	0.06	0.09

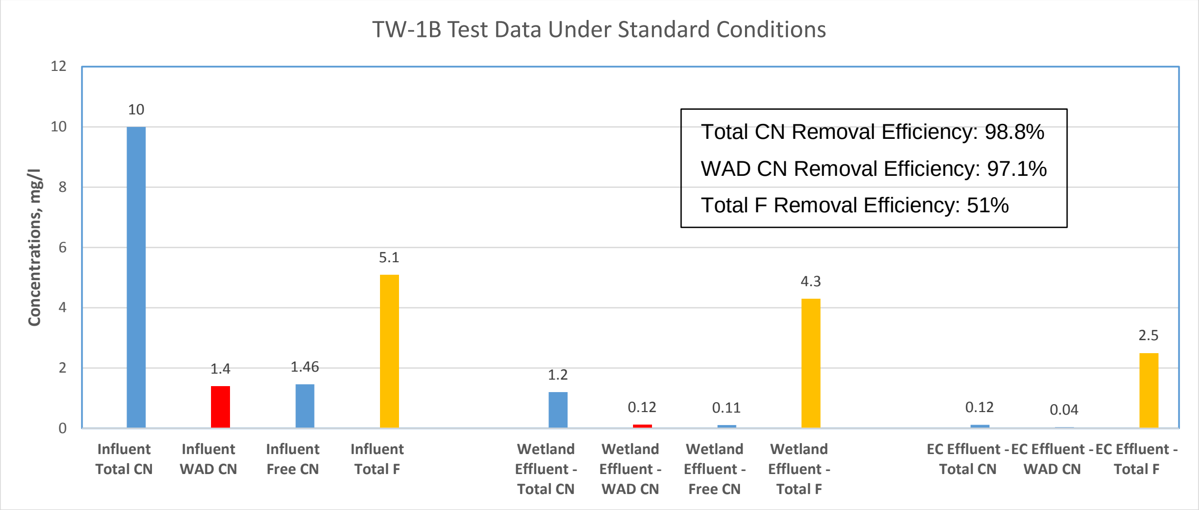
As shown in Table 4-1, the tests performed under summer temperature conditions also removed the primary constituents of concern below the regulatory compliance level. Figure 4-1 provides a graphical representation of the average total cyanide, WAD cyanide and fluoride concentration levels at different point of the treatment train (wetland influent, wetland effluent, EC effluent) and the associated removal efficiencies under standard conditions (HRT = 7 days, Solar Intensity = 153 Watt/m2 and Water Temperature = 22^{o}C) with the low strength water from well TW-1B. A total of 30 monitored influent data and corresponding effluent data was used for the wetland data analysis, with minimum and maximum total cyanide ranging between 0.2 and 2.74 mg/l while the WAD cyanide ranged from 0.08 to 0.19 mg/l at the wetland effluent.

The wetland vegetation looked healthy with no signs of any deleterious impact on the flora at the end of the operation under standard conditions with well TW-1B water as evidenced by Figure 4-2.

4.1.2 High Flow Conditions

Under the high flow conditions described in Table 3-4 (HRT = 4 days; Solar intensity = 153 Watt/m2, water temperature = 22^{o}C), the treatment of low strength water from well TW-1B for a period of 7 days resulted in an average total cyanide removal efficiency of 70%, with average concentration of total cyanide, WAD cyanide and free cyanide recorded to be 2.9 mg/l, 0.17 mg/l and 0.167 mg/l, respectively at the wetland effluent. The average fluoride

FIGURE 4-1. AVERAGE PROFILES OF TOTAL CYANIDE, WAD CYANIDE AND FLUORIDE THROUGHOUT THE WETLAND EC PROCESS TREATMENT TRAIN UNDER STANDARD CONDITIONS FOR WELL WATER TW-1B



concentration level recorded for this period at the wetland effluent was 4.8 mg/l, which indicated a mere 7% removal of total fluoride in the wetland. No water was sent to BakerCorp-Kaselco for further testing. However, based on results generated from standard condition tests reported earlier, it is reasonable to assume that the EC methodology will be able to treat this water to low levels as indicated in Table 4-1.

4.1.3 Low Flow Conditions

Under the low flow conditions described in Table 3-4 (HRT = 10 days; Solar intensity = 153 Watt/m^2, water temperature = 22^{o}C), the treatment of low strength water from well TW-1B for a period of 14 days resulted in an average total cyanide removal efficiency of 87%, with average concentration of total cyanide, WAD cyanide and free cyanide recorded to be 1.3

FIGURE 4-2. WETLAND VEGETATION AT THE CONCLUSION OF THE LOW STRENGTH WATER (TW-1B) TEST

mg/l, 0.046 mg/l and 0.029 mg/l, respectively at the wetland effluent. The average fluoride concentration level recorded for this period at the wetland effluent was 4.47 mg/l, which indicated a mere 13% removal of total fluoride in the wetland. Based on results generated from standard condition tests reported earlier, it is reasonable to assume that the EC methodology will be able to treat this water to low levels as indicated in Table 4-1.

4.1.4 Winter Conditions

Under the winter conditions described in Table 3-4 (HRT = 7 days; Solar intensity = 94 Watt/m2, water temperature = 4-5^{o}C), the treatment of low strength water from well TW-1B for a period of 8 days resulted in an average total cyanide removal efficiency of 85%, with average concentration of total cyanide, WAD cyanide and free cyanide recorded to be 1.45 mg/l, 0.036 mg/l and 0.033 mg/l, respectively at the wetland effluent. The average fluoride concentration level recorded for this period at the wetland effluent was around 5.0 mg/l, which indicated no appreciable removal of total fluoride in the wetland.

Table 4-3 shows typical results from EC testing on a sample batch under cold condition (33^{o}F ~ 0^{o}C water temperature). Note, some difference was observed between the water analyzed by BakerCorp labelled as "Low Strength-Post Wetland" in Table 4-3 and the data reported earlier for cyanide and fluoride levels (i.e., average concentration of total cyanide, WAD cyanide, free cyanide and total fluoride recorded at wetland effluent to be 1.45 mg/l, 0.036 mg/l and 0.033 mg/l and 5.0 mg/l, respectively). This is because, the post wetland data from ATC were average data over the entire course of wetland testing under that specific test condition, while the wetland treated water that was furnished to BakerCorp for EC testing was a grab sample within that test period. As shown in Table 4-3, the final effluent from the EC treatment resulted in very low concentrations of primary constituents, namely, total and WAD cyanide as well as fluoride, all of them were below the compliance levels. Table 4-4 outlines the results of the solids generation from the EC tests for this condition.

Figure 4-3 provides a pictorial representation of the average total cyanide, WAD cyanide and fluoride concentration levels at different point of the treatment train (wetland influent, wetland effluent, EC effluent) and the associated removal efficiencies under winter conditions [HRT = 7 days, Solar Intensity = 94 Watt/m2 and Water Temperature = 4-5^{o}C within wetland and 33^{o}F (~0^{o}C) for EC testing] with the low strength water from well TW-1B.

TABLE 4-3. RESULTS FROM EC TESTING OF LOW STRENGTH WATER UNDER COLD CONDITIONS (33^{O}F WATER TEMP)

Constituent	Low Strength - Post Wetland, mg/l	Test 12 - EC Effluent, mg/l
Aluminum	<0.1	<0.1
Arsenic	<0.02	<0.02
Barium	<0.02	<0.02
Boron	<0.5	<0.5
Cadmium	<0.01	<0.01
Calcium	7.99	7.58
Chromium	<0.02	<0.02
Copper	<0.02	0.0563
Iron	1.23	0.398
Lead	<0.02	<0.02
Magnesium	5.13	3.99
Manganese	0.0488	0.0798
Molybdenum	<0.02	<0.02
Nickel	<0.02	<0.02
Potassium	1.09	3.62
Selenium	<0.02	<0.02
Silicon	<2	<2
Silver	<0.01	<0.01
Sodium	131	143
Strontium	<0.05	<0.05
Zinc	<0.05	<0.05
Cyanide, Total	2.1	**0.171**
Cyanide, WAD	0.0593	**0.0092**
Fluoride	4.28	**<2.5**

As shown in Figure 4-3, the wetland-EC system was able to treat the TW-1B well water to below the regulatory compliance level.

4.2 TREATMENT OF MODERATE STRENGTH GROUNDWATER FROM WELL KMCP-4B

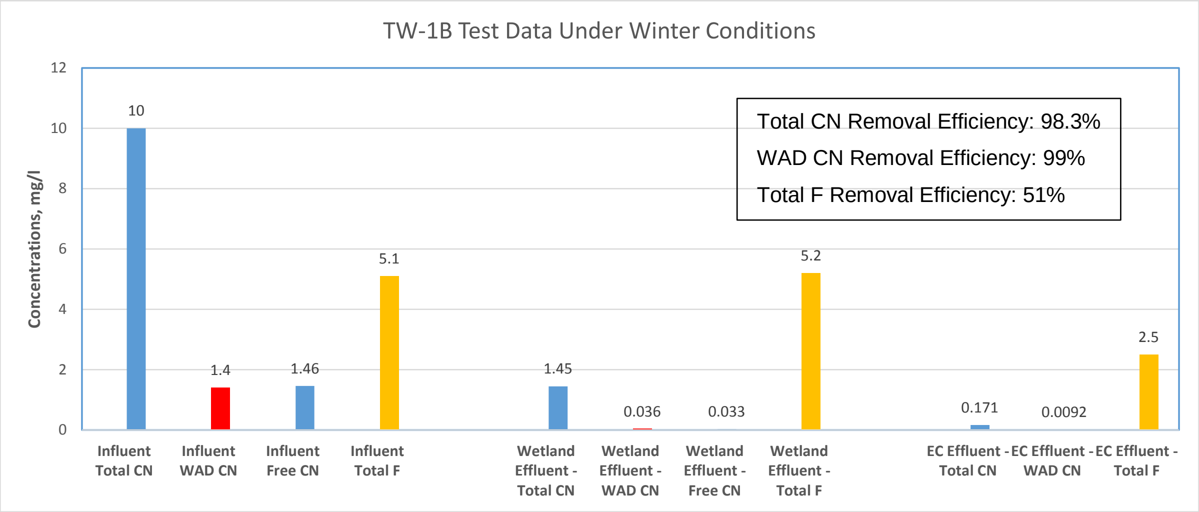
4.2.1 Standard Conditions

Under the standard conditions described in Table 3-4 (HRT = 7 days; Solar intensity = 153 Watt/m2, water temperature = 22^{o}C), the treatment of moderate strength water from well KMCP-4B for a period of 10 days resulted in an average total cyanide removal efficiency of

TABLE 4-4. SOLIDS GENERATION FROM LOW STRENGTH WATER TESTS UNDER COLD CONDITIONS

Solids Generation	Test 12
Lab Results (g/100mL)	0.058
Pressed Solids (ft^3/1,000 gallons)	0.06

FIGURE 4-3. AVERAGE PROFILES OF TOTAL CYANIDE, WAD CYANIDE AND FLUORIDE THROUGHOUT THE WETLAND EC PROCESS TREATMENT TRAIN UNDER WINTER CONDITIONS FOR WELL WATER TW-1B



84%, with average concentration of total cyanide, WAD cyanide and free cyanide recorded to be 2.9 mg/l, 0.14 mg/l and 0.1 mg/l, respectively at the wetland effluent. The average fluoride concentration level recorded for this period at the wetland effluent was 12.7 mg/l, which indicated a mere 18% removal of total fluoride in the wetland.

Approximately 10 gallons of water from the wetland effluent during the middle of the 10-day test period was sent to BakerCorp-Kaselco for evaluation of fluoride and cyanide treatment via the Electro-Coagulation (EC) test scheme. BakerCorp-Kaselco performed 10 different tests with this water (Bracket 1 and Bracket 2), 4 tests performed under cold conditions mimicking the winter conditions (Bracket 1) and 6 tests were performed using ambient water temperature (Bracket 2).

Table 4-5 shows the results from a typical moderate strength water tests under summer conditions (water temperature = 80^{o}F or 27^{o}C). Note, some difference was observed between the water analyzed by BakerCorp labelled as "Moderate Strength-Post Wetland" in Table 4-5 and the data reported earlier for cyanide and fluoride levels (i.e., average concentration of total cyanide, WAD cyanide, free cyanide and total fluoride recorded at wetland effluent to be 2.9 mg/l, 0.14 mg/l, 0.1 mg/l and 12.7 mg/l, respectively). This is because, the post wetland data from ATC were average data over the entire course of wetland testing under that specific test condition, while the wetland treated water that was furnished to BakerCorp for EC testing was a grab sample within that test period. Table 4-6 outlines the results of the solids generation from the EC tests for this condition. This information corresponds to the quantity of sludge generated per gallon of water treated, which is an important parameter related to determining the operating and maintenance costs for the technology.

As shown in Table 4-5, the tests performed under summer temperature conditions removed the primary constituents of concern below the regulatory compliance level. Figure 4-4 provides a pictorial representation of the average total cyanide, WAD cyanide and fluoride concentration levels at different point of the treatment train (wetland influent, wetland effluent, EC effluent) and the associated removal efficiencies under standard conditions (HRT = 7 days, Solar Intensity = 153 Watt/m2 and Water Temperature = 22^{o}C) with the moderate strength water from well KMCP-4B. A total of 10 data points were used to develop the concentration profiles in the wetland, with minimum and maximum total cyanide ranging between 0.3 and 8.5 mg/l while the WAD cyanide ranged from 0.08 to 0.18 mg/l at the wetland effluent.

TABLE 4-5. RESULTS FROM EC TESTING OF MODERATE STRENGTH WATER UNDER SUMMER CONDITIONS (80^{O}F WATER TEMP)

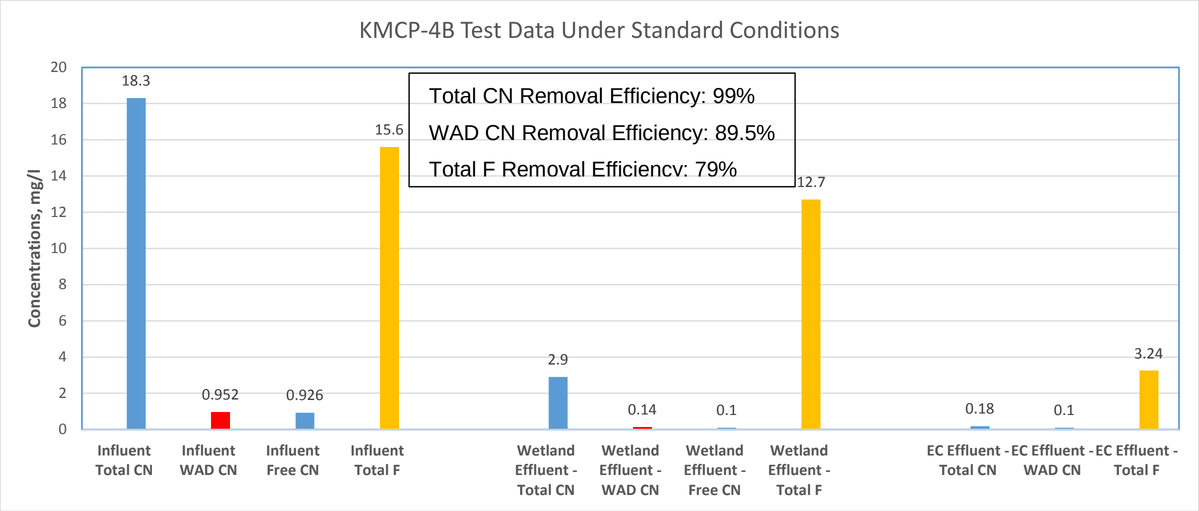
Constituent	Moderate Strength - Post Wetland, mg/l	Test 17 2A -EC Effluent, mg/l	Test 17 2B - EC Effluent, mg/l	Test 17 3A - EC effluent, mg/l
Aluminum	<0.1	0.153	0.15	0.116
Arsenic	<0.02	<0.02	<0.02	<0.02
Barium	0.0402	<0.02	<0.02	<0.02
Boron	<0.5	<0.5	<0.5	<0.5
Cadmium	<0.01	<0.01	<0.01	<0.01
Calcium	20.1	46	27.8	28.3
Chromium	<0.02	<0.02	<0.02	<0.02
Copper	<0.02	0.393	0.357	0.308
Iron	3.95	0.335	0.224	<0.2
Lead	<0.02	<0.02	<0.02	<0.02
Magnesium	13.8	11.3	10.1	9.54
Manganese	0.139	0.206	0.181	0.338
Molybdenum	<0.02	<0.02	<0.02	<0.02
Nickel	<0.02	<0.02	<0.02	<0.02
Potassium	3.24	5.35	6.51	7.41
Selenium	<0.02	<0.02	<0.02	<0.02
Silicon	<2	<2	<2	<2
Silver	<0.01	<0.01	<0.01	<0.01
Sodium	350	436	433	424
Strontium	0.0879	0.0616	<0.05	<0.05
Zinc	<0.05	<0.05	<0.05	<0.05
Cyanide, Total	2.82	**0.166**	**0.143**	**0.238**
Cyanide, WAD	0.529	**0.122**	**0.122**	**0.0749**
Fluoride	12.7	**3.93**	**3.29**	**2.5**

As shown in Figure 4-4, the wetland-EC system was able to treat the moderately strong well water KMCP-4B to levels below the regulatory compliance standard under the standard condition of testing. The wetland vegetation also looked healthy with no signs of any deleterious impact on the flora and fauna at the end of the operation under standard conditions with well KMCP-4B water as evidenced by Figure 4-5.

TABLE 4-6. SOLIDS GENERATION FROM MODERATE STRENGTH WATER TESTS UNDER SUMMER CONDITIONS

Solids Generation	Test 17 2A	Test 17 2B	Test 17 3A
Lab Results (g/100mL)	0.159	0.232	0.274
Pressed Solids (ft^3/1,000 gallons)	0.17	0.25	0.29

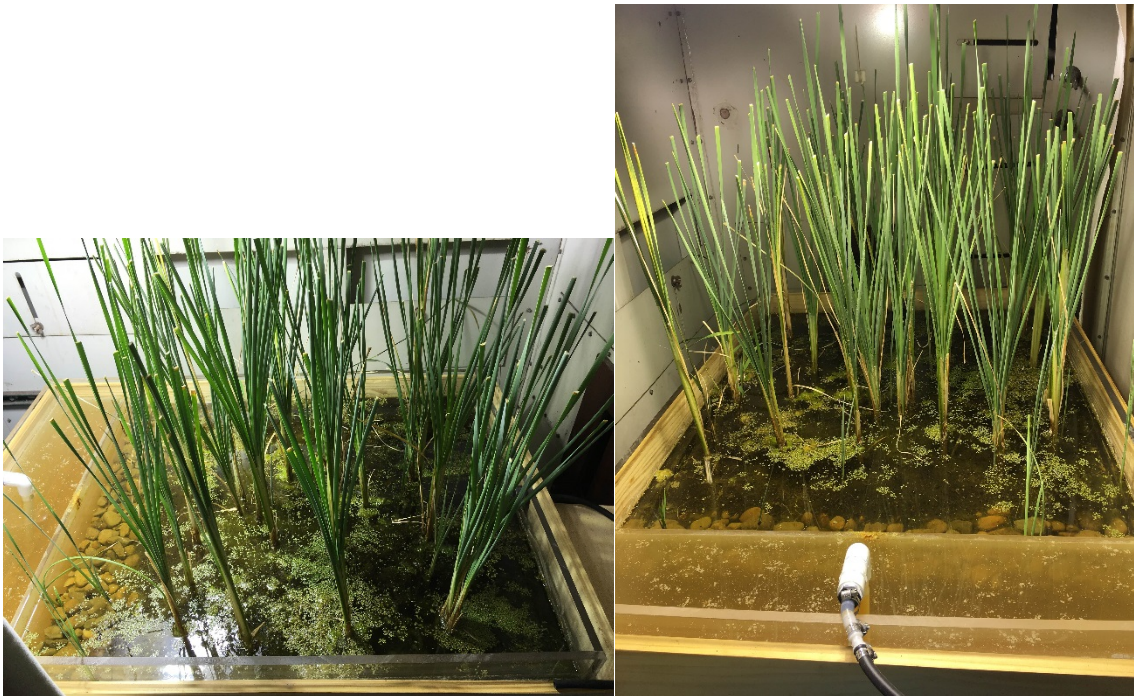
FIGURE 4-4. AVERAGE PROFILES OF TOTAL CYANIDE, WAD CYANIDE AND FLUORIDE THROUGHOUT THE WETLAND EC PROCESS TREATMENT TRAIN UNDER STANDARD CONDITIONS FOR WELL WATER KMCP-4B



4.2.2 Low Flow Conditions

Under the low flow conditions described in Table 3-4 (HRT = 10 days; Solar intensity = 153 Watt/m2, water temperature = 22°C), the treatment of moderate strength water from well KMCP-4B for a period of 27 days resulted in an average total cyanide removal efficiency of 65%, with average concentration of total cyanide, WAD cyanide and free cyanide recorded to be 6.3 mg/l, 0.14 mg/l and 0.05 mg/l, respectively at the wetland effluent. The average fluoride concentration level recorded for this period at the wetland effluent was 19 mg/l, which indicated no removal whatsoever. During this testing period, because of prolonged

FIGURE 4-5. WETLAND VEGETATION AT THE CONCLUSION OF THE MODERATE STRENGTH WATER (KMCP-4B) TEST



low flow situation, there were areas within the wetland where stagnant zones were created. This was evidenced by dye tests. As a result, short-circuiting of flow occurred creating confounding results with respect to removal efficiencies. Henceforth, all follow-on tests were performed with a maximum of 7-day HRT.

During this extended period of testing, a 55-gallon drum of wetland effluent was sent to BakerCorp. This test was conducted specifically to generate a sufficient volume of sludge for conducting an analysis to determine the TCLP characteristics of the solids removed from the waste stream during EC treatment.

4.2.3 Winter Conditions

Under the winter conditions described in Table 3-4 (HRT = 7 days; Solar intensity = 94 Watt/m2, water temperature = 4-5^{o}C), the treatment of moderate strength water from well KMCP-4B for a period of 11 days resulted in an average total cyanide removal efficiency of

55%, with average concentration of total cyanide, WAD cyanide and free cyanide recorded to be 8.24 mg/l, 0.26 mg/l and 0.14 mg/l, respectively at the wetland effluent. The average fluoride concentration level recorded for this period at the wetland effluent was around 15.8 mg/l, which indicated no appreciable removal of total fluoride in the wetland.

Table 4-7 shows typical results from EC testing on a sample batch under cold condition (33F water temperature). Note, some difference was observed between the water analyzed by BakerCorp labelled as "Moderate Strength-Post Wetland" in Table 4-7 and the data reported earlier for cyanide and fluoride levels (i.e., average concentration of total cyanide, WAD cyanide, free cyanide and total fluoride recorded at wetland effluent to be 8.24 mg/l, 0.26 mg/l, 0.14 mg/l and 15.8 mg/l, respectively). This is because, the post wetland data from ATC were average data over the entire course of wetland testing under that specific test condition, while the wetland treated water that was furnished to BakerCorp for EC testing was a grab sample within that test period. As shown in Table 4-7, the final effluent from the EC treatment resulted in very low concentrations of primary constituents, namely, total and WAD cyanide as well as fluoride, all of them were below the compliance levels. Table 4-8 outlines the results of the solids generation from the EC tests for this condition.

Figure 4-6 provides a pictorial representation of the average total cyanide, WAD cyanide and fluoride concentration levels at different point of the treatment train (wetland influent, wetland effluent, EC effluent) and the associated removal efficiencies under winter conditions [HRT = 7 days, Solar Intensity = 94 Watt/m2 and Water Temperature = 4-5^{o}C within wetland and 33^{o}F (0^{o}C) for EC testing] with the moderate strength water from well KMCP-4B.

As shown in Figure 4-6, the wetland-EC system was able to treat the moderately strong well water KMCP-4B to levels below the regulatory compliance standard.

TABLE 4-7. RESULTS FROM EC TESTING OF MODERATE STRENGTH WATER UNDER COLD CONDITIONS (33^{O}F WATER TEMP)

Constituent	Moderate Strength Post Wetland, mg/l	Test 1 2A - EC Effluent, mg/l	Test 1 2B - EC effluent, mg/l	Test 1 3A - EC effluent, mg/l	Test 4 - EC effluent, mg/l
Aluminum	<0.1	0.124	0.118	<0.1	0.171
Arsenic	<0.02	<0.02	<0.02	<0.02	<0.02
Barium	0.0402	<0.02	<0.02	<0.02	<0.02
Boron	<0.5	<0.5	<0.5	<0.5	<0.5
Cadmium	<0.01	<0.01	<0.01	<0.01	<0.01
Calcium	20.1	65.7	65.8	57.6	15.1
Chromium	<0.02	<0.02	<0.02	<0.02	<0.02
Copper	<0.02	0.265	0.243	0.234	0.308
Iron	3.95	0.337	0.385	<0.2	<0.2
Lead	<0.02	<0.02	<0.01	<0.02	<0.02
Magnesium	13.8	11.9	10.1	9.65	8.99
Manganese	0.139	0.0449	0.0404	0.0485	0.082
Molybdenum	<0.02	<0.02	<0.02	<0.02	<0.02
Nickel	<0.02	<0.02	<0.02	<0.02	<0.02
Potassium	3.24	4.79	4.59	5.21	7.52
Selenium	<0.02	<0.02	<0.02	<0.02	<0.02
Silicon	<2	<2	<2	<2	<2
Silver	<0.01	<0.01	<0.01	<0.01	<0.01
Sodium	350	343	352	348	351
Strontium	0.0879	0.0695	0.0677	0.0615	0.0518
Zinc	<0.05	<0.05	<0.05	<0.05	<0.05
Cyanide, Total	2.82	**0.457**	**0.398**	**0.29**	**0.445**
Cyanide, WAD	0.529	**0.158**	**0.199**	**0.143**	**0.187**
Fluoride	12.7	**3.85**	**3.4**	**2.5**	**3.78**

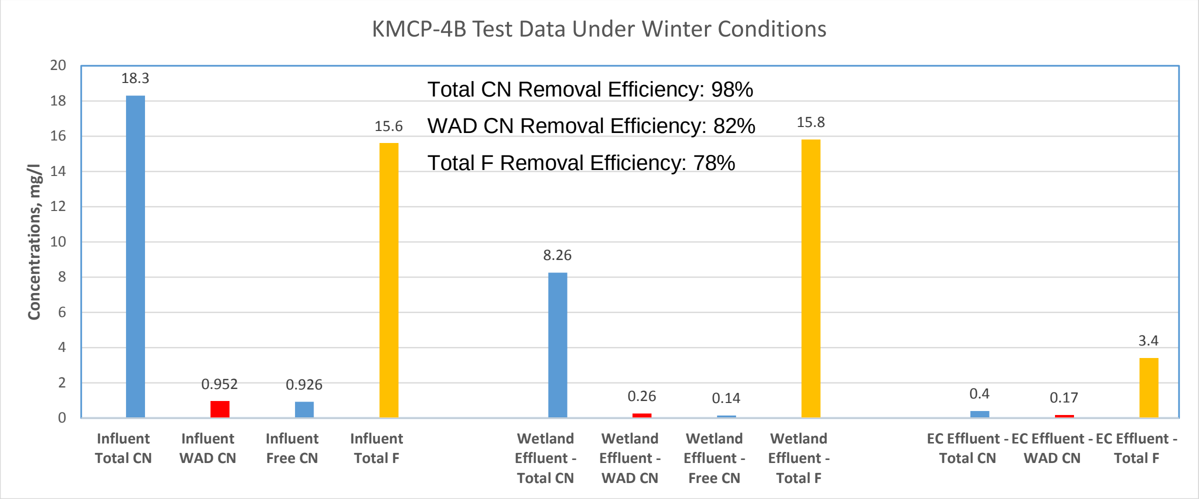
High Flow Conditions

Under the high flow conditions described in Table 3-4 (HRT = 4 days; Solar intensity = 153 Watt/m2, water temperature = 22^{o}C), the treatment of medium strength water from well KMCP-4B for a period of 7 days resulted in an average total cyanide removal efficiency of 41%, with average concentration of total cyanide, WAD cyanide and free cyanide recorded to be 11 mg/l, 0.57 mg/l and 0.3 mg/l, respectively at the wetland effluent. The average fluoride concentration level recorded for this period at the wetland effluent was 16 mg/l,

TABLE 4-8. SOLIDS GENERATION FROM MODERATE STRENGTH WATER TESTS UNDER COLD CONDITIONS

Solids Generation	Test 1 2A	Test 1 2B	Test 1 3A	Test 4
Lab Results (g/100mL)	0.211	0.191	0.228	0.125
Pressed Solids (ft^3/1,000 gallons)	0.23	0.2	0.24	0.13

FIGURE 4-6. AVERAGE PROFILES OF TOTAL CYANIDE, WAD CYANIDE AND FLUORIDE THROUGHOUT THE WETLAND EC PROCESS TREATMENT TRAIN UNDER WINTER CONDITIONS FOR WELL WATER KMCP-4B



which indicated no removal of total fluoride in the wetland. No water was sent from the high flow tests for submission to BakerCorp-Kaselco for EC evaluation.

4.3 TCLP TESTING RESULTS OF SLUDGE FROM EC TESTING USING WELL WATER FROM KMCP-4B

As described previously in Section 4.2.2, a 55 gallon drum of wetland effluent generated during the low flow testing of the well KMCP-4B water was used to generate the necessary solids amount to perform the TCLP testing. Prior to testing 62.5 g of calcium chloride was added to the 55-gallon sample, and the pH of the sample was adjusted to approximately 7.2 using 7 mL of sulfuric acid.

As with all the previous tests described, bench testing was conducted using BakerCorp's Hi-Flo® reactor in the 07 configuration with a combination of iron and aluminum plates. The flow rate was set to 0.83 gpm using an air-operated diaphragm pump, but did vary somewhat throughout the testing due to fluctuations in service air pressure.

Treatment was accomplished after two passes through the bench-scale reactor over a period of 90 minutes. Operational data were recorded at 15-minute intervals throughout the treatment process.

After EC treatment 40 gallons of water was aerated and mixed for 70 minutes. After aeration, the pH was adjusted to 7.2 by adding 4 mL of sulfuric acid. The sample was then dosed with 25 mL of polymer (1.2 g/L) and mixed for 10 minutes.

After mixing the floc that had been formed appeared to be extremely fragile, and it tended to shear if mixed too rapidly. The floc did settle in the water column, but the settling rate was very slow. At that point an additional 25 mL of polymer was added and mixed for 5 minutes; however, this produced no noticeable improvement in the durability or settling rate of the floc. An additional 20 mL of floc was added, and the sample mixed slowly for 1 minute. This significantly improved the quality of the floc, which quickly settled out of the water column. The optimum dose of polymer for this waste stream under the protocol described appears to be 70 mL (for 40 gallons of sample).

Solid-liquid separation was achieved using gravity flow through 1-micron bag filters. The resulting filtrate was clear. The solids were air dried, and 3.152 pounds of sludge with a moisture content of 91.4% was collected for TCLP analysis. The results from the TCLP analysis is provided in Table 4-9. As shown in Table 4-9, third party analysis revealed that the solids generated using BakerCorp's EC treatment protocol met the RCRA-8 metals TCLP

TABLE 4-9. TCLP ANALYSIS OF SAMPLES

Constituent	Test 19
Ignitability/Flash Point	Not Ignitable
pH (pH Units)	8.1
TCLP-Arsenic (mg/L)	<0.5
TCLP-Barium (mg/L)	<5
TCLP-Cadmium (mg/L)	<0.1
TCLP-Chromium (mg/L)	<0.5
TCLP-Lead (mg/L)	<0.2
TCLP-Mercury (mg/L)	<0.004
TCLP-Selenium (mg/L)	<0.1
TCLP-Silver (mg/L)	<0.5
Reactive cyanide (mg/kg)	<1
Reactive sulfide (mg/kg)	<20

criteria. The solids are not ignitable; reactive cyanide and sulfide concentrations were below detection limits; the pH is 8.1. After filtering 40 gallons of treated water, 3.152 pounds of solids were collected

The 3.152 lbs. of solids equates to approximately 0.03 ft^3 based on an estimated density of 110 lbs. per ft^3. This is approximately double the volume of solids removed during the individual tests conducted previously, but because of the large volumes of water processed during this test it should be regarded as more representative of the volume of solids that will be generated during ongoing operations.

4.4 TREATMENT OF HIGH STRENGTH GROUNDWATER FROM WELL KM-5

Under the standard conditions described in Table 3-4 (HRT = 7 days; Solar intensity = 153 Watt/m2, water temperature = 22^{o}C), the treatment of high strength water from well KM-5 for a period of 11 days resulted in an average total cyanide removal efficiency of 60%, with average concentration of total cyanide, WAD cyanide and free cyanide recorded to be 25 mg/l, 1.34 mg/l and 0.08 mg/l, respectively at the wetland effluent. The average fluoride concentration level recorded for this period at the wetland effluent was 38 mg/l, which indicated a mere 16% removal of total fluoride in the wetland.

Approximately 10 gallons of water from the wetland effluent during the middle of the 11-day test period was sent to BakerCorp-Kaselco for evaluation of fluoride and cyanide treatment via the Electro-Coagulation (EC) test scheme. BakerCorp-Kaselco performed 2 different tests with this water (Bracket 6). The first test (20) was performed under ambient water condition (80°F or 27°C) and the second test (21) was performed under cold water conditions (33°F or ~0°C). Prior to testing, the pH of the sample was adjusted to 7.13 using 0.8 mL of sulfuric acid. Calcium chloride was dosed at a rate of 1 gram per liter.

After EC treatment the sample was aerated for 30 minutes. After aeration the pH of each was adjusted to approximately 7.10 (range7.0 to 7.2) using 0.1 mL of sulfuric acid. After the pH was adjusted, 1.2 mL of polymer was added and the sample mixed for 10 minutes. After 10 minutes, solids were removed from the treated sample via gravity filtration. The settling rate of the solids removed was observed, and an estimate of the volume of solids that would result from dewatering the treated waste stream in a filter press was calculated.

Table 4-9 shows the results from Test 20 and Test 21. Note, some difference was observed between the water analyzed by BakerCorp labelled as “High Strength-Post Wetland” in Table 4-9 and the data reported earlier for cyanide and fluoride levels (i.e., average concentration of total cyanide, WAD cyanide, free cyanide and total fluoride recorded at wetland effluent to be 25 mg/l, 1.34 mg/l, 0.08 mg/l and 38 mg/l, respectively). This is because, the post wetland data from ATC were average data over the entire course of wetland testing under that specific test condition, while the wetland treated water that was furnished to BakerCorp for EC testing was a grab sample within that test period. As shown in the table, EC treatment under both ambient and cold water temperature exhibited significant removal of total cyanide and fluoride, with fluoride reaching concentrations lower than regulatory compliance levels. However, the WAD cyanide results did not meet the 0.2 mg/l compliance level. Between the two tests, the test conducted under ambient water temperature performed better with respect to total and WAD cyanide removal in contrast to the test conducted under winter water temperature. Table 4-10 outlines the results of solids generation from the EC tests under these conditions.

TABLE 4-10. RESULTS FROM EC TESTING OF HIGH STRENGTH WATER UNDER AMBIENT & COLD CONDITIONS

Constituent	High Strength - Post Wetland, mg/l	Test 20 3A - EC effluent, mg/l	Test 21 3A -EC Effluent, mg/l
Aluminum	0.209	<0.1	0.29
Arsenic	0.149	<0.02	<0.02
Barium	0.0226	<0.02	<0.02
Boron	<0.5	<0.5	<0.5
Cadmium	<0.01	<0.01	<0.01
Calcium	10.6	58.1	90
Chromium	0.0341	0.0348	<0.02
Copper	<0.02	0.835	0.58
Iron	14.6	7.97	9.54
Lead	<0.02	<0.02	<0.02
Magnesium	10.6	7.98	10.1
Manganese	0.0972	0.105	0.111
Molybdenum	<0.02	<0.02	<0.02
Nickel	<0.02	0.197	0.221
Potassium	8.25	9.06	9.34
Selenium	<0.02	<0.02	<0.02
Silicon	4.69	<2	<2
Silver	<0.01	<0.01	<0.01
Sodium	1080	1240	1260
Strontium	<0.05	<0.05	<0.05
Zinc	<0.05	<0.05	0.194
Cyanide, Total	16.6	1.54	3.81
Cyanide, WAD	4.11	0.762	2.44
Fluoride	37.7	2.9	3.61

Table 4-11 outlines the results of the solids generation from the EC tests for these conditions. Figure 4-7 provides a pictorial representation of the average total cyanide, WAD cyanide and fluoride concentration levels at different point of the treatment train (wetland influent, wetland effluent, EC effluent) and the associated removal efficiencies under standard conditions (HRT = 7 days, Solar Intensity = 153 Watt/m^2 and Water Temperature = 22^{o}C within wetland and 80F for EC testing) with the high strength water from well KM-5. As shown in Figure 4-7, the wetland-EC system was able to treat the high strength well water from KM-5 to a large extent and consequently this particular form of treatment process has potential to remove significant mass of cyanide and fluoride from the plume center of mass.

FIGURE 4-7. AVERAGE PROFILES OF TOTAL CYANIDE, WAD CYANIDE AND FLUORIDE THROUGHOUT THE WETLAND EC PROCESS TREATMENT TRAIN UNDER STANDARD CONDITIONS FOR WELL WATER KM-5

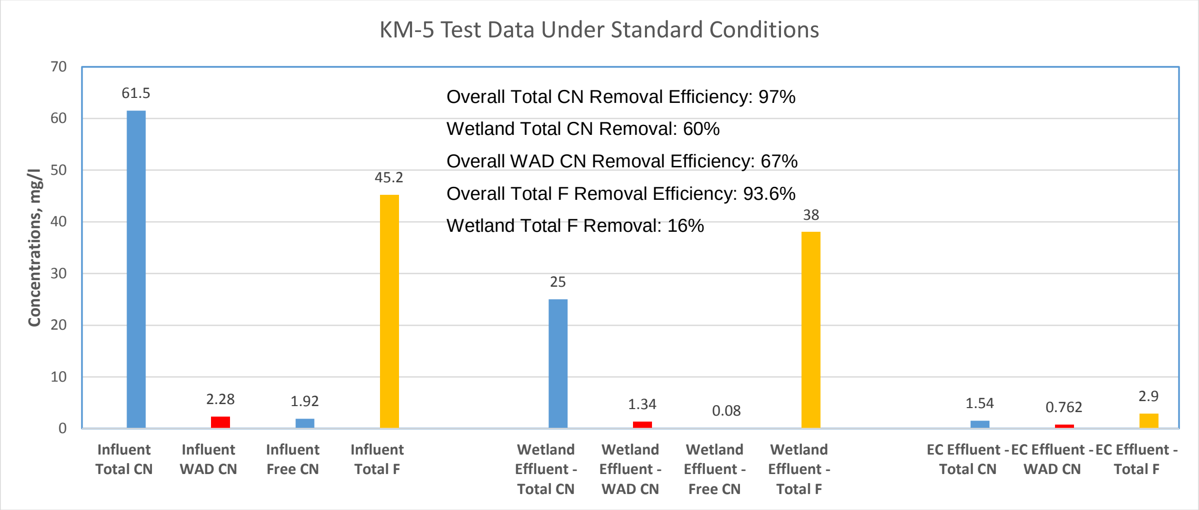


Figure 4-8 shows the state of wetland vegetation following the exposure to the high strength water for about 2 weeks. The wetland vegetation looked somewhat healthy (minor signs of fluorosis indicated by brownness of the shoots), which is usually recoverable. In fact, certain wetland organisms, such as worms and minnows were seen living in the environment even after being exposed to high concentrations of cyanide and fluoride. Following the exposure to high strength water, the wetland was flushed for few weeks with medium strength water and much of the brownness of the shoots seen earlier slowly changed into more greenish color indicating a reversible effect.

FIGURE 4-8. WETLAND VEGETATION FOLLOWING EXPOSURE TO HIGH STRENGTH WATER (KM-5) FOR 2 WEEKS

4.5 MASS BALANCE IN THE WETLAND

The wetland system coupled with the EC technology has been successful in removing significant amounts of cyanide and fluoride from the three well waters tested over a period of about 6 months. In total, 23 grams of total cyanide was removed in the wetland system during the course of active testing (acclimatization period not included), which amounts to a wetland total cyanide removal efficiency of 65%. Fluoride removal in the wetland was not very significant, a mere 1.7 grams which amounts to a wetland total fluoride efficiency of only 7%. Further removal of cyanide and a significant removal of fluoride is expected to occur in the EC unit. Because, of the low fluoride removal efficiency, no significant accumulation of fluoride has occurred in the wetland and as such the plants do not show any appreciable signs of fluorosis or any other detrimental effects on the flora and fauna.

Figure 4-9 shows the mass distribution percentages for total cyanide in the wetland during the entire active monitoring period. As shown in Figure 4-9, of the 23 grams of cyanide removed in the wetland, about 76% of the mass loss is attributed to complete cyanide removal via photolysis followed by volatilization and bio-decay, 23.8% is sorbed onto soil media that biodegrades over time and rest – an insignificant 0.4% resides in the plant mass. Cyanide sorbed in the soil matrix undergoes biological degradation over time provided the system maintains certain aerobic conditions, thereby providing long-term sink for effective treatment. Fluoride removal in the wetland is not very significant, which precluded us from performing a detailed mass balance. Previous laboratory and field pilot studies have reported similar mass distribution for cyanide in the wetland (Alcoa R&D Report 05-282).

FIGURE 4-9. MASS DISTRIBUTION OF TOTAL CYANIDE IN THE WETLAND

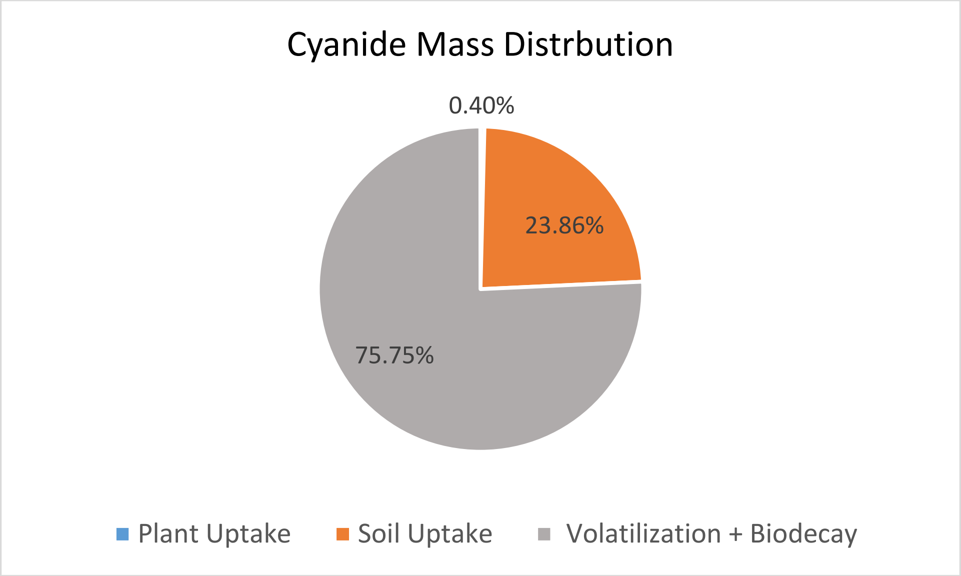


TABLE 4-11. SOLIDS GENERATION FROM HIGH STRENGTH WATER TESTS UNDER AMBIENT & COLD CONDITIONS

Solids Generation	Test 20 3A	Test 21 3A
Lab Results (g/100mL)	0.352	0.145
Pressed Solids (ft^3/1,000 gallons)	0.38	0.15

5.0 DISCUSSION OF RESULTS AND RECOMMENDATION FOR NEXT STEP

The wetland system coupled with the EC technology has been successful in removing significant amounts of cyanide and fluoride from the three well waters tested over a period of about 6 months. The key removal mechanism for cyanide in the wetland is based on photolysis, followed by biodegradation and volatilization. In addition, soil uptake and plant uptake plays secondary and tertiary roles. The wetland system did not affect fluoride removal to any significant extent. The follow-on treatment using electro-coagulation allowed primary treatment of fluoride and further polishing treatment of the already dissociated and attenuated cyanide levels emanating from the wetland. Overall, the wetland-EC coupled system was able to remove significant mass of cyanide and fluoride from the influent waters. The clean-up goals for both cyanide and fluoride were met for the low and moderate strength waters, while the clean-up goal for only fluoride was met for the high strength water.

Based on the testing done to date, certain wetland and EC design parameters seems more optimal than others when it comes to determining overall performance of the treatment system. This section summarizes some of the key findings with respect to:

- Design hydraulic retention time (HRT) to achieve maximum cyanide removal;
- Pilot/full-scale wetland design parameters to achieve optimum cyanide removal;
- % Fluoride and cyanide removal through the EC system;
- Quantity of sludge generated per gallon of water treated in the EC system;
- Sludge characterization results for waste disposal consideration from the EC system;
- Energy usage per gallon of water treated;
- Chemicals used and consumption per gallon of water treated;
- Consumables needed (including estimated life of the electrodes);
- Cost of replacement of electrodes and their availability; and
- Design and cost estimate to conduct a 10 gpm Phase II pilot study based on lab-evaluated design parameters.

5.1 PHASE II FIELD SCALE PILOT TEST WETLAND DESIGN & COST ESTIMATE FOR OPTIMUM CYANIDE REMOVAL

Based on the analysis of the concentration – time data for the low and medium strength water from well number TW-1B and KMCP-4B, respectively, a first order average rate of 0.265 day^{-1} can be calculated for total cyanide removal in the wetland. Based on the data acquired in course of the testing, a HRT of 7 days seems most appropriate for treating the range of cyanide concentrations exhibited by the well waters shown in the site plume (Figure 3-5). Increasing the HRT to 10 days did not make any improvement in the removal rates. An HRT of 4 days yielded a good removal efficiency of 70% for the low strength water from TW-1B but was not sufficient for higher concentration waters, such as from well KMCP-4B. In terms of wetland configuration, the following design parameters are considered optimal to design the Phase II pilot system treating ~10 gpm of well water with total cyanide concentration ranging from 10 to 60 ppm and fluoride levels between 5 and 45 ppm:

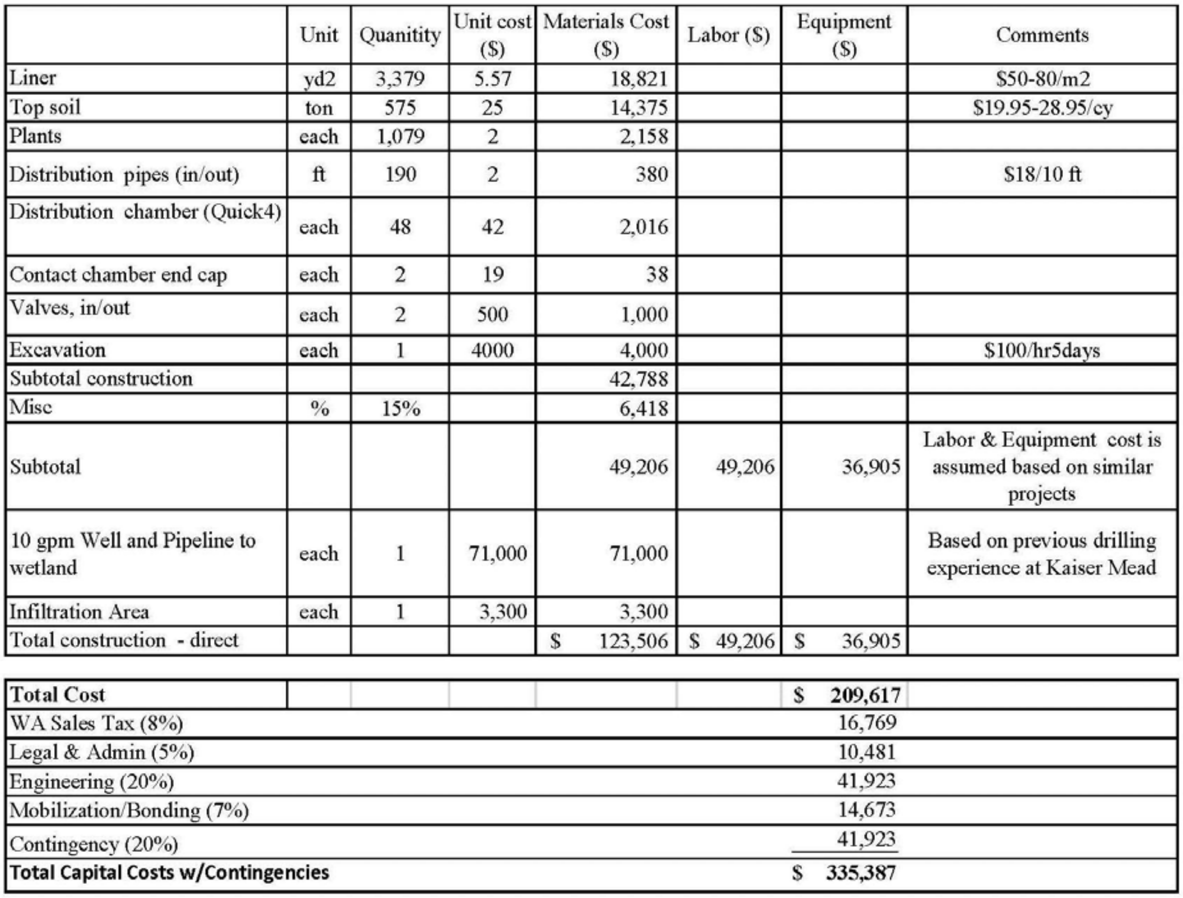
- HRT = 7 days;
- Wetland Length : Width ratio = 3:1 to promote uniform hydraulic mixing and prevent flow channeling;
- Surface water depth = 6-8 inches;
- Organic rich soil with TOC content at least 4% to be used as soil substrate (6-8 inches);
- Recommended Wetland flora: Emergent species like cattails plugs and Pondweed, Submergent and floating-leaned species (coontail) as cuttings;
- Inlet perforated pipe spanning across the width of the wetland can be used at the entrance and exit portion of the wetland for fluid conveyance; and
- About 15% of the entire wetland length should be kept free of vegetation at the entrance section to allow maximum photodissociation.

Based on the results of the laboratory-scale pilot testing, a 10 gpm Phase II field-scale pilot wetland treating moderate and high strength cyanide and fluoride loading would occupy an approximate water volume of 19,251 cu. ft. Such a wetland system would be designed to remove ~70% of total cyanide from the influent if the influent cyanide concentration is between 20 and 60 ppm; higher removal efficiency could be achieved for cyanide levels in the 10 ppm range. Estimated order of magnitude total cost to implement the wetland will be in the vicinity of $155,000. Table 5-1 provides estimated dimension of the free surface wetland system and Table 5-2 provides a rough order of magnitude cost as well as the bill of quantities. As shown in Table 5-1, the pilot wetland will cover an approximate total area of 0.58 acre.

TABLE 5-1. APPROXIMATE DIMENSIONS FOR THE PILOT SCALE WETLAND

Surface Flow Wetland Section (per cell basis)		
Top soil bulk density (sandy)	1.6	g/cm3
Topsoil Bulk Density	99.8784	lb/ft3
Use	100	lb/ft3
Porosity	0.7	Soil 0.36 to 0.43, water 1
Volume needs	19,251.34	ft3
Surface water	6.0	inch
Surface water	0.5	ft
Planting top soil height	0.5	ft
Treatment zone height	1	ft
wetland surface area	22,649	ft2
Aspect ratio	3	:1
Width	86.89	ft
Length	260.66	ft
Side Slopes	2	:1
Bottom Width	85.89	ft
Bottom Length	259.66	ft
Freeboard	1	ft
Top Width	93.89	ft
Top Length	267.66	ft
Footprint	0.58	acres

TABLE 5-2. APPROXIMATE BILL OF QUANTITIES AND CAPEX FOR THE PILOT WETLAND



	Unit	Quanitity	Unit cost ($)	Materials Cost ($)	Labor ($)	Equipment ($)	Comments
Liner	yd2	3,379	5.57	18,821			$50-80/m2
Top soil	ton	575	25	14,375			$19.95-28.95/cy
Plants	each	1,079	2	2,158			
Distribution pipes (in/out)	ft	190	2	380			$18/10 ft
Distribution chamber (Quick4)	each	48	42	2,016			
Contact chamber end cap	each	2	19	38			
Valves, in/out	each	2	500	1,000			
Excavation	each	1	4000	4,000			$100/hr5days
Subtotal construction				42,788			
Misc	%	15%		6,418			
Subtotal				49,206	49,206	36,905	Labor & Equipment cost is assumed based on similar projects
10 gpm Well and Pipeline to wetland	each	1	71,000	71,000			Based on previous drilling experience at Kaiser Mead
Infiltration Area	each	1	3,300	3,300			
Total construction - direct				$ 123,506	$ 49,206	$ 36,905	

Total Cost	**$ 209,617**
WA Sales Tax (8%)	16,769
Legal & Admin (5%)	10,481
Engineering (20%)	41,923
Mobilization/Bonding (7%)	14,673
Contingency (20%)	41,923
Total Capital Costs w/Contingencies	**$ 335,387**

The primary treatment process for cyanide in the water is based on photolysis followed by aerobic microbial metabolism. Hence the vegetation and the organic soil substrate will be the media that houses this microbial interaction. A high organic content soil layer will be installed over the liner in a layer that is approximately 6-8 inch thick. Offsite commercial sources will provide this material. The soil may be amended prior to placement with 5 pounds per cubic foot of organic amendment (wood chips, sawdust, composted leaf mulch, or locally available organic material).

The preferred method of placement of the organic soil is the use of a low ground pressure rubber tired equipment (i.e., ASV Posi Track). Organic soils will be placed along the edge of the wetland cell and spread with rubber tire equipment. If the topsoil becomes compacted during placement, then tilling of the soil will be necessary to a minimum depth of 3 inches. The surface of the organic substrate will be uniform with no slope to minimize scour.

Following the planting of vegetation (planting substrate depth ~ 4 inches) and prior to filling the wetland with water, a layer of straw will be placed on the top of the exposed substrate. The layer of straw will suspend in the water after the wetland is filled. The suspended straw will facilitate quicker microbial activity in the water column.

5.2 PHASE II FIELD SCALE PILOT TEST ELECTRO-COAGULATION UNIT DESIGN FOR OPTIMUM FLUORIDE REMOVAL

Based on the results of the testing, an electro-coagulation (EC) unit is deemed satisfactory to treat residual cyanide and fluoride existing in the wetland system. The data collected in course of testing indicates that an EC unit is capable of removing residual cyanide and fluoride with overall (wetland+EC) cyanide and fluoride removal efficiencies of >90% and 80%, respectively from the well water with total cyanide concentration ranging from 10 to 60 ppm and fluoride levels between 5 and 45 ppm.

In terms of an EC unit configuration downstream of the wetland system, the following design parameters and cost estimates are considered optimal for a Phase II pilot treating ~10 gpm of well water from the medium to high strength areas of the plume:

- Quantity of sludge generated per gallon of water treated in the EC system: Using the results from Test 19 of the bench scale tests (large volume sample we used for TCLP evaluation), we can assume that sludge will be generated during treatment at the rate of 3.152 lbs. (91.4% moisture) per 40 gallons of wastewater, or 0.0788 lbs./gal.

  The filter press to be provided under the proposed scope of work will be configured to allow the dried sludge to be emptied in a sludge hopper. The sludge materials are then transferred into 4’ x 4’ x 4’ SuperSacks for handling, storage, transport, and disposal; however, services under the proposed scope of work do not include sludge handling, storage, transport, or disposal.

- Sludge characterization results for waste disposal consideration from the EC system met RCRA metals TCLP criteria and met all RCRA characteristics waste criteria (non-hazardous).

- Energy usage per gallon of water treated: Based on information derived from bench-scale testing, operation of the electro-coagulation reactor is anticipated to consume 56.6 kWH per 1,000 gallons of wastewater treated. The average rate for industrial electrical power in the Spokane area is 4.13¢ per KwH, which yields a power cost for treatment of $2.34 per 1,000 gallons of wastewater treated. The treatment system will require electrical service of 480VAC, 3-phase, 200 amps; plus auxiliary service of 120/240 VAC, single-phase power, 125 amps.

- Chemicals used and consumption per gallon of water treated:

Reagent	Low Strength Waste Stream	Moderate Strength Waste Stream	High Strength Waste Stream
Calcium Chloride	1.135 grams/gallon	2.271 grams/gallon	3.7854 grams/gallon
H_2SO_4 Pre-Treat (98%)	0.292 gallons H_2SO_4 per 1,000 gallons wastewater treated		
H_2SO_4 Post-Treat (98%)	0.15 gallons H_2SO_4 per 1,000 gallons wastewater treated		
Anionic Polymer (conc.=1.2mL/L)	1.75 mL/gallon (9 grams/1,000 gal.)	1.75 mL/gallon (9 grams/1,000 gal.)	3.17 mL/gallon (16.3 grams/1,000 gal.)
All chemicals are available locally; check for local prices. Alternately, chemicals can be provided on a cost plus basis.			

Calcium chloride was consumed at the rate of 2.271 g/Gal for the moderate strength water. A 50# bag (22,680 grams) of calcium chloride sells for approximately $20; this results in a cost of $2.00 per 1,000 gallons of wastewater treated.

Sulfuric acid was consumed at 0.44 gallons per 1,000 gallons of wastewater treated. Today's price for 98% sulfuric acid is $180 per 55-gallon drum, which results in a cost of $1.44 per 1,000 gallons of wastewater treated.

Anionic polymer was consumed at the rates of 1.75 mL/Gal (dilute and concentrated samples) and 3.17mL/Gal (highly concentrated sample). We use Nalco 9901 Optimer Polymer. Cost is just under $3 per lb or $150 per bag. The powder is mixed to create a 1.2 g/L solution, so one 50-lb bag yields about 19,000 L (5,000 gallons) of liquid polymer. The associated cost for the low and moderate strength waste streams would be about $0.15 per 1,000 gallons of (dilute or concentrated) wastewater treated; $0.27 per 1,000 gallons for high strength concentrated waste stream.

- Consumables needed (including estimated life of the electrodes): Based on the information derived from bench-scale testing, operation of the electro-coagulation reactor is anticipated to consume one set of electrode plates for every 152,100 gallons of water treated. The cost of a set of plates is $678, which yields a unit cost of 0.458¢ ($0.00485) per gallon of wastewater treated.

  With the system operating 8 hours per day at a treatment rate of 10-GPM, the electrode plates will be consumed at the rate of approximately two sets every two months, which yields a projected consumable plate cost of $8,136 for one year’s operation.

The rest of the section provides the approximate cost estimate to conduct a 10 gpm Phase II EC pilot study based on lab-evaluated design parameters for a year:

The wastewater treatment system pilot proposed consists of the following components:

10-GPM Pilot EC Trailer with a Dual Cartridge Hi-Flo vessel and Control System	
pH adjustment Skid	Post Treatment Tank and pump
Equalization Tank	Bag Filter Assembly
Defoam/Floc Skid	Sludge Thickener
Clarifier	Filter Press with Sludge Hopper

Estimated costs related to equipment rental are as follows:

- $10,500 per month for the first six months of rental; $9,950 per month thereafter.
- System mobilization and set-up - $19,000.
- Initial system start-up (additional support labor) - $8,500. (optional if needed).
- System demobilization - $19,000.

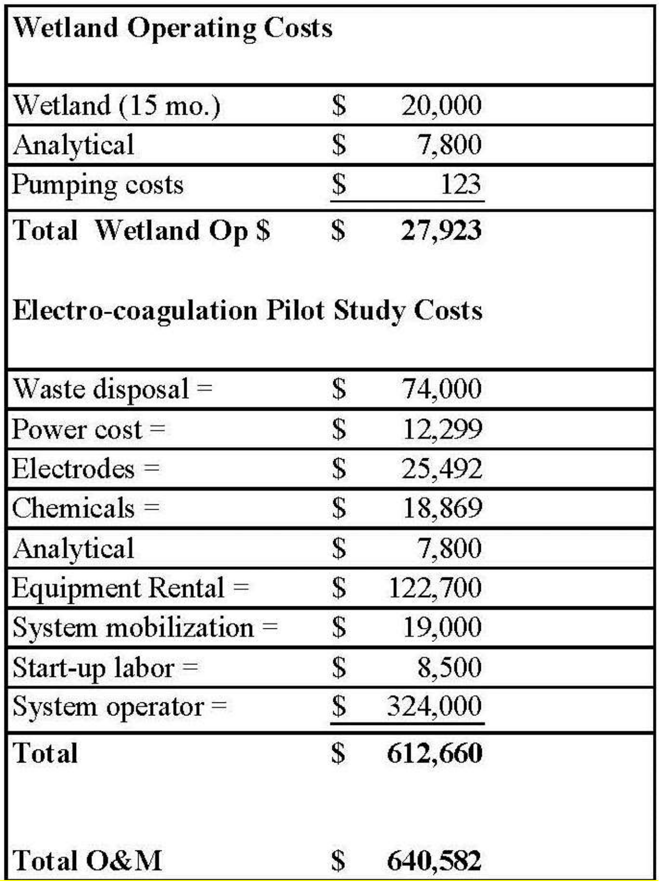
Operators:

BakerCorp will provide sufficient personnel to mobilize the treatment system and to assist with the initial start-up. After initial start-up Baker will provide one qualified operator to run the treatment system 8 hours per day, 5 days per week. Estimated costs related to Operators are as follows:

- One qualified system operator – lump sum of $18,000 per month; includes travel and per diem; and
- Labor and related costs for additional operators required for system set-up and initial start-up is included in the equipment prices delineated above.

Estimated cost of consumables, in terms of chemicals, electricity and electrodes are provided in the beginning of the section. Table 5-3 lists the combined costs of both the wetland and EC field scale pilot study.

TABLE 5-3. COMBINED OPERATION AND MAINTENANCE COST FOR COMBINED WETLAND/EC OPERATION

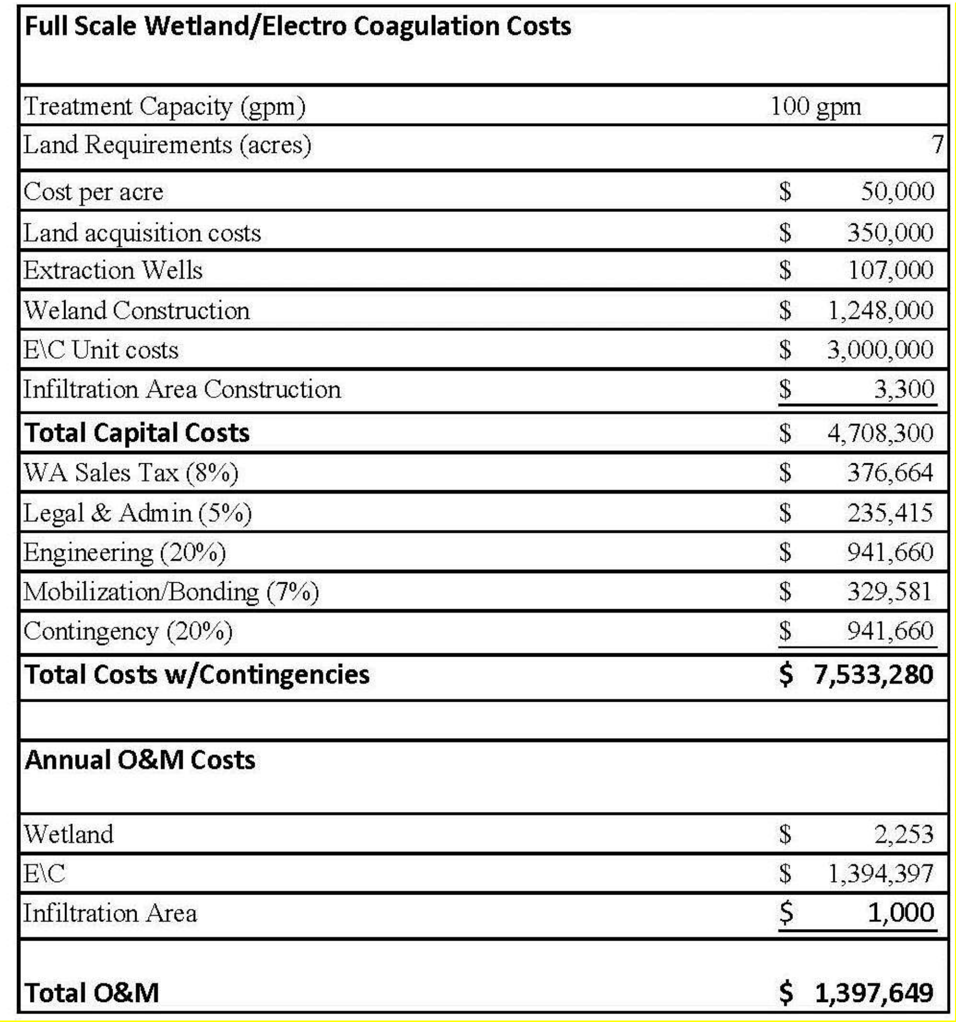


Wetland Operating Costs		
Wetland (15 mo.)	$	20,000
Analytical	$	7,800
Pumping costs	$	123
Total Wetland Op $	$	**27,923**
Electro-coagulation Pilot Study Costs		
Waste disposal =	$	74,000
Power cost =	$	12,299
Electrodes =	$	25,492
Chemicals =	$	18,869
Analytical	$	7,800
Equipment Rental =	$	122,700
System mobilization =	$	19,000
Start-up labor =	$	8,500
System operator =	$	324,000
Total	$	**612,660**
Total O&M	$	**640,582**

5.3 FULL SCALE COST ESTIMATES

Estimates for a full scale (100 gpm) construction and operation of a wetland-electro-coagulation system were developed using data from the pilot scale estimates and additional estimates from BakerCorp and Waste Management, and cost data from US EPA and construction estimate resource publications. The full scale estimates are shown in Table 5-4.

TABLE 5-4. FULL SCALE CONSTRUCTION AND O&M COSTS



Full Scale Wetland/Electro Coagulation Costs	
Treatment Capacity (gpm)	100 gpm
Land Requirements (acres)	7
Cost per acre	$ 50,000
Land acquisition costs	$ 350,000
Extraction Wells	$ 107,000
Weland Construction	$ 1,248,000
E\C Unit costs	$ 3,000,000
Infiltration Area Construction	$ 3,300
Total Capital Costs	$ 4,708,300
WA Sales Tax (8%)	$ 376,664
Legal & Admin (5%)	$ 235,415
Engineering (20%)	$ 941,660
Mobilization/Bonding (7%)	$ 329,581
Contingency (20%)	$ 941,660
Total Costs w/Contingencies	**$ 7,533,280**
Annual O&M Costs	
Wetland	$ 2,253
E\C	$ 1,394,397
Infiltration Area	$ 1,000
Total O&M	**$ 1,397,649**

6.0 REFERENCES

Alcoa Internal R&D Report 05-284. Duck Spring Pilot Scale Wetland Monitoring Project, March 2007

Bauer, 2013. Bauer Resources/Alcoa letter to Scott Mason, Hydrometrics, Inc. Re: Kaiser Mead Groundwater Remediation Project Treatability Study. July 26, 2013.

Ecology, 2005. Washington State Department of Ecology Water Quality Program. Stormwater Management in Western Washington, Appendix III-D Procedure for Conducting a Pit Infiltration Test. Publication 05-10-31. February 2005.

Ecology, 2014. Washington Department of Ecology letter to Dan Silver, Mead Custodial Trust. Re: Kaiser Mead Supplemental Feasibility Study Next Steps. December 8, 2014.

Hydrometrics, 2013a. *Draft Data Report on Additional Field Characterization for the Kaiser Mead Facility*. December 2013.

Hydrometrics, 2013b. *Draft Supplemental Site Characterization Analysis*. December 2013.

Hydrometrics, 2013c. *Draft Kaiser Mead Groundwater Conceptual Site Model (CSM)*. December 2013.

Hydrometrics, 2013d. *Draft Technical Memorandum for Source Control Evaluation for Cleanup Actions at the Kaiser Mead NPL Site*. December 2013.

Hydrometrics, 2013e. *Draft Ex Situ Treatability Study for Cleanup Actions at the Kaiser Mead NPL Site*. December 2013.

Hydrometrics, 2013f. *Draft In Situ Groundwater Treatment Proof of Concept Study for Cleanup Actions at the Kaiser Mead NPL Site*. December 2013.

Hydrometrics, 2014. *Draft Supplemental Feasibility Study Report for Kaiser Mead NPL Site*. January 2014.

Hydrometrics, 2016. *Work Plan for Ex Situ Treability Study 2016 Activities for Kaiser Mead NPL Site*. March 2016.

USEPA, 1992. Guidance for Conducting Treatability Studies under CERCLA, Final. EPA/540/R-92/071a. OSWER October 1992.

APPENDIX D

IN SITU TREATABILITY REPORT

Note: The following report and supporting studies were completed in December 2013. At the time of these studies, Ecology specified monitoring of WAD cyanide, rather than free cyanide for determination of compliance with groundwater cleanup levels (0.2 mg/L as free cyanide). Thus the focus of this report is treatment of WAD and total cyanide. Since that time, newer methods for analysis of free CN have been approved by US EPA that are more reliable than current WAD CN methods. Therefore, Ecology directed MCT to adopt free CN analysis in lieu of WAD CN at Kaiser Mead (Ecology, 2016).

IN SITU GROUNDWATER TREATMENT
PROOF OF CONCEPT STUDY FOR CLEANUP ACTIONS
AT THE KAISER MEAD NPL SITE

-DRAFT-

Prepared for:

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December 2013 revised January 2017

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

IN SITU GROUNDWATER TREATMENT
PROOF OF CONCEPT STUDY FOR CLEANUP ACTIONS
AT THE KAISER MEAD NPL SITE

-DRAFT-

1.0 INTRODUCTION

This In Situ Groundwater Treatment Proof of Concept Study (Study) was conducted on behalf of Mead Custodial Trust (MCT) as a component of the Supplemental Feasibility Study (SFS) for the Kaiser Mead NPL site (the Site). The Study was identified in the Draft Work Plan for Supplemental Feasibility Study for Cleanup Actions at the Kaiser Mead NPL Site that was approved by the Washington Department of Ecology on November 9, 2012. The Study was conducted as outlined in the In Situ Groundwater Treatment Assessment Work Plan (Work Plan) (Hydrometrics, 2013a) that was approved by the Washington Department of Ecology on July 19, 2013.

1.1 PURPOSE OF STUDY

The purpose of this study was to conduct proof of concept testing of potentially applicable in situ groundwater treatment methods using Site groundwater. Proof of concept testing is an evaluation of whether in situ approaches have the potential to be effective on Site waters (i.e., Does treatment remove cyanide and/or fluoride?) and thus, whether in situ approaches are worthy of further evaluation. Proof of concept testing is not intended to yield sufficient information for preliminary design of an in situ groundwater treatment system.

1.2 SCOPE OF STUDY

The scope of this study was to conduct limited, small-scale laboratory testing of potential in situ reagents using Site groundwater and to incorporate results from the Ex Situ Treatability

Study (Hydrometrics, 2013b) for commonly used ex situ treatment reagents that also have potential to be used in an in situ setting (i.e., within the groundwater system rather than in an above ground engineered treatment system). A literature review was conducted to identify potential treatment reagents and to estimate potential environmental effects of the reagents.

The in situ proof of concept testing included the following elements:

1. Characterization of groundwater and aquifer sediment;
2. Simulation of injection of ex situ treated water (by incorporation of results from the Ex Situ treatability study (Hydrometrics, 2013b));
3. Treatability testing of cyanide removal by soluble iron chemical precipitation and chemical oxidation (by incorporation of results from the Ex Situ treatability study (Hydrometrics, 2013b));
4. Treatability testing of fluoride removal by chemical precipitation (alum and lime) and adsorption (by incorporation of results from the Ex Situ treatability study (Hydrometrics, 2013b));
5. Laboratory simulation and testing of in situ cyanide removal by zero valent iron; and
6. Laboratory simulation and testing of in situ fluoride removal by calcium and phosphate.
7. Literature review of potential environmental effects of in situ treatment reagents

1.3 BACKGROUND AND RATIONALE FOR TESTING

No treatability studies for in situ treatment of Site groundwater have been previously conducted. A few laboratory-scale in situ treatment studies for removal of cyanide and/or fluoride from groundwater have been conducted and reported in the literature. Summaries of these studies may be found in the Work Plan (Hydrometrics, 2013a). The reported in situ treatment methods remove cyanide and fluoride through precipitation of cyanide-bearing and fluoride-bearing minerals. For cyanide removal, the in situ treatment methods cause the precipitation of iron cyanide minerals by the addition of soluble iron (from a solid iron reagent) and decrease in Eh or redox conditions. Some successful ex situ treatment methods for cyanide such as ferrous sulfate or ferric chloride addition also rely on a similar cyanide mineral precipitation process but employ dissolved rather than solid iron reagents. Removal of WAD and total cyanide by ferrous sulfate and ferric chloride iron addition has been proven to be effective on Site groundwater as described in the recently completed Ex Situ Treatability Study (Hydrometrics, 2013b). Since iron addition is a proven treatment for Site groundwater in an ex situ setting and is demonstrated to be potentially applicable to an in situ setting, proof of concept testing was recommended in the Work Plan.

In situ fluoride removal processes reported in the literature cause the formation of the minerals fluorite (CaF_2) or apatite ($Ca_5(PO_4)_3F$) by the addition of soluble calcium and/or phosphate. Removal of fluoride from Site groundwater by calcium addition has been proven to be effective by treatability testing of Site groundwater by MFG (2002). Removal of fluoride from groundwater by naturally-occurring phosphate in seawater at the Intalco Aluminum Corp. plant in Ferndale, Washington has been described by Anchor Environmental (2006). Since calcium and/or phosphate addition is a proven treatment for Site groundwater in an ex situ setting and is demonstrated to be potentially applicable to an in situ setting, proof of concept testing was recommended in the Work Plan.

2.0 DESCRIPTION OF TEST METHODS

In situ treatment methods were tested by a series of simple batch tests where groundwater, treatment reagents, and sediment were placed in bottles and agitated on a rotary extractor for 30 days. A summary of the tests and the treatment reagents that were tested is provided in Table 2-1. Additional detail regarding test procedures is provided in the following subsections.

TABLE 2-1. SUMMARY OF IN SITU TESTS REAGENTS

Test	Test Reagent/ Description	Well KM-6 Groundwater Volume (liters)	Sediment Mass (g)	Reagent Mass (g) or Volume (mL)	Initial Volume HCl added (mL)	Total Volume HCl added (mL)
C-1	KM-6 groundwater control sample	1.8L	180g	None	0	0
ZVI-2	Hepure Ferox Flow	1.8L	180g	18g	0	2
ZVI-3	Hepure Ferox Flow	1.8L	180g	18g	5	10
ZVI-4	FMC EHC-L	1.8L	180g	7g + 18mL emulsion	0	0
ZVI-5	FMC EHC-L	1.8L	180g	7g + 18mL emulsion	5	5
F-6	Calcium chloride	1.8L	180g	1g	0	2
F-7	Calcium chloride neutral pH	1.8L	180g	1g	5	5
F-8	Calcite	1.8L	180g	18g	0	2
F-9	Calcite neutral pH	1.8L	180g	18g	5	7
F-10	Calcium phosphate	1.8L	180g	18g	0	0
F-11	Calcium phosphate neutral pH	1.8L	180g	18g	5	5

2.1 MATERIALS AND REAGENTS

2.1.1 Groundwater

A bulk sample of site groundwater was collected from monitoring well KM-6 on August 12, 2013. The sample was chilled but was not filtered or preserved in the field. The bulk sample was delivered to SVL Analytical in Kellogg on the same day and was refrigerated prior to preparation of the treatment tests later the same day. Upon receipt, SVL removed and preserved a sample aliquot of the bulk sample and submitted the groundwater sample for analysis of a full suite of chemical constituents in accordance with Table 8-3 of the Work Plan. Composition of groundwater from well KM-6 that was used in the in situ testing is described in Table 2-2 and laboratory reports are included in Appendix A.

TABLE 2-2. MONITORING WELL KM-6
UNTREATED GROUNDWATER COMPOSITION

Analyte	Result (mg/L) unless specified
Bench Parameters	
Eh	178 millivolts
Major Minerals	
pH	9.42 s.u.
Calcium	3.92
Magnesium	9.55
Sodium	1430
Hardness as $CaCO_3$	49.1
Total Alkalinity as $CaCO_3$	2330
Carbonate	814
Bicarbonate	1520
Hydroxide	<1
Chloride	26.3
Fluoride	47.7
Sulfate	353
Total Dissolved Solids	3850
Silica (dissolved)	12.8
Total Organic Carbon	79.1
Chemical Oxygen Demand	127
Nitrogen Compounds	
Nitrate plus Nitrite as "N"	123
Total Kjeldahl Nitrogen	107
Cyanide Forms	
Total Cyanide (manual distillation)	125
WAD Cyanide	0.476
Dissolved Metals	
Iron	51.7

2.1.2 Sediment

Aquifer sediment used in the testing (sample TW-1A 150’) was collected during installation of test pumping well TW-1A, at a depth of 150 feet, on January 17, 2013. The sediment was analyzed for cyanide and fluoride during the in situ testing in August 2013. Results of the sediment analysis are summarized in Table 2-3 and laboratory reports are included in Appendix A.

TABLE 2-3. CYANIDE AND FLUORIDE CONTENT OF SEDIMENT SAMPLE

Sediment Sample	Total Cyanide (mg/kg or ppm)	WAD Cyanide (mg/kg or ppm)	Method 300 Readily Soluble Fluoride (mg/kg or ppm)
TW-1A-150	13.5	<0.5	11.7

2.1.3 Reagents

Treatment reagents used in the testing are described in Tables 2-4 and 2-5. In addition to treatment reagents, 12 molar hydrochloric acid (HCl) was used for pH adjustment.

TABLE 2-4. REAGENTS USED IN CYANIDE REMOVAL TESTS

Reagent Type	Reagent Name	Manufacturer/Supplier
Simple (unmodified) ZVI, solid form	Ferox™ Flow	Hepure Technologies
Emulsified (liquid) ZVI with carbon and nutrients	EHC-L®	FMC Environmental Solutions
Hydrochloric acid	Hydrochloric acid 37%	CCI

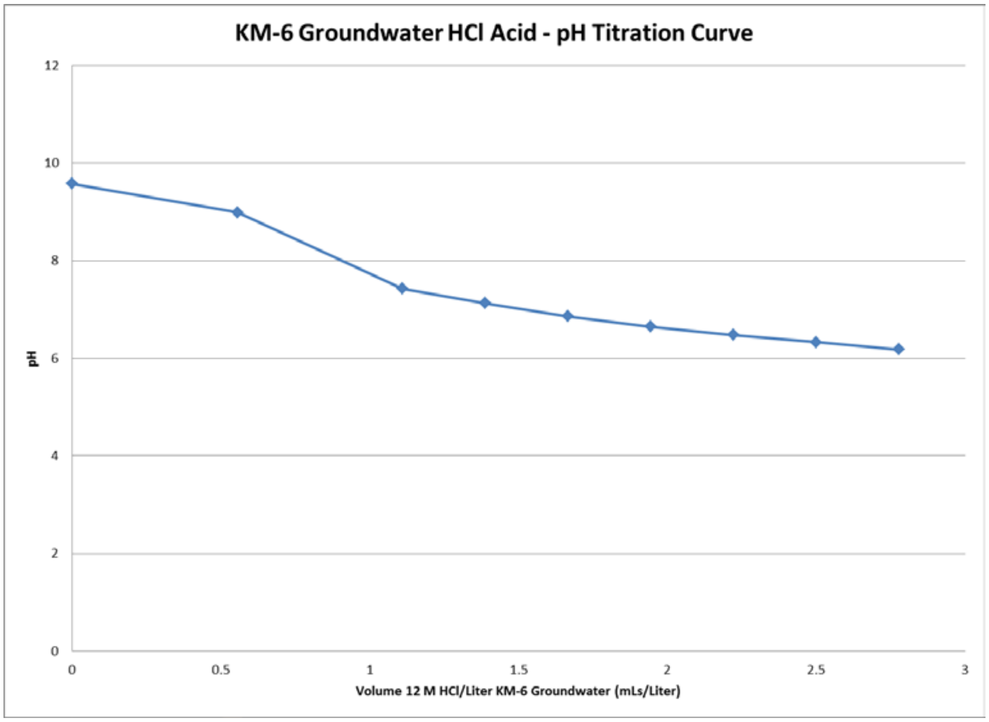
TABLE 2-5. REAGENTS USED IN FLUORIDE REMOVAL TESS

Reagent	Description	Manufacturer/Supplier
Calcium carbonate ($CaCO_3$)	Food grade dietary supplement	Nature Made
Calcium phosphate ($Ca(H_2PO_4)2 \cdot H_2O$)	Triple superphosphate fertilizer (0-45-0)	Bonide
Calcium chloride ($CaCl_2$)	ACS Grade 74-78%	Baker
Hydrochloric acid	Hydrochloric acid 37%	CCI

2.2 ACID TITRATION CURVE

Prior to preparation of the treatment tests, a sample of KM-6 groundwater was treated with successive amounts of 12 M HCl to determine the volume of acid necessary to reach a pH of approximately 6. Results of this titration are shown in Figure 2-1. This information was used to determine how much acid to add to the groundwater and reagent mixtures during the test period in order to achieve target pH values for the tests.

FIGURE 2-1. KM-6 GROUNDWATER TITRATION CURVE



2.3 TEST PROCEDURES

Test procedures were as follows:

1. A sample aliquot was collected from the bulk raw groundwater sample for chemical analysis of a full suite of analytical parameters as described in Section 2.1.1.
2. An HCl acid-pH titration curve was derived as described in Section 2.2.
3. Groundwater, sediment, reagents and HCl acid were combined in 2 liter polyethylene wide mouth bottles as described in Table 2-1 above.
4. Air space in the test bottles was displaced with nitrogen gas (10 liters/minute for 2 minutes) and the bottles were sealed.
5. Test bottles were placed on a rotary extractor (see Figure 2-2) and rotated at 30 rpm in a temperature-controlled room (23^o C).
6. On the third and eighth days of the test (August 16 and 21), solution pH was measured and additional HCl acid was added to selected test mixtures. Total acid added in the tests for each mixture is shown in Table 2-1 above.
7. On day 10 of the test (August 23), water sample aliquots were removed (decanted) from each test mixture and analyzed for pH, specific conductivity (SC) and Eh. Headspace was re-filled with nitrogen gas and bottles were replaced on the rotary extractor.
8. On day 30 the test was ended and all water samples were decanted and analyzed for pH, SC, and Eh. Water from the cyanide removal tests were also analyzed for dissolved iron, total cyanide and WAD cyanide. Water samples from the fluoride removal tests were also analyzed for fluoride, total alkalinity, calcium and chloride (calcium chloride addition tests only) or phosphate (phosphate addition tests only).

FIGURE 2-2. ROTARY EXTRACTOR APPARATUS

3.0 IN SITU LABORATORY TEST RESULTS AND OBSERVED CONTAMINANT REMOVAL

Results of the laboratory batch testing of in situ reagents with site groundwater are discussed in the following section. Laboratory analytical reports for batch testing may be found in Appendix A.

3.1 CYANIDE REMOVAL

Results of the batch testing of in situ cyanide removal reagents are summarized in Table 3-1 and are shown graphically in Figures 3-1 and through 3-5. Removal of WAD and total cyanide was excellent in all tests as all test configurations produced water with WAD cyanide concentrations lower (better) than the compliance limit of 0.2 mg/L and removed over 90 percent of the total cyanide (Figures 3-1 and 3-2).

The primary differences in the ZVI reagents were their effects on redox conditions (i.e., Eh and pH) of the treated water (Figure 3-3). Both ZVI reagents made the groundwater more reducing (lower Eh), more so for Hepure Ferox Flow than for FMC EHC-L. FMC EHC-L reduced groundwater pH substantially (to range of 6.89 to 7.26), both with and without the addition of HCl. Conversely, Hepure Ferox Flow increased groundwater pH even with small acid additions (pH 10.12 with 1.1 mL/L HCL acid addition) but this effect was counteracted somewhat by larger acid additions (pH 9.01 at 5.6 mL/L acid addition). Although WAD and total cyanide removal was excellent in all tests, the test results suggest that WAD cyanide removal was best under neutral to alkaline pH conditions (i.e., pH approximately 7 to 10.1; Figure 3-4) and more strongly reducing conditions (Figure 3-4). Removal of total cyanide was better under somewhat more neutral pH (6.8 to 9) and less reducing conditions (Figure 3-5).

TABLE 3-1. RESULTS OF CYANIDE REMOVAL BATCH TESTS

Test Name	Description	Initial pH	Final pH	Total HCl Added (mL/L)	Initial Eh (millivolts	Final Eh (millivolts)	Final Total Cyanide (mg/L)	WAD Cyanide (mg/L)	Dissolved Iron (mg/L)
KM-6	KM-6 Groundwater (untreated)	9.38	9.42	0	420.4	178	125	0.476	51.7
ZVI-2	Hepure Ferox Flow	9.51	10.12	1.1	374.4	-774	10.5	0.022	6.22
ZVI-3	Hepure Ferox Flow	6.36	9.01	5.6	345.2	-708	0.804	0.013	0.08
ZVI-4	FMC EHC-L	8.42	7.26	0	-167.2	-486	1.2	0.046	34.9
ZVI-5	FMC EHC-L + HCl acid	6.1	6.89	2.8	-110.2	-160	1.69	0.083	78.2

FIGURE 3-1. WAD CYANIDE REMOVAL BY ZERO VALENT IRON

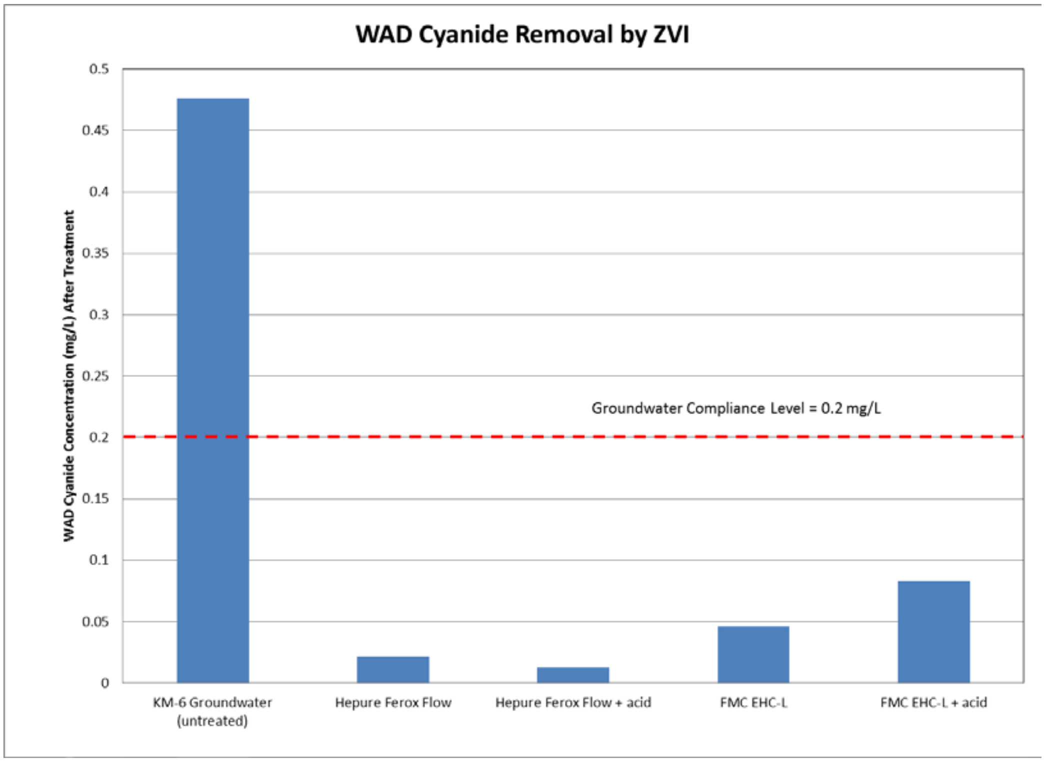


FIGURE 3-2. TOTAL CYANIDE REMOVAL BY ZERO VALENT IRON

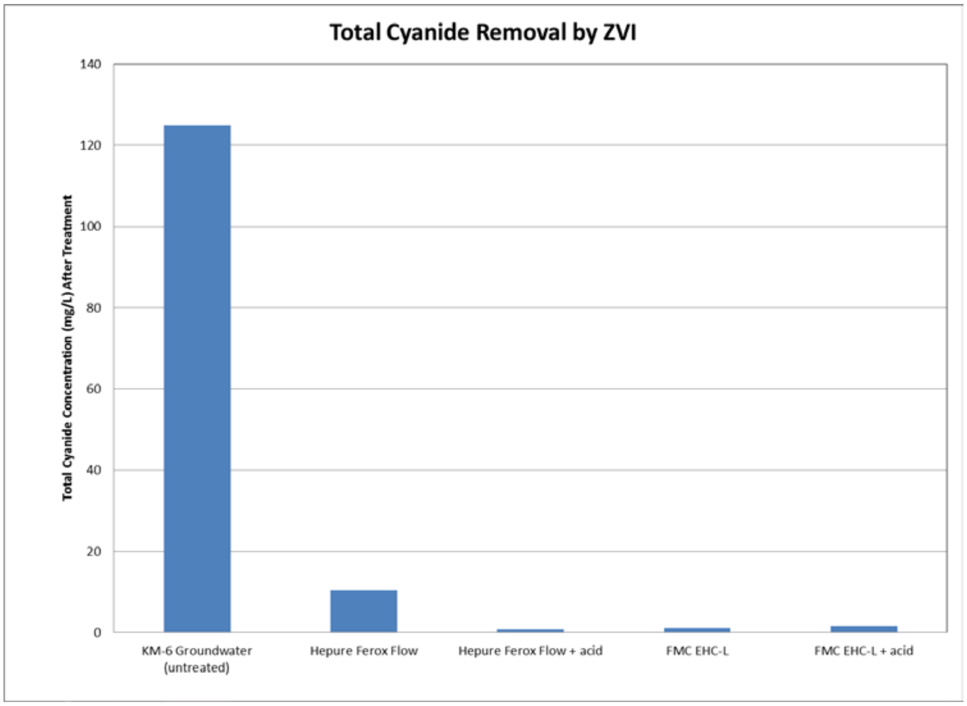


FIGURE 3-3. REDOX CONDITIONS DURING CYANIDE REMOVAL BATCH TESTS

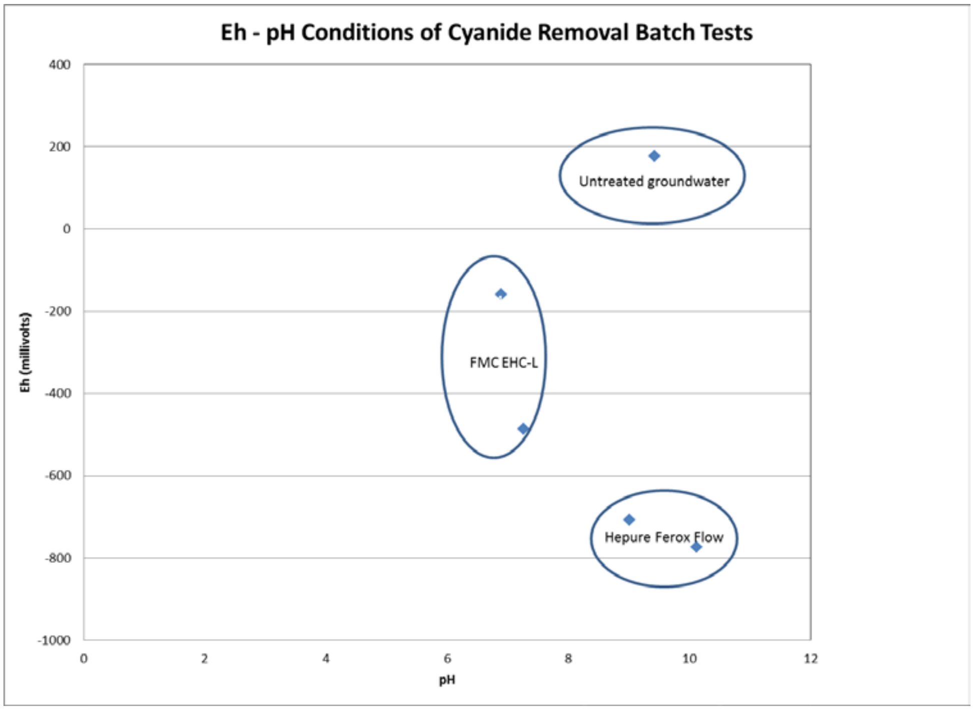


FIGURE 3-4. pH VERSUS FINAL CYANIDE CONCENTRATION

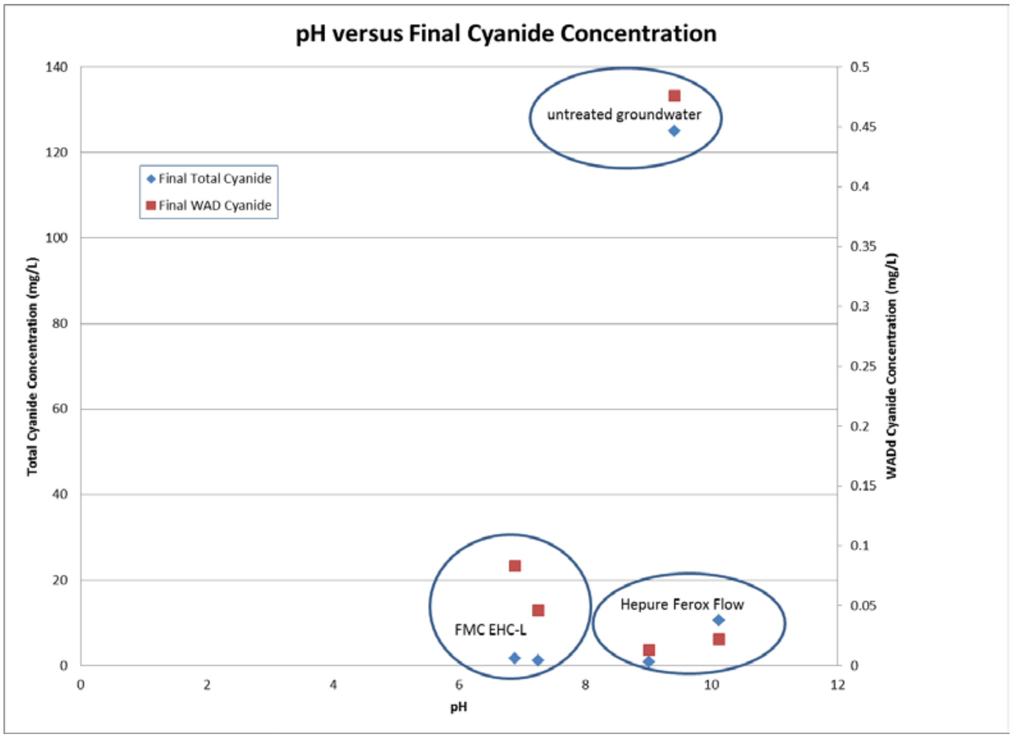
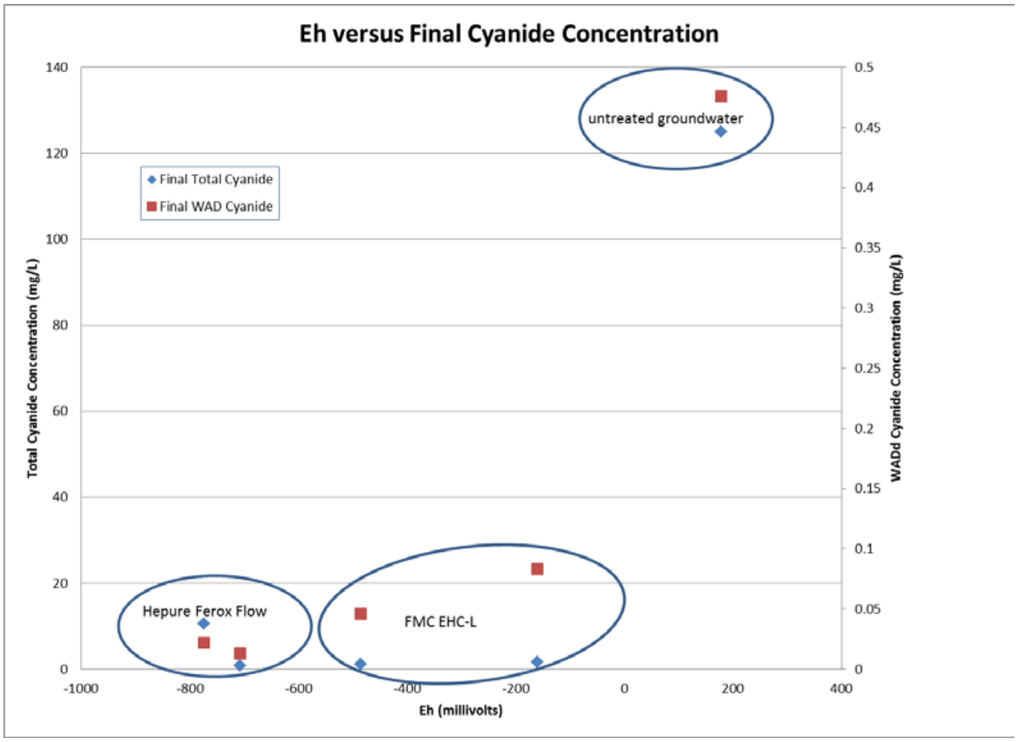


FIGURE 3-5. Eh VERSUS FINAL CYANIDE CONCENTRATION



3.2 IN SITU FLUORIDE REMOVAL

Results of the batch testing of in situ fluoride removal reagents are summarized in Table 3-2 and are shown graphically in Figures 3-6 through 3-8. None of the reagents and test conditions achieved the goal of reaching the compliance limit of 4 mg/L. However, calcium phosphate fertilizer reduced fluoride concentration significantly (from 47.7 in groundwater to 9.75 mg/L in treated water; Figure 3-6). Removal of fluoride appeared to be unrelated to calcium concentrations under most test conditions (Figure 3-7). However, pH and calcium concentrations may control final fluoride concentrations in the presence of phosphate. Under nearly identical phosphate concentrations (554 and 559 mg/L), significantly more fluoride was removed under lower pH and higher calcium concentrations (Figure 3-8).

TABLE 3-2. RESULTS OF FLUORIDE REMOVAL BATCH TESTS

Test Name	Description	Initial pH	Final pH	Total HCl Added (mL/L)	Final Eh (millivolts)	Final Fluoride (mg/L)	Calcium (mg/L)	Total Alkalinity (mg/L as CaCO3)	Chloride (mg/L)	Ortho phosphate as P (mg/L)
KM-6	KM-6 Groundwater (untreated)	9.38	9.42	0	178	47.7	3.92	2330	26.3	
F-6	$CaCl_2$	9.27	9.12	1.1	91	47.3	14.8	1900	240	
F-7	$CaCl_2$ +acid	6.17	7.89	2.8	142	35.2	173	916	1350	
F-8	$CaCO_3$	9.47	7.87	1.1	-128	66.8	1330	4090		
F-9	$CaCO_3$ + acid	6.42	6.97	3.9	-27	49.4	443	3360		
F-10	Ca phosphate	6.5	7.41	0	119	27.1	23.7	1670		559
F-11	Ca phosphate + acid	5.42	6.17	2.8	313	9.75	76.5	263		554

FIGURE 3-6. FLUORIDE REMOVAL BY TREATMENT REAGENTS

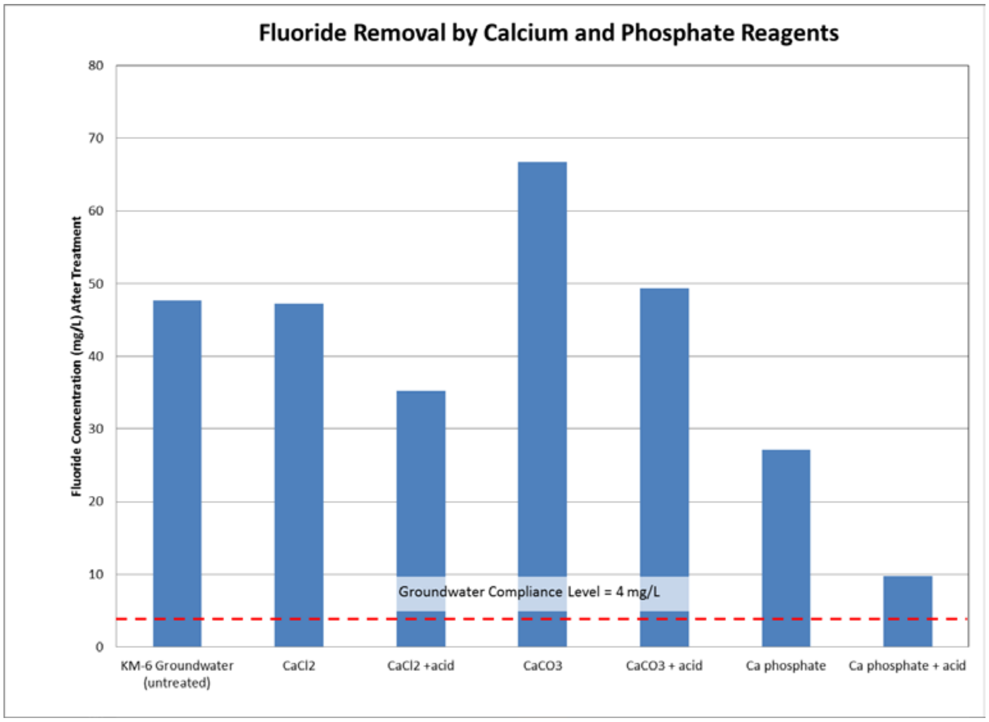


FIGURE 3-7. FLUORIDE AND CALCIUM CONCENTRATIONS IN BATCH TESTS

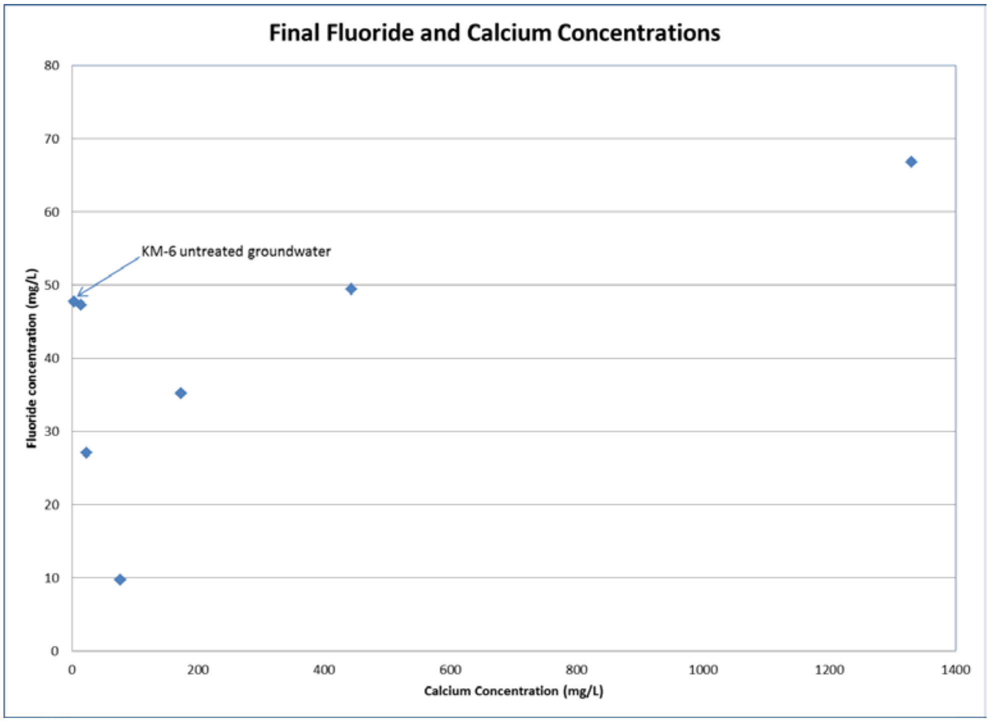
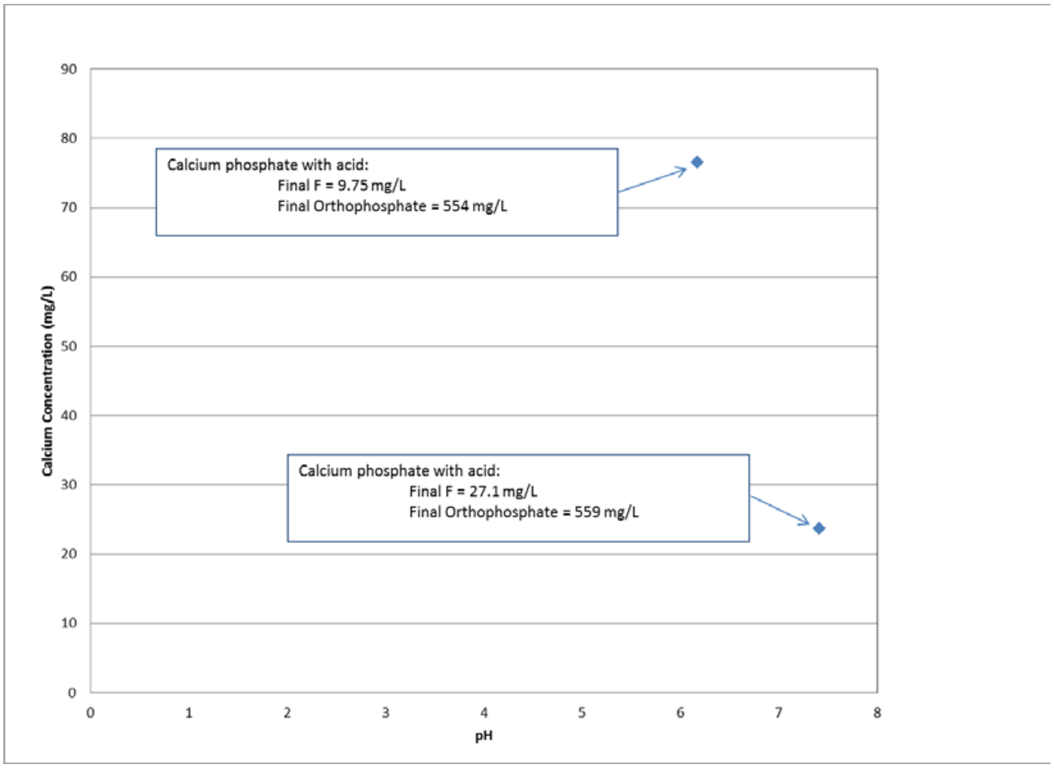


FIGURE 3-8. pH AND CALCIUM CONCENTRATIONS IN CALCIUM PHOSPHATE ADDITION BATCH TESTS



4.0 SUMMARY OF RESULTS FROM EX SITU TREATABILITY STUDY AND POTENTIAL APPLICABILITY TO IN SITU TREATMENT

Results of the Ex Situ Treatability Study that may pertain to in situ treatment are described in this section. A full description of the results of the Ex Situ Treatability Study may be found in Hydrometrics (2013b).

4.1 INJECTION OF EX SITU TREATED WATER

Injection of ex situ treated water is one potential method of disposal of treated water. Ex situ treated water may contain residual treatment reagents and/or may have geochemical characteristics (e.g., pH and Eh) that could further react with groundwater, potentially reducing contaminant concentrations in the groundwater after injection. Thus, injection of ex situ treated water is a potential method of in situ groundwater treatment. Laboratory simulation of treated water injection during the Ex Situ Treatability Study consisted of mixing two types of treated groundwater (ferrous sulfate/Alum/Xsorbx/IX and hydrogen peroxide treatments) with untreated groundwater and/or aquifer sediment from Test Well 1A in batch bottle roll tests. This test procedure was similar to the in situ batch tests described above in Section 2.

Test results indicated no significant changes in fluoride concentrations due to mixing of treated water with groundwater or groundwater plus sediment. Therefore, injection of water treated by these treatment methods (ferrous sulfate/Alum/Xsorbx/IX and hydrogen peroxide treatments) is unlikely to result in further in situ treatment of fluoride. The lack of fluoride removal is likely because neither of these treatment methods employed calcium addition and thus precipitation of calcium fluoride minerals was not stimulated.

Test results indicated no significant changes in WAD cyanide concentrations due to mixing of treated water with groundwater or groundwater plus sediment, but significant decreases (17 to 30 mg/L) in total cyanide was noted. These injection simulation test results suggest that treated water may react with groundwater in the presence of sediment to remove additional total cyanide from groundwater. The fate of the total cyanide lost from the treated water/groundwater/sediment mixture is not known with certainty as there were no significant changes in other chemical constituents that coincide with the loss of total cyanide, as would be expected if cyanide mineral precipitates were forming (e.g., pH, Eh, dissolved iron remained nearly stable, or shifted to conditions (higher pH and Eh) favoring dissolution of iron cyanide minerals). Based solely on the lack of evidence of cyanide mineral precipitation, it was speculated that cyanide may have been removed by adsorption to the sediment.

4.2 CYANIDE REMOVAL BY IRON REAGENTS

A summary of the Ex Situ testing results for iron reagents is provided in Table 4-1. Chemical precipitation processes using ferrous sulfate and ferric chloride were found to be effective in meeting the compliance limit (0.2 mg/L) for WAD cyanide. The ferrous sulfate process also resulted in significant reductions in total cyanide concentration. Based on the ex situ test results, it appears that iron addition by ferrous sulfate and/or ferric chloride is an effective method for cyanide removal in ex situ settings. These results suggest that ferrous sulfate and/or ferric chloride potentially may also be effective in an in situ setting.

TABLE 4-1. EX SITU TREATABILITY STUDY RESULTS FOR IRON REAGENTS

Test ID	Process Summary	Initial Total CN (mg/l)	Final Total CN (mg/l)	Total CN Removal (%)		Initial WAD CN (mg/l)	Final WAD CN (mg/l)	WAD CN Removal (%)
1	Ferrous Precipitation	66.9	71.2	-6.4%		0.532	0.119	77.6%
2	Ferrous Precipitation	66.9	44.5	33.5%		0.532	0.188	64.7%
5	Peroxide Oxidation	66.9	64.8	3.1%		0.532	0.142	73.3%
7	Peroxide Oxidation	66.9	66.4	0.7%		0.532	0.190	64.3%
9	Ferrous/Ferric Precipitation	66.9	68.2	-1.9%		0.532	0.132	75.2%
10	Ferrous/Ferric Precipitation	66.9	63.9	4.5%		0.532	0.122	77.1%
11	Ferric Precipitation	66.9	67	-0.1%		0.532	0.129	75.8%
12	Ferric Precipitation	66.9	83	-24.1%		0.532	0.119	77.6%
13	Ferrous Precipitation	66.9	0.956	98.6%		0.532	0.163	69.4%

4.3 FLUORIDE REMOVAL

A summary of the Ex Situ testing results for removal of fluoride by calcium reagents is provided in Table 4-2. Chemical precipitation processes using calcium chloride and lime were found to be ineffective in meeting the compliance limit (4 mg/L) for fluoride. Moreover, the treatment processes did not significantly reduce fluoride concentrations. The results of the ex situ tests are similar to results for the in situ tests that used calcium chloride and calcium carbonate reagents described in Section 3.2. During in situ testing, final fluoride concentrations ranged from 35 to 47 mg/L with calcium chloride and 49 to 66 mg/L using calcium carbonate. Based on the ex situ and in situ test results, it appears that calcium addition is an ineffective method for fluoride removal in either ex situ or in situ settings.

TABLE 4-2. EX SITU TREATABILITY RESULTS FOR CALCIUM REAGENTS

Test ID	Process Summary	Initial F (mg/l)	Final F (mg/l)	F Removal (%)
A	Calcium Chloride Precipitation	56.1	44.3	21.0%
B	Calcium Chloride Precipitation	56.1	57.6	-2.7%
H	Lime Precipitation	56.1	41.2	26.6%

5.0 SUMMARY AND RECOMMENDATIONS

In this proof of concept study, Site groundwater was treated with potentially applicable in situ groundwater treatment reagents in batch (bottle roll) laboratory tests to test the potential effectiveness of in situ treatment approaches. Results of laboratory testing of ex situ treatment methods during other studies of Site groundwater was also reviewed for potential application to in situ approaches.

5.1 POTENTIAL EFFECTIVENESS OF IN SITU CYANIDE REMOVAL

Cyanide removal by iron addition was found to be effective during both the in situ and ex situ laboratory tests on Site groundwater. The in situ tests used two types of solid iron reagents (Hepure Ferox Flow and FMC EHC-L), commonly referred to as zero valent iron or ZVI, while the ex situ tests used two types iron reagents (ferrous sulfate and ferric chloride dissolved in water) in liquid form. All four of the iron reagents tested were found to be effective in reducing WAD cyanide concentrations below the compliance limit of 0.2 mg/L. Additionally, Hepure Ferox Flow, FMC EHC-L, and ferrous sulfate significantly reduced total cyanide concentration. Based on these laboratory study results, in situ treatment of cyanide by iron addition is judged to be a potentially effective means of groundwater treatment for the Kaiser Mead Site.

5.2 POTENTIAL EFFECTIVENESS OF IN SITU FLUORIDE REMOVAL

Fluoride removal by calcium addition was found to be ineffective, neither meeting the compliance limit of 4 mg/L nor significantly reducing fluoride concentrations, during both the in situ and ex situ laboratory tests on Site groundwater. Fluoride removal by phosphate and calcium addition significantly reduced fluoride concentrations (from 47.7 mg/L to 9.75 mg/L) but also was not able to meet the fluoride compliance limit. However, it must be noted that no attempt was made in this in situ study to optimize the treatment process through varying reagent dosages or other conditions such as pH and it is possible that lower fluoride concentrations might be achieved by modification of the calcium phosphate addition process. Therefore, based on laboratory study results indicating significant removal of fluoride by calcium phosphate addition, in situ treatment of fluoride by calcium phosphate addition is judged to be a potentially effective means of groundwater treatment for the Kaiser Mead Site.

5.3 POTENTIAL ADVERSE ENVIRONMENTAL EFFECTS OF IN SITU TREATMENT

The primary potential adverse environmental effect of in situ treatment is the addition of phosphorous treatment reagents to groundwater and potentially surface water in the Little Spokane River watershed in possible violation of the established Total Maximum Daily Load (TMDL). Phosphate is a form of phosphorus that is a nutrient. Excessive levels of phosphorus and other nutrients may cause deleterious effects such as excessive aquatic life growth and diminished levels of dissolved oxygen in streams. To control (increase) dissolved oxygen levels in the Spokane River and Lake Spokane, WA Ecology (2010) has developed a Total Maximum Daily Load (TMDL) for phosphorus in the Spokane River and selected tributaries including the Little Spokane River. The TMDL establishes goals of:

- Maintaining maximum monthly average total phosphorus concentration of 0.05 mg/L in the Little Spokane River;
- Reducing existing total phosphorus loads to the Little Spokane River by 36 percent; and
- Limiting groundwater discharges upstream of Lake Spokane to 48 lbs/day and 0.0076 mg/L during the July-October period.

In addition to the TMDL goals and requirements, a number of phosphorus control programs and activities have been or are being implemented in conjunction with the TMDL, including:

- A ban on dishwashing detergents containing more than 0.5 percent phosphorus in Spokane County;
- A septic tank elimination program in Spokane County that is projected to remove 3,400 septic tanks and an estimated 20 lbs/day of total phosphorus loading to the Spokane River; and
- A program to reduce water consumption by users of publicly-owned NPDES permit holders by 10 to 20 percent.

In situ treatment for fluoride removal would use calcium phosphate reagents (bone char or calcium phosphate fertilizer (a.k.a. triple super phosphate or TSP)) since non-phosphate reagents that were tested (e.g., calcium chloride, calcium carbonate, lime) were found to be ineffective for in situ treatment. The addition of either of these calcium phosphate reagents would increase the concentrations of both calcium and phosphate in groundwater. A portion of the added calcium and phosphate would react to remove fluoride, but a residual portion of the phosphate would remain in groundwater unless naturally attenuated.

During Phase I bench testing of TSP reagent in 2013, a residual phosphate (as P) concentration of 554 mg/L was observed. Phase I testing was a proof of concept exercise and therefore it is anticipated that optimization could result in identifying effective dosages with lower residual phosphate concentrations. Bone char was not tested in the 2013 program; however, phosphate concentrations leached from bone char are estimated to range from approximately 1 to 20 mg/L based on values reported in the literature (USEPA, 2000; He and Cao, 1996; Sorlini and Palazinni, 2011). Assuming this range of residual phosphate concentrations and groundwater flux in the A-Zone aquifer of 100 gpm (see flux estimates in the Draft Supplemental Site Characterization Analysis (Hydrometrics, 2017a)), residual phosphate loads could range from approximately 1.4 to 700 lbs/day in the in-situ treatment zone. Phosphate reagent that does not react with fluoride is expected to be naturally attenuated by adsorption to aquifer sediments or precipitation with dissolved iron (naturally present or added as a mitigation step) to form iron phosphate minerals so that downgradient loads would be less than observed in the treatment zone. Phosphate reagent that remains dissolved in groundwater after natural attenuation and mitigation would be transported to the Little Spokane River.

Given the reductions in total phosphorus concentrations and loads required by the TMDL and the widespread limitations on the use of phosphorus compounds in Spokane County, it is likely that addition of significant levels of phosphorus to groundwater at Kaiser Mead will be unacceptable and therefore administratively not implementable unless phosphorus is subsequently controlled through natural attenuation, mitigation or offsets. Although a large portion of the residual phosphorus from in situ fluoride treatment could be attenuated on sediments in a manner similar to removal of phosphorus by septic systems. The rationale for elimination of septic systems by Spokane County is based on the assumption that the attenuated phosphorus will eventually “breakthrough” or be released to groundwater with subsequent loading to groundwater and eventually the Spokane River. Thus, natural attenuation of residual phosphorus from in situ fluoride treatment is viewed as a short term mitigation that is not administratively implementable.

5.4 RECOMMENDATIONS FOR FURTHER EVALUATION

Further evaluation of the potential implementability and potential cost of in situ groundwater treatment is not recommended as part of the development of the SFS. The increased contribution of phosphate through groundwater to the Little Spokane River that could arise from in situ treatment of fluoride is a potential “threshold exceedance” that would make calcium phosphate reagents administratively non-implementable. Residual phosphate concentrations in the in situ treatment zone could be on the order of 1 to 500 mg/L or more; and if not reduced by attenuation or mitigation, would significantly exceed the TMDL goal for groundwater upstream of Lake Spokane of 0.0076 mg/L.

1.

6.0 REFERENCES

Anchor Environmental, 2006. Fluoride Fate and Transport Analysis; Intalco Landfill Closure Program. Prepared for Alcoa Inc., Pittsburgh. February 2006.

He, GL and SR Cao, 1996. Assessment of Fluoride Removal from Drinking Water by Calcium Phosphate Systems. Fluoride, Vol 29, No. 4, p 212-216.

Hydrometrics, Inc., 2013a. Draft In Situ Groundwater Treatment Assessment Work Plan. Prepared for Mead Custodial Trust. May 2013.

Hydrometrics, Inc., 2013b. Ex Situ Treatability Study for Cleanup Actions at the Kaiser Mead NP Site. Prepared for Mead Custodial Trust. October 2013.

Hydrometrics, Inc., 2017. Site Characterization Analysis Report. Prepared for Mead Custodial Trust. February 2017.

McCulley Frick & Gilman, 2002. Technical Memorandum Groundwater Treatment Alternative Evaluation, Kaiser Mead Works. Prepared for Kaiser Aluminum & Chemical Corporation, Mead, WA. March 29, 2002.

Sorlini and Palazinni, 2011. Experimentation on bone char-based treatment for fluoride removal from drinking water in Senegal. 35th Water Engineering and Development Center Conference, Loughborough University, July 2011.

USEPA, 2000. Field Demonstration of Permeable Reactive Barriers to Remove Dissolved Uranium From Groundwater, Fry Canyon, Utah, September 1997 through September 1998.

Washington Department of Ecology, 2010. Spokane River and Lake Spokane, Dissolved Oxygen Total Maximum Daily Load, Water Quality Improvement Report Pub. No. 07-10-073, revised February 2010.

APPENDIX A

LABORATORY ANALYTICAL REPORTS FOR BATCH TESTING

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3H0210**
Reported: 26-Aug-13 11:54

ANALYTICAL REPORT FOR SAMPLES

Sample ID	Laboratory ID	Matrix	Date Sampled	Sampled By	Date Received
KM-6	W3H0210-01	Ground Water	12-Aug-13 09:00	AC	12-Aug-2013

Solid samples are analyzed on an as-received, wet-weight basis, unless otherwise requested.
Sample preparation is defined by the client as per their Data Quality Objectives.
This report supercedes any previous reports for this Work Order. The complete report includes pages for each sample, a full QC report, and a notes section.
The results presented in this report relate only to the samples, and meet all requirements of the NELAC Standards unless otherwise noted.

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3H0210**
Reported: 26-Aug-13 11:54

Client Sample ID: **KM-6**
SVL Sample ID: **W3H0210-01 (Ground Water)**

Sample Report Page 1 of 1

Sampled: 12-Aug-13 09:00
Received: 12-Aug-13
Sampled By: AC

Metals (Dissolved)

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 200.7	**Calcium**	3.92	mg/L	0.040	0.015		W333103	AS	08/25/13 08:14	
EPA 200.7	**Iron**	51.7	mg/L	0.060	0.019		W333103	AS	08/25/13 08:14	
EPA 200.7	**Magnesium**	9.55	mg/L	0.060	0.039		W333103	AS	08/25/13 08:14	
EPA 200.7	**Silica (SiO2)**	12.8	mg/L	0.17	0.05		W333103	AS	08/25/13 08:14	
EPA 200.7	**Sodium**	1430	mg/L	5.00	1.10	10	W333103	AS	08/25/13 10:42	D2
SM 2340B	**Hardness (as CaCO3)**	49.1	mg/L	0.347	0.198		N/A		08/25/13 08:14	

Classical Chemistry Parameters

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 335.4	**Cyanide (total)**	125	mg/L	10.0	1.90	1000	W334279	IIT	08/22/13 13:14	D2
EPA 351.2	**TKN**	107	mg/L	5.00	0.92	10	W333121	NCS	08/15/13 11:13	D2
EPA 353.2	**Nitrate/Nitrite as N**	123	mg/L	2.50	0.500	50	W333261	ARP	08/16/13 14:31	D2
EPA 410.4	**Chemical Oxygen Demand**	127	mg/L	20.0	10.0	4	W334058	SM	08/21/13 12:45	D1
SM 2320B/2310B	**Bicarbonate**	1520	mg/L as CaCO3	1.0			W334059	DKS	08/22/13 14:17	
SM 2320B/2310B	**Carbonate**	814	mg/L as CaCO3	1.0			W334059	DKS	08/22/13 14:17	
SM 2320B/2310B	Hydroxide	< 1.0	mg/L as CaCO3	1.0			W334059	DKS	08/22/13 14:17	
SM 2320B/2310B	**Total Alkalinity**	2330	mg/L as CaCO3	1.0			W334059	DKS	08/22/13 14:17	
SM 2540 C	**Total Diss. Solids**	3850	mg/L	40			W333139	JDM	08/13/13 14:40	D1
SM 2580B	**Eh**	178	mV				W333214	AGF	08/19/13 12:20	
SM 4500 H B	**pH @19.0°C**	9.42	pH Units				W334059	DKS	08/22/13 14:17	H5
SM 4500-CN-I	**Cyanide (WAD)**	0.476	mg/L	0.0500	0.0085	5	W334271	IIT	08/22/13 13:47	D2
SM 5310B	**Total Organic Carbon**	79.1	mg/L	3.00	0.60	3	W334224	SM	08/21/13 16:01	D1

Anions by Ion Chromatography

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 300.0	**Chloride**	26.3	mg/L	5.00	1.52	25	W333384	AEW	08/16/13 18:43	D2
EPA 300.0	**Fluoride**	47.7	mg/L	2.50	0.42	25	W333384	AEW	08/16/13 18:43	D2
EPA 300.0	**Sulfate as SO4**	353	mg/L	7.50	1.65	25	W333384	AEW	08/16/13 18:43	D2

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

Quality Control - BLANK Data

Metals (Dissolved)

Method	Analyte	Units	Result	MDL	MRL	Batch ID	Analyzed	Notes
EPA 200.7	Calcium	mg/L	<0.040	0.015	0.040	W333103	25-Aug-13	
EPA 200.7	Iron	mg/L	<0.060	0.019	0.060	W333103	25-Aug-13	
EPA 200.7	Magnesium	mg/L	<0.060	0.039	0.060	W333103	25-Aug-13	
EPA 200.7	Silica (SiO2)	mg/L	<0.17	0.05	0.17	W333103	25-Aug-13	
EPA 200.7	Sodium	mg/L	<0.50	0.11	0.50	W333103	25-Aug-13	

Classical Chemistry Parameters

Method	Analyte	Units	Result	MDL	MRL	Batch ID	Analyzed	Notes
EPA 335.4	Cyanide (total)	mg/L	<0.0050	0.0019	0.0050	W334279	22-Aug-13	
EPA 351.2	TKN	mg/L	<0.50	0.09	0.50	W333121	15-Aug-13	
EPA 353.2	Nitrate/Nitrite as N	mg/L	<0.050	0.010	0.050	W333261	16-Aug-13	
EPA 410.4	Chemical Oxygen Demand	mg/L	<5.0	2.5	5.0	W334058	21-Aug-13	
SM 2320B/2310B	Total Alkalinity	mg/L as CaCO3	<1.0		1.0	W334059	22-Aug-13	
SM 2320B/2310B	Bicarbonate	mg/L as CaCO3	<1.0		1.0	W334059	22-Aug-13	
SM 2320B/2310B	Carbonate	mg/L as CaCO3	<1.0		1.0	W334059	22-Aug-13	
SM 2320B/2310B	Hydroxide	mg/L as CaCO3	<1.0		1.0	W334059	22-Aug-13	
SM 2540 C	Total Diss. Solids	mg/L	<10		10	W333139	13-Aug-13	
SM 4500-CN-I	Cyanide (WAD)	mg/L	<0.0100	0.0017	0.0100	W334271	22-Aug-13	
SM 5310B	Total Organic Carbon	mg/L	<1.00	0.20	1.00	W334224	21-Aug-13	

Anions by Ion Chromatography

Method	Analyte	Units	Result	MDL	MRL	Batch ID	Analyzed	Notes
EPA 300.0	Fluoride	mg/L	<0.10	0.02	0.10	W333384	16-Aug-13	
EPA 300.0	Chloride	mg/L	<0.20	0.06	0.20	W333384	16-Aug-13	
EPA 300.0	Sulfate as SO4	mg/L	<0.30	0.07	0.30	W333384	16-Aug-13	

Quality Control - LABORATORY CONTROL SAMPLE Data

Metals (Dissolved)

Method	Analyte	Units	LCS Result	LCS True	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
EPA 200.7	Calcium	mg/L	18.5	20.0	92.3	85 - 115	W333103	25-Aug-13	
EPA 200.7	Iron	mg/L	9.72	10.0	97.2	85 - 115	W333103	25-Aug-13	
EPA 200.7	Magnesium	mg/L	18.7	20.0	93.5	85 - 115	W333103	25-Aug-13	
EPA 200.7	Silica (SiO2)	mg/L	10.7	10.7	100	85 - 115	W333103	25-Aug-13	
EPA 200.7	Sodium	mg/L	18.4	19.0	97.0	85 - 115	W333103	25-Aug-13	

Classical Chemistry Parameters

Method	Analyte	Units	LCS Result	LCS True	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
EPA 335.4	Cyanide (total)	mg/L	0.148	0.150	98.7	90 - 110	W334279	22-Aug-13	
EPA 351.2	TKN	mg/L	7.91	8.00	98.9	90 - 110	W333121	15-Aug-13	
EPA 353.2	Nitrate/Nitrite as N	mg/L	2.01	2.00	101	90 - 110	W333261	16-Aug-13	
EPA 410.4	Chemical Oxygen Demand	mg/L	107	114	93.8	90 - 110	W334058	21-Aug-13	
SM 2320B/2310B	Total Alkalinity	mg/L as CaCO3	102	97.2	105	85 - 115	W334059	22-Aug-13	
SM 2320B/2310B	Bicarbonate	mg/L as CaCO3	99.2	97.2	102	85 - 115	W334059	22-Aug-13	
SM 2580B	Eh	mV	217	220	98.6	98.59 - 101.4	W333214	19-Aug-13	
SM 4500-CN-I	Cyanide (WAD)	mg/L	0.149	0.150	99.3	90 - 110	W334271	22-Aug-13	
SM 5310B	Total Organic Carbon	mg/L	34.6	34.3	101	80 - 120	W334224	21-Aug-13	

Anions by Ion Chromatography

Method	Analyte	Units	LCS Result	LCS True	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
EPA 300.0	Fluoride	mg/L	1.89	2.00	94.6	90 - 110	W333384	16-Aug-13	
EPA 300.0	Chloride	mg/L	2.87	3.00	95.8	90 - 110	W333384	16-Aug-13	
EPA 300.0	Sulfate as SO4	mg/L	10.1	10.0	101	90 - 110	W333384	16-Aug-13	

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3H0210**
Reported: 26-Aug-13 11:54

Quality Control - DUPLICATE Data

Classical Chemistry Parameters

Method	Analyte	Units	Duplicate Result	Sample Result	RPD	RPD Limit	Batch ID	Analyzed	Notes
SM 2320B/2310B	Total Alkalinity	mg/L as CaCO3	2370	2330	1.7	20	W334059	22-Aug-13	
SM 2320B/2310B	Bicarbonate	mg/L as CaCO3	1530	1520	0.8	20	W334059	22-Aug-13	
SM 2320B/2310B	Carbonate	mg/L as CaCO3	841	814	3.2	20	W334059	22-Aug-13	
SM 2320B/2310B	Hydroxide	mg/L as CaCO3	<1.0	<1.0	UDL	20	W334059	22-Aug-13	
SM 2540 C	Total Diss. Solids	mg/L	1380	1370	0.7	10	W333139	13-Aug-13	
SM 2580B	Eh	mV	181	178	1.7	20	W333214	19-Aug-13	
SM 4500 H B	pH	pH Units	9.42	9.42	0.0	20	W334059	22-Aug-13	

Quality Control - MATRIX SPIKE Data

Method	Analyte	Units	Spike Result	Sample Result (R)	Spike Level (S)	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
Metals (Dissolved)										
EPA 200.7	Calcium	mg/L	177	150	20.0	R > 4S	70 - 130	W333103	25-Aug-13	M3
EPA 200.7	Calcium	mg/L	698	699	20.0	R > 4S	70 - 130	W333103	25-Aug-13	M3
EPA 200.7	Iron	mg/L	10.4	<0.060	10.0	104	70 - 130	W333103	25-Aug-13	
EPA 200.7	Iron	mg/L	10.6	1.10	10.0	95.1	70 - 130	W333103	25-Aug-13	
EPA 200.7	Magnesium	mg/L	33.5	12.6	20.0	104	70 - 130	W333103	25-Aug-13	
EPA 200.7	Magnesium	mg/L	374	361	20.0	R > 4S	70 - 130	W333103	25-Aug-13	M3
EPA 200.7	Silica (SiO2)	mg/L	23.1	11.9	10.7	105	70 - 130	W333103	25-Aug-13	
EPA 200.7	Silica (SiO2)	mg/L	54.2	44.9	10.7	86.4	70 - 130	W333103	25-Aug-13	
EPA 200.7	Sodium	mg/L	28.6	8.08	19.0	108	70 - 130	W333103	25-Aug-13	
EPA 200.7	Sodium	mg/L	36.9	18.5	19.0	96.8	70 - 130	W333103	25-Aug-13	
Classical Chemistry Parameters										
EPA 335.4	Cyanide (total)	mg/L	0.100	<0.0050	0.100	100	90 - 110	W334279	22-Aug-13	
EPA 351.2	TKN	mg/L	7.71	<0.50	8.00	94.0	90 - 110	W333121	15-Aug-13	
EPA 351.2	TKN	mg/L	7.92	<0.50	8.00	97.6	90 - 110	W333121	15-Aug-13	
EPA 353.2	Nitrate/Nitrite as N	mg/L	3.36	2.34	1.00	102	90 - 110	W333261	16-Aug-13	
EPA 353.2	Nitrate/Nitrite as N	mg/L	2.23	1.11	1.00	112	90 - 110	W333261	16-Aug-13	M1
EPA 410.4	Chemical Oxygen Demand	mg/L	51.8	<5.0	50.0	95.4	90 - 110	W334058	21-Aug-13	
SM 4500-CN-I	Cyanide (WAD)	mg/L	0.100	<0.0100	0.100	97.0	75 - 125	W334271	22-Aug-13	
SM 5310B	Total Organic Carbon	mg/L	54.7	4.08	50.0	101	75 - 125	W334224	21-Aug-13	
Anions by Ion Chromatography										
EPA 300.0	Fluoride	mg/L	2.48	0.48	2.00	99.9	90 - 110	W333384	16-Aug-13	
EPA 300.0	Fluoride	mg/L	2.09	0.15	2.00	97.1	90 - 110	W333384	16-Aug-13	
EPA 300.0	Chloride	mg/L	27.0	23.3	3.00	R > 4S	90 - 110	W333384	16-Aug-13	D2,M3
EPA 300.0	Chloride	mg/L	5.10	2.02	3.00	102	90 - 110	W333384	16-Aug-13	
EPA 300.0	Sulfate as SO4	mg/L	43.2	32.0	10.0	112	90 - 110	W333384	16-Aug-13	M1
EPA 300.0	Sulfate as SO4	mg/L	16.8	5.98	10.0	109	90 - 110	W333384	16-Aug-13	

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013
Work Order: **W3H0210**
Reported: 26-Aug-13 11:54

Quality Control - MATRIX SPIKE DUPLICATE Data

Method	Analyte	Units	MSD Result	Spike Result	Spike Level	RPD	RPD Limit	Batch ID	Analyzed	Notes
Metals (Dissolved)										
EPA 200.7	Calcium	mg/L	176	177	20.0	0.9	20	W333103	25-Aug-13	M3
EPA 200.7	Iron	mg/L	10.3	10.4	10.0	1.2	20	W333103	25-Aug-13	
EPA 200.7	Magnesium	mg/L	33.4	33.5	20.0	0.1	20	W333103	25-Aug-13	
EPA 200.7	Silica (SiO2)	mg/L	23.5	23.1	10.7	1.8	20	W333103	25-Aug-13	
EPA 200.7	Sodium	mg/L	28.8	28.6	19.0	0.5	20	W333103	25-Aug-13	
Classical Chemistry Parameters										
EPA 335.4	Cyanide (total)	mg/L	0.101	0.100	0.100	1.0	20	W334279	22-Aug-13	
EPA 351.2	TKN	mg/L	8.09	7.71	8.00	4.8	20	W333121	15-Aug-13	
EPA 353.2	Nitrate/Nitrite as N	mg/L	3.39	3.36	1.00	0.9	20	W333261	16-Aug-13	
EPA 410.4	Chemical Oxygen Demand	mg/L	52.2	51.8	50.0	0.7	20	W334058	21-Aug-13	
SM 4500-CN-I	Cyanide (WAD)	mg/L	0.100	0.100	0.100	0.0	20	W334271	22-Aug-13	
SM 5310B	Total Organic Carbon	mg/L	54.6	54.7	50.0	0.2	20	W334224	21-Aug-13	
Anions by Ion Chromatography										
EPA 300.0	Fluoride	mg/L	2.48	2.48	2.00	0.2	20	W333384	16-Aug-13	
EPA 300.0	Chloride	mg/L	26.5	27.0	3.00	1.8	20	W333384	16-Aug-13	D2,M3
EPA 300.0	Sulfate as SO4	mg/L	43.3	43.2	10.0	0.1	20	W333384	16-Aug-13	M1

Notes and Definitions

D1	Sample required dilution due to matrix.
D2	Sample required dilution due to high concentration of target analyte.
H5	This test is specified to be performed in the field within 15 minutes of sampling; sample was received and analyzed past the regulatory holding time.
M1	Matrix spike recovery was high, but the LCS recovery was acceptable.
M3	The spike recovery value is unusable since the analyte concentration in the sample is disproportionate to spike level. The LCS was acceptable.
LCS	Laboratory Control Sample (Blank Spike)
RPD	Relative Percent Difference
UDL	A result is less than the detection limit
R > 4S	% recovery not applicable, sample concentration more than four times greater than spike level
<RL	A result is less than the reporting limit
MRL	Method Reporting Limit
MDL	Method Detection Limit
N/A	Not Applicable

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser
Work Order: **W3G0778**
Reported: 15-Aug-13 12:22

ANALYTICAL REPORT FOR SAMPLES

Sample ID	Laboratory ID	Matrix	Date Sampled	Sampled By	Date Received
TWA - 150	W3G0778-01	Soil	17-Jan-13 14:00	LJ	31-Jul-2013

Solid samples are analyzed on an as-received, wet-weight basis, unless otherwise requested. Non-Detects are reported at the MDL.
Sample preparation is defined by the client as per their Data Quality Objectives.
This report supercedes any previous reports for this Work Order. The complete report includes pages for each sample, a full QC report, and a notes section.
The results presented in this report relate only to the samples, and meet all requirements of the NELAC Standards unless otherwise noted.

(Q6) SVL received the following containers outside of published EPA guidelines for preservation temperatures (0-6°C).
The guidelines do not pertain to nitric-preserved metals.

Default Cooler (Received Temperature: 7.0°C)

Labnumber	Container	Client ID
W3G0778-01 A	Bag, Ziploc	TWA - 150

Hydrometrics Inc. - CDA	**Project Name: Kaiser**
2736 White PIne Drive	Work Order: **W3G0778**
Coeur d Alene, ID 83815	Reported: 15-Aug-13 12:22

Client Sample ID: **TWA - 150**
SVL Sample ID: **W3G0778-01 (Soil)**

Sample Report Page 1 of 1

Sampled: 17-Jan-13 14:00
Received: 31-Jul-13
Sampled By: LJ

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Classical Chemistry Parameters										
SM 4500-CN-I	Cyanide (WAD)	< 0.500	mg/kg	0.500	0.011		W331360	IIT	08/02/13 14:45	H3
SW846 9012B	**Cyanide (total)**	13.5	mg/kg	0.50	0.10		W331356	IIT	08/02/13 15:22	H3
Anions by Ion Chromatography										
EPA 300.0	**Fluoride**	11.7	mg/kg	1.0	0.2		W333086	AEW	08/15/13 11:21	H3

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

John Kern

John Kern
Laboratory Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser
Work Order: **W3G0778**
Reported: 15-Aug-13 12:22

Quality Control - BLANK Data

Classical Chemistry Parameters

Method	Analyte	Units	Result	MDL	MRL	Batch ID	Analyzed	Notes
SM 4500-CN-I	Cyanide (WAD)	mg/kg	<0.500	0.011	0.500	W331360	02-Aug-13	
SW846 9012B	Cyanide (total)	mg/kg	<0.50	0.10	0.50	W331356	02-Aug-13	

Anions by Ion Chromatography

Method	Analyte	Units	Result	MDL	MRL	Batch ID	Analyzed	Notes
EPA 300.0	Fluoride	mg/kg	<1.0	0.2	1.0	W333086	14-Aug-13	

Quality Control - LABORATORY CONTROL SAMPLE Data

Classical Chemistry Parameters

Method	Analyte	Units	LCS Result	LCS True	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
SM 4500-CN-I	Cyanide (WAD)	mg/kg	0.148	0.150	98.7	80 - 120	W331360	02-Aug-13	
SW846 9012B	Cyanide (total)	mg/L	0.25	0.248	100	80 - 120	W331356	02-Aug-13	

Anions by Ion Chromatography

Method	Analyte	Units	LCS Result	LCS True	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
EPA 300.0	Fluoride	mg/kg	144	62.8	229	50 - 150	W333086	14-Aug-13	N3

Quality Control - MATRIX SPIKE Data

Classical Chemistry Parameters

Method	Analyte	Units	Spike Result	Sample Result (R)	Spike Level (S)	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
SM 4500-CN-I	Cyanide (WAD)	mg/kg	<0.500	<0.500	0.400	89.8	75 - 125	W331360	02-Aug-13	
SW846 9012B	Cyanide (total)	mg/kg	35.3	13.5	20.0	109	75 - 125	W331356	02-Aug-13	D2

Anions by Ion Chromatography

Method	Analyte	Units	Spike Result	Sample Result (R)	Spike Level (S)	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
EPA 300.0	Fluoride	mg/kg	22.8	5.2	20.0	88.1	75 - 125	W333086	14-Aug-13	

Quality Control - MATRIX SPIKE DUPLICATE Data

Classical Chemistry Parameters

Method	Analyte	Units	MSD Result	Spike Result	Spike Level	RPD	RPD Limit	Batch ID	Analyzed	Notes
SM 4500-CN-I	Cyanide (WAD)	mg/kg	0.353	0.359	0.400	1.7	20	W331360	02-Aug-13	
SW846 9012B	Cyanide (total)	mg/kg	35.4	35.3	20.0	0.4	20	W331356	02-Aug-13	D2

Anions by Ion Chromatography

Method	Analyte	Units	MSD Result	Spike Result	Spike Level	RPD	RPD Limit	Batch ID	Analyzed	Notes
EPA 300.0	Fluoride	mg/kg	22.5	22.8	20.0	1.2	20	W333086	14-Aug-13	

Hydrometrics Inc. - CDA	**Project Name: Kaiser**
2736 White PIne Drive	Work Order: **W3G0778**
Coeur d Alene, ID 83815	Reported: 15-Aug-13 12:22

Notes and Definitions

D2	Sample required dilution due to high concentration of target analyte.
H3	Sample was received and/or analysis requested past holding time.
N3	exceeded laboratory limits, but within the PT performance acceptance limits of 26.4 - 290 mg/kg
LCS	Laboratory Control Sample (Blank Spike)
RPD	Relative Percent Difference
UDL	A result is less than the detection limit
R > 4S	% recovery not applicable, sample concentration more than four times greater than spike level
<RL	A result is less than the reporting limit
MRL	Method Reporting Limit
MDL	Method Detection Limit
N/A	Not Applicable

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / 72 HR ANALYSIS
Work Order: **W3H0328**
Reported: 19-Aug-13 17:03

ANALYTICAL REPORT FOR SAMPLES

Sample ID	Laboratory ID	Matrix	Date Sampled	Sampled By	Date Received
C-1	W3H0328-01	Water	12-Aug-13 00:00	CM	13-Aug-2013
ZVI-2	W3H0328-02	Water	12-Aug-13 00:00	CM	13-Aug-2013
ZVI-3	W3H0328-03	Water	12-Aug-13 00:00	CM	13-Aug-2013
ZVI-4	W3H0328-04	Water	12-Aug-13 00:00	CM	13-Aug-2013
ZVI-5	W3H0328-05	Water	12-Aug-13 00:00	CM	13-Aug-2013
F-6	W3H0328-06	Water	12-Aug-13 00:00	CM	13-Aug-2013
F-7	W3H0328-07	Water	12-Aug-13 00:00	CM	13-Aug-2013
F-8	W3H0328-08	Water	12-Aug-13 00:00	CM	13-Aug-2013
F-9	W3H0328-09	Water	12-Aug-13 00:00	CM	13-Aug-2013
F-10	W3H0328-10	Water	12-Aug-13 00:00	CM	13-Aug-2013
F-11	W3H0328-11	Water	12-Aug-13 00:00	CM	13-Aug-2013

Solid samples are analyzed on an as-received, wet-weight basis, unless otherwise requested.
Sample preparation is defined by the client as per their Data Quality Objectives.
This report supercedes any previous reports for this Work Order. The complete report includes pages for each sample, a full QC report, and a notes section.
The results presented in this report relate only to the samples, and meet all requirements of the NELAC Standards unless otherwise noted.

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / 72 HR ANALYSIS
Work Order: **W3H0328**
Reported: 19-Aug-13 17:03

Client Sample ID: **C-1**
SVL Sample ID: **W3H0328-01 (Water)**

Sample Report Page 1 of 1

Sampled: 12-Aug-13 00:00
Received: 13-Aug-13
Sampled By: CM

Classical Chemistry Parameters

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 120.1	**Specific conductance**	7210	µmhos/cm	5.00			W333416	RS	08/16/13 13:40	
SM 2580B	**Eh**	214	mV				W333420	DKS	08/16/13 13:24	
SM 4500 H B	**pH @28.4°C**	6.44	pH Units				W333412	AGF	08/16/13 13:44	

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

SVL holds the following certifications:
AZ:0538, **CA**:2080, **FL**(**NELAC**):E87993, **ID**:ID00019 & ID00965 (Microbiology), **NV**:ID000192007A, **WA**:C573

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / 72 HR ANALYSIS
Work Order: **W3H0328**
Reported: 19-Aug-13 17:03

Client Sample ID: **ZVI-2**
SVL Sample ID: **W3H0328-02 (Water)**

Sample Report Page 1 of 1

Sampled: 12-Aug-13 00:00
Received: 13-Aug-13
Sampled By: CM

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Classical Chemistry Parameters										
EPA 120.1	**Specific conductance**	6080	µmhos/cm	5.00			W333416	RS	08/16/13 13:40	
SM 2580B	**Eh**	-728	mV				W333420	DKS	08/16/13 13:24	
SM 4500 H B	**pH @28.3°C**	9.57	pH Units				W333412	AGF	08/16/13 13:44	

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

SVL holds the following certifications:
AZ:0538, **CA**:2080, **FL**(**NELAC**):E87993, **ID**:ID00019 & ID00965 (Microbiology), **NV**:ID000192007A, **WA**:C573

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / 72 HR ANALYSIS
Work Order: **W3H0328**
Reported: 19-Aug-13 17:03

Client Sample ID: **ZVI-3**
SVL Sample ID: **W3H0328-03 (Water)**

Sample Report Page 1 of 1

Sampled: 12-Aug-13 00:00
Received: 13-Aug-13
Sampled By: CM

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Classical Chemistry Parameters										
EPA 120.1	**Specific conductance**	7070	µmhos/cm	5.00			W333416	RS	08/16/13 13:40	
SM 2580B	**Eh**	-709	mV				W333420	DKS	08/16/13 13:24	
SM 4500 H B	**pH @28.6°C**	8.89	pH Units				W333412	AGF	08/16/13 13:44	

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

SVL holds the following certifications:
AZ:0538, **CA**:2080, **FL**(**NELAC**):E87993, **ID**:ID00019 & ID00965 (Microbiology), **NV**:ID000192007A, **WA**:C573

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / 72 HR ANALYSIS
Work Order: **W3H0328**
Reported: 19-Aug-13 17:03

Client Sample ID: **ZVI-4**
SVL Sample ID: **W3H0328-04 (Water)**

Sample Report Page 1 of 1

Sampled: 12-Aug-13 00:00
Received: 13-Aug-13
Sampled By: CM

Classical Chemistry Parameters

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 120.1	**Specific conductance**	6330	µmhos/cm	5.00			W333416	RS	08/16/13 13:40	
SM 2580B	**Eh**	-107	mV				W333420	DKS	08/16/13 13:24	
SM 4500 H B	**pH @28.2°C**	6.22	pH Units				W333412	AGF	08/16/13 13:44	

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / 72 HR ANALYSIS
Work Order: **W3H0328**
Reported: 19-Aug-13 17:03

Client Sample ID: **ZVI-5**
SVL Sample ID: **W3H0328-05 (Water)**

Sample Report Page 1 of 1

Sampled: 12-Aug-13 00:00
Received: 13-Aug-13
Sampled By: CM

Classical Chemistry Parameters

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 120.1	**Specific conductance**	7020	µmhos/cm	5.00			W333416	RS	08/16/13 13:40	
SM 2580B	**Eh**	-62.1	mV				W333420	DKS	08/16/13 13:24	
SM 4500 H B	**pH @24.4°C**	6.90	pH Units				W333412	AGF	08/16/13 13:44	

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / 72 HR ANALYSIS
Work Order: **W3H0328**
Reported: 19-Aug-13 17:03

Client Sample ID: **F-6**
SVL Sample ID: **W3H0328-06 (Water)**

Sample Report Page 1 of 1

Sampled: 12-Aug-13 00:00
Received: 13-Aug-13
Sampled By: CM

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Classical Chemistry Parameters										
EPA 120.1	**Specific conductance**	6160	µmhos/cm	5.00			W334033	JDM	08/19/13 11:40	
SM 2580B	**Eh**	152	mV				W334002	HJG	08/19/13 12:25	
SM 4500 H B	**pH @22.8°C**	9.05	pH Units				W334003	AGF	08/19/13 09:55	

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / 72 HR ANALYSIS
Work Order: **W3H0328**
Reported: 19-Aug-13 17:03

Client Sample ID: **F-7**
SVL Sample ID: **W3H0328-07 (Water)**

Sample Report Page 1 of 1

Sampled: 12-Aug-13 00:00
Received: 13-Aug-13
Sampled By: CM

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Classical Chemistry Parameters										
EPA 120.1	**Specific conductance**	7420	µmhos/cm	5.00			W334033	JDM	08/19/13 11:40	
SM 2580B	**Eh**	244	mV				W334002	HJG	08/19/13 12:25	
SM 4500 H B	**pH @22.9°C**	6.32	pH Units				W334003	AGF	08/19/13 09:55	

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / 72 HR ANALYSIS
Work Order: **W3H0328**
Reported: 19-Aug-13 17:03

Client Sample ID: **F-8**
SVL Sample ID: **W3H0328-08 (Water)**

Sample Report Page 1 of 1

Sampled: 12-Aug-13 00:00
Received: 13-Aug-13
Sampled By: CM

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Classical Chemistry Parameters										
EPA 120.1	**Specific conductance**	5770	µmhos/cm	5.00			W334033	JDM	08/19/13 11:40	
SM 2580B	**Eh**	62.0	mV				W334002	HJG	08/19/13 12:25	
SM 4500 H B	**pH @22.8°C**	9.17	pH Units				W334003	AGF	08/19/13 09:55	

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

SVL holds the following certifications:
AZ:0538, **CA**:2080, **FL**(**NELAC**):E87993, **ID**:ID00019 & ID00965 (Microbiology), **NV**:ID000192007A, **WA**:C573

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / 72 HR ANALYSIS
Work Order: **W3H0328**
Reported: 19-Aug-13 17:03

Client Sample ID: **F-9**
SVL Sample ID: **W3H0328-09 (Water)**

Sample Report Page 1 of 1

Sampled: 12-Aug-13 00:00
Received: 13-Aug-13
Sampled By: CM

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Classical Chemistry Parameters										
EPA 120.1	**Specific conductance**	7000	µmhos/cm	5.00			W334033	JDM	08/19/13 11:40	
SM 2580B	**Eh**	90.0	mV				W334002	HJG	08/19/13 12:25	
SM 4500 H B	**pH @22.5°C**	6.55	pH Units				W334003	AGF	08/19/13 09:55	

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

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Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / 72 HR ANALYSIS
Work Order: **W3H0328**
Reported: 19-Aug-13 17:03

Client Sample ID: **F-10**
SVL Sample ID: **W3H0328-10 (Water)**

Sample Report Page 1 of 1

Sampled: 12-Aug-13 00:00
Received: 13-Aug-13
Sampled By: CM

Classical Chemistry Parameters

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 120.1	**Specific conductance**	5910	µmhos/cm	5.00			W334033	JDM	08/19/13 11:40	
SM 2580B	**Eh**	190	mV				W334002	HJG	08/19/13 12:25	
SM 4500 H B	**pH @22.7°C**	6.53	pH Units				W334003	AGF	08/19/13 09:55	

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Kirby Gray

Kirby Gray
Technical Director

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2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / 72 HR ANALYSIS
Work Order: **W3H0328**
Reported: 19-Aug-13 17:03

Client Sample ID: **F-11**
SVL Sample ID: **W3H0328-11 (Water)**

Sample Report Page 1 of 1

Sampled: 12-Aug-13 00:00
Received: 13-Aug-13
Sampled By: CM

Classical Chemistry Parameters

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 120.1	**Specific conductance**	7210	µmhos/cm	5.00			W334033	JDM	08/19/13 11:40	
SM 2580B	**Eh**	349	mV				W334002	HJG	08/19/13 12:25	
SM 4500 H B	**pH @23.1°C**	5.32	pH Units				W334003	AGF	08/19/13 09:55	

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

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Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / 72 HR ANALYSIS
Work Order: **W3H0328**
Reported: 19-Aug-13 17:03

Quality Control - LABORATORY CONTROL SAMPLE Data

Classical Chemistry Parameters

Method	Analyte	Units	LCS Result	LCS True	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
EPA 120.1	Specific conductance	µmhos/cm	321	322	99.6	90 - 110	W333416	16-Aug-13	
EPA 120.1	Specific conductance	µmhos/cm	318	322	98.9	90 - 110	W334033	19-Aug-13	
SM 2580B	Eh	mV	222	220	101	98.59 - 101.4	W333420	16-Aug-13	
SM 2580B	Eh	mV	217	220	98.6	98.59 - 101.4	W334002	19-Aug-13	
SM 4500 H B	pH	pH Units	6.90	6.95	99.3	85 - 115	W333412	16-Aug-13	
SM 4500 H B	pH	pH Units	6.90	6.95	99.3	85 - 115	W334003	19-Aug-13	

Quality Control - DUPLICATE Data

Classical Chemistry Parameters

Method	Analyte	Units	Duplicate Result	Sample Result	RPD	RPD Limit	Batch ID	Analyzed	Notes
EPA 120.1	Specific conductance	µmhos/cm	6070	6160	1.5	20	W334033	19-Aug-13	
EPA 120.1	Specific conductance	µmhos/cm	7200	7210	0.1	20	W333416	16-Aug-13	
SM 2580B	Eh	mV	152	152	0.0	20	W334002	19-Aug-13	
SM 2580B	Eh	mV	214	214	0.3	20	W333420	16-Aug-13	
SM 4500 H B	pH	pH Units	6.48	6.44	0.6	20	W333412	16-Aug-13	
SM 4500 H B	pH	pH Units	9.04	9.05	0.1	20	W334003	19-Aug-13	

Notes and Definitions

LCS	Laboratory Control Sample (Blank Spike)
RPD	Relative Percent Difference
UDL	A result is less than the detection limit
R > 4S	% recovery not applicable, sample concentration more than four times greater than spike level
<RL	A result is less than the reporting limit
MRL	Method Reporting Limit
MDL	Method Detection Limit
N/A	Not Applicable

Hydrometrics Inc. - CDA	**Project Name: Kaiser In-Lab Treatability Study 2013 / 177 HR ANALYSIS**
2736 White PIne Drive	Work Order: **W3H0828**
Coeur d Alene, ID 83815	Reported: 29-Aug-13 12:28

ANALYTICAL REPORT FOR SAMPLES

Sample ID	Laboratory ID	Matrix	Date Sampled	Sampled By	Date Received
C-1	W3H0626-01	Water	23-Aug-13 00:00	CM	23-Aug-2013
ZVI-2	W3H0626-02	Water	23-Aug-13 00:00	CM	23-Aug-2013
ZVI-3	W3H0626-03	Water	23-Aug-13 00:00	CM	23-Aug-2013
ZVI-4	W3H0626-04	Water	23-Aug-13 00:00	CM	23-Aug-2013
ZVI-5	W3H0626-05	Water	23-Aug-13 00:00	CM	23-Aug-2013
F-6	W3H0626-06	Water	23-Aug-13 00:00	CM	23-Aug-2013
F-7	W3H0626-07	Water	23-Aug-13 00:00	CM	23-Aug-2013
F-8	W3H0626-08	Water	23-Aug-13 00:00	CM	23-Aug-2013
F-9	W3H0626-09	Water	23-Aug-13 00:00	CM	23-Aug-2013
F-10	W3H0626-10	Water	23-Aug-13 00:00	CM	23-Aug-2013
F-11	W3H0626-11	Water	23-Aug-13 00:00	CM	23-Aug-2013

Solid samples are analyzed on an as-received, wet-weight basis, unless otherwise requested.
Sample preparation is defined by the client as per their Data Quality Objectives.
This report supercedes any previous reports for this Work Order. The complete report includes pages for each sample, a full QC report, and a notes section.
The results presented in this report relate only to the samples, and meet all requirements of the NELAC Standards unless otherwise noted.

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / 177 HR ANALYSIS
Work Order: **W3H0828**
Reported: 29-Aug-13 12:28

Client Sample ID: **C-1**
SVL Sample ID: **W3H0626-01 (Water)**

Sample Report Page 1 of 1

Sampled: 23-Aug-13 00:00
Received: 23-Aug-13
Sampled By: CM

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Classical Chemistry Parameters										
EPA 120.1	**Specific conductance**	7160	µmhos/cm	5.00			W334394	JDM	08/23/13 14:45	
SM 2580B	**Eh**	203	mV				W334392	DKS	08/23/13 13:45	
SM 4500 H B	**pH @2. 4°6C**	6.93	pH Units				W334393	DKS	08/23/13 13:08	H5

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / 177 HR ANALYSIS
Work Order: **W3H0828**
Reported: 29-Aug-13 12:28

Client Sample ID: **ZVI-2**
SVL Sample ID: **W3H0626-02 (Water)**

Sample Report Page 1 of 1

Sampled: 23-Aug-13 00:00
Received: 23-Aug-13
Sampled By: CM

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Classical Chemistry Parameters										
EPA 120.1	**Specific conductance**	6620	µmhos/cm	5.00			W334394	JDM	08/23/13 14:45	
SM 2580B	**Eh**	-734	mV				W334392	DKS	08/23/13 13:45	
SM 4500 H B	**pH @29406C**	9.31	pH Units				W334393	DKS	08/23/13 13:08	H5

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / 177 HR ANALYSIS
Work Order: **W3H0828**
Reported: 29-Aug-13 12:28

Client Sample ID: **ZVI-3**
SVL Sample ID: **W3H0626-03 (Water)**

Sample Report Page 1 of 1

Sampled: 23-Aug-13 00:00
Received: 23-Aug-13
Sampled By: CM

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Classical Chemistry Parameters										
EPA 120.1	**Specific conductance**	8360	µmhos/cm	5.00			W334394	JDM	08/23/13 14:45	
SM 2580B	**Eh**	-691	mV				W334392	DKS	08/23/13 13:45	
SM 4500 H B	**pH @28496C**	8.29	pH Units				W334393	DKS	08/23/13 13:08	H5

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

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Technical Director

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Hydrometrics Inc. - CDA	**Project Name: Kaiser In-Lab Treatability Study 2013 / 177 HR ANALYSIS**
2736 White PIne Drive	Work Order: **W3H0828**
Coeur d Alene, ID 83815	Reported: 29-Aug-13 12:28

Client Sample ID: **ZVI-4**
SVL Sample ID: **W3H0626-04 (Water)**

Sample Report Page 1 of 1

Sampled: 23-Aug-13 00:00
Received: 23-Aug-13
Sampled By: CM

Classical Chemistry Parameters

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 120.1	**Specific conductance**	6130	µmhos/cm	5.00			W334394	JDM	08/23/13 14:45	
SM 2580B	**Eh**	-72.5	mV				W334392	DKS	08/23/13 13:45	
SM 4500 H B	**pH @2. 486C**	6.60	pH Units				W334393	DKS	08/23/13 13:08	H5

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Kirby Gray

Kirby Gray
Technical Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / 177 HR ANALYSIS
Work Order: **W3H0828**
Reported: 29-Aug-13 12:28

Client Sample ID: **ZVI-5**
SVL Sample ID: **W3H0626-05 (Water)**

Sample Report Page 1 of 1

Sampled: 23-Aug-13 00:00
Received: 23-Aug-13
Sampled By: CM

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Classical Chemistry Parameters										
EPA 120.1	**Specific conductance**	7330	µmhos/cm	5.00			W334394	JDM	08/23/13 14:45	
SM 2580B	**Eh**	-82.9	mV				W334392	DKS	08/23/13 13:45	
SM 4500 H B	**pH @28456C**	5.91	pH Units				W334393	DKS	08/23/13 13:08	H5

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

Hydrometrics Inc. - CDA	**Project Name: Kaiser In-Lab Treatability Study 2013 / 177 HR ANALYSIS**
2736 White PIne Drive	Work Order: **W3H0828**
Coeur d Alene, ID 83815	Reported: 29-Aug-13 12:28

Client Sample ID: **F-6**
SVL Sample ID: **W3H0626-06 (Water)**

Sample Report Page 1 of 1

Sampled: 23-Aug-13 00:00
Received: 23-Aug-13
Sampled By: CM

Classical Chemistry Parameters

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 120.1	**Specific conductance**	6010	µmhos/cm	5.00			W334394	JDM	08/23/13 14:45	
SM 2580B	**Eh**	126	mV				W334392	DKS	08/23/13 13:45	
SM 4500 H B	**pH @2. 476C**	9.08	pH Units				W334393	DKS	08/23/13 13:08	H5

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / 177 HR ANALYSIS
Work Order: **W3H0828**
Reported: 29-Aug-13 12:28

Client Sample ID: **F-7**
SVL Sample ID: **W3H0626-07 (Water)**

Sample Report Page 1 of 1

Sampled: 23-Aug-13 00:00
Received: 23-Aug-13
Sampled By: CM

Classical Chemistry Parameters

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 120.1	**Specific conductance**	7580	µmhos/cm	5.00			W334394	JDM	08/23/13 14:45	
SM 2580B	**Eh**	218	mV				W334392	DKS	08/23/13 13:45	
SM 4500 H B	**pH @2. 4 6C**	6.80	pH Units				W334393	DKS	08/23/13 13:08	H5

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

One Government Gulch - PO Box 929 Kellogg ID 83837-0929 (208) 784-1258 Fax (208) 783-0891

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / 177 HR ANALYSIS
Work Order: **W3H0828**
Reported: 29-Aug-13 12:28

Client Sample ID: **F-8**
SVL Sample ID: **W3H0626-08 (Water)**

Sample Report Page 1 of 1

Sampled: 23-Aug-13 00:00
Received: 23-Aug-13
Sampled By: CM

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Classical Chemistry Parameters										
EPA 120.1	**Specific conductance**	6200	µmhos/cm	5.00			W334394	JDM	08/23/13 14:45	
SM 2580B	**Eh**	23.4	mV				W334392	DKS	08/23/13 13:45	
SM 4500 H B	**pH @2. 426C**	7.40	pH Units				W334393	DKS	08/23/13 13:08	H5

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / 177 HR ANALYSIS
Work Order: **W3H0828**
Reported: 29-Aug-13 12:28

Client Sample ID: **F-9**
SVL Sample ID: **W3H0626-09 (Water)**

Sample Report Page 1 of 1

Sampled: 23-Aug-13 00:00
Received: 23-Aug-13
Sampled By: CM

Classical Chemistry Parameters

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 120.1	**Specific conductance**	7800	µmhos/cm	5.00			W334394	JDM	08/23/13 14:45	
SM 2580B	**Eh**	99.5	mV				W334392	DKS	08/23/13 13:45	
SM 4500 H B	**pH @29406C**	6.54	pH Units				W334393	DKS	08/23/13 13:08	H5

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Hydrometrics Inc. - CDA
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Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / 177 HR ANALYSIS
Work Order: **W3H0828**
Reported: 29-Aug-13 12:28

Client Sample ID: **F-10**
SVL Sample ID: **W3H0626-10 (Water)**

Sample Report Page 1 of 1

Sampled: 23-Aug-13 00:00
Received: 23-Aug-13
Sampled By: CM

Classical Chemistry Parameters

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 120.1	**Specific conductance**	5870	µmhos/cm	5.00			W334394	JDM	08/23/13 14:45	
SM 2580B	**Eh**	163	mV				W334392	DKS	08/23/13 13:45	
SM 4500 H B	**pH @29436C**	6.84	pH Units				W334393	DKS	08/23/13 13:08	H5

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

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Hydrometrics Inc. - CDA
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Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / 177 HR ANALYSIS
Work Order: **W3H0828**
Reported: 29-Aug-13 12:28

Client Sample ID: **F-11**
SVL Sample ID: **W3H0626-11 (Water)**

Sample Report Page 1 of 1

Sampled: 23-Aug-13 00:00
Received: 23-Aug-13
Sampled By: CM

Classical Chemistry Parameters

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
EPA 120.1	**Specific conductance**	6950	µmhos/cm	5.00			W334394	JDM	08/23/13 14:45	
SM 2580B	**Eh**	313	mV				W334392	DKS	08/23/13 13:45	
SM 4500 H B	**pH @2. 4°6C**	5.62	pH Units				W334393	DKS	08/23/13 13:08	H5

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Technical Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / 177 HR ANALYSIS
Work Order: **W3H0828**
Reported: 29-Aug-13 12:28

Quality Control - LABORATORY CONTROL SAMPLE Data

Method	Analyte	Units	LCS Result	LCS True	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
Classical Chemistry Parameters									
EPA 120.1	Specific conductance	µmhos/cm	306	322	95.1	90 - 110	W334394	23-Aug-13	
SM 2580B	Eh	mV	218	220	99.2	98.59 - 101.4	W334392	23-Aug-13	

Quality Control - DUPLICATE Data

Method	Analyte	Units	Duplicate Result	Sample Result	RPD	RPD Limit	Batch ID	Analyzed	Notes
Classical Chemistry Parameters									
EPA 120.1	Specific conductance	µmhos/cm	6920	7160	3.4	20	W334394	23-Aug-13	
SM 2580B	Eh	mV	206	203	1.5	20	W334392	23-Aug-13	
SM 4500 H B	pH	pH Units	6.89	6.93	0.6	20	W334393	23-Aug-13	

Notes and Definitions

H5	This test is specified to be performed in the field within 15 minutes of sampling; sample was received and analyzed past the regulatory holding time.
LCS	Laboratory Control Sample (Blank Spike)
RPD	Relative Percent Difference
UDL	A result is less than the detection limit
R > 4S	% recovery not applicable, sample concentration more than four times greater than spike level
<RL	A result is less than the reporting limit
MRL	Method Reporting Limit
MDL	Method Detection Limit
N/A	Not Applicable

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / 30 DAY ANALYSIS
Work Order: **W3I0374**
Reported: 19-Sep-13 12:21

ANALYTICAL REPORT FOR SAMPLES

Sample ID	Laboratory ID	Matrix	Date Sampled	Sampled By	Date Received
C-1	W3I0374-01	Water	16-Sep-13 00:00	CM	16-Sep-2013
ZVI-2	W3I0374-02	Water	16-Sep-13 00:00	CM	16-Sep-2013
ZVI-3	W3I0374-03	Water	16-Sep-13 00:00	CM	16-Sep-2013
ZVI-4	W3I0374-04	Water	16-Sep-13 00:00	CM	16-Sep-2013
ZVI-5	W3I0374-05	Water	16-Sep-13 00:00	CM	16-Sep-2013
F-6	W3I0374-06	Water	16-Sep-13 00:00	CM	16-Sep-2013
F-7	W3I0374-07	Water	16-Sep-13 00:00	CM	16-Sep-2013
F-8	W3I0374-08	Water	16-Sep-13 00:00	CM	16-Sep-2013
F-9	W3I0374-09	Water	16-Sep-13 00:00	CM	16-Sep-2013
F-10	W3I0374-10	Water	16-Sep-13 00:00	CM	16-Sep-2013
F-11	W3I0374-11	Water	16-Sep-13 00:00	CM	16-Sep-2013

Solid samples are analyzed on an as-received, wet-weight basis, unless otherwise requested.
Sample preparation is defined by the client as per their Data Quality Objectives.
This report supercedes any previous reports for this Work Order. The complete report includes pages for each sample, a full QC report, and a notes section.
The results presented in this report relate only to the samples, and meet all requirements of the NELAC Standards unless otherwise noted.

Case Narrative

09/19/2013mab: Report reissued. Analysis list has been revised.

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / 30 DAY ANALYSIS
Work Order: **W3I0374**
Reported: 19-Sep-13 12:21

Client Sample ID: **C-1**
SVL Sample ID: **W3I0374-01 (Water)**

Sample Report Page 1 of 1

Sampled: 16-Sep-13 00:00
Received: 16-Sep-13
Sampled By: CM

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Metals (Dissolved)										
EPA 200.7	**Iron**	51.5	mg/L	0.060	0.019		W338086	TJK	09/17/13 12:05	
Classical Chemistry Parameters										
EPA 120.1	**Specific conductance**	7060	µmhos/cm	5.00			W338061	RS	09/16/13 11:27	
EPA 335.4	**Cyanide (total)**	126	mg/L	10.0	1.90	1000	W338081	vrh	09/17/13 14:03	D2
SM 2580B	**Eh**	213	mV				W338058	AGF	09/16/13 12:29	
SM 4500 H B	**pH @19.6°C**	7.87	pH Units				W338057	DKS	09/16/13 14:51	H5
SM 4500-CN-I	**Cyanide (WAD)**	1.92	mg/L	0.500	0.0850	50	W338060	vrh	09/17/13 10:25	D2

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

SVL holds the following certifications:
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Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / 30 DAY ANALYSIS
Work Order: **W3I0374**
Reported: 19-Sep-13 12:21

Client Sample ID: **ZVI-2**
SVL Sample ID: **W3I0374-02 (Water)**

Sample Report Page 1 of 1

Sampled: 16-Sep-13 00:00
Received: 16-Sep-13
Sampled By: CM

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Metals (Dissolved)										
EPA 200.7	**Iron**	6.22	mg/L	0.060	0.019		W338086	TJK	09/17/13 12:10	
Classical Chemistry Parameters										
EPA 120.1	**Specific conductance**	6450	µmhos/cm	5.00			W338061	RS	09/16/13 11:27	
EPA 335.4	**Cyanide (total)**	10.5	mg/L	1.00	0.190	100	W338081	vrh	09/17/13 14:05	D2
SM 2580B	**Eh**	-774	mV				W338058	AGF	09/16/13 12:29	
SM 4500 H B	**pH @19.9°C**	10.12	pH Units				W338057	DKS	09/16/13 14:53	H5
SM 4500-CN-I	**Cyanide (WAD)**	0.0220	mg/L	0.0100	0.0017		W338060	vrh	09/17/13 10:27	

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / 30 DAY ANALYSIS
Work Order: **W3I0374**
Reported: 19-Sep-13 12:21

Client Sample ID: **ZVI-3**
SVL Sample ID: **W3I0374-03 (Water)**

Sample Report Page 1 of 1

Sampled: 16-Sep-13 00:00
Received: 16-Sep-13
Sampled By: CM

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Metals (Dissolved)										
EPA 200.7	**Iron**	0.080	mg/L	0.060	0.019		W338086	TJK	09/17/13 12:16	
Classical Chemistry Parameters										
EPA 120.1	**Specific conductance**	8480	µmhos/cm	5.00			W338061	RS	09/16/13 11:27	
EPA 335.4	**Cyanide (total)**	0.804	mg/L	0.100	0.0190	10	W338081	vrh	09/17/13 14:07	D2
SM 2580B	**Eh**	-708	mV				W338058	AGF	09/16/13 12:29	
SM 4500 H B	**pH @20.0°C**	9.01	pH Units				W338057	DKS	09/16/13 14:55	H5
SM 4500-CN-I	**Cyanide (WAD)**	0.0130	mg/L	0.0100	0.0017		W338060	vrh	09/17/13 10:29	

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

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2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / 30 DAY ANALYSIS
Work Order: **W3I0374**
Reported: 19-Sep-13 12:21

Client Sample ID: **ZVI-4**
SVL Sample ID: **W3I0374-04 (Water)**

Sample Report Page 1 of 1

Sampled: 16-Sep-13 00:00
Received: 16-Sep-13
Sampled By: CM

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Metals (Dissolved)										
EPA 200.7	**Iron**	34.9	mg/L	0.060	0.019		W338086	TJK	09/17/13 12:22	
Classical Chemistry Parameters										
EPA 120.1	**Specific conductance**	6390	µmhos/cm	5.00			W338061	RS	09/16/13 11:27	
EPA 335.4	**Cyanide (total)**	1.20	mg/L	0.100	0.0190	10	W338081	vrh	09/17/13 14:09	D2
SM 2580B	**Eh**	-486	mV				W338058	AGF	09/16/13 12:29	
SM 4500 H B	**pH @20.0°C**	7.26	pH Units				W338057	DKS	09/16/13 14:57	H5
SM 4500-CN-I	**Cyanide (WAD)**	0.0460	mg/L	0.0100	0.0017		W338060	vrh	09/17/13 10:31	

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

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2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / 30 DAY ANALYSIS
Work Order: **W3I0374**
Reported: 19-Sep-13 12:21

Client Sample ID: **ZVI-5**
SVL Sample ID: **W3I0374-05 (Water)**

Sample Report Page 1 of 1

Sampled: 16-Sep-13 00:00
Received: 16-Sep-13
Sampled By: CM

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Metals (Dissolved)										
EPA 200.7	**Iron**	78.2	mg/L	0.060	0.019		W338086	TJK	09/17/13 12:28	
Classical Chemistry Parameters										
EPA 120.1	**Specific conductance**	7670	µmhos/cm	5.00			W338061	RS	09/16/13 11:27	
EPA 335.4	**Cyanide (total)**	1.69	mg/L	0.200	0.0380	20	W338081	vrh	09/17/13 14:11	D2
SM 2580B	**Eh**	-160	mV				W338058	AGF	09/16/13 12:29	
SM 4500 H B	**pH @20.2°C**	6.89	pH Units				W338057	DKS	09/16/13 14:59	H5
SM 4500-CN-I	**Cyanide (WAD)**	0.0830	mg/L	0.0100	0.0017		W338060	vrh	09/17/13 10:33	

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

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Technical Director

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2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / 30 DAY ANALYSIS
Work Order: **W3I0374**
Reported: 19-Sep-13 12:21

Client Sample ID: **F-6**
SVL Sample ID: **W3I0374-06 (Water)**

Sample Report Page 1 of 1

Sampled: 16-Sep-13 00:00
Received: 16-Sep-13
Sampled By: CM

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Metals (Dissolved)										
EPA 200.7	**Calcium**	14.8	mg/L	0.040	0.015		W338086	TJK	09/17/13 12:34	
Classical Chemistry Parameters										
EPA 335.4	**Cyanide (total)**	86.9	mg/L	10.0	1.90	1000	W338081	vrh	09/17/13 14:13	D2
SM 2320B/2310B	**Bicarbonate**	1540	mg/L as CaCO3	1.0			W338057	DKS	09/16/13 16:24	
SM 2320B/2310B	**Carbonate**	357	mg/L as CaCO3	1.0			W338057	DKS	09/16/13 16:24	
SM 2320B/2310B	Hydroxide	< 1.0	mg/L as CaCO3	1.0			W338057	DKS	09/16/13 16:24	
SM 2320B/2310B	**Total Alkalinity**	1900	mg/L as CaCO3	1.0			W338057	DKS	09/16/13 16:24	
SM 4500-CN-I	**Cyanide (WAD)**	0.112	mg/L	0.0100	0.0017		W338060	vrh	09/17/13 10:35	
Anions by Ion Chromatography										
EPA 300.0	**Chloride**	240	mg/L	10.0	3.05	50	W338067	AEW	09/16/13 13:42	D2
EPA 300.0	**Fluoride**	47.3	mg/L	5.00	0.85	50	W338067	AEW	09/16/13 13:42	D2

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / 30 DAY ANALYSIS
Work Order: **W3I0374**
Reported: 19-Sep-13 12:21

Client Sample ID: **F-7**
SVL Sample ID: **W3I0374-07 (Water)**

Sample Report Page 1 of 1

Sampled: 16-Sep-13 00:00
Received: 16-Sep-13
Sampled By: CM

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Metals (Dissolved)										
EPA 200.7	**Calcium**	173	mg/L	0.040	0.015		W338086	TJK	09/17/13 13:14	
Classical Chemistry Parameters										
SM 2320B/2310B	**Bicarbonate**	916	mg/L as CaCO3	1.0			W338057	DKS	09/16/13 15:10	
SM 2320B/2310B	Carbonate	< 1.0	mg/L as CaCO3	1.0			W338057	DKS	09/16/13 15:10	
SM 2320B/2310B	Hydroxide	< 1.0	mg/L as CaCO3	1.0			W338057	DKS	09/16/13 15:10	
SM 2320B/2310B	**Total Alkalinity**	916	mg/L as CaCO3	1.0			W338057	DKS	09/16/13 15:10	
Anions by Ion Chromatography										
EPA 300.0	**Chloride**	1350	mg/L	50.0	15.2	250	W338067	AEW	09/16/13 14:50	D2
EPA 300.0	**Fluoride**	35.2	mg/L	5.00	0.85	50	W338067	AEW	09/16/13 13:53	D2

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

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Technical Director

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Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / 30 DAY ANALYSIS
Work Order: **W3I0374**
Reported: 19-Sep-13 12:21

Client Sample ID: **F-8**
SVL Sample ID: **W3I0374-08 (Water)**

Sample Report Page 1 of 1

Sampled: 16-Sep-13 00:00
Received: 16-Sep-13
Sampled By: CM

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Metals (Dissolved)										
EPA 200.7	**Calcium**	1330	mg/L	0.400	0.150	10	W338086	TJK	09/17/13 14:20	D2
Classical Chemistry Parameters										
SM 2320B/2310B	**Bicarbonate**	4090	mg/L as CaCO3	1.0			W338117	DKS	09/17/13 13:16	
SM 2320B/2310B	Carbonate	< 1.0	mg/L as CaCO3	1.0			W338117	DKS	09/17/13 13:16	
SM 2320B/2310B	Hydroxide	< 1.0	mg/L as CaCO3	1.0			W338117	DKS	09/17/13 13:16	
SM 2320B/2310B	**Total Alkalinity**	4090	mg/L as CaCO3	1.0			W338117	DKS	09/17/13 13:16	
Anions by Ion Chromatography										
EPA 300.0	**Fluoride**	66.8	mg/L	5.00	0.85	50	W338067	AEW	09/16/13 14:05	D2

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Technical Director

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Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / 30 DAY ANALYSIS
Work Order: **W3I0374**
Reported: 19-Sep-13 12:21

Client Sample ID: **F-9**
SVL Sample ID: **W3I0374-09 (Water)**

Sample Report Page 1 of 1

Sampled: 16-Sep-13 00:00
Received: 16-Sep-13
Sampled By: CM

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Metals (Dissolved)										
EPA 200.7	**Calcium**	443	mg/L	0.040	0.015		W338086	TJK	09/17/13 13:26	
Classical Chemistry Parameters										
SM 2320B/2310B	**Bicarbonate**	3360	mg/L as CaCO3	1.0			W338057	DKS	09/16/13 15:37	
SM 2320B/2310B	Carbonate	< 1.0	mg/L as CaCO3	1.0			W338057	DKS	09/16/13 15:37	
SM 2320B/2310B	Hydroxide	< 1.0	mg/L as CaCO3	1.0			W338057	DKS	09/16/13 15:37	
SM 2320B/2310B	**Total Alkalinity**	3360	mg/L as CaCO3	1.0			W338057	DKS	09/16/13 15:37	
Anions by Ion Chromatography										
EPA 300.0	**Fluoride**	49.4	mg/L	5.00	0.85	50	W338067	AEW	09/16/13 14:16	D2

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

SVL holds the following certifications:
AZ:0538, **CA**:2080, **FL**(**NELAC**):E87993, **ID**:ID00019 & ID00965 (Microbiology), **NV**:ID000192007A, **WA**:C573

Hydrometrics Inc. - CDA
2736 White PIne Drive
Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / 30 DAY ANALYSIS
Work Order: **W3I0374**
Reported: 19-Sep-13 12:21

Client Sample ID: **F-10**
SVL Sample ID: **W3I0374-10 (Water)**

Sample Report Page 1 of 1

Sampled: 16-Sep-13 00:00
Received: 16-Sep-13
Sampled By: CM

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Metals (Dissolved)										
EPA 200.7	**Calcium**	23.7	mg/L	0.040	0.015		W338086	TJK	09/17/13 13:33	
Classical Chemistry Parameters										
SM 2320B/2310B	**Bicarbonate**	1670	mg/L as CaCO3	1.0			W338057	DKS	09/16/13 16:05	
SM 2320B/2310B	Carbonate	< 1.0	mg/L as CaCO3	1.0			W338057	DKS	09/16/13 16:05	
SM 2320B/2310B	Hydroxide	< 1.0	mg/L as CaCO3	1.0			W338057	DKS	09/16/13 16:05	
SM 2320B/2310B	**Total Alkalinity**	1670	mg/L as CaCO3	1.0			W338057	DKS	09/16/13 16:05	
SM 4500-P-E	**Orthophosphate as P**	559	mg/L	10.0	4.00	1000	W338205	SM	09/18/13 16:52	D2,M4
Anions by Ion Chromatography										
EPA 300.0	**Fluoride**	27.1	mg/L	5.00	0.85	50	W338067	AEW	09/16/13 14:27	D2

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Technical Director

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Coeur d Alene, ID 83815

Project Name: Kaiser In-Lab Treatability Study 2013 / 30 DAY ANALYSIS
Work Order: **W3I0374**
Reported: 19-Sep-13 12:21

Client Sample ID: **F-11**
SVL Sample ID: **W3I0374-11 (Water)**

Sample Report Page 1 of 1

Sampled: 16-Sep-13 00:00
Received: 16-Sep-13
Sampled By: CM

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Metals (Dissolved)										
EPA 200.7	**Calcium**	76.5	mg/L	0.040	0.015		W338086	TJK	09/17/13 13:44	
Classical Chemistry Parameters										
SM 2320B/2310B	**Bicarbonate**	263	mg/L as CaCO3	1.0			W338057	DKS	09/16/13 16:16	
SM 2320B/2310B	Carbonate	< 1.0	mg/L as CaCO3	1.0			W338057	DKS	09/16/13 16:16	
SM 2320B/2310B	Hydroxide	< 1.0	mg/L as CaCO3	1.0			W338057	DKS	09/16/13 16:16	
SM 2320B/2310B	**Total Alkalinity**	263	mg/L as CaCO3	1.0			W338057	DKS	09/16/13 16:16	
SM 4500-P-E	**Orthophosphate as P**	554	mg/L	10.0	4.00	1000	W338205	SM	09/18/13 16:52	D2
Anions by Ion Chromatography										
EPA 300.0	**Fluoride**	9.75	mg/L	5.00	0.85	50	W338067	AEW	09/16/13 14:39	D2

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

Kirby Gray

Kirby Gray
Technical Director

Quality Control - BLANK Data

Method	Analyte	Units	Result	MDL	MRL	Batch ID	Analyzed	Notes
Metals (Dissolved)								
EPA 200.7	Calcium	mg/L	<0.040	0.015	0.040	W338086	17-Sep-13	
EPA 200.7	Iron	mg/L	<0.060	0.019	0.060	W338086	17-Sep-13	
Classical Chemistry Parameters								
EPA 335.4	Cyanide (total)	mg/L	<0.0100	0.0019	0.0100	W338081	17-Sep-13	
SM 2320B/2310B	Total Alkalinity	mg/L as CaCO3	<1.0		1.0	W338057	16-Sep-13	
SM 2320B/2310B	Total Alkalinity	mg/L as CaCO3	<1.0		1.0	W338117	17-Sep-13	
SM 2320B/2310B	Bicarbonate	mg/L as CaCO3	<1.0		1.0	W338057	16-Sep-13	
SM 2320B/2310B	Bicarbonate	mg/L as CaCO3	<1.0		1.0	W338117	17-Sep-13	
SM 2320B/2310B	Carbonate	mg/L as CaCO3	<1.0		1.0	W338057	16-Sep-13	
SM 2320B/2310B	Carbonate	mg/L as CaCO3	<1.0		1.0	W338117	17-Sep-13	
SM 2320B/2310B	Hydroxide	mg/L as CaCO3	<1.0		1.0	W338057	16-Sep-13	
SM 2320B/2310B	Hydroxide	mg/L as CaCO3	<1.0		1.0	W338117	17-Sep-13	
SM 4500-CN-I	Cyanide (WAD)	mg/L	<0.0100	0.0017	0.0100	W338060	17-Sep-13	
SM 4500-P-E	Orthophosphate as P	mg/L	<0.0100	0.0040	0.0100	W338205	18-Sep-13	
Anions by Ion Chromatography								
EPA 300.0	Fluoride	mg/L	<0.10	0.02	0.10	W338067	16-Sep-13	
EPA 300.0	Chloride	mg/L	<0.20	0.06	0.20	W338067	16-Sep-13	

Quality Control - LABORATORY CONTROL SAMPLE Data

Method	Analyte	Units	LCS Result	LCS True	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
Metals (Dissolved)									
EPA 200.7	Calcium	mg/L	19.2	20.0	96.2	85 - 115	W338086	17-Sep-13	
EPA 200.7	Iron	mg/L	8.92	10.0	89.2	85 - 115	W338086	17-Sep-13	
Classical Chemistry Parameters									
EPA 120.1	Specific conductance	µmhos/cm	316	322	98.3	90 - 110	W338061	16-Sep-13	
EPA 335.4	Cyanide (total)	mg/L	0.159	0.150	106	90 - 110	W338081	17-Sep-13	
SM 2320B/2310B	Total Alkalinity	mg/L as CaCO3	95.9	97.2	98.7	85 - 115	W338057	16-Sep-13	
SM 2320B/2310B	Total Alkalinity	mg/L as CaCO3	98.1	97.2	101	85 - 115	W338117	17-Sep-13	
SM 2320B/2310B	Bicarbonate	mg/L as CaCO3	93.4	97.2	96.1	85 - 115	W338057	16-Sep-13	
SM 2320B/2310B	Bicarbonate	mg/L as CaCO3	94.3	97.2	97.0	85 - 115	W338117	17-Sep-13	
SM 2580B	Eh	mV	220	220	100	98.59 - 101.4	W338058	16-Sep-13	
SM 4500-CN-I	Cyanide (WAD)	mg/L	0.153	0.150	102	90 - 110	W338060	17-Sep-13	
SM 4500-P-E	Orthophosphate as P	mg/L	0.773	0.777	99.4	90 - 110	W338205	18-Sep-13	
Anions by Ion Chromatography									
EPA 300.0	Fluoride	mg/L	1.98	2.00	99.0	90 - 110	W338067	16-Sep-13	
EPA 300.0	Chloride	mg/L	3.02	3.00	101	90 - 110	W338067	16-Sep-13	

Quality Control - DUPLICATE Data

Classical Chemistry Parameters

Method	Analyte	Units	Duplicate Result	Sample Result	RPD	RPD Limit	Batch ID	Analyzed	Notes
EPA 120.1	Specific conductance	µmhos/cm	7090	7060	0.4	20	W338061	16-Sep-13	
SM 2320B/2310B	Total Alkalinity	mg/L as CaCO3	260	263	1.0	20	W338057	16-Sep-13	
SM 2320B/2310B	Bicarbonate	mg/L as CaCO3	260	263	1.0	20	W338057	16-Sep-13	
SM 2320B/2310B	Carbonate	mg/L as CaCO3	<1.0	<1.0	UDL	20	W338057	16-Sep-13	
SM 2320B/2310B	Hydroxide	mg/L as CaCO3	<1.0	<1.0	UDL	20	W338057	16-Sep-13	
SM 2580B	Eh	mV	214	213	0.5	20	W338058	16-Sep-13	
SM 4500 H B	pH	pH Units	6.08	6.17	1.5	20	W338057	16-Sep-13	

Quality Control - MATRIX SPIKE Data

Metals (Dissolved)

Method	Analyte	Units	Spike Result	Sample Result (R)	Spike Level (S)	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
EPA 200.7	Calcium	mg/L	34.0	14.8	20.0	96.1	70 - 130	W338086	17-Sep-13	
EPA 200.7	Calcium	mg/L	42.9	23.7	20.0	95.7	70 - 130	W338086	17-Sep-13	
EPA 200.7	Iron	mg/L	59.7	60.3	10.0	R > 4S	70 - 130	W338086	17-Sep-13	M3
EPA 200.7	Iron	mg/L	48.4	42.4	10.0	R > 4S	70 - 130	W338086	17-Sep-13	M3

Classical Chemistry Parameters

Method	Analyte	Units	Spike Result	Sample Result (R)	Spike Level (S)	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
EPA 335.4	Cyanide (total)	mg/L	11.3	10.5	0.100	R > 4S	90 - 110	W338081	17-Sep-13	D2,M3
EPA 335.4	Cyanide (total)	mg/L	126	126	0.100	R > 4S	90 - 110	W338081	17-Sep-13	D2,M3
SM 4500-CN-I	Cyanide (WAD)	mg/L	0.0760	0.0220	0.100	54.0	75 - 125	W338060	17-Sep-13	M2
SM 4500-P-E	Orthophosphate as P	mg/L	565	559	0.500	R > 4S	75 - 125	W338205	18-Sep-13	D2,M4

Anions by Ion Chromatography

Method	Analyte	Units	Spike Result	Sample Result (R)	Spike Level (S)	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
EPA 300.0	Fluoride	mg/L	2.43	0.41	2.00	101	90 - 110	W338067	16-Sep-13	
EPA 300.0	Fluoride	mg/L	2.36	0.52	2.00	92.3	90 - 110	W338067	16-Sep-13	
EPA 300.0	Chloride	mg/L	5.40	2.35	3.00	101	90 - 110	W338067	16-Sep-13	
EPA 300.0	Chloride	mg/L	7.40	5.20	3.00	73.3	90 - 110	W338067	16-Sep-13	M2

Quality Control - MATRIX SPIKE DUPLICATE Data

Metals (Dissolved)

Method	Analyte	Units	MSD Result	Spike Result	Spike Level	RPD	RPD Limit	Batch ID	Analyzed	Notes
EPA 200.7	Calcium	mg/L	34.3	34.0	20.0	0.9	20	W338086	17-Sep-13	
EPA 200.7	Iron	mg/L	60.0	59.7	10.0	0.4	20	W338086	17-Sep-13	M3

Classical Chemistry Parameters

Method	Analyte	Units	MSD Result	Spike Result	Spike Level	RPD	RPD Limit	Batch ID	Analyzed	Notes
EPA 335.4	Cyanide (total)	mg/L	11.6	11.3	0.100	2.3	20	W338081	17-Sep-13	D2,M3
SM 4500-CN-I	Cyanide (WAD)	mg/L	0.0750	0.0760	0.100	1.3	20	W338060	17-Sep-13	M2
SM 4500-P-E	Orthophosphate as P	mg/L	558	565	0.500	1.3	20	W338205	18-Sep-13	D2,M4

Anions by Ion Chromatography

Method	Analyte	Units	MSD Result	Spike Result	Spike Level	RPD	RPD Limit	Batch ID	Analyzed	Notes
EPA 300.0	Fluoride	mg/L	2.56	2.43	2.00	5.1	20	W338067	16-Sep-13	
EPA 300.0	Chloride	mg/L	5.37	5.40	3.00	0.5	20	W338067	16-Sep-13	

Notes and Definitions

D2	Sample required dilution due to high concentration of target analyte.
H5	This test is specified to be performed in the field within 15 minutes of sampling; sample was received and analyzed past the regulatory holding time.
M2	Matrix spike recovery was low, but the LCS recovery was acceptable.
M3	The spike recovery value is unusable since the analyte concentration in the sample is disproportionate to spike level. The LCS was acceptable.
M4	The analysis of the spiked sample required a dilution such that the spike recovery calculation does not provide useful information. The LCS recovery was acceptable.
LCS	Laboratory Control Sample (Blank Spike)
RPD	Relative Percent Difference
UDL	A result is less than the detection limit
R > 4S	% recovery not applicable, sample concentration more than four times greater than spike level
<RL	A result is less than the reporting limit
MRL	Method Reporting Limit
MDL	Method Detection Limit
N/A	Not Applicable

APPENDIX E

CONCEPTUAL SITE MODEL

KAISER MEAD GROUNDWATER
CONCEPTUAL SITE MODEL (CSM)

-DRAFT-

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March 2017

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

KAISER MEAD GROUNDWATER
CONCEPTUAL SITE MODEL (CSM)

-DRAFT-

1.0 INTRODUCTION

1.1 PURPOSE

This updated conceptual site model (CSM) is provided to help focus and inform the Supplemental Feasibility Study (SFS). Specifically, the revised CSM is intended to:

1. Support development of the Supplemental Feasibility Study (SFS);
2. Guide the development and evaluation of remedial alternatives;
3. Summarize existing information on site conditions; and
4. Provide a communication tool for ongoing discussions with interested parties.

The CSM is intended to be a dynamic document that is revised as needed to reflect the most current understanding of the Site. This CSM represents the best understanding of the Site as of approximately March 2017. It is impossible to remove all uncertainties regarding the CSM, (see Section 2.5 for discussion of uncertainties); however, the CSM is believed to be appropriate and sufficient for evaluation and selection of remedial alternatives.

The CSM is organized in three primary parts:

- Section 1 – provides the background, purpose and scope of the CSM;
- Section 2 – describes the updated CSM; and
- Section 3 – explains significant differences between the updated CSM and the previous CSM that was the basis of the Cleanup Action Plan (Ecology, 2002).

1.2 SCOPE

The CSM is a representation of the physical, chemical and biological processes that control the transport, migration and actual/potential impacts to groundwater. Consideration of impacts to other media (e.g., air, surface water) and to ecological receptors from all media has been previously considered and is only briefly updated in this document.

Media considered in the groundwater CSM include:

1. Soil (surface sediment);
2. Subsurface sediment; and
3. Groundwater.

As per the Consent Decree governing this cleanup action (Task 5 of the RAP), this CSM is focused on addressing groundwater contamination at the compliance monitoring wells (Compliance Wells; see Figure 1-1) at the downgradient southwestern border of Parcel 6 (area that borders State Highway 2).

1.3 PROBLEM STATEMENT/BACKGROUND

1. WAD (weak acid dissociable) cyanide, free cyanide[1] and fluoride concentrations in groundwater exceed cleanup levels at the Compliance Wells, as well as areas upgradient and downgradient of the Compliance Wells.

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[1] Free cyanide refers to the sum of HCN and CN ions in a sample and is the most toxic form of cyanide. Weak to moderately strong metal cyanide complexes are compounds that dissociate and release HCN under mildly acidic conditions. The WAD method was developed to quantify available cyanide, which measures the weak and moderately strong metal cyanide complexes plus free cyanide (Lipps). Task 2 of the 2004 Remedial Action Plan (Attachment E to the 2004 Consent Decree) specified that WAD CN be analyzed in the groundwater monitoring program. Ecology elected to use the WAD CN method at that time as they determined the analytical method for WAD CN provided more consistent results at low levels than free CN methods and its use is consistent with the state clean water act for surface water (WAC 173-201A-240). From 2004 to 2016, WAD cyanide was measured during groundwater monitoring. Due to improvements to the analytical methods for free cyanide, free cyanide analyses were incorporated into routing groundwater monitoring in 2015. In October 2016, Ecology supported the switch from WAD to free cyanide analyses for future monitoring and compliance determinations.

FIGURE 1-1. SITE LOCATION MAP

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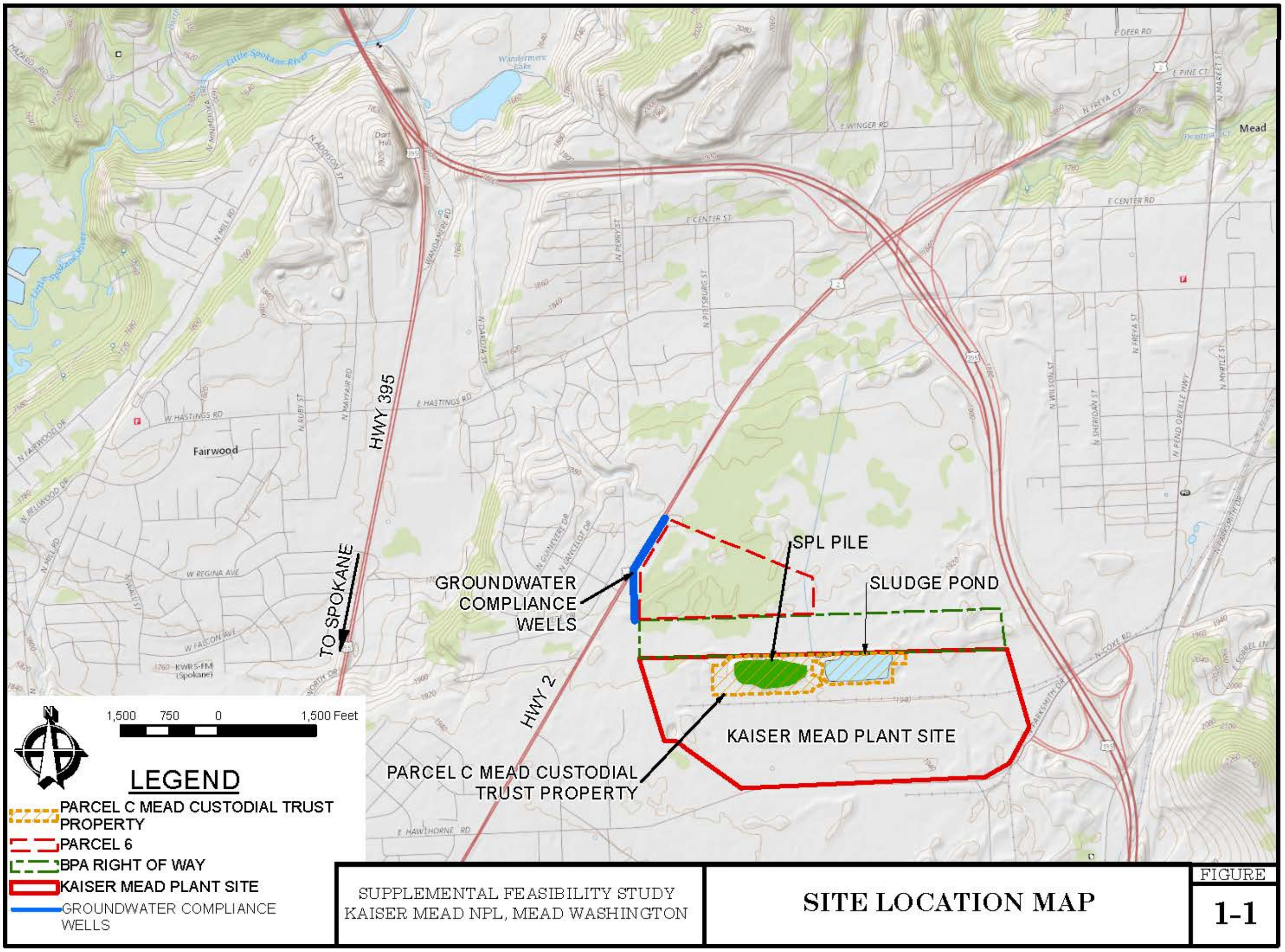


Hydrometrics, Inc.
Consulting Scientists and Engineers

SUPPLEMENTAL FEASIBILITY STUDY
KAISER MEAD NPL, MEAD WASHINGTON

SITE LOCATION MAP

FIGURE
1-1

2. Cleanup remedies consisting of source controls were evaluated (Ecology, 2002 and MF&G, 2004) and were predicted to be effective in attaining compliance in a relatively short period of time (five to ten years). The cleanup remedies were implemented and completed in approximately 2006; however, ten years after the cleanup, little to no improvement in groundwater concentrations (relative to compliance levels) has been observed at the POC. At the POC, fluoride and cyanide concentrations have steadily increased since 2006, in two of the five monitoring wells and remain approximately five times higher than the fluoride cleanup level (4 mg/L) and ten or more times higher than the WAD/free cyanide cleanup level (0.2 mg/L). Reductions in groundwater contaminant concentrations have occurred at some locations, primarily in the plume center and adjacent to the SPL pile, but these reductions are not believed to be sufficient to result in attainment of compliance levels in the near future.

    1. The SFS considers remedial alternatives to potentially address the lack of compliance with cleanup levels at the Compliance Wells. Understanding the behavior of groundwater contaminants, the source of ongoing groundwater contamination, and why the cleanup remedies completed in 2006, failed to achieve cleanup levels is needed in order to accurately evaluate and predict potential effects of remedial alternatives for the SFS.

2.0 SUMMARY OF CURRENT CONCEPTUAL SITE MODEL

This section presents a summary of the current, updated CSM. Supporting information and rationale for the CSM is provided in Appendix A (Supplemental Site Characterization Analysis).

2.1 AFFECTED MEDIA/ENVIRONMENTAL RECEPTORS

The media affected by the contaminants of concern, WAD/free cyanide and fluoride, include:

- Groundwater, as monitored at the Compliance Wells; and
- Surface water, as monitored at hillside springs where groundwater becomes surface water above the Little Spokane River.

Surface soils and sediments exceeding cleanup levels (MTCA B) for the contaminants of concern were placed beneath the engineered impermeable cap of the consolidated waste pile (SPL pile). Surface soils and sediments below cleanup levels were covered with asphalt caps to prevent disturbance and limit contact with precipitation (rain and snowmelt).

Pathways to environmental receptors are considered to be incomplete or inconsequential. Potentially impacted domestic wells were closed and owners were connected to the public water supply, thereby eliminating human ingestion of groundwater as a pathway. Since this action was taken in the early 1980s no new wells are known to have been installed for potable use. Studies conducted on the Little Spokane River in 1980 and 1995, concluded that no effects on fish or macro-invertebrates attributable to cyanide were found in the Little Spokane River (Ecology, 2002).

As per the Consent Decree governing this cleanup action (Task 5 of the RAP), this CSM is focused on addressing groundwater contamination at the Compliance Wells at the downgradient southwestern border of Parcel 6 (area that borders State Highway 2).

2.2 CONTAMINANT SOURCES

Contaminant sources responsible for impacting area groundwater have transitioned from historical waste handling/management operations and primary sources to leaching of secondary sources created by historic impacts to subsurface sediments. For purposes of this discussion, the following terms are used and defined:

- Historic sources are contaminant sources that were active prior to the completion of cleanup actions;
- Ongoing sources are contaminant sources that are potentially active;
- Primary sources are the contaminant sources that were originally created and that remain in their original form and approximate location (e.g., SPL material);
- Secondary sources are contaminant sources that are located some distance away from where the contaminating activity or original contaminant was located (e.g., contaminated unsaturated and saturated sediment beneath the SPL pile and within the contaminated groundwater plume and associated aquifer sediment);
- Tier I sources are potential ongoing sources that are judged to be potentially significant in terms of meeting cleanup levels based on the current understanding of the Site; and
- Tier II sources are potential ongoing sources that are judged not to be potentially significant based on the current understanding of the Site.

The most significant (Tier I) source of continued contamination of groundwater resides in four potential ongoing secondary source areas:

1. Unsaturated sediments beneath the SPL pile area;
2. Sediments within the saturated zone of the A-Zone[2] aquifer beneath the SPL pile area;

---

[2] Groundwater at the site is in the regional Spokane Valley- Rathdrum Prairie aquifer. Previous site investigators divided the site aquifer stratigraphy into three permeable zones (A, B, and C from upper to lower-most) for defining contaminant transport. Directly beneath the Site, the A Zone aquifer is impacted while the underlying B Zone aquifer is un-impacted and separated by the A Zone aquifer by a low permeability unit. Near the Compliance Wells the intervening low permeability unit is absent and the B Zone aquifer is impacted.

3. Sediments within the saturated zone of the A-Zone aquifer outside of the footprint (downgradient) of the SPL pile area and within the B-Zone aquifer near the Compliance Wells; and
4. A combination of two or more of the above source areas.

These ongoing Tier I sources are considered to be the most likely to have significant impact on the A-Zone aquifer because they are known to contain cyanide and fluoride; are known or suspected to be exposed to a water source (e.g., A-Zone aquifer or perched groundwater) capable of leaching cyanide and fluoride to groundwater; and are known or suspected of generating water with elevated cyanide and fluoride concentrations.

See Figure 2-1 for a depiction of current potential source areas.

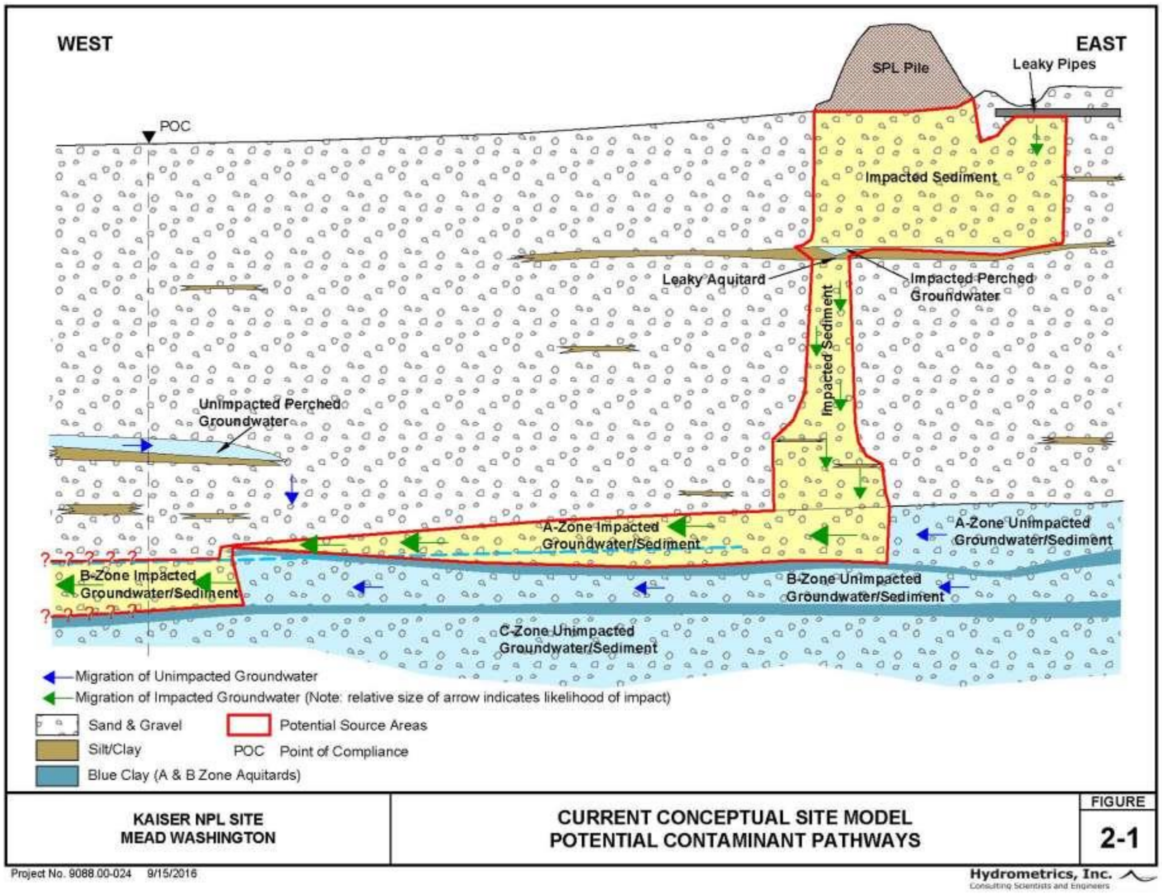
Other possible sources that are judged to be less significant (Tier II) includes waste that remains on site under the following conditions:

1. Waste that was consolidated within the SPL pile;
2. Uncontrolled waste outside of the SPL pile, such as the sludge pond;
3. Unidentified uncontrolled waste outside of the SPL pile, such as may remain in the plant production area; and
4. Waste left in place and covered with an asphalt surface, such as Area 2.

These wastes are considered Tier II sources as there appear to be weak migration pathways from these sources. A number of environmental conditions must exist before they can contribute contamination to the extent that results in concentrations seen in area monitoring wells.

These Tier II sources are further discussed in Appendix A as the focus of the CSM is on the Tier I sources.

FIGURE 2-1. CURRENT CONCEPTUAL SITE MODEL POTENTIAL CONTAMINANT PATHWAYS



2.3 CONTAMINANT MIGRATION PATHWAYS

Historically, cyanide and fluoride were transported from the surface to underlying sediments and to groundwater by disposal of cyanide and fluoride-bearing process waters and by leaching of SPL, other waste materials and contaminated sediment by process waters, rainfall/snowmelt, and stormwater (Hart Crowser, 1988). From 1978 to 2006, a number of remedial actions and operational changes occurred to isolate source areas and prevent contaminant migration (see Table 2-1).

TABLE 2-1. OPERATIONAL HISTORY AND REMEDIAL ACTION TIMELINE

Date	Action
Early 1940s to 1979	SPL stored exposed to precipitation.
1965 to 1978	Pot cleaning/soaking water discharged to ground surface.
1950s to 1970s	Wet scrubber sludge stored in sludge bed area.
1964 to 1974	Pot soaking liquor used for make-up water for wet scrubber system.
1971 to 1974	Sewage effluent discharged to sludge bed.
1978	Use of sludge bed, pot soaking operations, discharge of sewage effluent to sludge bed ceased.
1979	SPL material covered with asphalt cap.
1979	Pot cleaning activities conducted on asphalt pad.
1981	SPL handling and storage activities moved into SPL building.
1981	Tharp Lake unlined settling basin abandoned.
1983	Pipe leak repaired.
1986	Pot cleaning activities moved to building.
1986	Area 2 capped with asphalt.
2001	Waste materials (butt pile, rubble pile, asphalt covered SPL pile) consolidated into the current SPL pile and capped with synthetic over liner.
2002	Cured-in-place liners installed in stormwater and sanitary sewer lines.
2005	Semi-annual inspections of SPL and asphalt cap areas and surface water drainage features.
2005	Compliance monitoring well network installed.
2006	Pressure main water supply pipelines replaced and sanitary sewer line break repaired above shallow aquitard.
2006	Quarterly leak detection surveys of pressure main water supply system. Frequency changed to annual in 2012.
2005 to 2016	Groundwater and surface water monitoring.

As a result of these actions, transport by process waters has been eliminated and leaching of waste materials within the SPL pile by rainfall/snowmelt and stormwater is believed to be greatly reduced, if not eliminated, by the SPL cap. The current migration pathways are similar to the historic pathways except:

1. There is no longer any process water being infiltrated through soils and waste to the groundwater system;
2. Waste material has been substantially isolated from precipitation infiltration by the SPL cap; and
3. The plant water pipe systems have been replaced and/or lined and pressure and gravity line transported waters are assumed to no longer be a source of water in the vicinity of waste storage and impacted sediments. As a result there is less water being infiltrated to the groundwater system from the SPL pile area and transport of contaminants to groundwater is diminished.

Currently, cyanide and fluoride can potentially migrate to groundwater by three mechanisms:

1. Leaching of impacted sediments in the unsaturated zone beneath the SPL Pile by an unidentified water source (i.e., leaching of sediments by zones of saturated flow within the otherwise unsaturated zone above the regional water table, such as could occur above a shallow aquitard);
2. Leaching of impacted sediments within the saturated zone of the A-Zone aquifer and downgradient B-Zone aquifer by groundwater; and
3. Contaminant release to unsaturated flow of soil moisture through the vadose zone.

Of these three potential mechanisms, leaching of impacted aquifer sediments by groundwater (bullet 2) is believed to be dominant. Although plausible, leaching of sediment above the A-Zone aquifer as described in bullets 1 and 3 is believed to be minor. Further description of these three potential mechanisms is provided in the following paragraphs.

The vertical migration of cyanide and fluoride from the unsaturated zone is influenced by lower permeability zones or layers in the unsaturated sediments, as shown in Figure 2-1. When present, layers of fine-grained material within the unsaturated zone slows the rate of vertical migration of infiltrating water, causes limited areas of saturation to form a thin perched aquifer, and disperses the water horizontally. One such fine-grained layer is the shallow aquitard (SAQ) that exists at approximately 50 to 60 feet below ground surface and is present beneath at least a portion of the area where process water was historically infiltrated to the groundwater system. The SAQ and associated thin perched aquifer could provide a pathway for an unidentified source of shallow water to flow to the area beneath the SPL pile where the water contacts impacted sediments above the saturated A-Zone. In this potential pathway and contaminant migration scenario (bullet item 1 above and depicted on Figure 2-1 as the area beneath SPL pile), the unidentified source of water is sufficient to leach contaminants from the impacted sediments and transport the leachate to the A-Zone aquifer in the form of saturated flow. Although plausible, at present there is no data or information to support the existence of the unidentified source of water. Furthermore based on results of sediment leaching studies (Appendix A and Hydrometrics, 2017a), the source contribution of fluoride, and possibly cyanide, from leaching of impacted sediments in the saturated A-Zone appears to be sufficient to generate the observed groundwater contaminant plume without any contribution from unsaturated sediments. For these reasons, the unsaturated sediment migration pathway is believed to be minor or insignificant in comparison to other known sources.

In the second potential sediment to groundwater migration pathway that is believed to be the dominant pathway currently, the historic transport of process water and SPL leachate to the saturated sediments of the A-Zone has resulted in the formation of a secondary source of contaminants within the saturated sediments beneath the footprint of the SPL pile and extending downgradient of the SPL pile to the Compliance Wells and likely beyond. The secondary source was formed by chemical reactions (i.e., adsorption, mineral precipitation, mineral alteration, and ion exchange) between the process water/SPL leachate and aquifer sediments. Groundwater flowing through the contaminated sediments continues to leach cyanide and fluoride to groundwater by desorption, mineral dissolution and/or ion exchange.

Field sampling and laboratory testing demonstrate this pathway to be significant and to have caused an extensive area of enriched, or contaminated sediment. Leaching of aquifer sediment samples in laboratory tests demonstrate this mechanism to release significant concentrations of fluoride and cyanide. Sediment:groundwater partition modelling (see Appendix A) indicates that this pathway will continue to cause groundwater to exceed cleanup levels at Compliance Wells for an extended period of time.

In the third potential sediment to groundwater pathway scenario, cyanide and fluoride are transported by soil moisture and residual process water and stormwater within the SPL pile and unsaturated sediments either directly beneath the footprint of the SPL pile or downgradient of the pile. The historic transport of process water and SPL leachate has resulted in the formation of a secondary source of contaminants within the unsaturated zone (as described for saturated sediments) and/or has left residual process water and SPL leachate within the unsaturated zone. Drainage of residual soil moisture through unsaturated flow mechanisms transports cyanide and fluoride to groundwater. Movement of contaminants through this migration pathway is likely much slower, and potentially much smaller, than the two previously described migration pathways. Similar to the first pathway, this pathway is believed to be minor or insignificant.

Once in the groundwater system, cyanide and fluoride migrate through groundwater flow and are transported through the A-Zone aquifer to the northwest. The A-Zone aquitard is discontinuous in the vicinity of monitoring well KM-4, allowing contaminated groundwater within the A-Zone to mix with the underlying B-Zone aquifer. The B-Zone aquifer transports cyanide and fluoride to the downgradient Compliance Wells. Within the groundwater system the transport of cyanide and fluoride are controlled by the aquifer properties. Groundwater flow average linear velocity is approximately 3 to 5 ft/day and estimated travel time from the SPL pile to the Compliance Wells (distance of approximately 2,000 feet) is approximately one to two years (see Appendix A and Hydrometrics, 2017c). See Figure 2-2 for a plan view of monitoring well and cross section locations and Figure 2-3 for a representative geologic cross section.

FIGURE 2-2. CROSS SECTION LOCATIONS

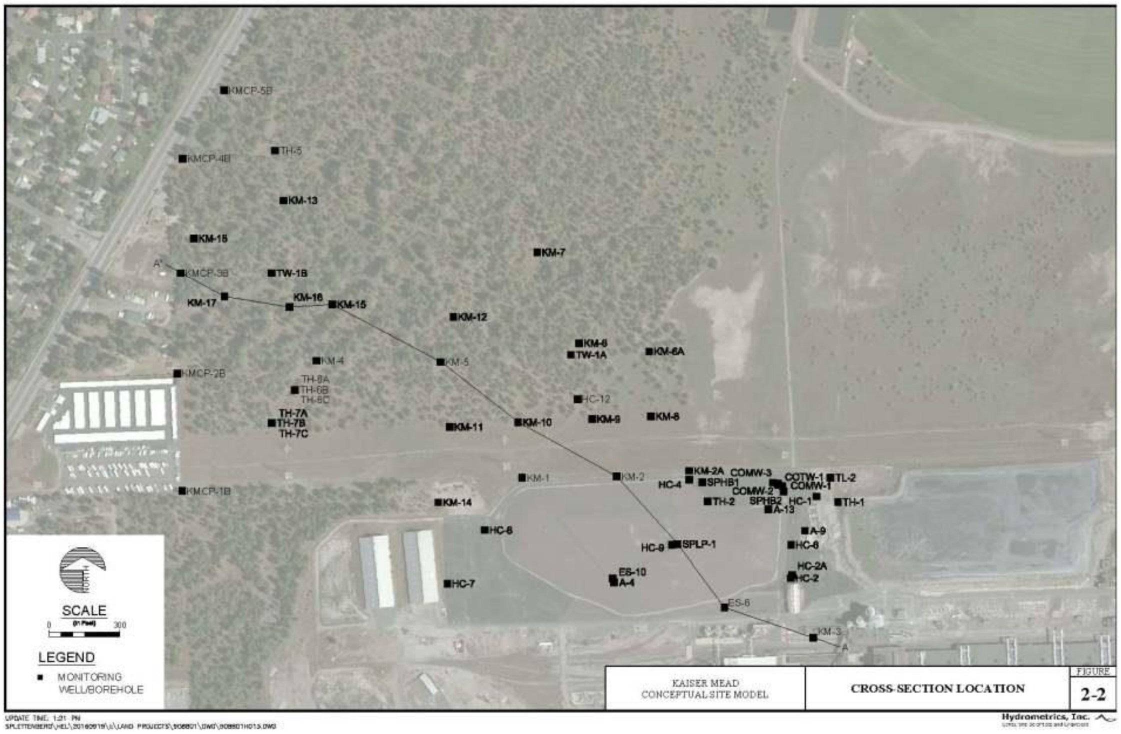
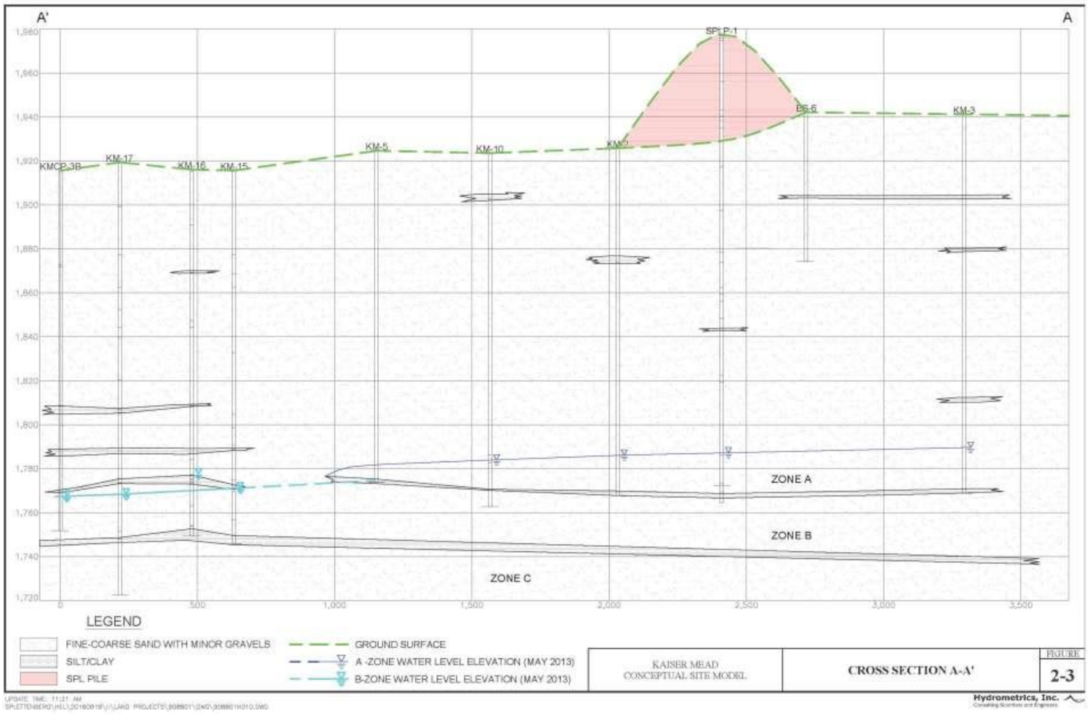


FIGURE 2-3. CROSS SECTION A-A’



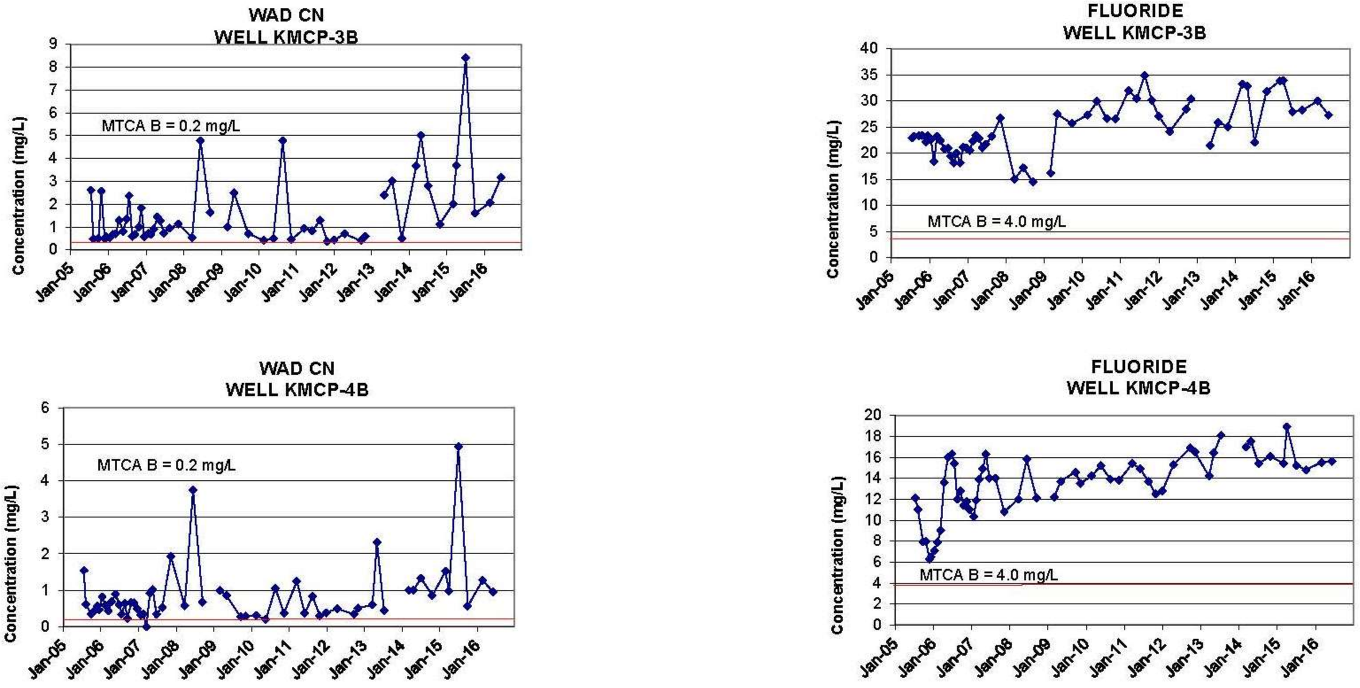
During groundwater transport, cyanide and fluoride are subject to dilution by mixing and dispersion and react with the aquifer sediments through the chemical processes of mineral dissolution, mineral precipitation, adsorption/desorption, and ion-exchange. These physical and chemical processes cause cyanide and fluoride transport to be retarded (or slowed) relative to groundwater transport velocity. These mechanisms also resulted in the formation of secondary contaminant sources within the aquifer downgradient of the SPL pile area.

2.4 ESTIMATED FUTURE GROUNDWATER TRENDS

Absent, or in spite of, additional effective corrective actions, groundwater contaminant concentrations, overall, are likely to decrease slowly. In some locations, contaminant concentrations appear to be improving more rapidly while in other locations little improvement has been observed. Compliance monitoring wells in the middle of the contaminant plume at the Compliance Wells (KMCP-3B and KMCP-4B) routinely exceed cleanup levels for WAD/free cyanide and fluoride and have actually shown an increase in contaminant concentrations since the cleanup remedy was completed (Figures 2-4 through 2-6).

Overall, cyanide and fluoride concentrations within the groundwater contaminant plume may have declined slightly since the implementation of the cleanup remedy, particularly near the SPL area and in some downgradient locations near the plume center (e.g., near monitoring wells KM-5 and KM-6). Thus it appears that contaminant loading to groundwater from the SPL area and the mass of contaminants present in groundwater may have been reduced. The observed reductions in groundwater concentrations may represent a groundwater response to the implemented source control corrective actions. Aquifer sediments comprise a secondary contaminant source in the form of adsorbed and/or mineral precipitated fluoride and cyanide. The secondary sources of fluoride and cyanide are being slowly leached by groundwater and groundwater concentrations decline as the secondary source contaminant mass is diminished. The observed reductions in groundwater concentrations in the SPL and plume center areas likely represent groundwater responses to the ongoing leaching of the secondary aquifer sediment source.

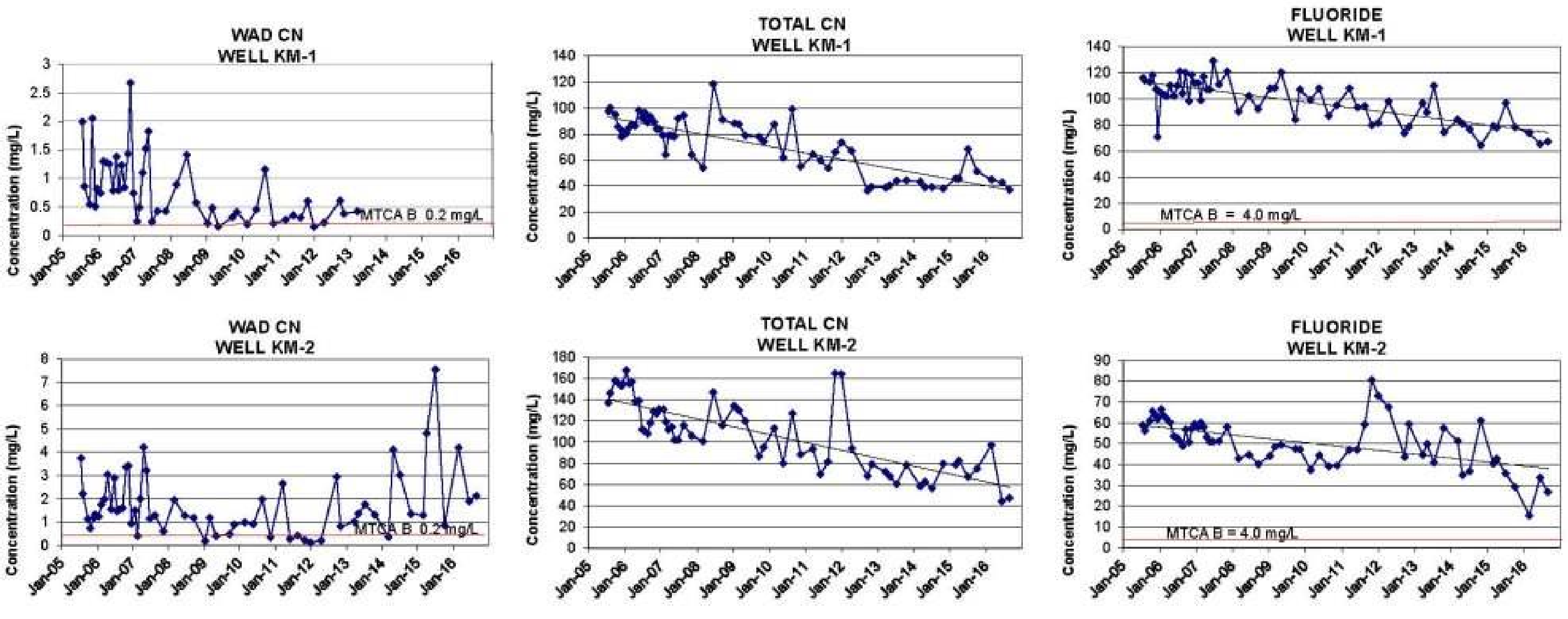
FIGURE 2-4. CYANIDE AND FLUORIDE WATER QUALITY TRENDS AT COMPLIANCE WELLS



KAISER MEAD CONCEPTUAL SITE MODEL	CYANIDE AND FLUORIDE WATER QUALITY TRENDS AT COMPLIANCE WELLS	FIGURE 2-4

FIGURE 2-5. CYANIDE AND FLUORIDE WATER QUALITY TRENDS NEAR SPL PIPE

Monitoring Wells Immediately Downgradient of SPL Pile



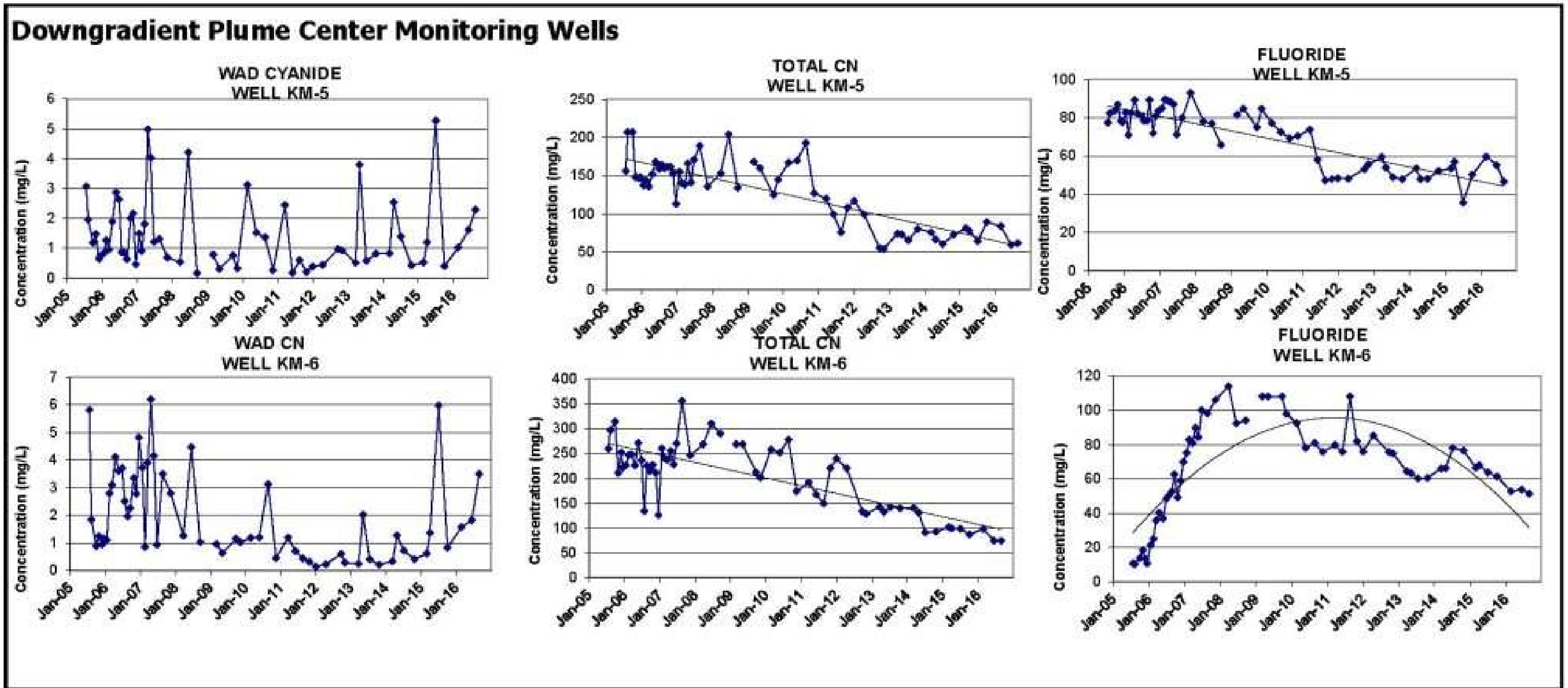
KAISER MEAD NPL SITE MEAD WASHINGTON

CYANIDE AND FLUORIDE WATER QUALITY
TRENDS NEAR SPL PILE

FIGURE

2-5

FIGURE 2-6. CYANIDE AND FLUORIDE WATER QUALITY TRNEDS AT PLUME CENTERWELLS



KAISER MEAD NPL SITE MEAD WASHINGTON	CYANIDE AND FLUORIDE WATER QUALITY TRENDS AT PLUME CENTERWELLS	FIGURE 2-6

The additional lag time that will occur between groundwater response in the SPL and plume center area and the downgradient Compliance Wells is not known with certainty, but based on groundwater and sediment partitioning models (Table 2-2 and see Appendix A for more detail), is estimated to be on the order of decades. Time to cleanup values in Table 2-2 are estimated for three scenarios:

1. Base Case Model – this is believed to be the most probable case and the uncertainty or range in the estimated time to cleanup reflects uncertainty in the key input parameters.

2. Base Case Model with Leaky SPL Cap – this is a plausible case and reflects a condition where the SPL Cap is damaged or not fully competent.

3. Base Case Model with No SPL Cap – this is an unlikely case and represents a condition where the SPL Cap is catastrophically failed such that it does not limit rainfall precipitation and leaching of waste in the SPL pile at all.

The purposes of including the leaky and no cap scenarios is primarily to evaluate the sensitivity of model results to the uncertainty of an unknown source of water and contaminants from the SPL pile area. As evidenced by the model results summarized in Table 2-2, the addition of an unknown source contribution increases the estimated amount of time to reach cleanup levels at the Compliance Wells by only a few years. Thus, it is concluded that model simulation results are relatively insensitive to a potential unknown source.

2.5 UNCERTANITIES

Principal uncertainties associated with the current CSM are:

1. There are no known and significant uncontrolled sources of water that could contribute to leaching of contaminated sediments beneath the SPL pile. The pathway to the SPL pile area for uncontrolled water sources is assumed to be areas of

TABLE 2-2. SUMMARY OF BASE CASE SEDIMENT PARTITION MODEL SIMULATIONS AND ADDITIONAL SOURCE SENSITIVITY SIMULATIONS

	Estimated Range of Time to Cleanup at Compliance Wells (Years)		
	Base Case Model (Sediment Source Only)	Base Case Model With Leaky SPL Cap	Base Case Model with No SPL Cap
Fluoride	53 to 132 years	56 to 137 years	70 to 184 years
Cyanide	33 to 80 years	35 to 81 years	38 to 94 years

1) Assumes the additional source is SPL in the capped SPL pile. SPL is present throughout the capped SPL pile (area of 10 acres). SPL leachate assumed to contain 925 mg/L fluoride and 700 mg/L total cyanide.

2) Leaky cap scenario: infiltration through the cap to groundwater is assumed to equal 0.1 inches/year over the 10-acre SPL pile (i.e., 27,152 gallons/year).

3)No Cap Scenario - Assuming the SPL Cap has catastrophically failed so that it performs as if there is no cap, infiltration through the cap to groundwater is assumed to equal 0.55 inches/year (2.8% of annual precipitation) over the 10-acre SPL pile (i.e., 149,388 gallons/year).

saturation above the SAQ, but there are also uncertainties regarding the boundaries of the SAQ. Saturated conditions on the SAQ detected in recent borings were limited to one foot or less in thickness, divided over several lenses of silty sediment. These conditions produced little if any water, which suggests perched groundwater above the SAQ is not a significant source of water, thus the pathway between saturated contaminated sediments beneath the SPL pile and the underlying A-Zone aquifer appears to be incomplete or negligible.

2. Total cyanide concentrations in sediment may be biased low by the laboratory analytical methods and actual cyanide concentrations may be higher than reported. As further described in Appendix A, comparison of different analytical methods in 2015 and 2016, suggest that the common method of acid extraction of sediments prior to analysis may be less effective than alkaline extraction and may lead to under reporting of actual cyanide concentrations. Thus, data collected prior to 2016, may be biased low. Underestimation of sediment cyanide concentrations would cause underestimation of sediment cyanide mass and potentially under prediction of the length of time that sediment would contribute to elevated cyanide concentrations in groundwater.

3. The physical and chemical mechanism by which cyanide forms are attenuated from groundwater and enriched in sediment and subsequently released by sediment to groundwater have not been clearly established. Reports in the scientific literature suggest that attenuation by precipitation of iron cyanide minerals is most likely and that adsorption or ion exchange reactions are unlikely. However, laboratory leaching tests results most closely resemble some sort of partitioning behavior (i.e., solution concentration is proportional to sediment concentration) such as is typical of adsorption reactions, therefore the leaching models used in the current Supplemental Feasibility Study assume partitioning behavior for cyanide.

4. The degree to which conversion of cyanide forms (e.g., conversion of total cyanide to WAD and free cyanide forms, and vice versa) occurs during groundwater transport or during leaching of total cyanide from sediment is unknown. Some scientific papers (Meeussen et al., 1992) suggest that decomposition of iron cyanide complexes (total cyanide form) is exceedingly slow at neutral or alkaline pH conditions such as occur at the Site. Other scientific papers (Ghosh et al., 1999) suggest that decomposition of iron cyanide complexes is slow, perhaps a few percent per year, but potentially large enough to interfere with attainment of cleanup standards in cases such as Mead, where total cyanide concentrations are high. Attempts to evaluate whether cyanide conversion occurs in site groundwater by comparison of total, free and WAD cyanide concentration patterns have not been definitive. There is some indication that WAD/free cyanide may be subject to less dilution and retardation during transport. This difference in behavior could be an indication of conversion of total cyanide to WAD/free cyanide forms or it may merely indicate that total cyanide and fluoride are more strongly affected by attenuation mechanisms such as adsorption and mineral precipitation. In laboratory leaching tests of sediment collected in 2015, WAD and free cyanide were found to increase over time in extended testing (20 to 60 days). This may suggest conversion of total cyanide to WAD and free cyanide or dissolution of iron cyanide minerals to form free and WAD cyanide. However, it is also possible that this is a laboratory artifact, perhaps due to photo-dissociation from laboratory light, which would not occur in the groundwater system. Evaluation of cyanide

behavior is confounded by the apparent high variability in WAD cyanide concentrations in site groundwater which may be due in part to high variability (poor precision) in WAD cyanide measurements by the approved laboratory method (SM 4500-CN-I).[3]

There are many uncertainties and unknowns regarding the exact nature, extent, leaching characteristics, and impact of cyanide-enriched sediments in the saturated zone as described in the issues above. These uncertainties are attributable to the complexity of cyanide chemistry and the concomitant difficulty in analyzing and characterizing cyanide in sediment. These uncertainties lead to a broad range in the predicted and modelled effects of sediment on current and future concentrations of cyanide in groundwater. In spite of this uncertainty in potential predicted effects, due to similar past and current mechanisms of sediment contamination (i.e., contaminated process water containing high levels of both cyanide and fluoride), overall similar behavior in groundwater (similar pattern of groundwater contamination, lingering for decades), cyanide in sediment is most likely to have a similar (and significant) impact on groundwater as does fluoride in sediment.

The alternative hypothesis that sediment contributes little cyanide contamination in groundwater while at the same time contributing significant fluoride contamination would require an additional contaminant source to explain the “missing” cyanide. This additional cyanide source would have to have the unusual and unlikely characteristic of high cyanide contributions while also having low fluoride contribution. No such source is or was known to exist at the Site. Thus, it is more likely sediment is a significant contributor of cyanide to groundwater, similar to fluoride, and consistent with the upper range of predicted sediment effects on cyanide in groundwater.

---

[3] A study comparing the precision of method SM 4500 with the ligand exchange/amperometry method EPA OIA-1677 (reported by some to be more precise) on site water samples was conducted in 2007 (LFR, 2007). However, the new method was found to be no more precise than the method historically used.

3.0 EXPLANATION OF SIGNIFICANT DIFFERENCES BETWEEN CURRENT CSM AND CAP CSM

The CSM referenced by the state of Washington in the 2002 Cleanup Action Plan (CAP) (Ecology, 2002) relied in large part on the work performed in the late 1980s by Hart Crowser. A summary of the CAP CSM is as follows:

1. The source of groundwater contamination is soil/sediment beneath the spent potliner handling area that is within the migration pathway of plant-induced recharge water sources.

2. Natural precipitation alone is not sufficient to cause migration of contaminants from the vadose zone to the water table and the measured concentrations of cyanide and fluoride.

3. Primary plant-induced water sources include infiltration from the now closed settling basin (aka Tharp Lake), pile leaks, and infiltration of ponded runoff or snowmelt.

4. The unsaturated (vadose) zone beneath the plant site is composed of a series of fine to coarse sand units interbedded with silty clay and clayey silt units. Some of the units are up to several feet in thickness and are thin and pinch out to the west. At least one clayey silt unit is continuous beneath the potliner pile and forms a small perched aquifer. The discontinuous sand and clay units thin to the west.

5. The top portion of the regional aquifer (approximately 35 feet) is vertically stratified into relatively permeable zones separated by fine-grained sediments that form aquitards. These units at the Kaiser Site are known as A, B and C-Zones (with increasing depths). A-Zone is an unconfined aquifer while B-Zone and C-Zone are semi-confined aquifers. The majority of the cyanide and fluoride in groundwater is found in A-Zone aquifer.

6. Concentrations of total cyanide and fluoride in monitoring wells on the plant site have decreased in the past (i.e., 1980s) due to implementation of remedial measures

that have reduced migration of contaminants from spent potlining and contaminated soils. This pattern has been reversed (concentrations increase) when significant pipe leaks have occurred, thus, control of contamination is very dependent on control of man-made infiltration events.

7. Free and WAD cyanide concentrations in groundwater constitute a small fraction of total cyanide concentrations found in the plume at the site. Free and WAD cyanide is generally no more than 2.5% to 10% of total cyanide. Total cyanide in the contaminant plume is comprised mostly of iron-cyanide complexes.

The CAP CSM does not discuss groundwater transport of contaminants or interactions between groundwater, contaminants and aquifer sediments. The CAP CSM assumed and predicted that groundwater cleanup would occur in a short time period because:

1. It was assumed and predicted that completion of remedial actions to consolidate and cap waste in conjunction with actions to prevent and detect future pipeline leaks would result in cessation of leachate generation and loading of contaminants to groundwater;
2. Potential secondary sources (contaminated unsaturated sediment) were assumed to be outside of migration pathways; and
3. Contaminants were assumed to behave conservatively in the groundwater system (i.e., contaminant mass is conserved within the groundwater and is not affected by interactions with sediment) such that contaminants in groundwater were not transferred to aquifer sediments.

The Supplemental Groundwater Modeling Report (MFG, 2004) largely incorporated the assumptions in the CAP CSM:

1. The model assumed the aquifers are homogeneous and did not consider the effects of heterogeneity and fine-grained, low transmissivity unsaturated layers on contaminant transport.

2. The model did not account for secondary contaminant sources present within the aquifer sediments.

3. The models assumed that cyanide and fluoride behave conservatively (non-reactively) during groundwater transport and did not incorporate contaminant retardation factors that would slow and prolong contaminant transport. Cyanide and fluoride were assumed to migrate completely through advective groundwater transport, were not affected by geochemical processes in the groundwater system, and did not interact with the aquifer (i.e., no dispersion or adsorption/mineral precipitation).

4. The source term used in the model to generate observed groundwater concentrations in the MFG groundwater model was based on loading of cyanide to groundwater in the SPL pile area for approximately seven years followed by a complete and instantaneous cessation of cyanide loading to groundwater. Since the source term was of short duration and transport was conservative, the only contaminant mass stored in the groundwater system was the dissolved mass, which was predicted to be flushed from the aquifer at the groundwater advective transport rates.

5. The model did not consider the unsaturated (vadose) zone and the potential lag time required for the effects of source controls to propagate from the source area to groundwater.

Based on the assumptions of complete and instantaneous source cessation and non-reactive transport, the model predicted groundwater cleanup to occur in a similar amount of time as the period of groundwater contamination used to calibrate the model (i.e., if on average the model requires seven years of transport for contaminants to travel to the Compliance Wells and attain quasi-steady state concentrations for the contaminated condition once the source is removed from the model, it would take a similar amount of time for the contaminated groundwater to be replaced by clean groundwater and attain a new quasi-steady state clean groundwater condition.).

However, recent characterization of the Site indicates that concentrations of fluoride and total, free, and WAD cyanide in groundwater have not decreased as predicted by the MFG groundwater model, indicating that contaminated groundwater continues to be generated and/or groundwater cleanup occurs much slower than was predicted (Hydrometrics, 2017b). Testing of saturated sediments from the aquifer and aquitard within the contaminated groundwater plume indicate enrichment in fluoride, and to a lesser extent cyanide, that is a secondary contaminant source. The presence of this secondary source indicates partitioning (chemical interactions) between the sediment and groundwater. Leaching of aquifer/aquitard sediments in laboratory tests indicates that the enriched sediments are capable of generating elevated fluoride and cyanide concentrations for substantial periods of time under Site groundwater conditions. Thus, it appears that some of the CAP CSM assumptions are incorrect. The CSM has been modified based on recent data to update the CAP CSM. The primary differences between the current CSM and the earlier CAP CSM and groundwater model are:

1. Although active water sources have not been identified, it is possible that there are unknown water sources that are still actively leaching contaminated sediment beneath the SPL pile that have not been entirely controlled by corrective actions. Thus, the current CSM includes the possibility that groundwater contaminant loading from the SPL area may continue at some unknown rate.

2. Secondary contaminant sources are identified within the aquifer and aquitard sediments in the area of the groundwater contaminant plume, from the SPL area downgradient to the Compliance Wells and likely beyond (based on test wells and borings completed in 2013, 2015, and 2016). The current CSM considers the secondary source in aquifer sediments to be the primary source of ongoing contaminant loading to groundwater.

3. Fluoride in aquifer/aquitard sediments is leached by groundwater. In laboratory testing, aquifer/aquitard sediments were leached by Site groundwater and were found to yield high fluoride concentrations for extended periods of time. Mathematical models of sediment leaching (Hydrometrics, 2017b) predict that at the laboratory

measured sediment leaching rates, the secondary contaminant source sediments will sustain high groundwater fluoride concentrations for extended periods of time (i.e., 53 to 132 years).

4. Total, WAD and free cyanide in sediments are leached by groundwater. In laboratory testing, aquifer/aquitard sediments were leached by Site groundwater and were found to yield low to moderate cyanide concentrations for extended periods of time. Mathematical models of sediment leaching predict that at the laboratory measured sediment leaching rates (Hydrometrics, 2017b), the secondary contaminant source sediments will sustain high groundwater cyanide concentrations for extended periods of time (i.e., 33 to 80 years).

5. The A-Zone and B-Zone aquifers are not entirely homogeneous and contain finer-grained, lower hydraulic conductivity zones or layers. Transport rates and potential groundwater cleanup rates within the fine-grained aquifer zones are likely much slower than average rates.

Ramifications of these changes in the CSM are:

1. If an active water source to vadose zone sediment beneath the SPL pile exists, then contaminant loading to groundwater will likely continue. If the water source were sufficiently large, loading rates could possibly be sufficient to preclude attainment of cleanup levels. Saturated conditions on the SAQ detected in recent borings were limited to one foot or less in thickness, divided over several lenses of silty sediment. These conditions produced little if any water, which suggests the SAQ is not a significant source of water.

2. The presence of contaminants within the aquifer matrix demonstrates that contaminants do not behave conservatively during groundwater transport. Thus contaminant transport rates are much slower than groundwater advective transport rates.

3. The contaminant-bearing aquifer sediments constitute a secondary contaminant source that can release significant concentration and mass of fluoride and cyanide to groundwater.

4. The contaminant-bearing aquifer sediments constitute a much larger contaminant mass within the groundwater system than previously modeled by MFG (2004).

5. Groundwater cleanup under existing conditions is predicted to take significantly longer than previously predicted.

4.0 REFERENCES

Ecology, 2002. Washington Department of Ecology, Cleanup Action Plan, Kaiser Aluminum National Priorities List Site, Mead, Washington. May 1, 2002.

Ghosh, RS, DA Dzombak, RG Luthy, and DV Nakles, 1999. Subsurface Fate and Transport of Cyanide Species at a Manufactured-Gas Plant Site. Water Environment Research, Sep/Oct 1999, 71, 7, pg. 1205.

Hart Crowser. 1988. Site Characterization Analysis, KACC – Mead Plant. Prepared for Kaiser Aluminum & Chemical Corporation, December 1988.

Hydrometrics, Inc., 2017a. Draft Data Report on Additional Field Characterization for the Kaiser Mead Facility. . Prepared for Kaiser Mead Custodial Trust. March 2017.

Hydrometrics, Inc., 2017b. Kaiser Mead Sediment:Groundwater Partitioning and Mass Balance Model. Prepared for Kaiser Mead Custodial Trust. March 2017.

Hydrometrics, Inc., 2017c. Groundwater Model Report, Kaiser Mead NPL Site, Mead, WA. Prepared for Kaiser Mead Custodial Trust. March 2017.

LFR, 2007. Kaiser Mead NPL – Results of WAD CN Analytical Methods Study. Letter Report from Antonio Chavez to Mead Custodial Trust. January 24, 2007.

McCulley, Frick & Gilman, 2004. Supplemental Groundwater Modeling Report Kaiser Aluminum & Chemical Corp. Mead, Washington. Draft January 29, 2004.

Meeussen, JCL, MG Keizer, and FAM deHaan, 1992. Chemical Stability and Decomposition Rate of Iron Cyanide Complexes in Soil Solutions. Environmental Science and Technology, 26, pp 511-516.

APPENDIX A

SUPPLEMENTAL SITE CHARACTERIZATION ANALYSIS

SUPPLEMENTAL
SITE CHARACTERIZATION ANALYSIS

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

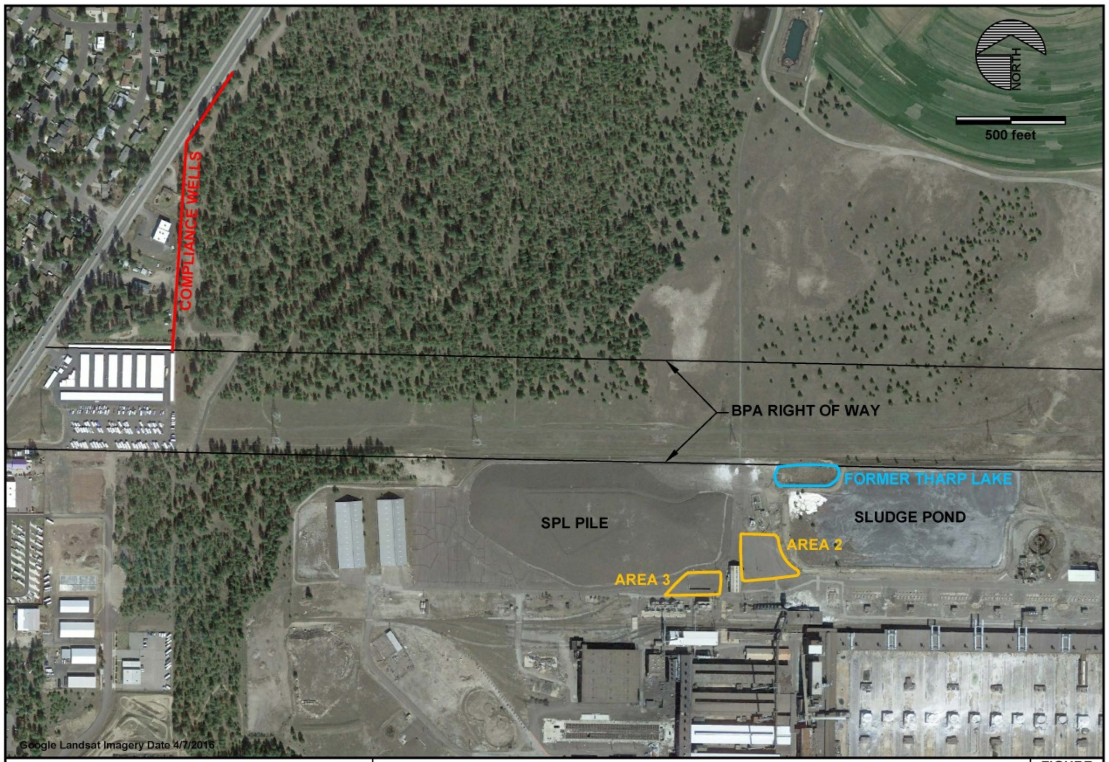
SUPPLEMENTAL SITE CHARACTERIZATION ANALYSIS

1.0 INTRODUCTION

This report presents an analysis of site characterization data collected in the 1980s and more recent data collected by Hydrometrics since 2011. The purpose of this analysis is to supplement and update the findings reported by Hart Crowser in their Site Characterization Analysis in 1988 and to provide support for the current Conceptual Site Model developed by Hydrometrics. As such, this report discusses changes in site conditions from the 1980s to present day conditions and expands the discussion on site geochemistry and hydrogeological conditions as they pertain to the contaminant migration pathways.

Features of the site are shown on Figure 1-1.

FIGURE 1-1. SITE FEATURES MAP



KAISER NPL SITE
MEAD WASHINGTON

SITE FEATURES MAP

FIGURE
1-1

Project No. 9088.00-024 10/17/2016

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Consulting Scientists and Engineers

2.0 CURRENT GROUNDWATER CONDITIONS

Cleanup levels have been established for groundwater at the compliance monitoring wells (Compliance Wells) as follows:

- Free[1] cyanide cleanup level is 0.2 mg/L; and
- Fluoride cleanup level is 4 mg/L.

Results from quarterly groundwater monitoring events in 2016, indicate that groundwater concentrations at the Compliance Wells continue to exceed cleanup standards (Hydrometrics, 2017a). Wells upgradient of the Compliance Wells, back to the spent potliner (SPL) pile, also indicate that elevated levels of cyanide (free, WAD and total) and fluoride remain in area groundwater. Figure 2-1 shows the location of area monitoring wells. Figure 2-2 shows groundwater flow direction on the Site. Current (2016) concentrations of fluoride, WAD cyanide, total and free cyanide in Site groundwater are shown on attached Figures 2-3, 2-4, 2-5, and 2-6, respectively. It should be noted that 1) groundwater concentrations are variable (see discussion and trend graphs in Section 2.5) and as a result, the concentration maps for other times may vary from the 2016 maps; 2) concentrations reflect the shallowest affected portions of the regional aquifer – generally A Zone aquifer at upgradient locations and B Zone aquifer near the Compliance Wells; and 3) groundwater monitoring schedules are variable and as a result the concentration maps include data from multiple monitoring events in order to include data for all wells.

---

[1] Free cyanide refers to the sum of HCN and CN ions in a sample and is the most toxic form of cyanide. Weak to moderately strong metal-cyanide complexes are compounds that dissociate and release HCN under mildly acidic conditions. The WAD method was developed to quantify available cyanide, which measures the weak and moderately strong metal cyanide complexes plus free cyanide (Lipps). Task 2 of the 2004 Remedial Action Plan (Attachment E to the 2004 Consent Decree) specified that WAD CN be analyzed in the groundwater monitoring program. Ecology elected to use the WAD CN method at that time as they determined the analytical method for WAD CN provided more consistent results at low levels than free CN methods and its use is consistent with the state clean water act for surface water (WAC 173-201A-240). From 2004 to 2016 WAD cyanide was measured during groundwater monitoring. Due to improvements to the analytical methods for free cyanide, free cyanide analyses were incorporated into routing groundwater monitoring in 2015. In October 2016, Ecology supported the change from WAD to free cyanide analyses for future monitoring and compliance determinations.

FIGURE 2-1. MONITORING WELL LOCATIONS

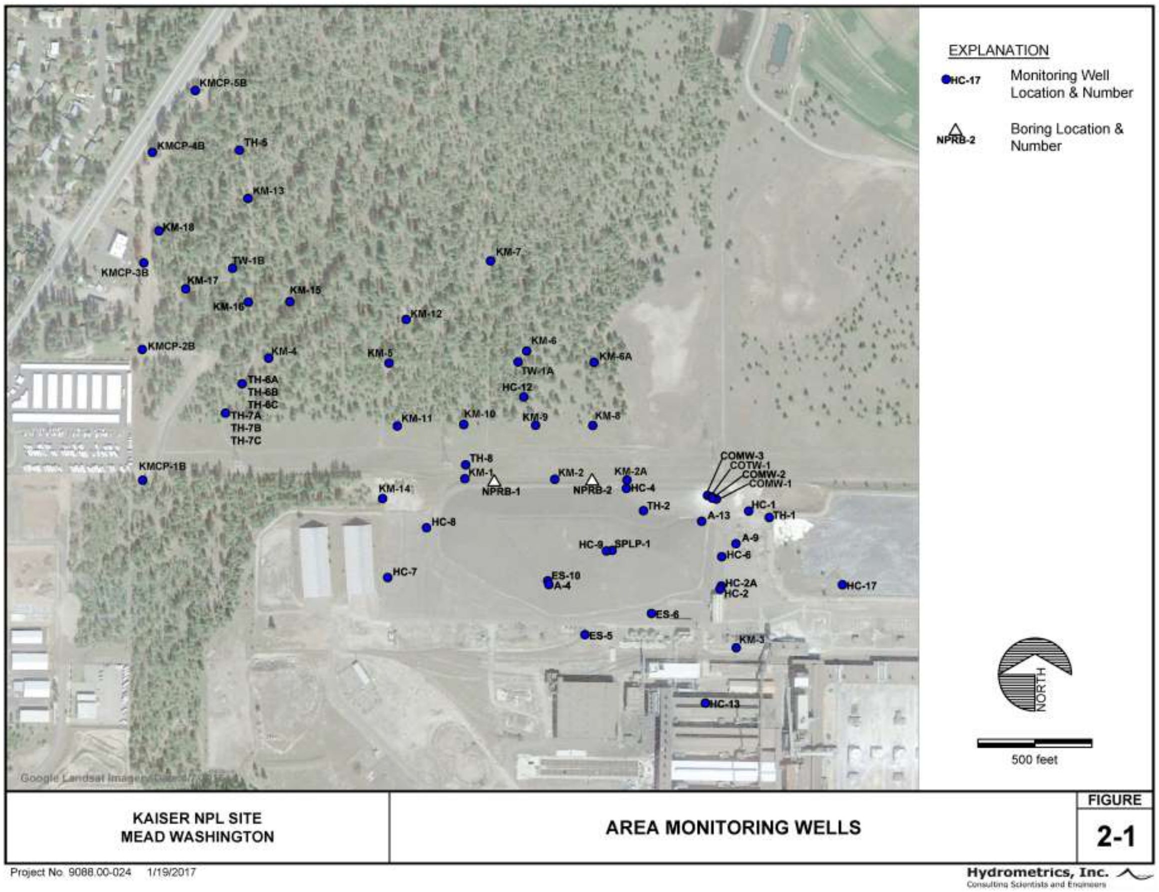


FIGURE 2-2. GROUNDWATER FLOW DIRECTION

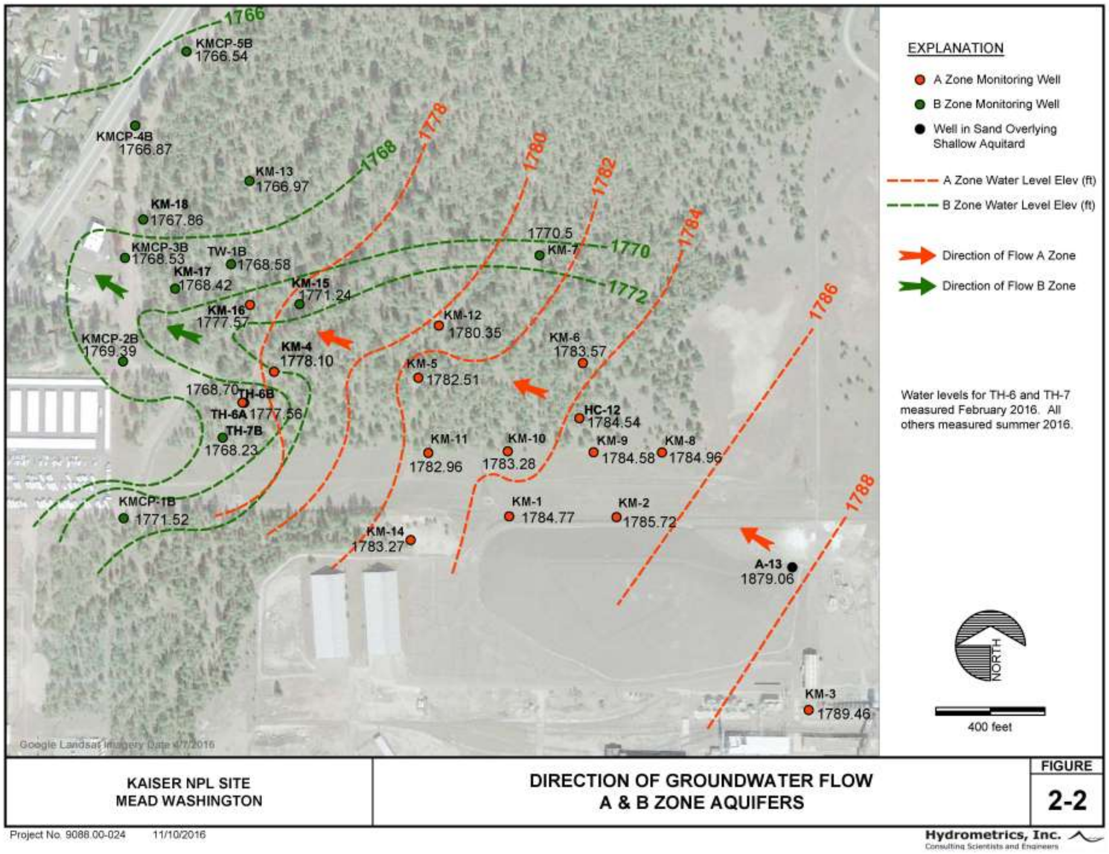
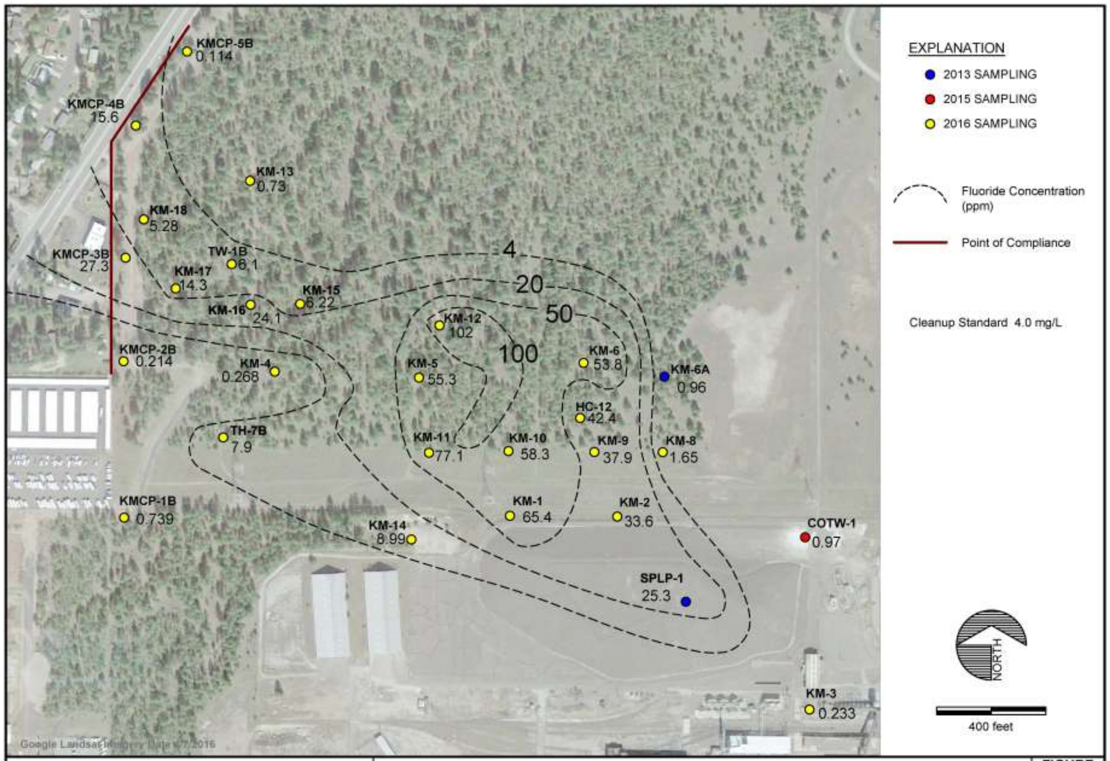


FIGURE 2-3. FLUORIDE CONCENTRATION IN GROUNDWATER



KAISER NPL SITE
MEAD WASHINGTON

FLUORIDE CONCENTRATION
IN GROUNDWATER RESULTS

FIGURE
2-3

Project No. 9088.00-024 1/16/2017

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FIGURE 2-4. WAD CYANIDE CONCENTRATION IN GROUNDWATER

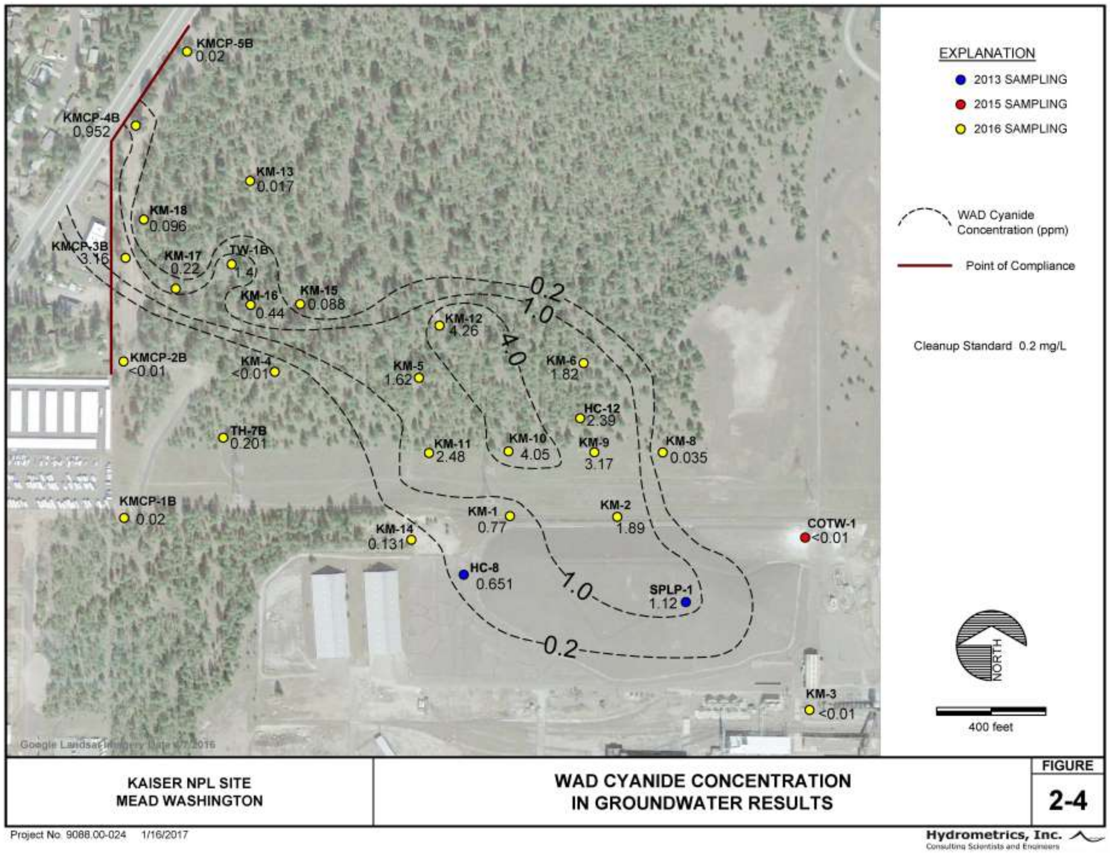


FIGURE 2-5. TOTAL CN CONCENTRATION IN GROUNDWATER

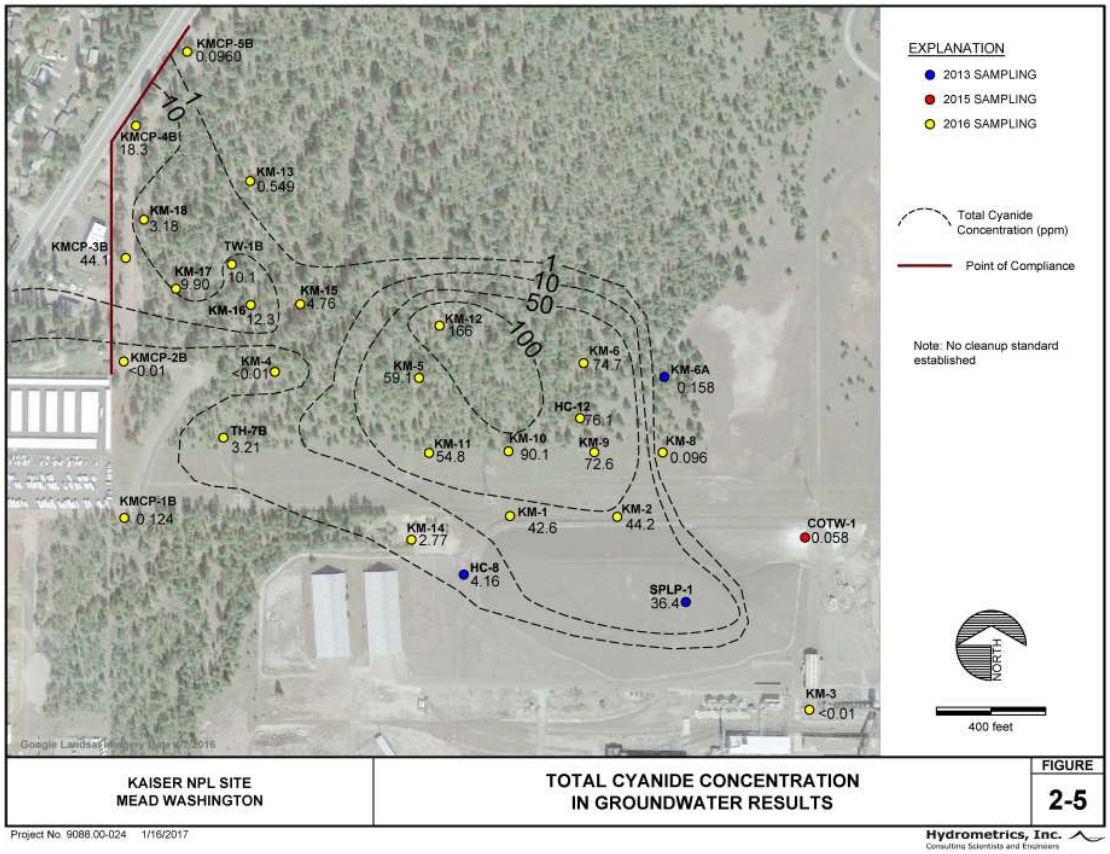
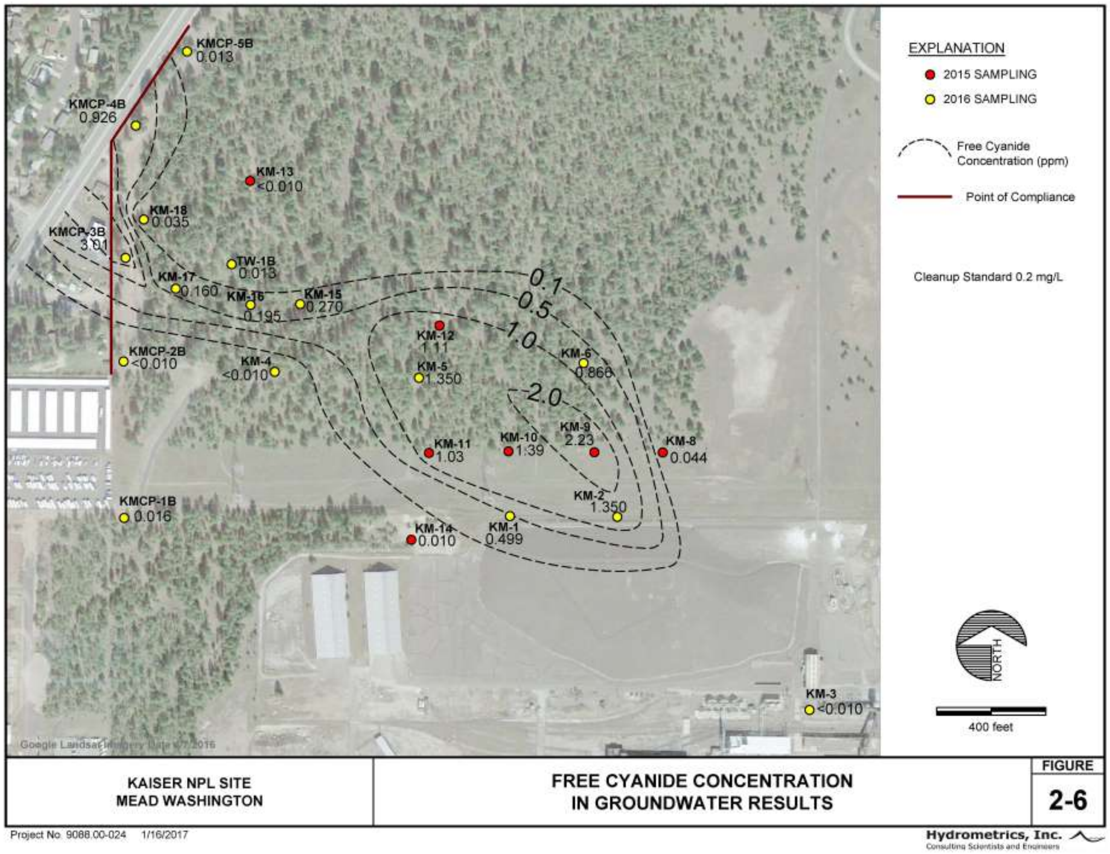


FIGURE 2-6. FREE CN CONCENTRATION IN GROUNDWATER



2.1 GROUNDWATER FLOW AND HYDROSTRATIGRAPHY

This section provides a brief overview of groundwater flow and hydrostratigraphy of the Site to aid in the discussion and understanding of current conditions. Additional detail is provided in discussion of the groundwater migration pathway in Section 4.3 below.

A mixed glacial outwash package of fine to coarse sands with minor gravel, and thin intervening layers of silt and clay underlie the Kaiser Mead site (see cross-sections in Figures 4-30 through 4-33 in Section 4-4). The glacial outwash sequence is approximately 285 feet thick in the vicinity of the site and underlain by a regional aquitard. Many boreholes and wells located in the vicinity of the SPL pile have encountered what has been historically described as a silt/clay lens between 50 and 60 feet below ground surface that comprises a leaky, discontinuous aquitard. In historical reports and in this report, this silt/clay lens is referred to as the shallow aquitard or the SAQ.

Previous investigators have divided the aquifer stratigraphy into three zones for purposes of defining contaminant transport at the site. The uppermost zone, A Zone, is composed of fine to coarse and/or medium to coarse sand with discrete zones of silt and very fine sand. The A Zone is approximately 10 to 20 feet thick and underlain by a silt and clay layer that is present beneath the SPL pile but is laterally discontinuous to the west and is not present in the Compliance Wells area. A Zone is the shallowest aquifer in the vicinity of the SPL pile and is the most highly contaminated. The B Zone consists of fine sand, fine to medium sand, and/or medium to coarse sand, sometimes silty or with silt layers (MFG, 2000) and is underlain by a silt/clay layer. The B Zone is reported in boring logs to range from 6 to 20 feet in thickness. B Zone is not contaminated in the area of the SPL pile but is contaminated in the area of the Compliance Wells where the aquitard separating the A and B Zones is absent. C Zone consists of fine to medium sands or fine to coarse sands with some gravel. Sediments in the lower half of C Zone are cleaner and coarser-grained containing coarse sand and fine to coarse gravel with boulders. C Zone is up to 100 feet thick, however, the monitoring wells on the site typically only penetrate 10 to 25 feet into C Zone. There is no evidence that C Zone is contaminated.

Groundwater flows to the northwest in the A Zone aquifer as shown in Figure 2-2. There is a more northerly component to flow in the immediate vicinity of the SPL pile. The average gradient across the A Zone aquifer is approximately 0.005, the gradient is more flat in the vicinity of the SPL pile (0.003) and more steep near monitoring wells KM-4 and KM-15 (0.01). Groundwater flow average linear velocity is approximately 3 to 5 ft/day (see Table 4-5, Section 4.4) and estimated travel time from the SPL pile to the Compliance Wells (distance of approximately 2,000 feet) is approximately 1 to 2 years.

2.2 FLUORIDE

Current fluoride concentrations in site groundwater are shown on Figure 2-3. Overall, fluoride concentrations are low and near background conditions upgradient and adjacent to the SPL pile and elevated, exceeding the cleanup level of 4 mg/L, downgradient of the SPL pile to the Compliance Wells and likely beyond.

Background fluoride concentration in the area, represented by well KM-3 (upgradient and south of the SPL pile) is approximately 0.2 mg/L. Fluoride concentrations to the east and west of the SPL pile are slightly elevated above background concentrations but generally lower than the cleanup level. In 2013, fluoride concentrations were found to be slightly elevated (1 to <4 mg/L) above background (but lower than the cleanup standard) in the area between the SPL pile and sludge pond (east of SPL and west of the sludge pond; and the adjacent area directly to the west of the SPL pile. In 2015 a sample from a new well at the northeast corner of the SPL pile (COTW-1) indicate fluoride concentrations remain below cleanup east of the SPL pile. In 2016, a sample from a well west of the northwest corner of the SPL pile (KM-14) indicate fluoride concentrations are above cleanup levels northwest of the SPL pile.

In 2013, the highest concentrations of fluoride in groundwater (50 to 111 mg/L) were found in monitoring wells and borings immediately downgradient of the SPL pile (wells KM-1, KM-2, NPRB-1, and NPRB-2). Fluoride concentrations were slightly lower (50 to 71 mg/L) in the plume center approximately 600 feet downgradient of the SPL pile (wells KM-5, KM-6, TW-1A, and HC-12). The highest concentrations for fluoride at the downgradient

Compliance Wells were at KMCP-3B (25.9 mg/L) and KMCP-4B (18.1 mg/L). Fluoride concentrations at adjacent Compliance Wells KMCP-1B, -2B, and -5B are much lower and meet the cleanup level of <4 mg/L.

In 2015 and 2016, the addition of data points KM-15, -16, and -17 east of the Compliance Wells KMCP-3B and KMCP-4B has resulted in the narrowing of the delineation of the contaminant plume in that area.

2.3 CYANIDE

Current cyanide (weak acid dissociable (WAD), total and free) concentrations in site groundwater are shown on Figures 2-4, 2-5, and 2-6. Cyanide concentrations are low and near background conditions upgradient and adjacent to the SPL pile and elevated, exceeding the cleanup level of 0.2 mg/L free[2] cyanide, downgradient of the capped SPL pile to the Compliance Wells and likely beyond.

Background total, free and WAD cyanide concentrations in the area, represented by well KM-3, are approximately 0.01 mg/L or less. In 2013, WAD cyanide concentrations were slightly elevated above background (but lower than the cleanup standard) in the area between the SPL pile and sludge pond (east of the SPL pile); and in the area directly to the west of the SPL pile. In 2015 and 2016, samples from new wells at the northeast corner of the SPL pile and west of the northwest corner of the SPL pile indicate WAD and free cyanide concentrations remain below cleanup levels directly east and west of SPL pile.

Free and WAD cyanide concentrations are considerably less than total cyanide concentrations at all monitoring wells. In 2016, the highest free and WAD cyanide

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[2] As noted in footnote 1 above, although the cleanup level is based on free cyanide, Task 2 of the 2004 Remedial Action Plan (Attachment E to the 2004 Consent Decree) specified that WAD CN be analyzed in the groundwater monitoring program. From 2004 to 2016 WAD cyanide was measured during groundwater monitoring. Due to improvements to the analytical methods for free cyanide, free cyanide analyses were incorporated into routing groundwater monitoring in 2015. In October 2016, Ecology supported the switch from WAD to free cyanide analyses for future monitoring and compliance determinations. WAD cyanide concentrations are typically slightly higher than free cyanide concentrations, therefore, when WAD concentrations are less than or equal to the cleanup level it may be assumed that free cyanide concentrations are also less than the cleanup level.

concentrations (approximately 3 to 4 mg/L) were identified in the new wells KM-9 and KM-10, located within the Bonneville Power Association (BPA) right-of-way (ROW), and KM-12 located in the plume center area. Free and WAD cyanide concentrations in Compliance Wells range from significantly better than cleanup levels at KMCP-1B, -2B, and -5B to concentrations similar to upgradient areas (1 to 3 mg/L) in KMCP-3B and -4B. As noted with fluoride, the addition of new data points KM-15 and KM-16 located just east of the Compliance Wells KMCP-3B and KMCP-4B has resulted in the narrowing of the plume in the vicinity of the new data points.

Although there is no cleanup standard for total cyanide, total cyanide concentrations are monitored and considered because they may offer insight to contaminant sources and transport and overall plume behavior (see Figure 2-5 for a depiction of total CN in site groundwater). In 2016, total cyanide concentrations were highest north (downgradient) of the SPL pile in the plume center and ranged from approximately 50 to 100 mg/L. Total cyanide concentrations decreased considerably to the south and east of the SPL area with wells located between the SPL pile and former Tharp Lake/sludge pond area being below 0.1 mg/L. Elevated concentrations of total cyanide extend downgradient to Compliance Wells KMCP-3B and KMCP-4B (approximately 18 to 40 mg/L). As with fluoride and WAD CN, the addition of data points just east of the Compliance Wells KMCP-3B and KMCP-4B has resulted in the narrowing of the plume near those data points.

2.4 PH AND REDOX CONDITIONS

Typical SPL leachate generated at Mead had a high (alkaline) pH of approximately 11 (Ecology, 2002). A prominent characteristic of the groundwater plume is also high pH, ranging from approximately 9.5 to 10 beneath, and immediately downgradient (north) of the SPL pile, and extending to the Compliance Wells KMCP-3B and 4B as shown on Figure 2-7. Background pH in the area, represented by well KM-3 is approximately 8. Groundwater pH appears to be near background outside of the cyanide and fluoride plume including the area between the SPL pile and sludge pond (east of SPL and west of sludge pond at wells HC-1, TH-1, HC-2A); and the area to the west of the SPL pile (HC-7). Coincident with high pH, alkalinity is also very high (1,000 to 5,000 mg/L) within the groundwater plume (Figure 2-8) but total alkalinity, a measure of pH buffering capacity, decreases from the SPL and Plume Center area to the Compliance Wells. This decrease in alkalinity is likely due to the influx of un-impacted groundwater from the B Zone that occurs between the Plume Center and Compliance Wells.

Redox conditions measured in site groundwater by several methods in March 2011 are shown in Figure 2-9 along with the stability diagram for common iron cyanide minerals (Hydrometrics, 2011a). As is commonly observed, there is some discrepancy between field-measured pe, and pe calculated from the redox pairs sulfide/sulfate and ammonia/nitrate.

FIGURE 2-7. GROUNDWATER PH

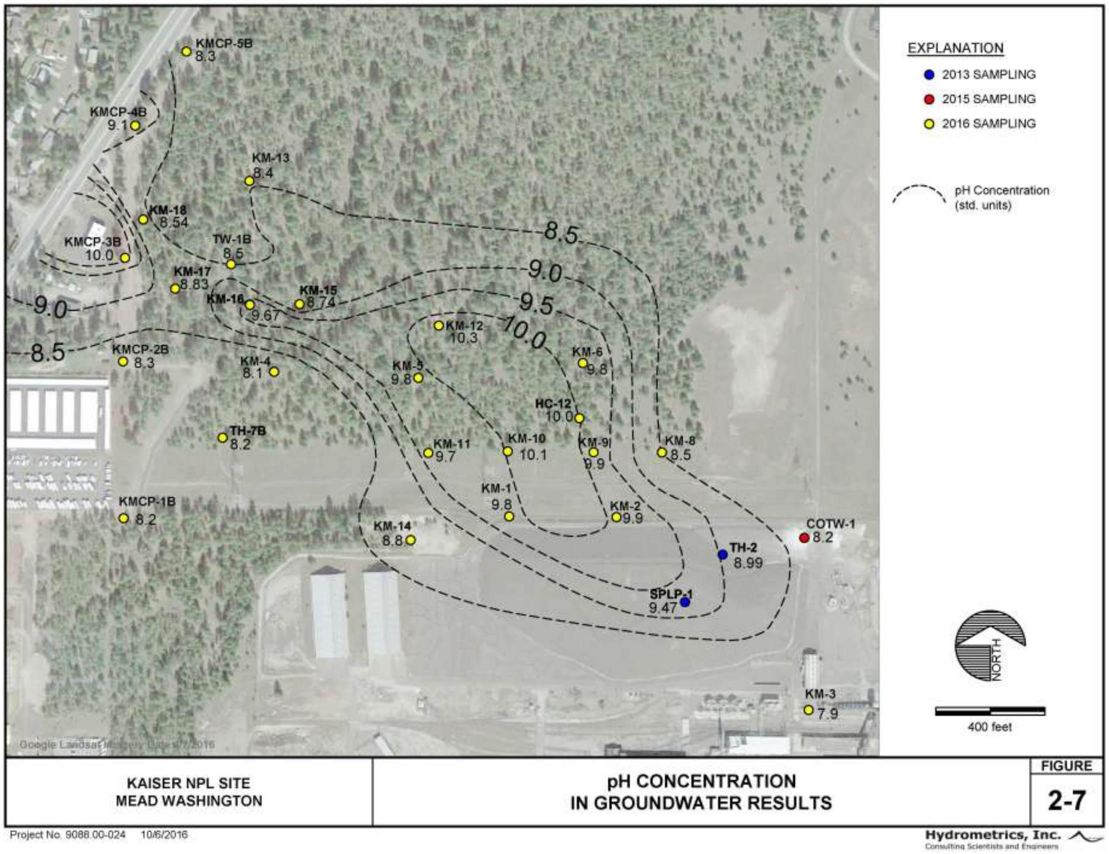


FIGURE 2-8. TOTAL ALKALINITY IN GROUNDWATER

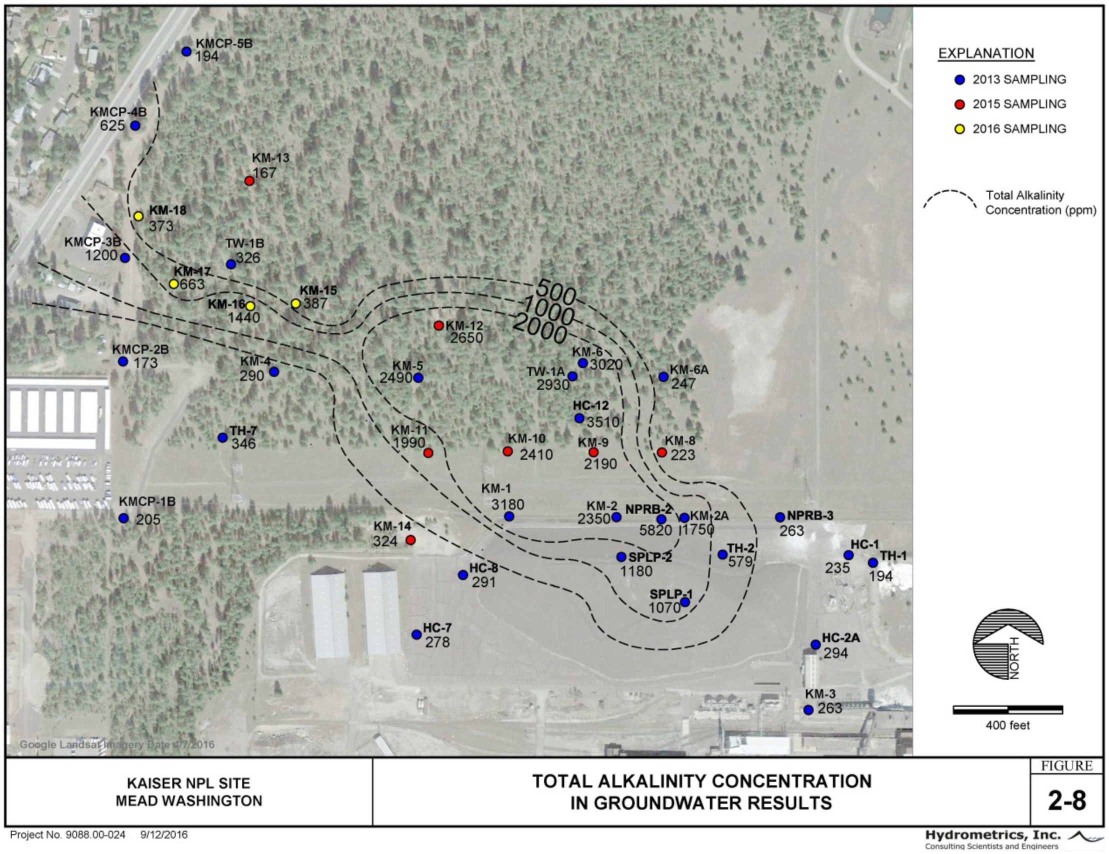
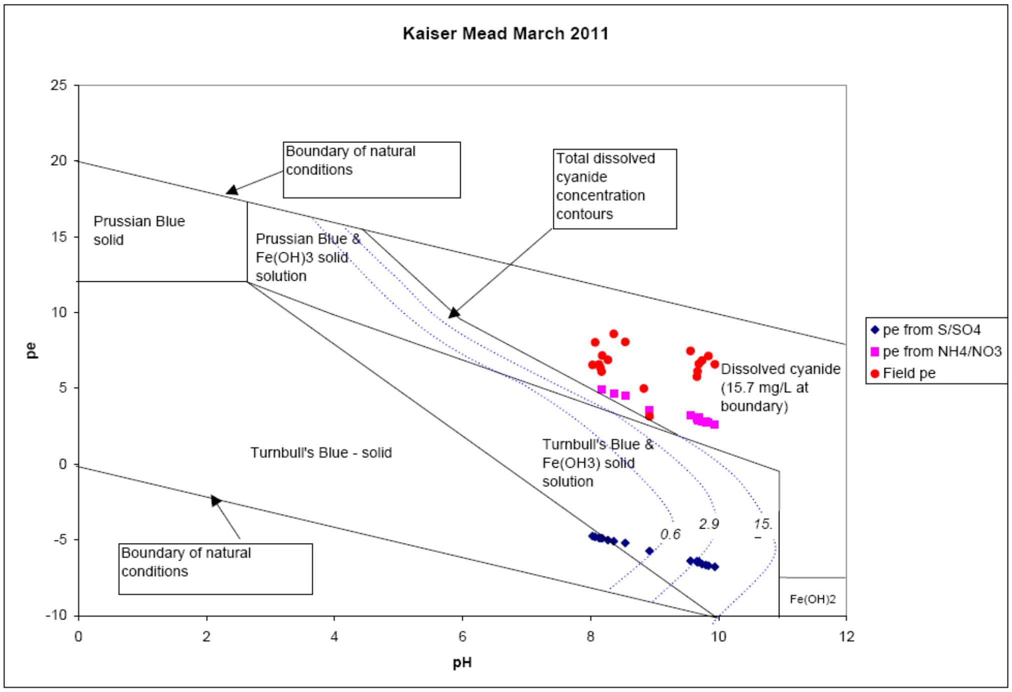


FIGURE 2-9. REDOX CONDITIONS IN SITE GROUNDWATER IN MARCH 2011

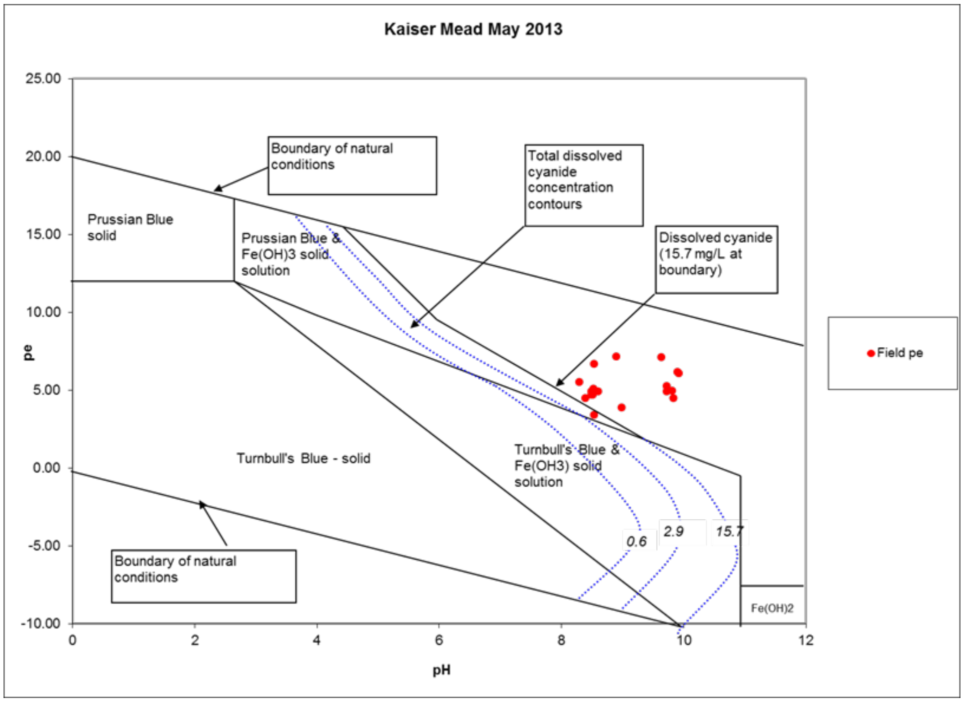


Iron cyanide stability diagram is from Ghosh et al, 1999.

For various reasons (e.g., sulfide concentrations very near reporting limit and thus more subject to uncertainty, better agreement between field and ammonia/nitrate values, high concentrations of cyanide that are more likely at moderately oxidizing conditions), groundwater pe/pH is believed to be best represented by field measurements and ammonia/nitrate equilibrium, implying moderately oxidizing conditions.

Field pe measurements collected in May 2013 (Figure 2-10) also indicate moderately oxidizing conditions. In May 2013, water samples were analyzed again for sulfide, a reduced form of sulfur that is indicative of moderately reducing redox conditions. Sulfide was found to be non-detectable in all samples, thus corroborating the conclusion of mildly oxidizing conditions based on the March 2011 data.

FIGURE 2-10. REDOX CONDITIONS IN SITE GROUNDWATER IN MAY 2013



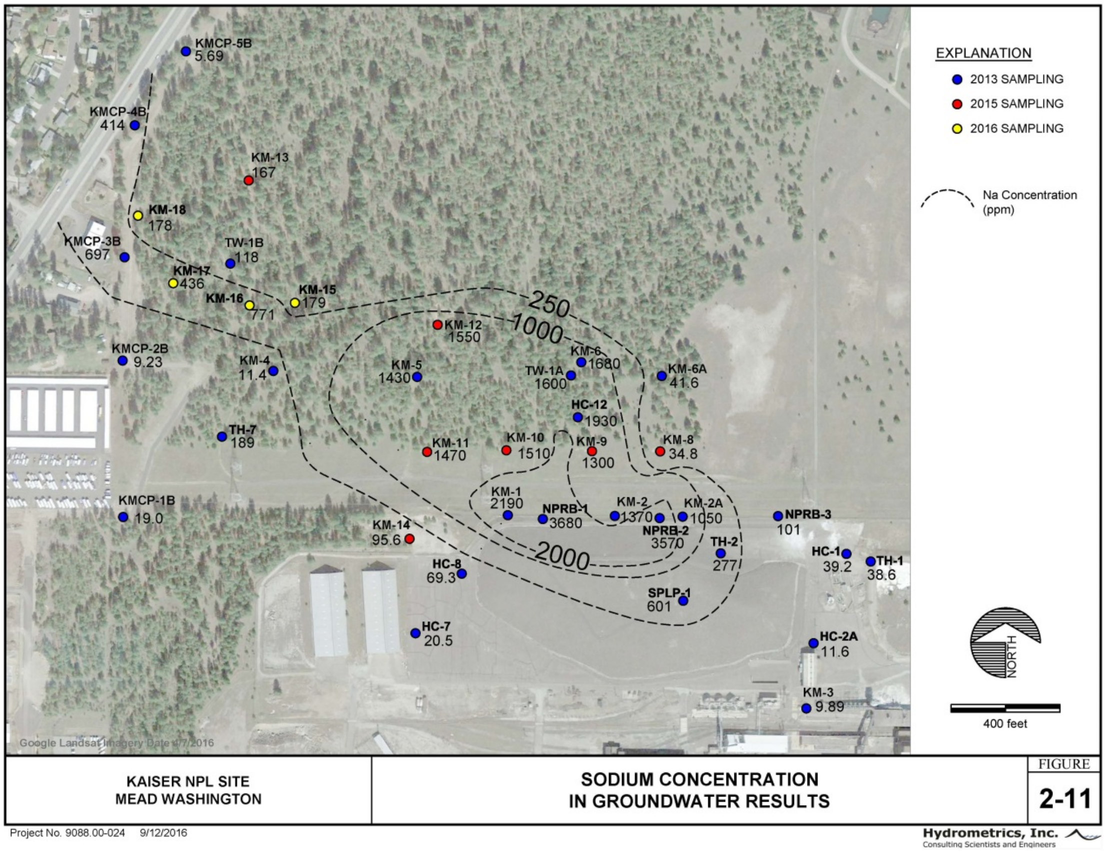
Iron cyanide stability diagram is from Ghosh et al, 1999.

2.5 COMMON CONSERVATIVE CHEMICALS

“Conservative” chemicals are defined as those that do not react or interact with aquifer sediments during groundwater transport, thus the chemical mass is “conserved” within the groundwater rather than partitioning via adsorption or mineral precipitation with the sediments. Chemicals that exhibit conservative behavior may serve as chemical tracers of groundwater movement. Chemicals that typically may exhibit conservative behavior include cations and anions of highly soluble salts that are poorly adsorbed by sediment such as sodium and chloride. Evaluation of the distribution and behavior of conservative chemicals can aid in the identification of ongoing active sources. However, sodium and to a lesser extent chloride do not appear to behave conservatively at the Site. Laboratory leach testing of aquifer sediments with site groundwater demonstrates that sodium (and fluoride and to a lesser extent chloride and cyanide) in groundwater interact and partition with aquifer sediments (see discussion of sediment testing in Section 4.3).

Spent pot liner from Mead typically contained approximately 14 percent sodium and 16 percent fluoride by weight (Ecology, 2002). Sodium concentrations in groundwater are shown on Figure 2-11. Background groundwater sodium concentrations appear to be on the order of approximately 6 to 11 mg/L as estimated based on upgradient well KM-3 and non-impacted downgradient well (KMCP-5B). Sodium concentrations are significantly higher immediately downgradient of the SPL pile (approximately 1,100 to 3,700 mg/L) and in the center of the groundwater plume (1,300 to 1,900 mg/L). Sodium (and fluoride) concentrations were highest at the northwestern corner of the SPL pile area (vicinity of well KM-1 and boring NPRB-1). Sodium concentrations decreased further downgradient in the vicinity of the Compliance Wells (approximately 400 to 700 mg/L in KMCP-3B and KMCP-4B).

FIGURE 2-11. SODIUM CONCENTRATIONS IN GROUNDWATER



In 2015 and 2016, analyses of sodium in groundwater were limited to the new wells and KM-3. The 2015 and 2016, data appear to be consistent with the 2013, data except the inclusion of data from new wells KM-15 and KM-16 results in the narrowing of the plume in that area, just east of the Compliance Wells.

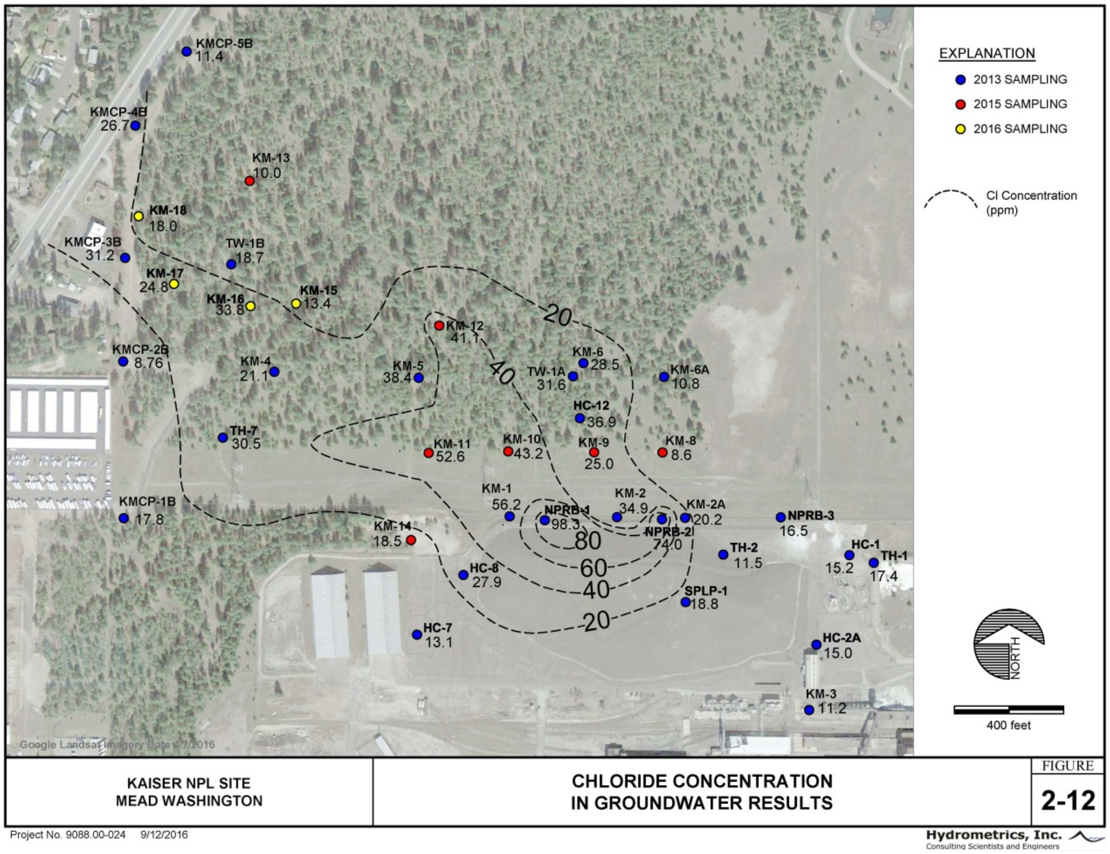
Observations/hypotheses that arise from sodium behavior are:

1. The sodium concentration map looks very similar to the cyanide and fluoride concentration maps in terms of overall shape, indicating that sodium is a fairly good indicator and tracer of cyanide and fluoride contamination.
2. There appears to be a fairly significant sodium source that is located in the vicinity of the SPL pile. The groundwater sodium “hot spot” mostly closely coincides with the fluoride hot spot at the northwest corner of the SPL pile.
3. Similar to cyanide and fluoride, there are three potential sources of sodium: leaching of SPL waste; contaminated unsaturated sediments beneath the SPL pile, and contaminated aquifer sediments. Of these sources, only leaching of contaminated aquifer sediments is proven to occur based on laboratory testing of sediment (see Section 4.3.2) and is known to have a demonstrated pathway to groundwater through direct contact with groundwater.

Chloride is not known to be present above background concentrations in Mead SPL leachate (10 mg/L as reported in Hart Crowser, 1988); however, the groundwater contaminant plume has a distinct chloride signature. Chloride concentrations in groundwater in May 2013, (most recent monitoring event in which chloride was determined site-wide) are shown on Figure 2-12. Background chloride concentrations appear to be on the order of 9 to 15 mg/L as estimated based on upgradient well KM-3 and non-impacted downgradient well (KMCP-2B). Chloride concentrations are significantly higher immediately downgradient of the SPL pile (approximately 60 to 100 mg/L). Chloride concentrations decrease further downgradient in the center of the plume extending to the vicinity of the Compliance Wells (approximately 30 to 40 mg/L in KM-5 and KMCP-4B, respectively). Observations and hypotheses that arise from chloride concentrations are:

1. The chloride concentration map looks very similar to the cyanide and fluoride concentration maps in terms of overall shape, indicating that chloride is a fairly good indicator and tracer of cyanide and fluoride contamination.
2. There appears to be a fairly significant chloride source that is located in the vicinity of the SPL pile. The groundwater chloride "hot spot" mostly closely coincides with the fluoride hot spot at the northwest corner of the SPL pile.

FIGURE 2-12. CHLORIDE CONCENTRATION

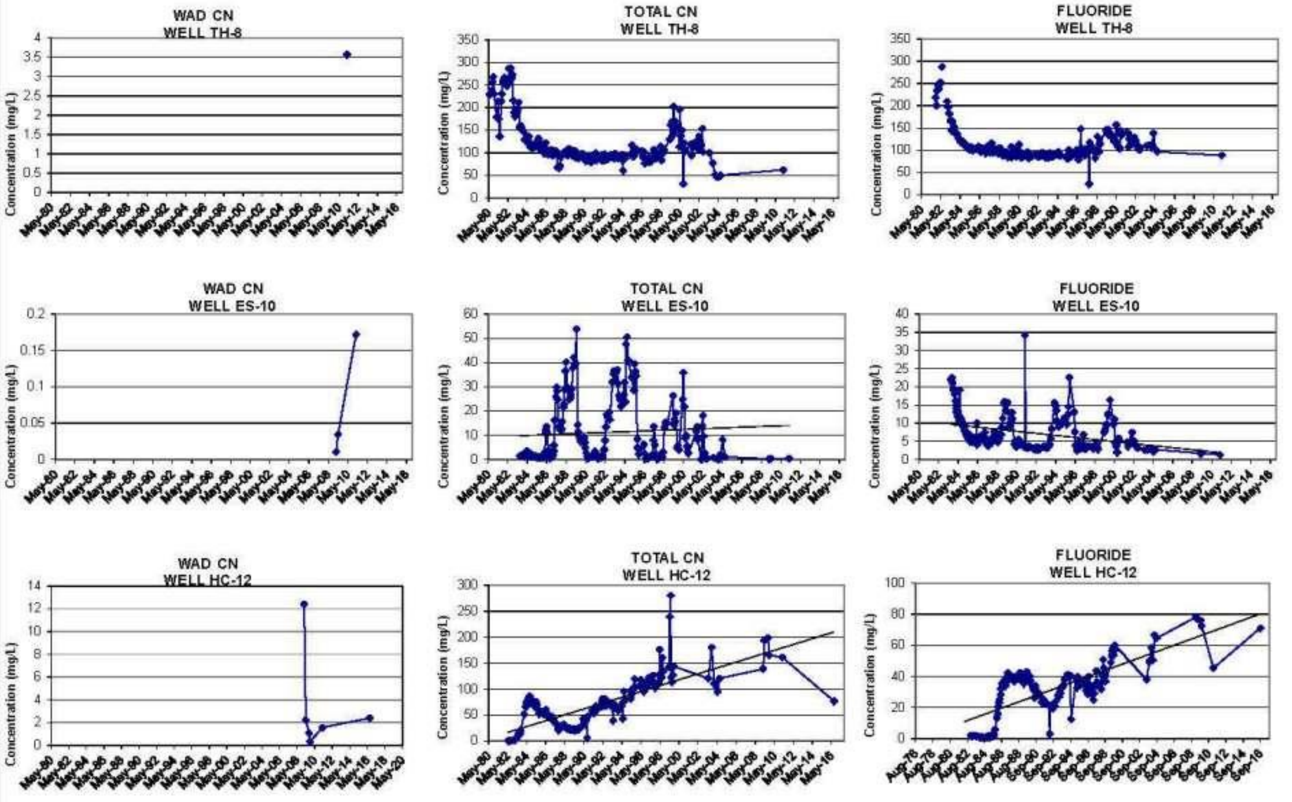


3. Similar to cyanide and fluoride, there are three potential sources of chloride: leaching of SPL waste; contaminated unsaturated sediments beneath the SPL pile, and contaminated aquifer sediments. However, none of these sources are known to contain sufficiently high chloride levels to generate the observed groundwater concentrations. Of these sources, only leaching of contaminated aquifer sediments is proven to occur based on laboratory testing of sediment and is known to have a demonstrated pathway to groundwater due to direct contact. However, concentrations leached from sediment in laboratory testing (10 to 18 mg/L, see Section 4.3.2) are low relative to observed groundwater concentrations.

2.6 CONTAMINANT CONCENTRATION TRENDS

Time series graphs (trendplots) of total and WAD cyanide and fluoride concentration in selected monitoring wells are shown in Figures 2-13, 2-14, 2-15, and 2-16. For discussion and evaluation purposes, trendplots are grouped for the following well sets: historic monitoring wells (wells with available data prior to cleanup actions, including SPL area wells), wells immediately downgradient of the SPL pile wells in the center of the contaminant plume, and Compliance Wells. Some wells belong to more than one group and thus may be shown/discussed multiple times. Although cleanup levels apply only to fluoride and WAD cyanide, concentration data for total cyanide is presented and discussed as a general indicator of water quality and to allow comparison with historic water quality data as WAD cyanide was not routinely monitored prior to 2005. Observations and hypotheses regarding concentration trends are described below.

FIGURE 2-13. CYANIDE AND FLUORIDE WATER QUALITY TRENDS AT HISTORIC WELLS



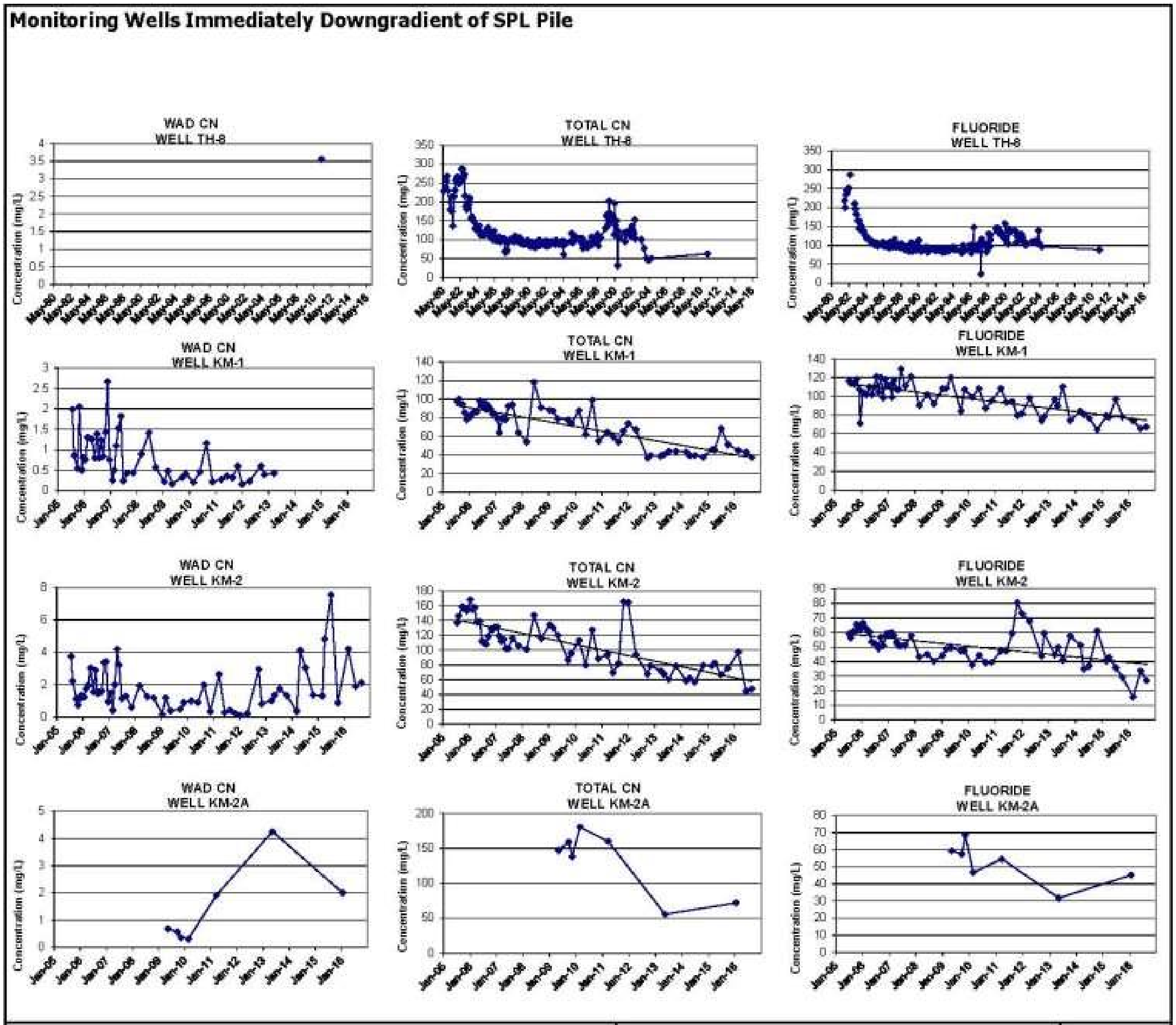
KAISER MEAD NPL SITE MEAD WASHINGTON

CYANIDE AND FLUORIDE WATER QUALITY TRENDS AT HISTORIC WELLS

FIGURE

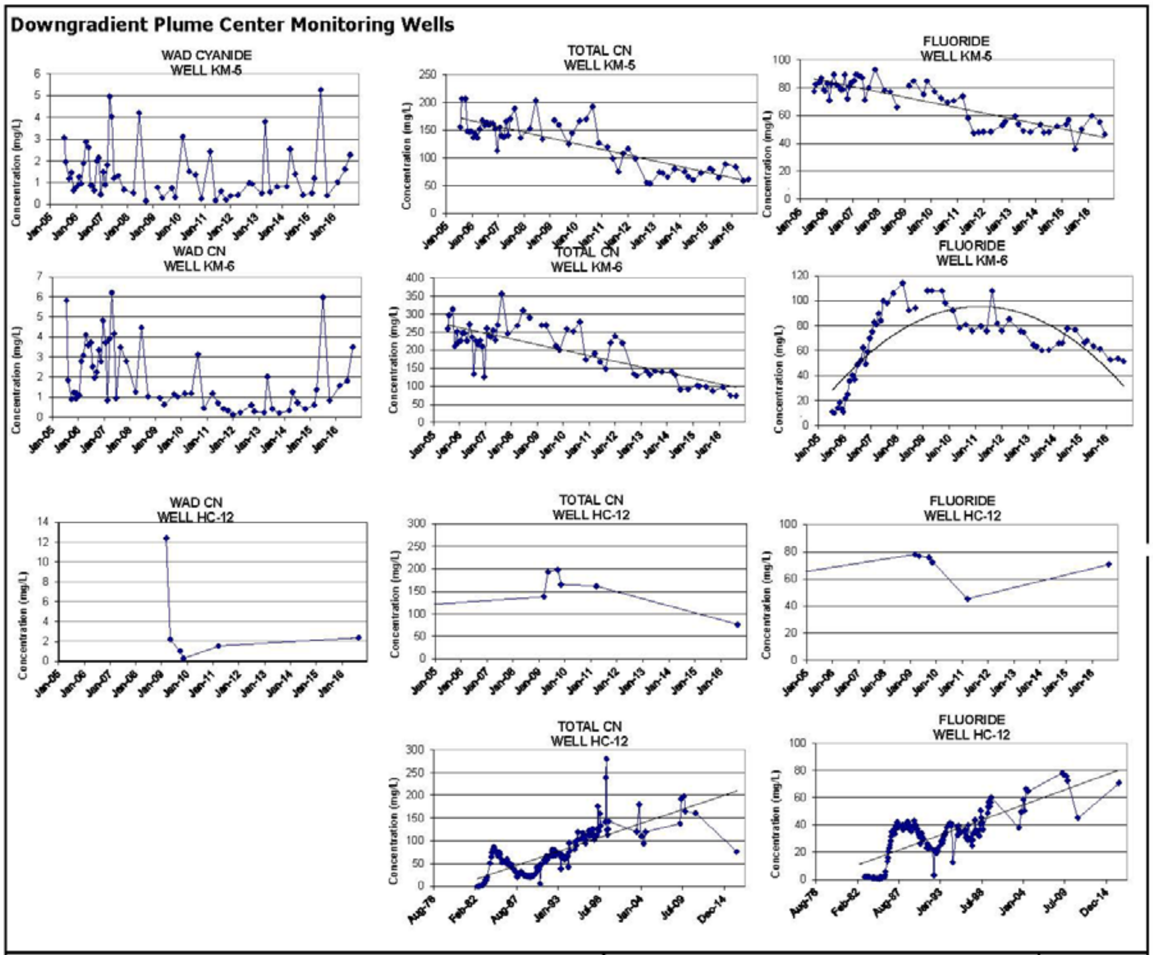
2-13

FIGURE 2-14. CYANIDE AND FLUORIDE WATER QUALITY TRENDS NEAR SPL WELLS



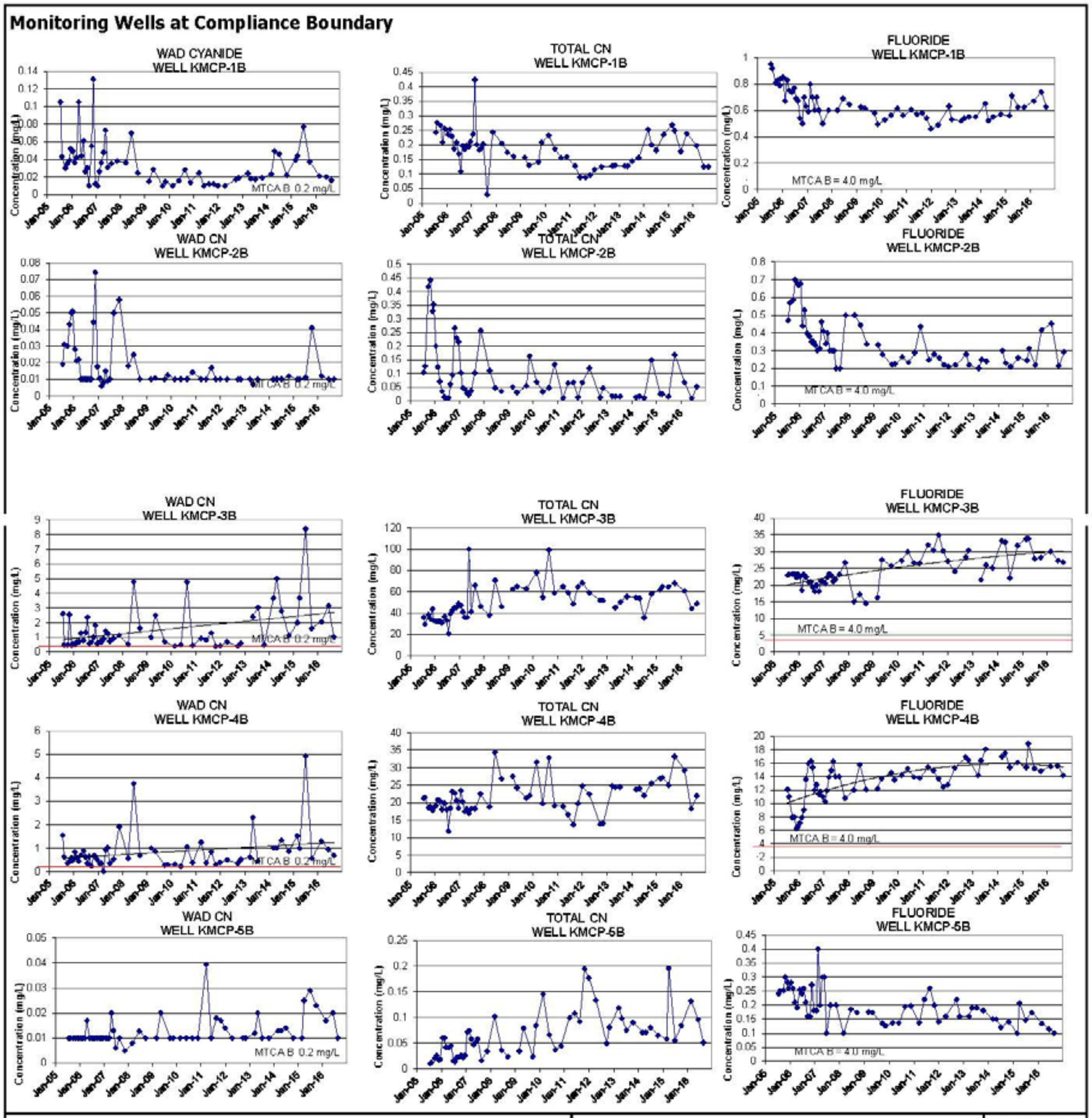
KAISER MEAD NPL SITE MEAD WASHINGTON	CYANIDE AND FLUORIDE WATER QUALITY TRENDS NEAR SPL WELLS	FIGURE 2-14

FIGURE 2-15. CYANIDE AND FLUORIDE WATER QUALITY TRENDS AT PLUME CENTER WELLS



KAISER MEAD NPL SITE MEAD WASHINGTON	CYANIDE AND FLUORIDE WATER QUALITY TRENDS AT PLUME CENTERWELLS	FIGURE 2-15

FIGURE 2-16. CYANIDE AND FLUORIDE WATER QUALITY TRENDS AT COMPLIANCE WELLS



KAISER MEAD NPL SITE MEAD WASHINGTON	CYANIDE AND FLUORIDE WATER QUALITY TRENDS AT COMPLIANCE WELLS	FIGURE 2-16

General Observations:

1. Many monitoring wells exhibit short-term and long-term variations in cyanide and fluoride concentrations. These variations can make it difficult to accurately identify concentration trends. In wells with short monitoring records, short-term variations may falsely appear to be trends. This problem is made worse at the Site because monitoring of many historic wells with long term records was discontinued in the early 2000s as the new monitoring well network was developed.
2. Overall, cyanide and fluoride concentrations within the groundwater contaminant plume have declined slightly since the implementation of the cleanup remedy (2001-2005). Thus it appears that the mass of contaminants present in groundwater may have been reduced, suggesting a groundwater response to the implemented source controls.

Historic Wells (Figure 2-13):

1. Historic wells include wells ES-10 and HC-9A, located in the SPL pile area, well TH-8 located immediately downgradient of the current SPL pile area, and HC-12 located in the center of the groundwater plume. All of these wells were monitored routinely from approximately 1982 through 2000. HC-9A was plugged and abandoned in approximately 2000/2001. ES-10 continued to be monitored routinely through 2004, and has been monitored infrequently since. ES-10 cannot be monitored currently due to an apparent blockage in the well. TH-8 was monitored routinely through 2004 and was last monitored in 2011. HC-12 is still monitored occasionally, most recently in August 2016. WAD cyanide was not monitored in historic wells until 2009.
2. All of the historic wells exhibit periodic variations in total cyanide and fluoride concentrations (Figure 2-13).
3. Historically (early 1980s), cyanide and fluoride concentrations were highest immediately downgradient of the current SPL pile (TH-8), intermediate beneath the current SPL pile (ES-10 and HC-9A), and lowest further downgradient (HC-12).

From the mid-1980s through the 1990s, downgradient concentrations increased and the current location of the highest cyanide concentration is HC-12.

4. Downgradient well TH-8 (adjacent northwest corner of SPL pile near well KM-1) exhibits a fairly pronounced long-term decline in total cyanide and fluoride concentrations from 1982 to approximately 1998 (similar to ES-10 and HC-9A) that may have been related to changes in SPL management prior to the cleanup remedy. From approximately 1998 through 2002, cyanide and fluoride concentrations increased, before decreasing from 2002 through 2004. Since 2004, TH-8 was only sampled once and concentrations were found to be similar to 2004 values. The cause of the spike in concentrations in 1998 through 2002 is not known. The decrease in concentrations from 2002 through 2004 followed the remediation of the SPL pile and associated waste materials but it is not known with certainty that the cleanup caused the slight groundwater improvement.
5. Wells ES-10 and HC-9A (located in the SPL area) appear to have exhibited a slight decrease in contaminant concentrations from 1982 through 2000 that may have been related to changes in SPL management done prior to the cleanup remedy. In particular, Hart Crowser hypothesized that the concentration increase observed in ES-10 in the early to mid-1980s was due to infiltration of stormwater through Area 4, located south of ES-10. The subsequent decrease in concentration was attributed to asphalt paving of Area 4 which likely reduced stormwater infiltration. However, concentration increased again in ES-10 in the mid-1990s. Since 2000, the few data points available suggest that concentrations in ES-10 may have decreased further, possibly in response to the cleanup remedy. However, given the documented variations in water quality in the well and the infrequency of monitoring since 2000, there is a great deal of uncertainty regarding trends in ES-10.
6. Well HC-12 continues to exhibit an overall long term increasing trend in total cyanide and fluoride concentrations. Data from 2009 through 2013, showed a short-term decreasing fluoride concentration trend, however, the most recent data from August 2016 demonstrate that fluoride concentrations have rebounded to approximately 2004 (about 70 mg/L) levels.

Groundwater Immediately Downgradient of SPL Pile (Figure 2-14 and contour Figures 2-3, 2-4, and 2-5):

1. Monitoring wells immediately downgradient of the SPL pile include (from west to east) TH-8/KM-1 (adjacent wells), KM-2 and KM-2A. TH-8 is one of the few wells with historic and continuous monitoring data from 1979 through 2011. Wells KM-1, KM-2 have been monitored since 2005 while well KM-2A has only been monitored since 2009.
2. Groundwater contaminant concentrations immediately downgradient of the SPL pile exhibit mixed but possibly generally declining trends with three of four wells (KM-1, KM-2 and KM-2A (fluoride, WAD and total cyanide)) exhibiting apparent declining concentration trends beginning in approximately 2005.
3. Fluoride concentrations in all wells remain well above the cleanup standard.
4. WAD cyanide concentrations have occasionally met the cleanup standard (e.g., less than 0.2 mg/L), but concentrations are highly variable (e.g., from 1.3 to 7.5 mg/L in KM-2 in 2015) and concentrations routinely exceed the standard.
5. As described above, historic monitoring well TH-8 exhibits 2 cycles of concentration declines, from 1982 to approximately 1998 (possibly associated with pre-remediation SPL management changes) and from 2002 through 2004. Contaminant concentrations are poorly documented in TH-8 from 2004 through present but appear to be steady or declining.
6. Well KM-1 appears to exhibit overall decreasing trends, even meeting the cleanup level for WAD cyanide on several occasions. Although fluoride concentrations exhibit periodic variations, the overall trend appears to be downward.
7. Well KM-2 appears to exhibit overall decreasing trends, even meeting the cleanup level for WAD cyanide on several occasions. However, it is uncertain whether this general trend represents the beginning of significant long term trend that is attributable to corrective actions as there continues to be significant short-term variations in concentrations in the well. Both total cyanide and fluoride concentrations decreased significantly (nearly 50 percent) in KM-2 from 2005 to 2016, with periodic increases mixed in the overall decline. In spite of the decreases in

total cyanide, WAD cyanide concentrations were the highest recorded in 2015 and 2016.

Downgradient Plume Center Monitoring Wells (Figure 2-15 and contour Figures 2-3, 2-4, and 2-5):

1. Highest total cyanide and near-highest fluoride concentrations in Site groundwater occur in the vicinity of wells KM-5, KM-6, and new wells KM-9, KM-10, KM-11, and KM-12, located approximately 300 to 800 feet downgradient of the SPL pile. KM-5 and KM-6 have been monitored since 2005, while the new wells do not have sufficient data points to project a trend.
2. Overall, groundwater contaminant concentrations in the plume center, downgradient of the SPL pile, appear to have decreased since the cleanup remedy was completed in 2004. Nevertheless, fluoride concentrations remain 10 to 20 times higher than cleanup levels, total cyanide concentrations remain high, and WAD cyanide concentrations routinely exceed the cleanup level.
3. Well KM-5 has exhibited overall decreases in total cyanide and fluoride concentrations since monitoring began in 2005 through 2016. However, most of the decline occurred from 2005 through 2011/2012 and since that time concentrations have been fairly steady. WAD concentrations are highly variable and although cleanup standards are infrequently attained (most recently in 2011), concentrations frequently exceed the cleanup standard (range of 0.4 to 5.3 mg/L in 2016) and overall have shown no consistent reduction (e.g., highest measured value occurred in 2016).
4. Well KM-6 has exhibited decreases in concentrations of total cyanide (since monitoring began in 2005) and fluoride (since 2008). WAD cyanide concentrations are highly variable and after averaging less than 1 mg/L for the period of 2011 to 2013 rose to the second-highest recorded value (6 mg/L in July 2015).
5. In some cases (fluoride in well KM-6 from 2005 to 2008; fluoride and cyanide in well HC-12 from 1983 to 2009), contaminant concentrations in the plume center have increased since the cleanup remedy was completed. Well KM-6 has since exhibited significant decreases. Possible explanations for these increases are:

   a. There is significant travel time and/or retardation of contaminants between the SPL area and the plume center that causes a lag time in groundwater response to cleanup activities. Hydraulic conductivity measured in well HC-12 is the lowest (0.5 ft/day) measured on the site and it is to be expected that groundwater effects would be delayed in low conductivity areas of the aquifer.
   b. A spike or pulse of contamination is moving through the groundwater system.
6. Well HC-12 continues to exhibit an overall long term increasing trend in total cyanide and fluoride concentrations. Data from 2009 through 2013, showed a short-term decreasing fluoride concentration trend, however, the most recent data from August 2016 demonstrate that fluoride concentrations have rebounded to approximately 2004 (about 70 mg/L) levels.

Point of Compliance Monitoring Wells (Figure 2-16 and contour Figures 2-3, 2-4, and 2-5):

1. Three of the five Compliance Wells (KMCP-1B, -2B, and -5B) met cleanup levels when first monitored in 2005, and continue to meet cleanup levels presently.
2. Compliance Wells in the middle of the contaminant plume (KMCP-3B and -4B) routinely exceed cleanup levels for WAD cyanide and fluoride and have shown an overall increase in contaminant concentrations since the cleanup remedy was completed.
3. 2015-2016 data for KMCP-3B and -4B appear to display short-term declining fluoride concentrations, additional time and monitoring data is required to confirm these trends.

2.7 GROUNDWATER CONTAMINANT LOADS

In addition to looking at contaminant concentrations (mass per unit volume, e.g., mg/L), evaluation of groundwater contaminant loads (mass flux per unit time, e.g., lbs/day) provides information about the relative size of the contaminant source and the amount (mass) of contaminants that are leaving source areas and moving beyond the Compliance Wells over a given time period. Additionally, comparison of contaminant loads and conservative chemicals may give an indication of the amount of dilution and attenuation occurring in the groundwater system.

Two locations were selected for load calculation, the plume center area downgradient of the SPL pile and where the plume crosses the line of Compliance Wells—approximately from KMCP-2 to KMCP-4 (see Figure 2-17). Groundwater flux through the areas of interest was determined via two methods. One being a simple calculation based on Darcy's Law and the range of aquifer characteristics measured on-site, and the second being output from the groundwater flow numeric model. Due to variations in hydraulic conductivity measurements, gradient, and saturated thickness, estimates of the groundwater flux based on these aquifer characteristics produce a large range of potential values. Therefore, flux based on Darcy's Law and aquifer characteristics serve only as secondary estimate with which to compare and check flux output from the groundwater flow model. Based on aquifer characteristics,
A Zone estimates of groundwater flux into the area of interest range from 18 gpm to 82 gpm, and B Zone estimates of groundwater flux into the Compliance Wells area of interest range from 109 gpm to 253 gpm.

The recently completed groundwater flow model has been calibrated to water levels in 20 on-site wells (May 2013 dataset), including A Zone and B Zone wells and is believed to represent groundwater conditions more accurately than the simple Darcy flux estimates. Therefore output from the model is used in load calculations (Hydrometrics, 2017b). Table 2-1 provides aquifer characteristics utilized in the steady-state model. The calibrated steady-state model resulted in estimated flux values of 46 gpm through the A Zone area of interest and 100 gpm through the B Zone area of interest. The model flux values are within the bounds provided by the estimates based on Darcy's Law and the range of aquifer properties.

FIGURE 2-17. GROUNDWATER MODEL AREAS UTILIZED FOR LOAD CALCULATIONS

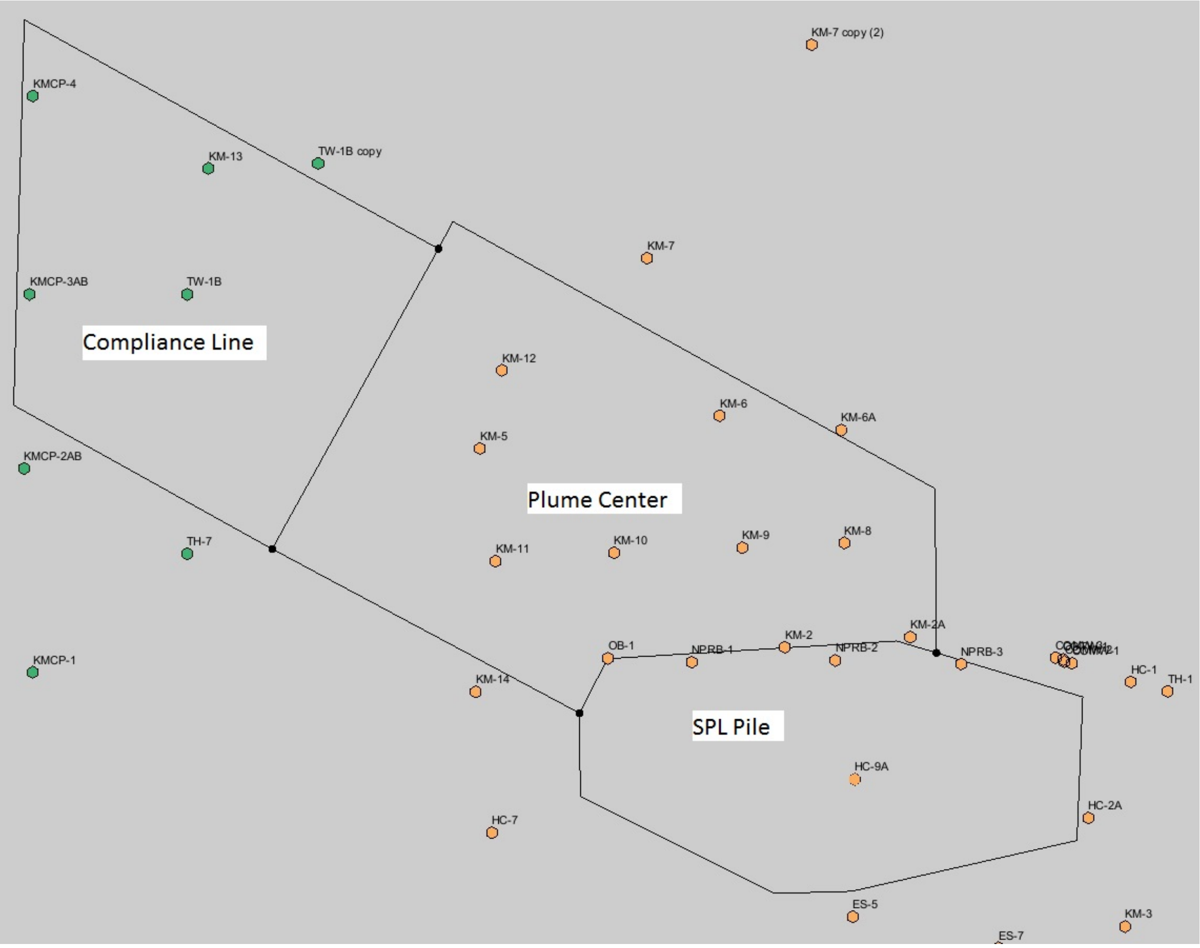


TABLE 2-1. GROUNDWATER MODEL STEADY STATE CALIBRATION AQUIFER CHARACTERISTICS

	Horizontal K (ft/day)	Vertical K (ft/day)	Horizontal Anisotropy	Vertical Anisotropy
A-Sand 1	100	5	1	20
A-Sand 2	100	5	1	20
A-Sand 3	100	5	1	20
A-Sand 4	100	5	1	20
A-Sand 5	100	5	1	20
A-Sand lower	20	1	1	20
A-Clay	0.0001	2.5E-06	1	40
B-Sand	225	22.5	1	10

Estimated average chemical loads at the upgradient (SPL pile) and downgradient Compliance Wells locations are shown in Table 2-2. In spite of the increase in groundwater flux of 117 percent, the loads of all parameters except chloride are estimated to decrease between the SPL pile and the Compliance Wells. These decreases are likely caused by natural attenuation processes such as adsorption in the aquifer. In lab testing of sediments and groundwater from the A Zone and B Zone aquifer (see Section 4.3), fluoride, sodium, and cyanide have been shown to partition between groundwater and sediment, most likely through adsorption reactions. The estimated increase in chloride load between the SPL pile and the Compliance Wells is believed to be largely due to the influx of clean background groundwater (containing approximately 15 mg/L chloride) and the associated natural chloride load.

TABLE 2-2. ESTIMATED GROUNDWATER CONTAMINANT LOADS

	Average Chemical Loads (lbs/day)[1]					**Groundwater Flow (gpm)**
	WAD Cyanide	**Total Cyanide**	**Fluoride**	**Sodium**	**Chloride**	
A Zone @ SPL pile	0.82	58.1	34	721	21	46
B Zone @ Compliance Boundary	0.75	30.4	15	446	28	100
Percent Change from SPL pile to Compliance Boundary	-9%	-48%	-56%	-38%	+34%	+117

[1] Loads calculated using average concentrations for period of 2005 to May 2013.

2.8 ESTIMATED TIME TO ACHIEVE CLEANUP LEVELS

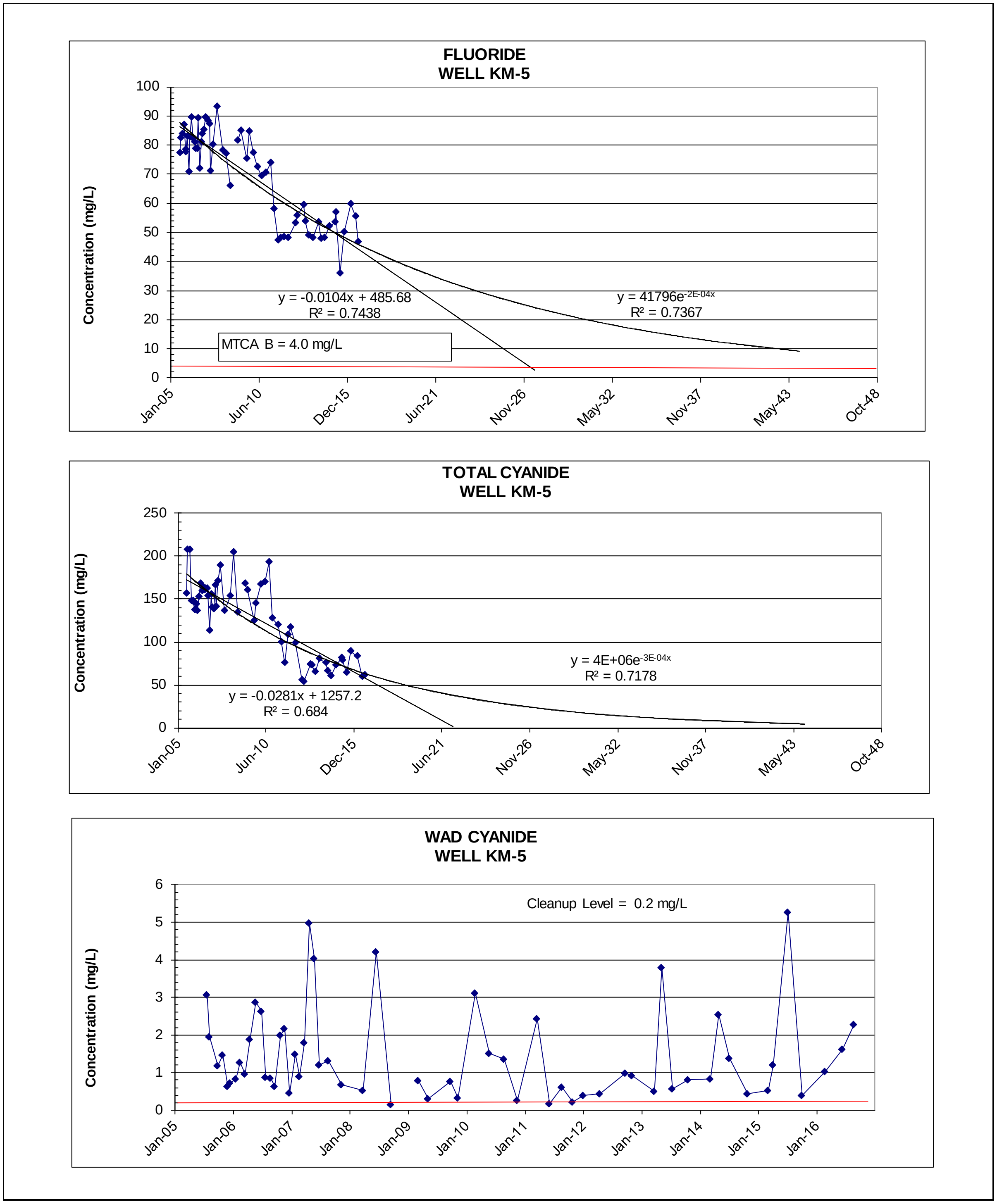
Accurate estimation of time to achieve cleanup levels is dependent on a thorough and accurate understanding of the site and accurate knowledge or assumption of the effectiveness of cleanup remedies. Time to meet cleanup levels is estimated by two methods. In the extrapolation of observed trends method (Section 2.8.1), estimation of time to cleanup levels is based on the simple assumption that the past and current conditions and rates of cleanup will continue in the future. In the mass balance - partitioning model approach, estimation of time to cleanup levels is based on the assumption that contaminant transport and rates of groundwater cleanup are controlled by sediment/groundwater interactions (i.e., partitioning, characterized by laboratory testing) and groundwater flux through the plume area (characterized by field and laboratory hydraulic testing and a numeric groundwater flow model).

It is important to note that previous estimates have underestimated the time required to attain cleanup levels in spite of significant efforts to characterize and model the Site. In 1988, Hart Crowser (1988) concluded "extrapolating the trends over the next four to five years appears to indicate that at the end of this period cyanide concentrations of wells finished within the A Zone should be less than 20 percent of their highest observed average concentration value assuming that no substantial recharge events occur in or within the vicinity of the potlining handling area." As noted in the discussion of historic monitoring well data above, the predicted continued decreases did not occur. Similarly, the groundwater model developed by MFG, Inc. (MFG) (2004) predicted that the majority of the cyanide and fluoride would be flushed from the groundwater system in about 10 years after the cleanup remedy source controls were completed and yet little decrease in contamination has been observed. The estimates discussed below are believed to be more accurate than earlier estimates because of a longer period of record for extrapolation and because the partitioning and mass balance model accounts for contaminant retardation, which the MFG groundwater model did not.

2.8.1 Extrapolation of Observed Trends

Extrapolation of observed trends is one way that is commonly used to estimate time to achieve cleanup levels. As described above, decreasing trends in cyanide and fluoride concentrations in groundwater appear to be occurring at most locations on the Site, but the trends are of relatively short duration at the Compliance Wells. Thus, it is not possible to reliably estimate the time to attain cleanup levels by extrapolation of trends at the Compliance Wells at this time. Based on extrapolation of observed concentration trends in well KM-5 located upgradient of the Compliance Wells it is estimated that reduction of fluoride concentration to approximately 5 to 10 mg/L would occur in 10 (linear extrapolation) to 30 (exponential extrapolation) years (Figure 2-18). Assuming additional dilution of contaminant concentrations occurs between KM-5 and the Compliance Wells it is reasonable to assume that cleanup levels may be met at the Compliance Wells in a similar time frame of 10 to 30 years.

FIGURE 2-18. EXTRAPOLATED CONCENTRATIONS AT WELL KM-5



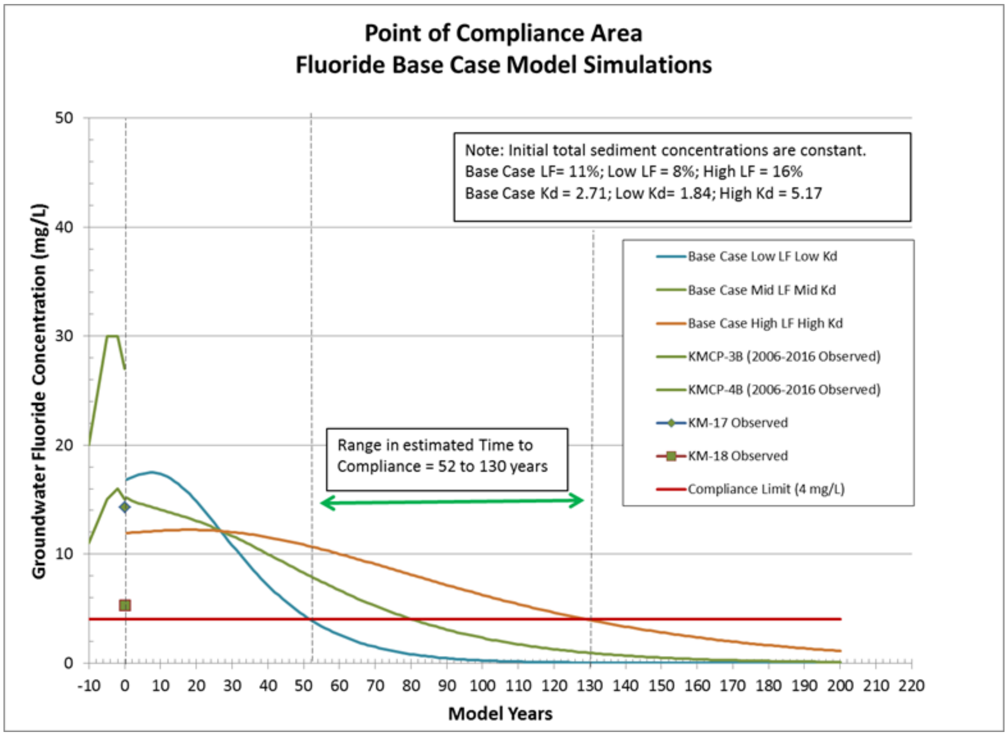
WAD cyanide concentrations do not show a clear decreasing trend. However, total cyanide concentrations are estimated to be reduced to about 10 mg/L in 5 (linear extrapolation) to 40 (exponential extrapolation). At compliance well KMCP-3B, the ratio of WAD cyanide to total cyanide averages 0.03. Assuming this ratio continues in the future, reduction of total cyanide to approximately 10 mg/L would result in reduction of WAD cyanide to approximately the cleanup level (0.2 mg/L) in a similar amount of time.

2.8.2 Groundwater:Sediment Mass Balance and Partitioning Model

Saturated sediments within the groundwater contaminant plume are enriched in fluoride and cyanide from contact and reaction with the contaminated groundwater. Laboratory testing of the leaching and adsorption characteristics of the sediment indicates that the concentration of fluoride and cyanide in sediment and in groundwater in contact with the sediment are proportionally related. Thus, the concentrations of sediment and groundwater can be mathematically described through a partitioning factor or distribution coefficient (commonly represented by the mathematical symbol Kd). The groundwater:sediment partitioning and mass balance models for fluoride and cyanide are described in Section 4.3.2.5.

The mass balance and partitioning model estimates of the time to cleanup levels at Compliance Wells (Figure 2-19) range from approximately 52 to 130 years for fluoride and 33 to 80 years for cyanide. These estimates are approximately five times longer than estimated based on simple extrapolation of concentration trends, although the highest trend-based estimate of 30 years is somewhat similar to the shortest partition model estimate of 50 years.

FIGURE 2-19. ESTIMATED TIME TO CLEANUP LEVELS AT COMPLIANCE WELLS BASED ON PARTITIONING MODEL



3.0 CONTAMINANT SOURCES

Contaminant sources responsible for impacting area groundwater have transitioned from primarily historical waste management operations to primarily ongoing leaching of secondary sources created by historic impacts to subsurface sediments. The following sections delineate contaminant sources on the basis of time during which they are or were active (historic versus potential ongoing sources) and on the basis of whether they are potentially significant (Tier I) or potential but likely insignificant (Tier II) ongoing sources. Table 3-1 summarizes source descriptions and tier classifications. Sections 3.1 and 3.2 describe the contaminant sources while evaluation of the significance of the sources is in Sections 3.3 and 3.4.

TABLE 3-1. SUMMARY AND CLASSIFICATION OF CONTAMINANT SOURCES

	Description	**Classification and Rationale**
Historic	Spent Potlining Material and Waste	Tier II – material isolated by engineered cap
	Sludge Pond	Tier II – low groundwater concentrations in vicinity, lack of significant water source and pathway to groundwater
	Waste Below Asphalt – Areas 2 and 3	Tier II – lack of significant water source and pathway to groundwater
Potential Ongoing	Contaminated Saturated Aquifer Sediments	Tier I – large mass of contaminants, demonstrated source of high concentrations, active groundwater pathway
	Contaminated Unsaturated Sediments and Saturated Sediments Above SAQ	Tier II – lack of significant water source and pathway to groundwater
	Spent Potlining Material and Waste	Tier II – material isolated by engineered cap

3.1 HISTORIC SOURCES – TIER II

The purpose of describing historic sources is to document what and where activities were conducted which led to contamination. This understanding of historic sources and actions is important in identifying where potential ongoing secondary sources occur. Previous studies have documented the waste management activities that were conducted at the facility from the 1940s to the 1970s (Hart Crowser, 1988). These studies concluded that the handling of SPL material and associated waters was the largest source of groundwater and subsurface sediment contamination. A second waste management activity, operation of the sludge pond (for disposal of air pollution control wet scrubber sludge), was also considered to be a source of contamination, although the available information suggests that it is not a significant source.

The following subsections discuss these activities and their contribution to the historic contamination of groundwater. The contaminant pathway figure (adopted from Hart Crowser, 1988), is included herein as Figure 3-1.

3.1.1 Spent Pot Lining (SPL)

Historic SPL handling activities that were sources of contamination include:

1. Disposal of SPL material; and
2. Disposal of SPL-contaminated process water.

Evidence suggesting that SPL was a historic source is:

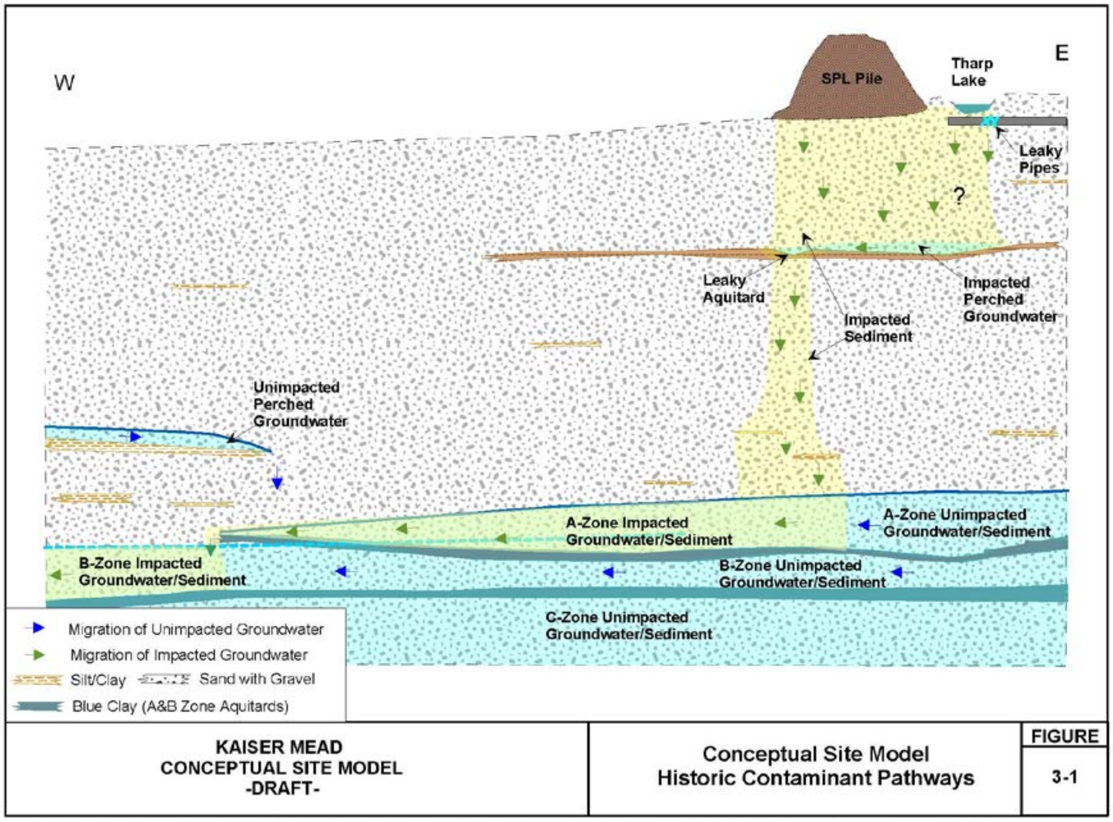
1. High concentrations of cyanide and fluoride in SPL material and in soils/sediment and groundwater beneath and downgradient of SPL material handling and storage areas; and
2. Improvement in groundwater quality following modification of SPL management practices and cessation of process water disposal.

The historic migration pathways, in order of importance, are believed to have been:

1. Primarily the disposal and infiltration of process water (primarily pot-soaking water);
2. Secondarily the leaching of SPL material by non-process waters on the site (i.e., water supply system, stormwater, and sanitary sewer leaks); and

3. Leaching of SPL material and SPL contaminated soil by rainfall, snowmelt and stormwater.

FIGURE 3-1. CONCEPTUAL SITE MODEL, HISTORIC CONTAMINANT PATHWAYS



Evidence suggesting that SPL process water was the largest source is:

1. SPL process water contained very high contaminant concentrations (KACC-Mead analyses of SPL leachate indicate concentrations of approximately 700 to 1,000 ppm total cyanide; over 2,500 ppm fluoride) and was disposed by infiltration to groundwater (Hart Crowser, 1988).
2. Groundwater levels in A Zone wells declined following cessation of process water disposal (Hart Crowser, 1988).

3. The largest improvement in groundwater quality observed on the site to date occurred following the cessation of SPL disposal practices in the late 1970s/early 1980s (see trend plots and associated discussion for historic wells in Section 2.6 above).

Evidence that leaching of SPL material and contaminated soil/sediments beneath the SPL material by residual pot soaking water and non-process waters (pipe leakage, stormwater runoff) was an additional but smaller source is:

1. Highest soil/sediment cyanide concentrations (200 to 1,000 ppm) exist beneath the area where SPL material was disposed (extending to depths of over 40 feet below the bottom of the SPL material). Downward migration of cyanide to these undisturbed sediments is presumed to have occurred by infiltration of pot soaking water and infiltration of stormwater runoff in closed depressions (Hart Crowser, 1988).
2. There is very little natural groundwater recharge by rainwater (estimated to be approximately 10 percent of precipitation or 2 inches/year (Hydrometrics, 2017b)) and this amount is not believed to be sufficient to carry significant amounts of contaminants to groundwater, thus process waters were believed to have been the dominant historic pathway for transport to the groundwater system (Hart Crowser, 1988). Partition/mass balance modeling (see Section 4.3.2.5) also supports the conclusion that natural precipitation/recharge alone, even through a failed SPL cap is not sufficient to cause the observed groundwater concentrations throughout the groundwater contaminant plume.
3. In the mid-1980s, several incidences of pipe leaks and pipe repairs occurred that appeared to correlate with cycles of localized contaminant concentration increases in groundwater in A Zone monitoring wells (Hart Crowser, 1988).

Evidence that leaching of SPL material by natural rainfall/snowmelt was a minor source is:

1. There is very little natural groundwater recharge by rainwater (estimated to be approximately 2 inches/year).
2. Little, if any, improvement in groundwater quality was observed following capping of the SPL material in 1979 and following consolidation of waste material and

> upgrading of the SPL cap in 2004. Although, A Zone well TH-1 showed a decrease in total cyanide from 0.4 to 0.04 total cyanide following asphalt capping of the SPL, concentrations in other wells (e.g., ES-10 and HC-9a as described above) showed no response to SPL capping, leading Hart-Crowser (1988) to conclude that the improvements in TH-1 were largely the result of cessation of disposal of pot soaking liquids to the southwest corner of the sludge pond.

The known waste storage areas were evaluated during the waste consolidation and engineered cap construction actions in 2001/2002. Wastes determined to contain elevated concentrations of cyanide and fluoride were consolidated beneath the engineered cap of the SPL pile. Areas with "low concentration waste" (below MTCA Method B standards, F <4,800 mg/kg, total CN <1,600 mg/kg) were covered with an asphalt cover that is maintained (see Section 3.1.3).

Wastes placed beneath the engineered cap (and impacted subsurface sediments) are presumed to be effectively isolated from direct precipitation, although determining the integrity of the cap components is difficult over such a large area. Even if a small failure were to occur it is unlikely that sufficient runoff would be directed to the failure point to generate leachate in a quantity sufficient to impact groundwater. It is conceivable that a failure of the liner beneath the south or east perimeter drainage ditch would direct a sufficient volume of runoff beneath the SPL pile to impact contaminated sediments or even buried waste materials. Groundwater contamination adjacent to the SPL pile continues to exhibit characteristics (high pH, sodium, alkalinity, chloride, nitrate) that are typical of SPL leachate which could be an indication of an ongoing migration of SPL leachate. However, laboratory testing of the leaching characteristics of contaminated saturated zone sediments demonstrate that groundwater that contacts the sediments acquires similar characteristics of high pH, sodium, alkalinity, and nitrate. Thus, the persistence of the SPL leachate characteristics in groundwater is attributed to the effects of groundwater contact with sediments in the contaminated groundwater plume. Although there is no known information or data suggesting that the SPL cap was improperly constructed or has failed, it is difficult to verify whether the cap is properly functioning. For these reasons, the SPL pile is considered to be a potential Tier II source, even though the SPL pile has been remediated.

3.1.2 Sludge Pond

The sludge pond (aka sludge bed) was operated prior to 1974 as a repository for sludge from the wet-air pollution control system and is known to contain fluoride and cyanide. During wet-scrubbing, calcium carbonate and calcium oxide slurry was sprayed through the off-gas venturi scrubbers to precipitate calcium fluoride that formed a sludge that is stored in the sludge pond. Pot-soaking water containing high levels of cyanide and fluoride and sewage effluent containing pot-soaking water was also occasionally released to the sludge pond (Hart Crowser, 1988).

Kaiser personnel collect 30 sludge bed samples in 1978/1979, for analysis of total cyanide and water soluble cyanide (Hart Crowser, 1988). The procedures that were used to measure total and water soluble cyanide and the water to sediment ratio of the water soluble method were not specified. Cyanide was detected in all sludge samples with highest concentrations occurring near the southwest corner of the sludge bed. Surface samples ranged from 1.8 to 610 mg/kg total cyanide and 0.3 to 38 mg/kg water soluble cyanide.

In October 2011, Hydrometrics conducted additional borings and sampling/analysis of sludge pond sediments to verify sludge contaminant concentrations. As expected, sludge was found to contain low to moderate concentrations of water soluble (Method 300.0) fluoride (423 to 29 mg/kg) and total cyanide 76 to < 0.5 mg/kg), but no sludge was found to contain concentrations exceeding MTCA B or dangerous waste criteria (Hydrometrics, 2011a).

In spite of low to moderate cyanide and fluoride concentrations (compared to SPL concentrations and dangerous waste criteria), the sludge pond was likely only a minor source of contaminants historically, primarily during the period when pot-soaking liquor was used for makeup water for the wet scrubber system and during the period when sewage effluent was disposed in the sludge pond. Evidence that the sludge pond was a minor source is:

1. Historically (and currently), relatively low concentrations of contaminants in groundwater adjacent to, and downgradient of, the sludge pond (fluoride < 2 mg/L, WAD cyanide < 0.01 mg/L, and total cyanide < 1.0 mg/L for monitoring wells HC-2A and TH-1).
2. Lack of a source of water other than natural precipitation to leach the sludge.
3. A boring (EPSPLB-2) was completed to the SAQ in the area between the SPL pile and the sludge bed in June 2013. Saturated conditions were encountered and a water sample was collected and analyzed. The water was found to contain low total cyanide (0.02 mg/L) and fluoride (4.2 mg/L) concentrations (Hydrometrics, 2017a).

While the presence of uncontrolled waste may indicate a potential for contributing low levels of contaminants to the subsurface, a sustained water source is not present to drive the contaminants to the A Zone and therefore the sludge pond is not a significant source (Tier II). Studies of the sludge pond have consistently assigned little impact from the stored waste in the pond and notably, nearby wells show low contaminant levels.

3.1.3 Wastes Remaining Below Asphalt

Two areas (Area 2 and Area 3) where waste was managed still contain minor quantities of waste and have been covered with asphalt to shield the waste from disturbance or direct precipitation. Area 2 is immediately adjacent the southeast side of the current SPL pile and was used to store SPL waste until it could be sent back to the production facility for recycle. Area 3 is an area where failed pots were soaked to remove pot-lining material and contaminated water soaked into the soil. In February 2000, MFG installed borings in Area 2 and 3 to characterize the soil/sediment/waste material and potentially to identify waste requiring removal and placement beneath the engineered cap. Because the material was determined to contain cyanide and fluoride concentrations below MTCA B limits (1,630 mg/kg cyanide and 4,800 mg/kg fluoride), it was considered to be “low concentration waste” and the material was allowed to remain in place beneath the existing pavement. In 2011, Hydrometrics conducted additional boring and sampling/ analysis of Area 2 sediments to verify contaminant concentrations and to test the hypothesis that the total cyanide analytical method under reports cyanide by utilizing three different cyanide extraction methods (low, neutral and high pH extractions). Results of the 2000 and 2011 investigations are summarized in Table 3-2.

The results of the two investigations are similar and confirm that cyanide and fluoride-containing material is present in the areas. The alternative cyanide extraction methods were found to not yield significantly higher results for these waste materials than the method (EPA 9012B) typically used. However, subsequent exploration of alternative total cyanide methods (described in Section 4.1) has confirmed that EPA9012B may underestimate concentrations for some sediment samples. Site studies (see Section 4.1) have also confirmed that the EPA Method 300 fluoride analytical method is best described as a measure of readily water soluble fluoride. Method 300 has been shown to underestimate total fluoride concentration of site sediments by a factor of approximately 5 to 25.

The concentrations given in Table 3-2 are fluoride concentrations on a solid weight basis. The fluoride concentration in the extraction water, on a water weight basis, is one tenth of the solid weight basis, meaning that the soils yielded leachate water concentrations ranging from 11 to 172 mg/L. The peak leachate concentrations are therefore higher than the highest groundwater concentrations observed on the Site. Thus, although fluoride concentrations of the waste material in Area 2 and Area 3 are lower than MTCA B limits, the waste is a potential source of soluble fluoride.

The waste remaining beneath the asphalt covers (dispersed waste and impacted surface soils) is considered to be sufficiently isolated, although there is evidence that portions of Area 2 may be impacted by episodic high water table levels associated with rainfall events. It is unknown if these interactions are sufficient to drive leachate down to the SAQ where a sustained source of water would be required to deliver the leachate to the SPL pile. Based on the improbability of meeting the right conditions to generate and deliver leachate to the SPL pile, the asphalt covered areas are not considered a significant source.

TABLE 3-2. CYANIDE AND FLUORIDE CONCENTRATION IN AREAS 2 AND 3 SOIL/SEDIMENT

	2000 Investigation Results – Area 2*	**2000 Investigation Results – Area 3**	**2011 Investigation Results – Area 2**
Number of Samples (Cyanide/Fluoride)	16/1	12/1	6/6
Total Cyanide (Method 9012B) Range (mg/kg)	<0.5 to 191	<0.5 to 369	0.85 to 96.4
Water Soluble Fluoride (Method 300.0) Range (mg/kg)	1,230	465	111 to 1,720

Data Sources: Engineering Design Report (MFG, 2000); Data Gap Investigation Project Report (Hydrometrics, 2011b)

Shortly following rainfall events, water was observed to emerge from seeps through the asphalt in Area 2, south of the former sewage treatment plant. In November 2011, seep water was sampled and was found to contain 19.8 mg/L of fluoride. The source of this water is unknown but the fluoride concentration could be representative of water that has contacted "low concentration waste" in the area.

Available information described above, points to these areas as potential sources of contaminants, yet, as with the sludge pond, the lack of a sustained water source defines them as minor sources.

3.2 POTENTIAL ONGOING SOURCES

Potential ongoing sources are described in the following subsections and include:

- Tier I (significant and likely) sources: A and B Zone contaminated saturated sediments; and
- Tier II (insignificant or unlikely) sources: unsaturated sediments, shallow saturated sediments above the SAQ, on-site waste and additional unidentified sources.

Following completion of remedial activities from 2002 to 2006, the pathways to/from SPL material and unsaturated contaminated sediments underlying the capped SPL pile were presumably eliminated or highly limited by isolation of the material from contact with water. SPL material and underlying unsaturated materials are therefore presumed to no longer to be active sources to groundwater (i.e., Tier II sources). However, the continued detection of elevated concentrations of cyanide and fluoride in groundwater in monitoring wells along the north perimeter of the SPL pile suggests either that one or more of the remedial activities were ineffective or incomplete or that additional sources were not previously identified and controlled by the remedial activities in 2002-2006. Site characterization data collected in 2011 through 2016, demonstrate that there is an additional source in the form of a secondary contaminant source in the saturated sediments of the A Zone aquifer that is an ongoing source of fluoride and cyanide to groundwater (i.e., Tier I source).

3.2.1 Contaminated Unsaturated and Shallow Saturated Sediments – Tier II

Contaminated sediments in the vicinity of the SPL pile include unsaturated sediment and saturated sediment within perched layers beneath the SPL pile as identified in the CAP. Unsaturated contaminated sediments and shallow saturated sediments above the SAQ located beneath the capped SPL pile are considered to be Tier II (insignificant) sources because of the lack of a significant migration pathway to the underlying groundwater. Although the sediments are enriched in cyanide and fluoride, there is no significant source of water available to provide a transport mechanism to the underlying groundwater system.

Data for unsaturated and saturated sediment beneath the SPL pile was collected and presented in the Site Assessment (Hart Crowser, 1988). Sediment beneath the SPL pile to the depth of the SAQ generally contained over 100 ppm cyanide. In boring/well ES-1 sediment immediately beneath the SPL contained over 1,000 ppm cyanide and over 20,000 ppm fluoride; the saturated zone immediately above the SAQ contained 400 ppm cyanide and 700 ppm fluoride. In well HC-9A, highest sediment concentrations (112 ppm cyanide and 220 ppm fluoride) were found to occur in the unsaturated zone just above the A Zone water table. Based on this information, Hart Crowser (1988) identified subsurface sediments beneath the SPL pile as having elevated concentrations of contaminants that could be mobilized from a concentrated water source such as a leaky pipeline.

In 2013, additional data for unsaturated sediment and A Zone saturated sediment beneath the SPL pile was collected from two borings (SPLP-1, SPLP-2) installed through the SPL pile (Hydrometrics, 2013b). Total cyanide and fluoride concentrations in sediment samples from these borings are shown in Figures 3-2 and 3-3 and corroborate the 1988 Site Assessment data that indicate enrichment in underlying sediment in fluoride and cyanide.

The contaminated subsurface sediments would leach contamination during contact with perched water at the SAQ or as perched water infiltrates down below the SAQ contacting the unsaturated sediments as the water migrates down to the A Zone. The primary limitation to this contamination pathway and the reason that the sediments are considered to be a Tier II source is the lack of a significant water source to leach the sediments and complete the pathway to groundwater. From 2002 through 2006, gravity and pressure pipe lying above the SAQ (as delineated by Hart Crowser) were lined or replaced thus eliminating or greatly reducing this potential water source. Characterization work has in 2013 identified perched water above the SAQ near the northeast corner of the SPL pile (well A-13), but the full extent of the perched water and areas impacted beneath the SPL pile are unknown. If the SAQ actually extends beyond the southeast boundary identified by Hart-Crowser in 1989, then pipe leaks in the production facility (either stormwater sewer lines or pressure water pipes) may be able to reach impacted sediments beneath the SPL pile. However, present data from accessing monitor wells and borings completed at the SAQ in 2013 indicate that any such potential horizontal flow above the SAQ is likely to be limited as all of the SAQ wells (except for A-13) are dry.

FIGURE 3-2. TOTAL CYANIDE IN SEDIMENT BENEATH SPL PILE

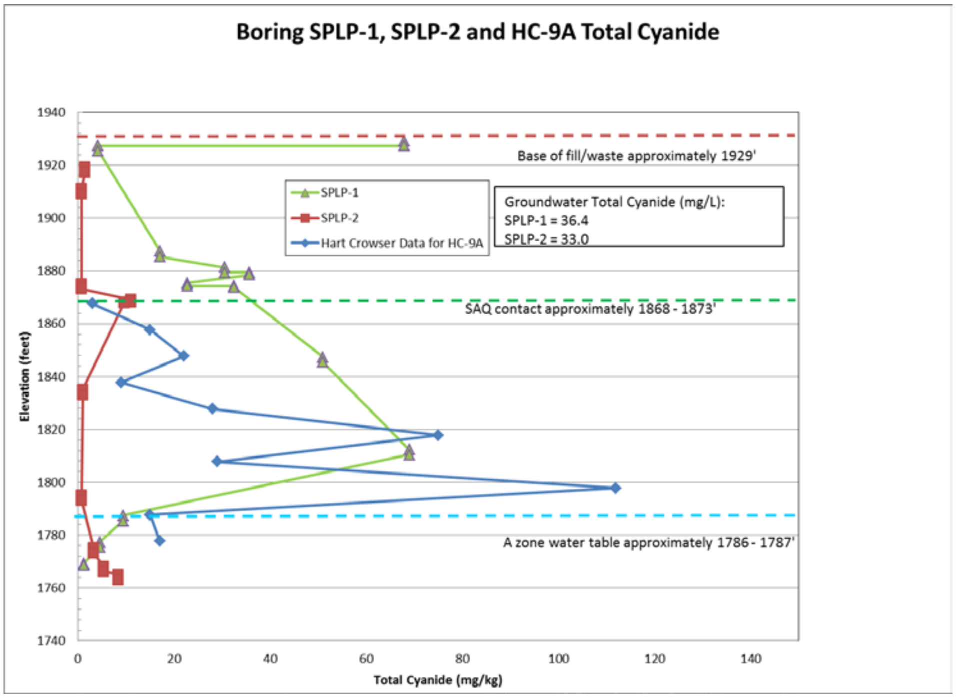
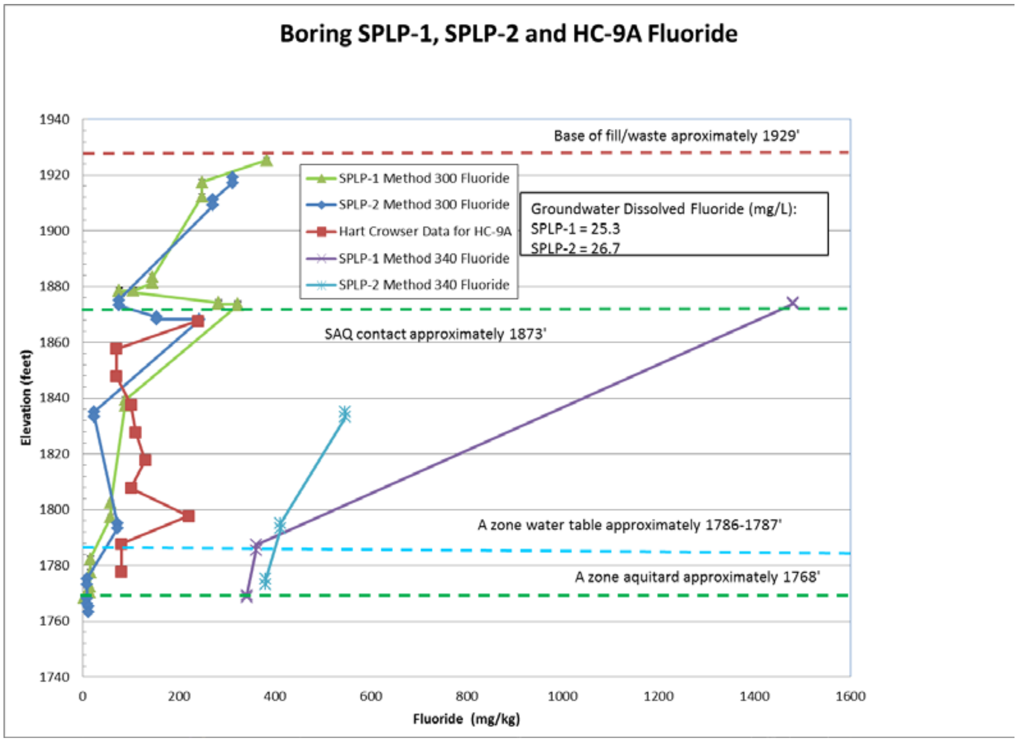


FIGURE 3-3. TOTAL FLUORIDE IN SEDIMENT BENEATH SPL PILE



3.2.2 Contaminated Saturated Sediments in the A and B Zone Aquifers-Tier I

Contaminated saturated sediments in the A and B Zone aquifers are Tier I (significant and likely) sources due to the large size (in terms of both areal extent and mass) of the secondary source and the constant, ongoing, and uncontrolled exposure of the sediments to groundwater. Laboratory testing of the sediment leaching and groundwater partitioning characteristics and sediment:groundwater partitioning and mass balance models demonstrate that the contaminated sediments would be a steady source of contamination to the groundwater for an extended period of time. The contaminated sediments include:

1. Saturated sediment within the A Zone aquifer beneath the SPL pile; and
2. Saturated sediment within the A Zone and B Zone aquifer outside of the footprint of the SPL pile within the contaminated groundwater plume.

In 2015 and 2016, 11 additional borings were installed downgradient of the SPL pile to delineate the extent of contaminated saturated sediments associated with the contaminated groundwater plume. Testing of sediment samples from borings drilled further downgradient of the SPL pile indicate the presence of fluoride- and cyanide-enriched sediments throughout the groundwater plume area as shown on Figures 3-4 and 3-5. Laboratory testing of the leaching characteristics of the enriched sediments and sediment:groundwater partition modeling (described further in Section 4.3.2) indicates that the sediments are capable of releasing significant concentrations and mass load of fluoride and cyanide to groundwater over a long period of time. A sediment:groundwater partitioning and mass balance model was constructed based on the laboratory test data to evaluate potential effects on groundwater of the leaching (release) of contaminants from sediment (see 4.3.2.5 and The draft Sediment:Groundwater Partitioning Model Report (Hydrometrics,(2017c)). The model simulations indicate that contaminated saturated sediment is a significant source, and perhaps the largest ongoing source, of groundwater contamination. Additional discussion of the data from the 2015-2016 borings is included in Section 4.3 below.

FIGURE 3-4. CYANIDE AND FLUORIDE IN 2015 BORING SAMPLES

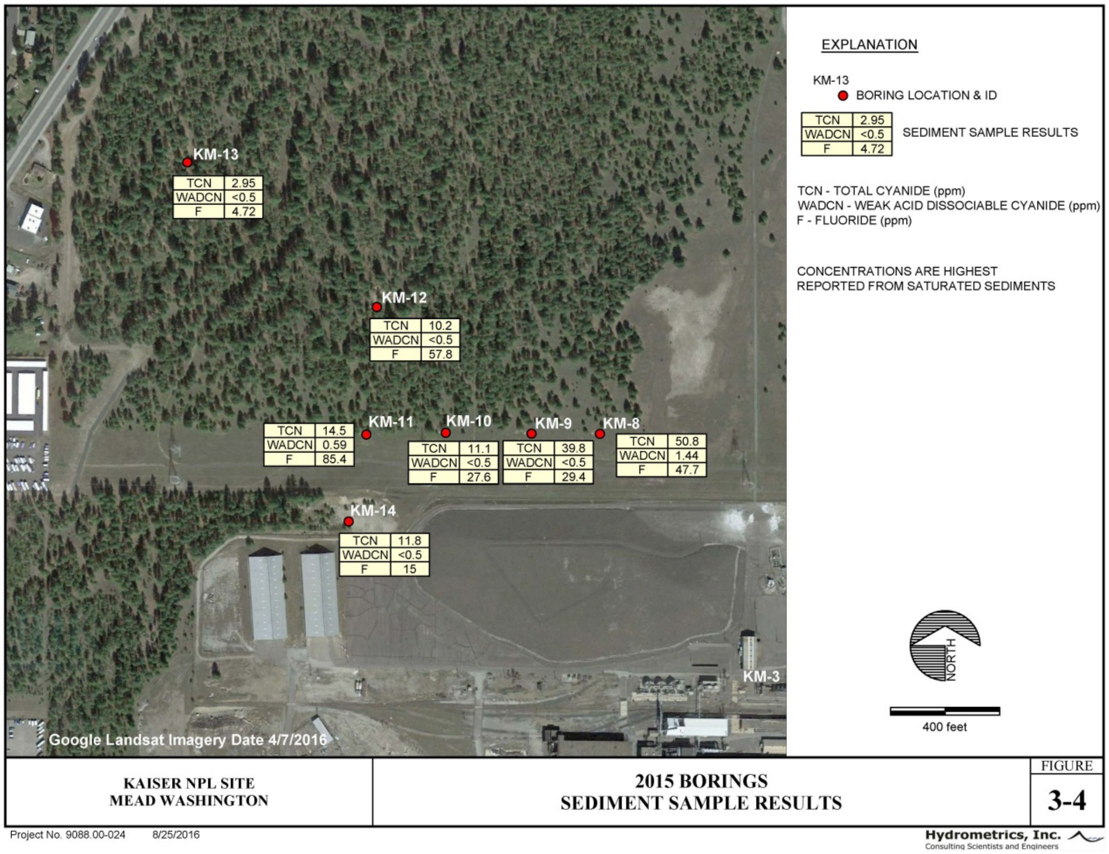
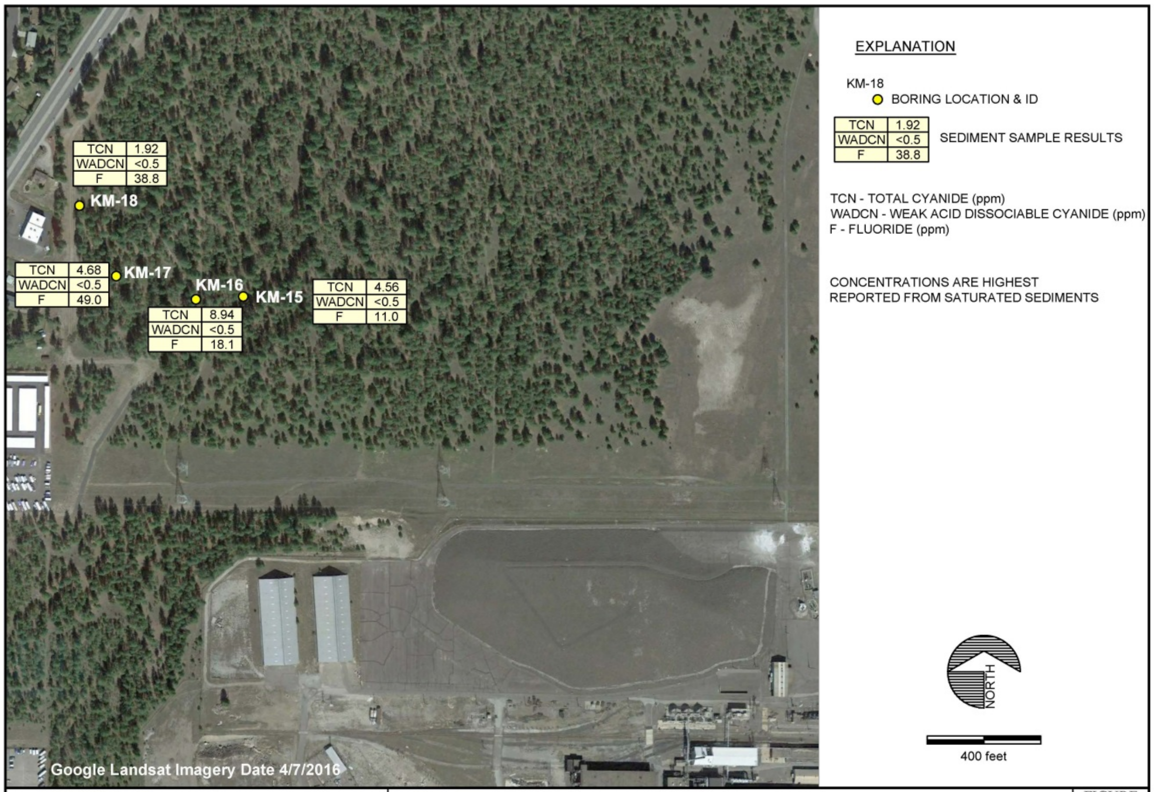


FIGURE 3-5. CYANIDE AND FLUORIDE IN 2016 BORING SAMPLES



KAISER NPL SITE
MEAD WASHINGTON

2016 BORINGS
SEDIMENT SAMPLE RESULTS

FIGURE
3-5

Project No. 9088.00-024 8/25/2016

Hydrometrics, Inc.
Consulting Scientists and Engineers

3.2.3 On-Site Wastes – Tier II

On-site waste includes:

1. The waste consolidated beneath the SPL pile engineered cap;
2. The sludge pond; and
3. Dispersed waste or impacted surface soils beneath asphalt areas.

These potential sources are all historic sources that are described in Section 3.1 above.

3.2.4 Potential Unidentified Sources – Tier II

Potential unidentified sources include:

1. Uncontrolled materials remaining in the production facility; and
2. Subsurface A Zone saturated sediments at unidentified locations upgradient of the SPL pile.

These sources are listed as potential sources only for completeness in accounting all possible sources. There is no knowledge or reason to suspect that these sources exist and no evidence in the groundwater data to suggest their presence.

Unidentified contaminant sources in the former production facility would likely consist of an accumulation of spent potliner material (the only source of cyanide at the site) or an accumulation of fluoride-contaminated air borne dust. These accumulation areas would have to be subjected to water in order to leach and drive the contaminants to the subsurface and eventually the A Zone aquifer. Discussions with former plant personnel indicates that all spent potliner material was stored outside in the previously identified handling areas as there was no room in the operating areas to conduct potliner removal/replacement activities. Kaiser did recycle a limited amount of SPL by roasting the SPL in a high temperature oven (effectively destroying the cyanide) for recovery of fluoride. But the operation was in an enclosed building with concrete flooring, eliminating the potential for waste spills to the environment. As fluoride was critical to the smelting process and expensive to replace, air control equipment was utilized and was fairly effective at controlling fugitive dust containing fluoride. The operating pot rooms (the source of both potential sources) are located southeast of the SPL and A Zone completed monitoring wells between the two areas show little or no contamination. Therefore, the production facility is not considered to be a significant source.

4.0 CHARACTERIZATION OF MIGRATION PATHWAYS

Based on recent site characterization work the likely pathways for migration of contaminants through groundwater to the Compliance Wells are the following:

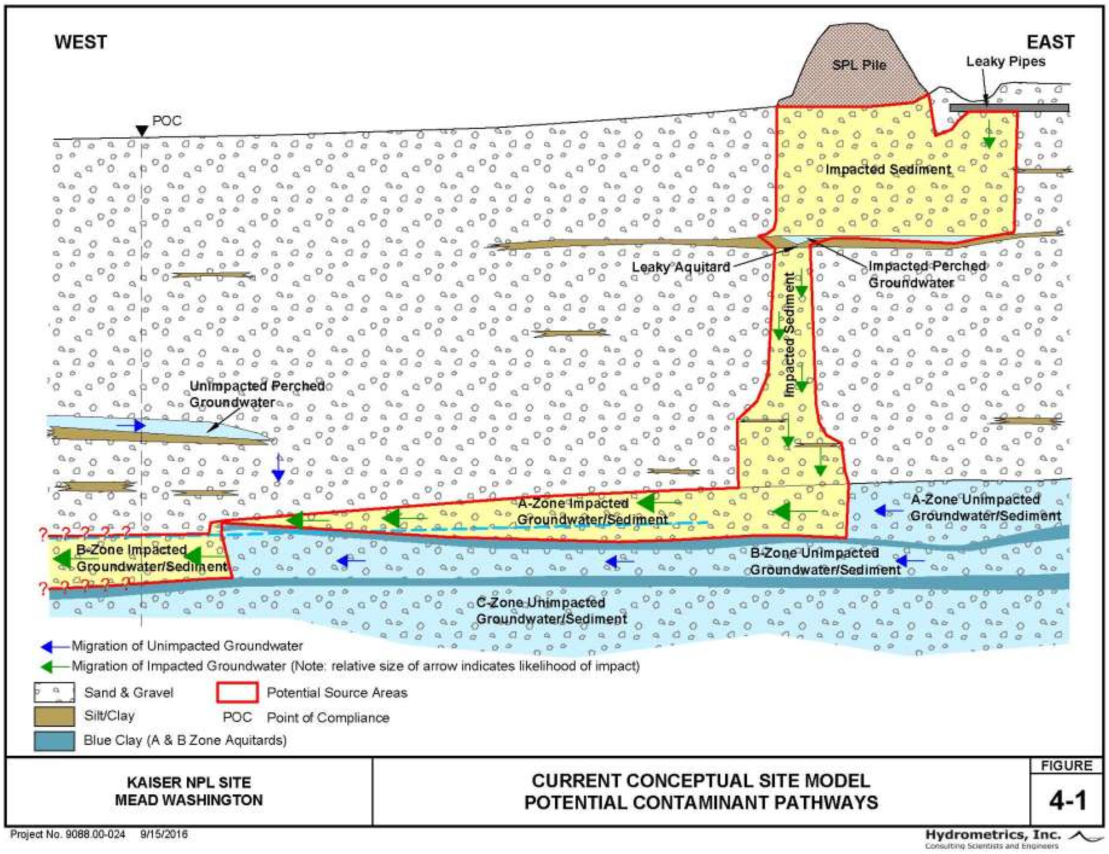
- Impacted subsurface sediments in unsaturated zone to groundwater; and/or
- Impacted subsurface sediments in saturated zone to groundwater; and
- Impacted groundwater to Compliance Wells.

These three pathways are discussed in the following sections and illustrated in Figure 4-1. Although present, the pathway from unsaturated sediments to groundwater is minor in comparison to the pathways from saturated sediment to groundwater and from groundwater to the Compliance Wells.

4.1 SEDIMENT ANALYTICAL METHODS

Multiple methods of analysis and characterization of sediments have been used in the various site investigations that have been conducted over the last 30 years. The changes in analytical methods have resulted from changes and improvements of the available laboratory methods for cyanide and fluoride; advancement of the science of cyanide chemistry; and better understanding of the nature of fluoride and cyanide forms present at the Site. The following summary of analytical methods is provided as an aid to understanding and interpretation of laboratory data.

FIGURE 4-1. POTENTIAL CONTAMINANT PATHWAYS



4.1.1 Fluoride

Fluoride in sediment and soil samples was routinely analyzed by EPA Method 300 during investigations prior to 2013. Since 2013, sediments have been analyzed by both Method 300 and Method 340. The methods are summarized as follows:

- Method 300 consists of mixing the sediment with de-ionized water to form a slurry (2:1 (Energy Labs) or 10:1 (SVL) water:sediment ratio, depending on laboratory), the slurry is allowed to set for approximately 10 to 30 minutes at room temperature (approx. 20^o C), and the water is decanted or filtered from the sediment and analyzed by ion chromatography.

- Method 340 consists of hot (approx. 180^o C) sulfuric acid extraction of the sediment. The distillate from the extraction is analyzed by ion selective electrode or spectrophotometry.

Because of the relatively gentle extraction method used in Method 300, Method 300 fluoride results are probably most representative of the “readily soluble” fraction of fluoride in sediment that primarily measures a portion of the adsorbed or exchangeable fluoride. The more rigorous extraction used in Method 340 likely measures a portion of the mineral fluoride in addition to exchangeable/adsorbed fluoride and for purposes of this report is termed “total fluoride.” Split sample analyses of Site sediments by both Method 300 and Method 340 demonstrate that the Total Method 340 recovers from 5 to 50 times more fluoride than Method 300.

A comparison of Method 300, Method 340, and Method 1312 results for sediment samples collected and analyzed in 2013 is provided in Table 4-1. Total fluoride concentrations in sediment are found to be significantly higher than Method 300 water soluble fluoride concentrations. On average, total fluoride was about 6 times higher than water soluble fluoride but in one case was nearly 100 times higher. The ramifications of this are:

1. It is likely that the concentrations of soil and sediment previously measured using Method 300 and reported in RI/FS reports by Hart Crowser, MFG, Ecology, and Hydrometrics underreport actual total fluoride concentrations. Actual total concentrations may be on the order of 5 to 50 times higher than reported.
2. Secondary sources of fluoride identified in the subsurface sediments may contain more fluoride than previously estimated.

TABLE 4-1. COMPARISON OF WATER SOLUBLE VERSUS TOTAL FLUORIDE IN SEDIMENT

Boring	Sample Depth (feet below ground surface)	Method 300 Readily Water Soluble Fluoride Sediment Concentration (mg/kg)	Method 300 Leaching Solution Concentration (2:1 water to sediment ratio) (mg/L)	Method 340 Total Fluoride Sediment Concentration (mg/kg)	Percent Readily Water Soluble Fluoride	Method 1312 SPLP Leaching Solution Concentration (20:1 water to sediment ratio) (mg/L)
NPRB-1	116-135	179	89.5	713	25	25.1
	146-147	271	135.5	739	37	19
	147-150	165	82.5	6,230	3	10.2
NPRB-2	105-126	74.7	37.4	351	21	5.3
	140	35.8	17.9	406	9	3.2
	145.7- 146.8	50.2	25.1	577	9	5.6
SPLP-1	103.1-103.6	323	161.5	1,480	22	27
	190-192	16	8	361	4	0.9
	208.1-208.8	3	1.5	342	1	2.7
SPLP-2	130-132	24	12	547	4	2
	170-172	72	36	412	17	0.34
	190-192	8	4	381	2	0.4

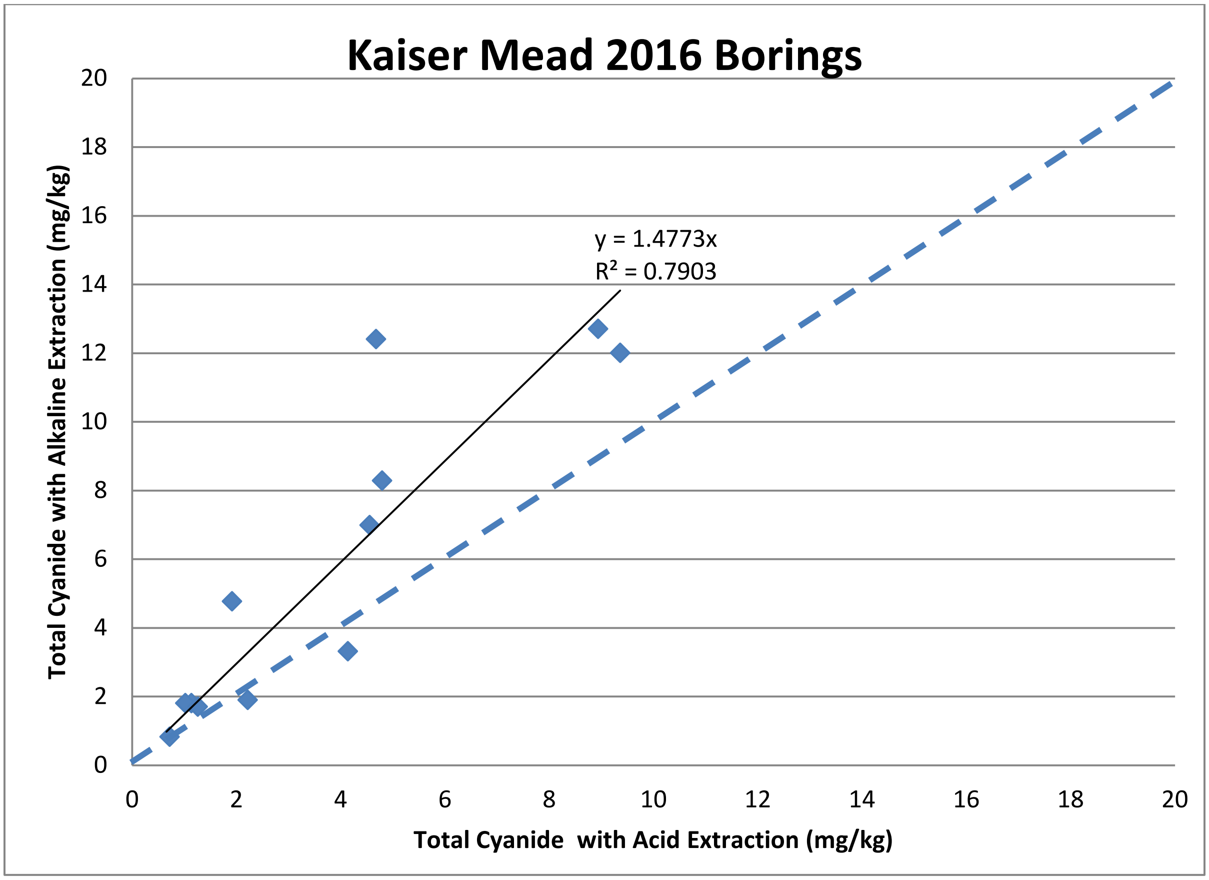
4.1.2 Total Cyanide in Sediments

Commonly, solid samples are analyzed for “total cyanide” by an aqueous extraction with acidic solutions followed by distillation and analysis of the extract solution. In some instances, such as sediment containing abundant iron and/or iron-cyanide mineral precipitates that are common at aluminum smelters (Dzombak et al., 2006) the acid extraction is ineffective in liberating all of the cyanide from the solid, and thus cyanide results are biased low (under reported). Solid samples collected for the 1988 Site Assessment were analyzed by the Kaiser Meal in-house laboratory and the method was not reported. Although it is not known for certain, it is likely that these analyses used an acid extraction which was typical at the time.

Sediment samples collected by MFG in Area 2 and 3 in 2000, and in Area 2 by Hydrometrics in 2011, (see discussion in Section 3.1.3) were analyzed by EPA Method 9012B utilizing an acid extraction pre-analysis step, and by laboratory-customized neutral and alkaline extractions to determine if there was bias caused by acid extraction. On Area 2 and 3 samples which were relatively un-impacted, there appeared to be little difference in extraction method.

Samples collected from borings downgradient of the SPL pile in 2015, were analyzed by EPA Method 9012B and were also subjected to sequential (repeated) leaches or extractions by site groundwater. During this testing it was found that the cumulative amount of cyanide leached from the samples often exceeded the reported “total” cyanide content of the samples. To determine possible analytical bias caused by the acid extractions, samples collected in 2016, were analyzed by Method 9012b after acid extractions and after alkaline extractions (pH of 12) as described in EPA Method 9013. A comparison of results obtained by acid and alkaline extractions (Figure 4-2) indicates that overall the alkaline extraction recovered approximately 50 percent more cyanide than the acid extraction. Because the number of samples analyzed was fairly small, the results do not definitively prove the better recovery of cyanide by alkaline extraction for all possible sediment samples. However, the results are consistent with literature reports and thus some caution and awareness of potential low bias is warranted in evaluating total cyanide data for sediment. Additional evidence of low bias in total cyanide analyses is that in sequential SPLP leach tests, the cumulative amount of total cyanide leached from sediment samples was often greater than the measured total cyanide concentration.

FIGURE 4-2. COMPARISON OF CYANIDE EXTRACTION METHODS



4.1.3 Leach Testing Methods

Leach testing consists of rinsing, extracting, or “leaching” sediments with a fluid to determine the amount of contaminants that can be liberated or “leached” from the sediment and the characteristics (e.g., total soluble mass, rate, etc.) of the leaching process. The primary leaching test applied to site sediments in 2013, was EPA Method 1312 Synthetic Precipitation Leaching Procedure (SPLP). For samples collected in 2015 and 2016, a modified version of the SPLP test was used. The primary modifications to SPLP were the use of a lower liquid:solid ratio (4:1 versus the standard 20:1), the use of site groundwater (instead of a laboratory-prepared synthetic rainwater), and repeated or sequential leachings of samples. These modifications make the leach tests more representative of site groundwater conditions.

In sequential leaching tests, the sediment and upgradient un-impacted groundwater from well KM-3 were placed in jars at a ratio of 4:1 (by weight) groundwater to sediment. The jars were then agitated/mixed on a rotary extractor for 18 hours, the leachate water was decanted/filtered from the sediment, and the water was analyzed for fluoride, cyanide (total, WAD, and free) and other chemical constituents (e.g., pH, sodium, chloride). The sediment samples were then air-dried and weighed (to determine amount of water needed), fresh groundwater from well KM-3 was added to re-establish a 4:1 weight ratio, and another leaching cycle was conducted (e.g., agitation, followed by removal of water for analysis, etc.). The sequential extractions were repeated up to four cycles for each sediment sample but in some cases leaching cycles were suspended when cyanide and fluoride either were not detected or were present at very low levels.

In the 2015, sediment testing, selected extract mixtures of sediment and solution were allowed to remain in contact after the first and second leaching cycles for an additional 20 or approximately 60 days to determine if test results were affected by the duration of the tests. Results of these “aging tests” are shown in Figures 4-3 through 4-6). The aging tests show that fluoride and total cyanide results were not significantly affected by the duration of the test (less than 10 percent difference in test results) but that WAD and free cyanide concentrations were two to four times higher after aging. In field conditions, groundwater and sediment would be exposed for much longer periods of time than the duration of the laboratory tests. Thus, the modified SPLP leaching tests may underestimate WAD and free cyanide concentrations that would be observed under field conditions.

FIGURE 4-3. MODIFIED SPLP TEST EFFECT OF LEACH DURATION ON FLUORIDE CONCENTRATION

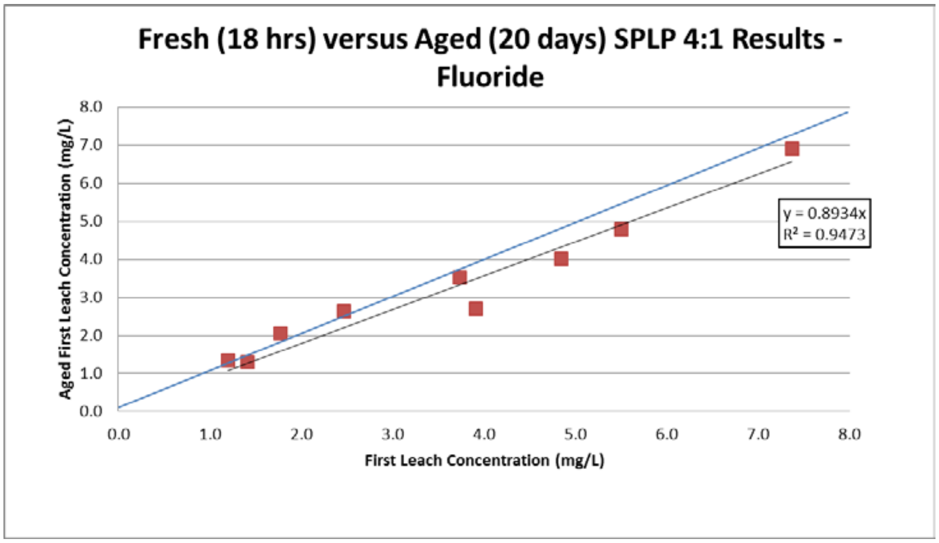


FIGURE 4-4. MODIFIED SPLP TEST EFFECT OF LEACH DURATION ON TOTAL CYANIDE CONCENTRATION

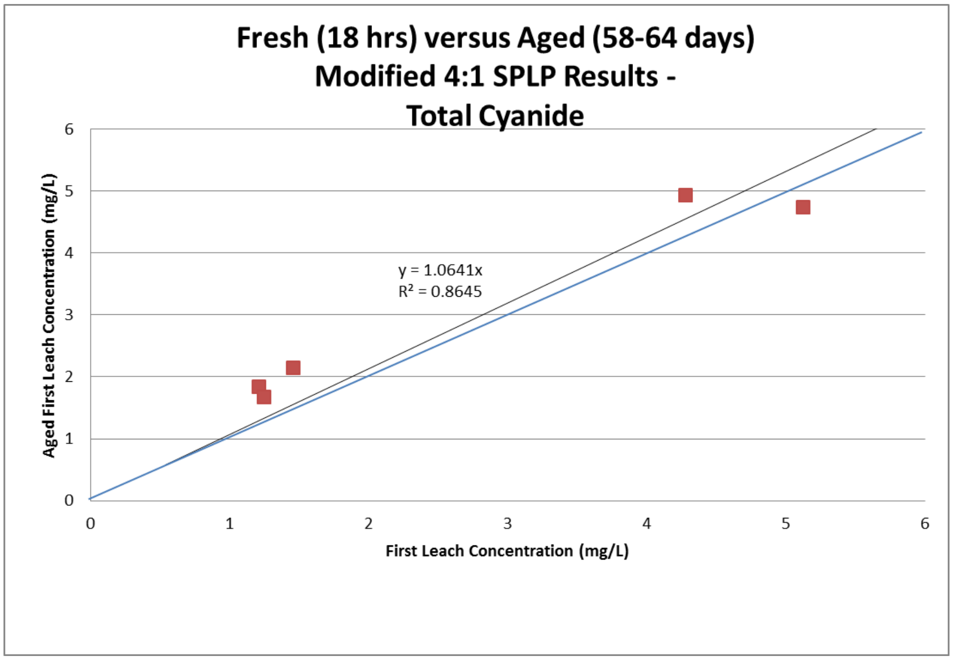


FIGURE 4-5. MODIFIED SPLP TEST EFFECT OF LEACH DURATION ON WAD CYANIDE CONCENTRATION

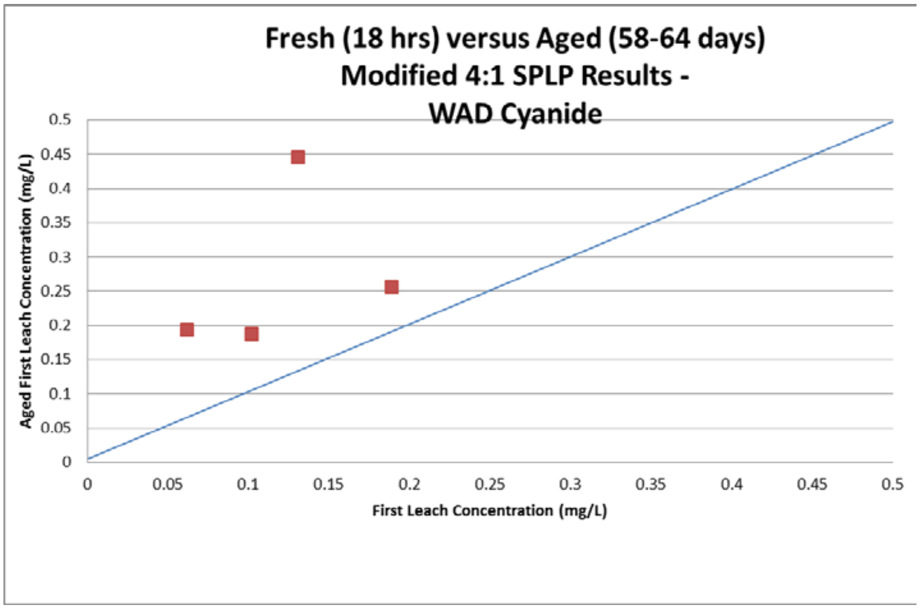
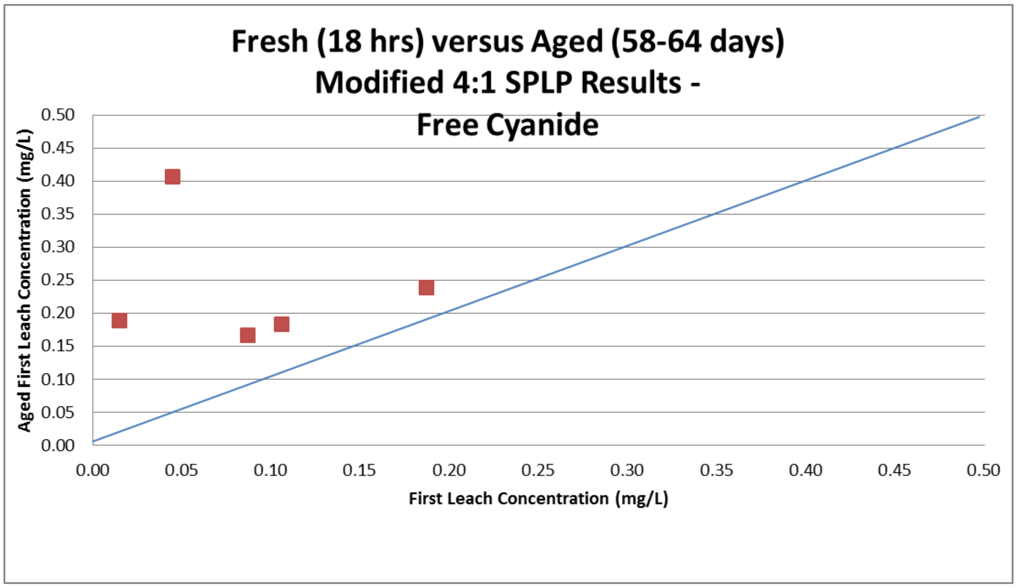


FIGURE 4-6. MODIFIED SPLP TEST EFFECT OF LEACH DURATION ON FREE CYANIDE CONCENTRATION



4.1.4 Batch Adsorption Testing

Batch adsorption testing conducted on selected sediment samples collected in 2015 followed similar jar testing protocols as modified SPLP testing described for leach testing in Section 4.1.3 (18 hour agitation on rotary extraction) but differed in that extractions were done at two liquid:solid ratios (4:1 and 20:1) and that highly-impacted groundwater (e.g., 75 mg/L fluoride) from monitoring well KM-2 was used as the solution.

4.2 IMPACTED SUBSURFACE SEDIMENT IN UNSATURATED ZONE TO GROUNDWATER

As described in the CAP (Ecology, 2002) and the Hart Crowser Site Assessment (1988), fluoride and cyanide-impacted sediments exist below the SPL pile at the shallow aquitard (SAQ, approximately 60 feet below surface) and extend down to the A Zone aquifer (approximately 140 feet below surface). The most likely pathway from this potential source to groundwater in the A Zone aquifer is by contact of impacted sediment with perched groundwater that exists in a thin saturated zone above the SAQ. Perched groundwater likely leaches contamination from the impacted sediments and infiltrates through thin or missing sections of the SAQ, flowing down to the A Zone aquifer. Once infiltrated through the SAQ, the water likely also leaches contamination from impacted sediments that are below the SAQ and transports this contamination to the A Zone aquifer.

The past or historical existence of this pathway is evidenced by the presence of contaminated sediments below the SAQ. Historically, the pathway was enhanced by water disposal practices which provided large amounts of water to underlying sediments and to the A Zone aquifer. This pathway likely continues to exist and function but in a capacity that is much reduced by corrective and management actions including cessation of water disposal practices, repair and monitoring of water lines in the area, and engineered capping of waste. The current flux of water to and through unsaturated contaminated sediments is believed to be low since it originates solely through infiltration and recharge from snowmelt and rainfall, which is very low in the area.

An additional pathway from unsaturated sediment to groundwater is transport by residual soil moisture, process water and stormwater within the SPL pile and unsaturated sediments either directly beneath the footprint of the SPL pile or downgradient of the pile. Movement of contaminants through this migration pathway is much slower, and much smaller, than the two previously described migration pathways as the amount of residual moisture within the SPL pile is low, as determined by two borings completed through the SPL pile in 2013. The relative importance of this migration pathway is likely low.

4.3 IMPACTED SUBSURFACE SEDIMENT IN SATURATED ZONE TO GROUNDWATER

Sampling and testing of saturated zone sediments indicates that sediments in the A Zone aquifer beneath the SPL pile and in the central portion of the groundwater contaminant plume; and sediments in the A and B Zone aquifers in the vicinity of the Compliance Wells at the downgradient edge of the site; are enriched in fluoride, and to a lesser extent cyanide; and release fluoride and cyanide to groundwater. Laboratory leaching tests of sediment and sediment:groundwater partitioning and mass balance model simulations demonstrate that the fluoride content of the sediments likely contributes a substantial portion of the fluoride present in groundwater. Although the laboratory evidence is not as clear as for cyanide, leaching of cyanide from sediment is also likely to contribute a significant portion of the cyanide dissolved in groundwater. Model simulations suggest that release of fluoride and cyanide from impacted saturated zone sediments may account for most, if not all of the observed ongoing groundwater contamination.

Saturated aquifer sediments beneath, and in the immediate vicinity of the SPL pile were characterized for soluble fluoride and total cyanide during the 1988 Site Characterization Analysis (Hart Crowser, 1988). To further characterize and delineate the extent of impacted sediments, additional borings were installed through the SPL pile and immediately downgradient of the SPL pile in 2013. Additional borings/wells were installed further downgradient of the SPL pile in the groundwater contaminant plume in 2015 and 2016. Sediment samples from borings completed in 2013-2016, were characterized for total and soluble fluoride, total cyanide, WAD cyanide, free cyanide, and sediment leaching characteristics. Sediment leaching characteristics derived from the 2015-2016, testing were used in a sediment:groundwater partitioning mass balance model (Section 4.3.2.5 below and The draft Sediment:Groundwater Partitioning Model Report (Hydrometrics,(2017c)) to evaluate the effects of sediment fluoride and cyanide on future groundwater concentrations. Overall, the saturated sediment results obtained prior to 1988, and during 2013- 2016, are consistent and therefore the data is combined for presentation in maps and figures, where possible. However, because the 2015/2016, investigations utilized slightly different laboratory analytical methods, the data from 2013 and 2015/2016, are discussed separately in the following sections.

4.3.1 Borings and Sediment Testing in Vicinity of SPL Pile in 2013

Five borings were completed through or adjacent to the SPL pile in summer/fall 2013. Locations of the borings are shown on Figure 4-7 and the results of sediment analyses are summarized below. Figures 4-8 and 4-9 summarize total cyanide concentrations (on a sediment weight basis) for sediment profile samples collected from borings NPRB-1, -2 and -3 in May/June and SPLP-1 and SPLP-2 in September 2013. For comparison, total cyanide and fluoride measured in groundwater in the A Zone aquifer encountered in the borings are also shown. Boring SPLP-1 was completed at the approximate location of former Hart Crowser monitoring well HC-9A. Sediment concentrations for HC-9A described in Hart Crowser (1988) are also presented on Figure 4-9 for comparison.

4.3.1.1 Total Cyanide

Total cyanide (Method 9012B acid extraction) concentrations in sediment immediately north of the SPL pile (Figure 4-8 are low (< 5 mg/kg (ppm)) and likely represent uncontaminated background sediment concentrations in all borings from the surface to depths of 120 feet or more and become elevated (10 to 40 mg/kg) below and in the vicinity of the water table. Highest concentrations are observed in the zone above the water table in borings NPRB-1 and NPRB-2. Groundwater encountered in these borings also contained elevated total cyanide concentrations of 46 to 77 mg/L.

Sediment beneath the center of the SPL pile in boring SPLP-1 (Figure 4-9) is enriched in cyanide in three zones: immediately below the fill/SPL waste material, in the vicinity of the SAQ, and above the water table. This pattern in SPLP-1 is similar to the concentration pattern observed in historic boring/well HC-9A and to the pattern observed in north perimeter borings NPRB-1 and NPRB-2 (Figure 4-8). In boring SPLP-2, sediment cyanide concentrations are low (< 11 mg/kg) throughout the profile).

FIGURE 4-7. 2013 SPL PILE BORING LOCATIONS

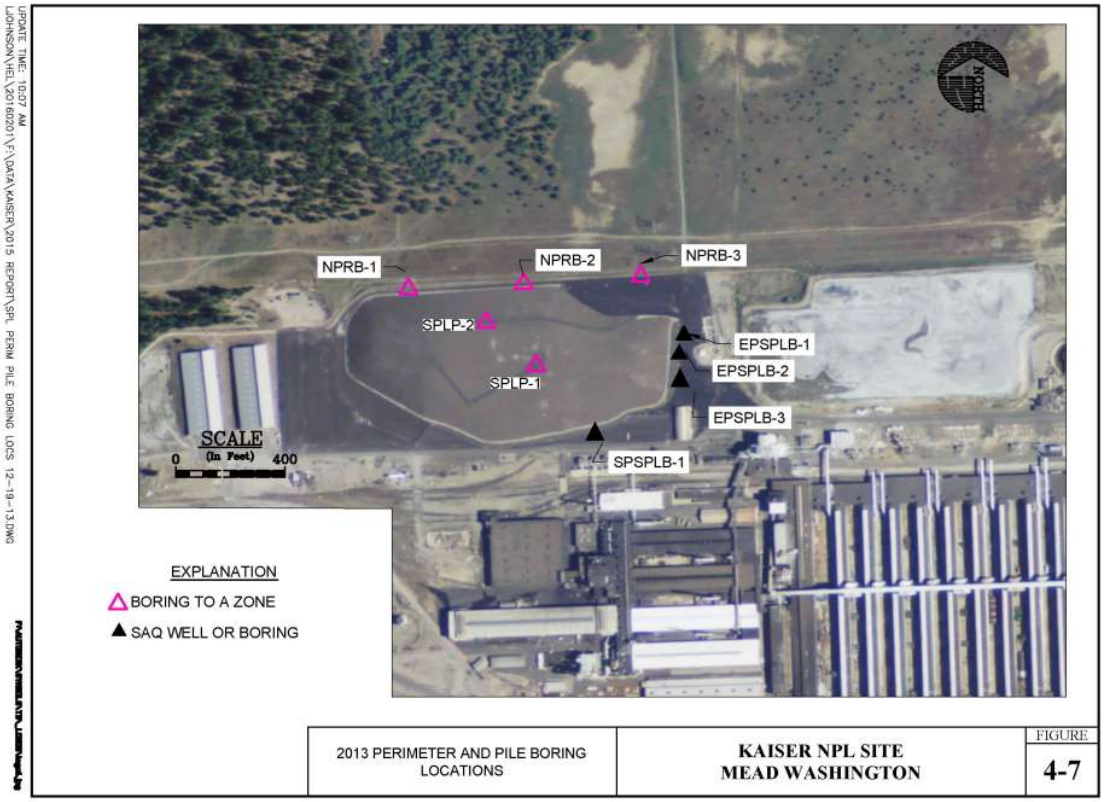


FIGURE 4-8. TOTAL CYANIDE IN SEDIMENT IMMEDIATELY DOWNGRADIENT OF SPL PILE

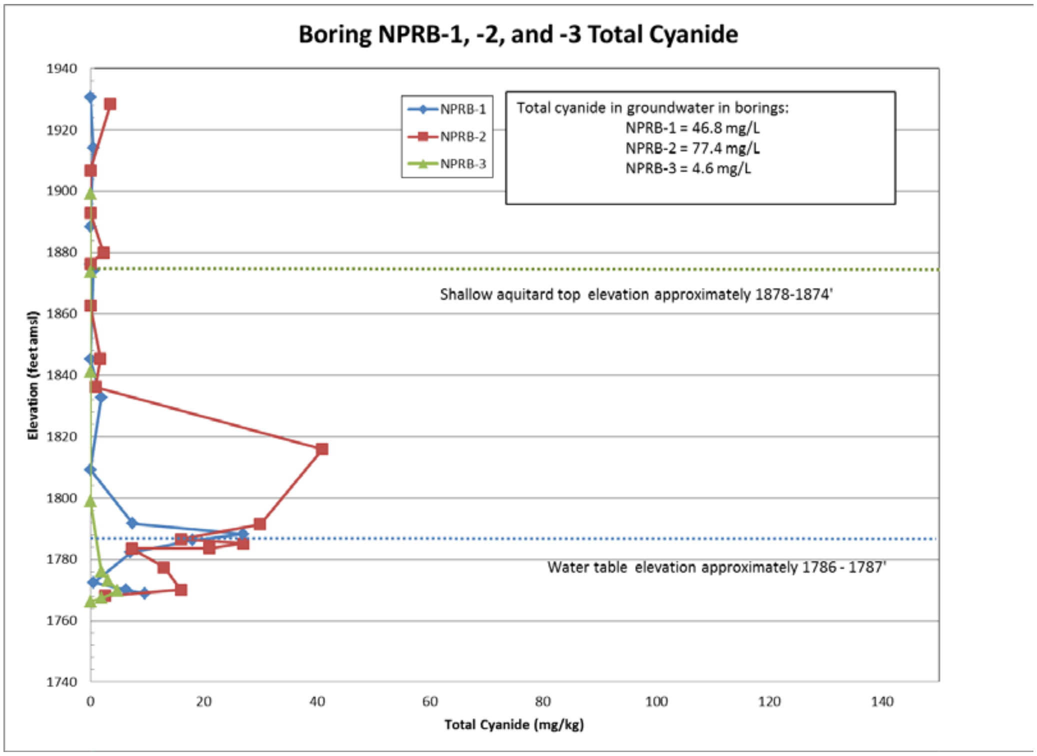
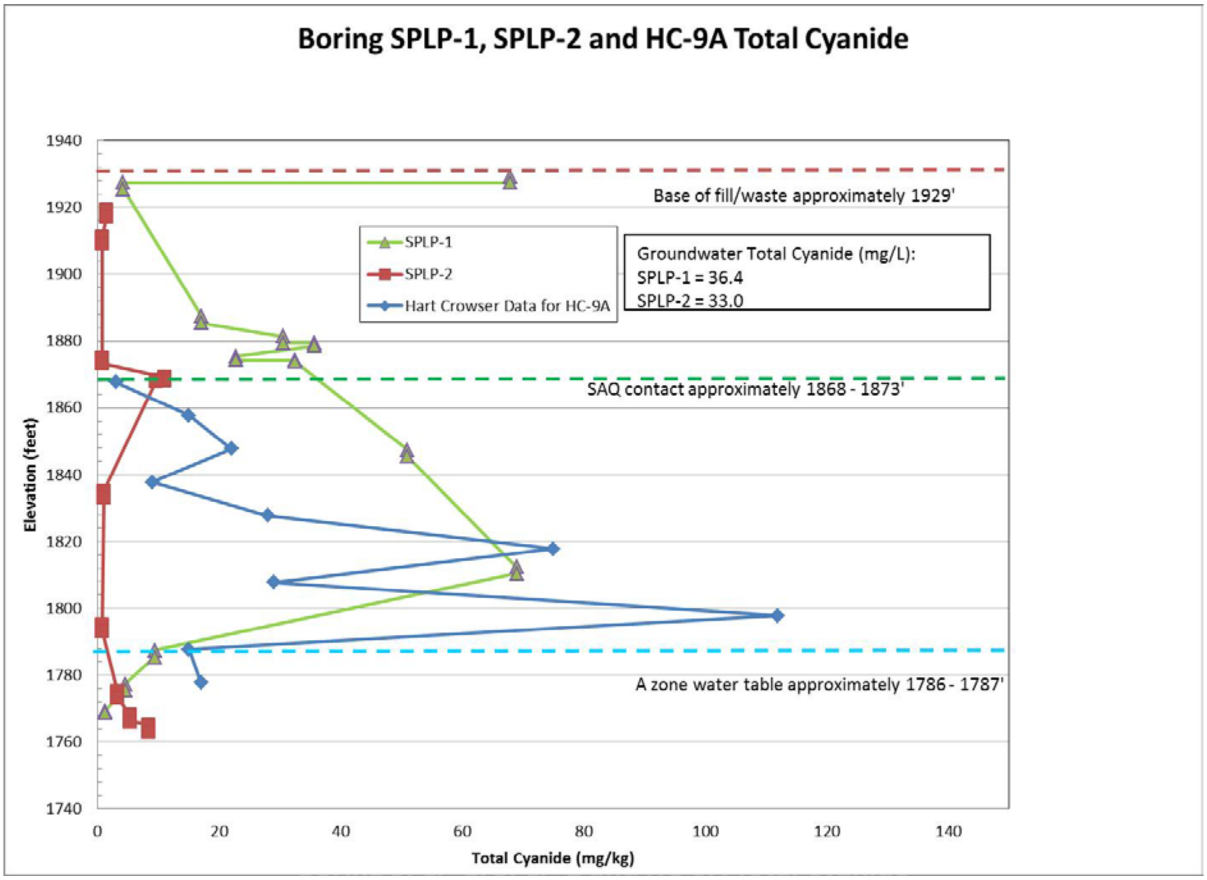


FIGURE 4-9. TOTAL CYANIDE IN SEDIMENT BENEATH THE CENTER OF SPL PILE



The overall pattern of cyanide concentrations in sediment beneath and immediately downgradient of the capped SPL pile is consistent with the transport of cyanide by water (leachate) from fill and waste to the underlying unsaturated and saturated sediments. The lower cyanide concentrations observed below the water table suggests either 1) fill/waste leachate enriched saturated sediment to a lesser degree than unsaturated sediment; and/or 2) if sediment was previously enriched in cyanide by fill/waste leachate, the enrichment has been significantly leached and removed from the saturated sediment by groundwater; and/or 3) the total cyanide analytical method is not sufficiently sensitive to detect the level of enrichment present in sediment samples. In either case, the sediment data from the borings completed in 2013, indicate that there is no (or a relatively small) secondary source of cyanide in saturated sediments immediately beneath and adjacent the SPL pile. As noted previously by Hart Crowser (1988) and confirmed by 2013, sediment data, unsaturated sediments beneath the SPL pile constitute a secondary source of cyanide.

4.3.1.2 Fluoride

In 2013, analyses of fluoride in sediment were conducted by three different analytical methods: EPA Method 300 (readily water soluble fluoride); EPA Method 340 (total fluoride); and EPA Method 1312 (SPLP) leachable fluoride. Profiles of fluoride concentration versus depth (elevation) for sediment borings beneath and near the SPL pile are shown in Figures 4-10 through 4-12. For comparison, concentrations measured in samples of groundwater in the A Zone aquifer encountered in the borings are also shown. Fluoride concentration patterns are similar to cyanide concentrations patterns with the exception that fluoride concentrations are significantly higher (over 6,000 mg/kg in one sample). Fluoride enrichment is most notable in three zones: just beneath the fill/waste, near the SAQ, and near (above and below) the water table. The overall pattern of fluoride concentrations in sediment is consistent with the transport of fluoride by leachate from fill and waste to the underlying unsaturated and saturated sediments.

The concentrations of fluoride observed in groundwater are similar to concentrations measured in the Method 1312 leachable fluoride tests (summarized in Table 4-1, above). Therefore, it appears that leaching of sediments by water is capable of generating the observed groundwater concentrations in the vicinity of the SPL pile.

FIGURE 4-10. READILY WATER SOLUBLE (METHOD 300) FLUORIDE IN SEDIMENT IMMEDIATELY DOWNGRADIENT OF SPL PILE

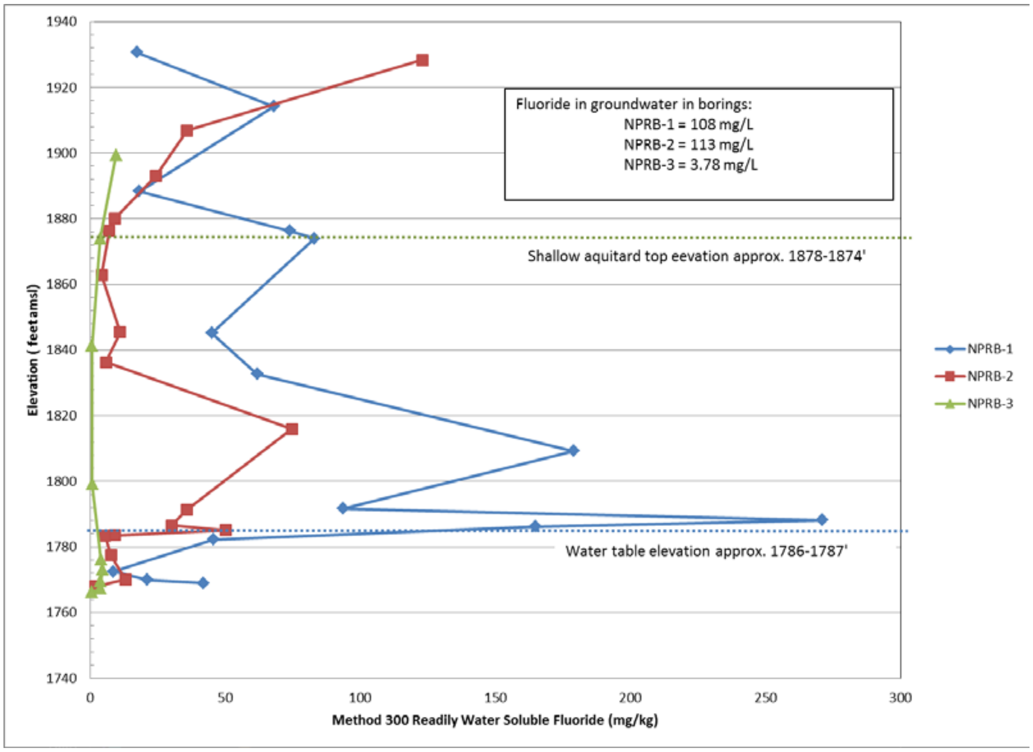
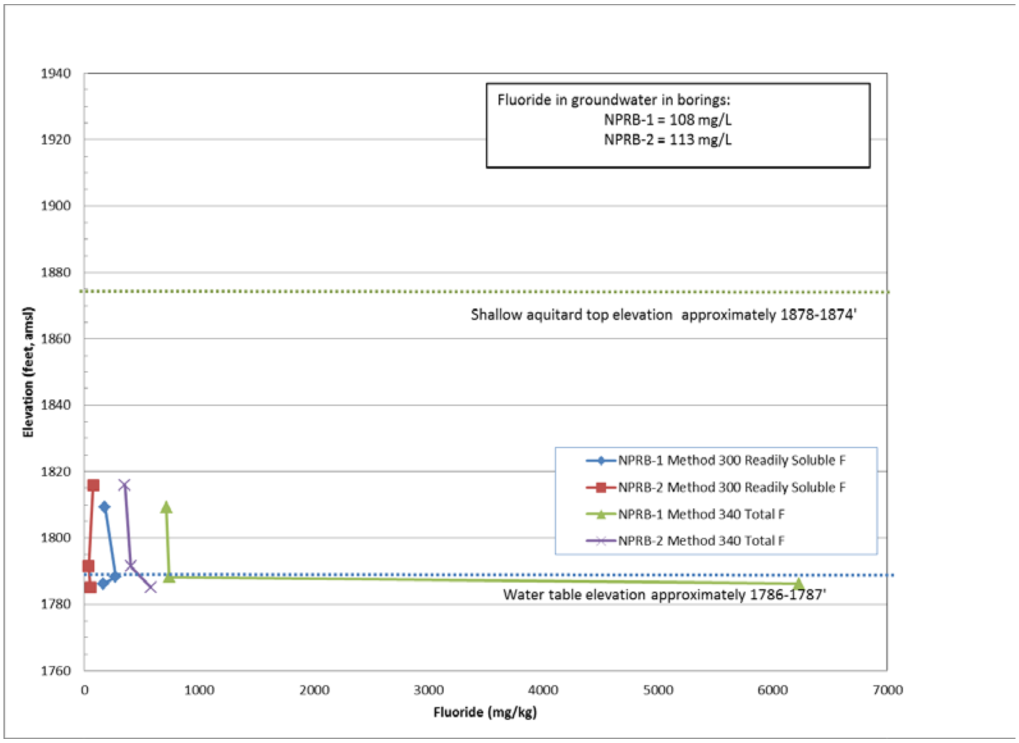
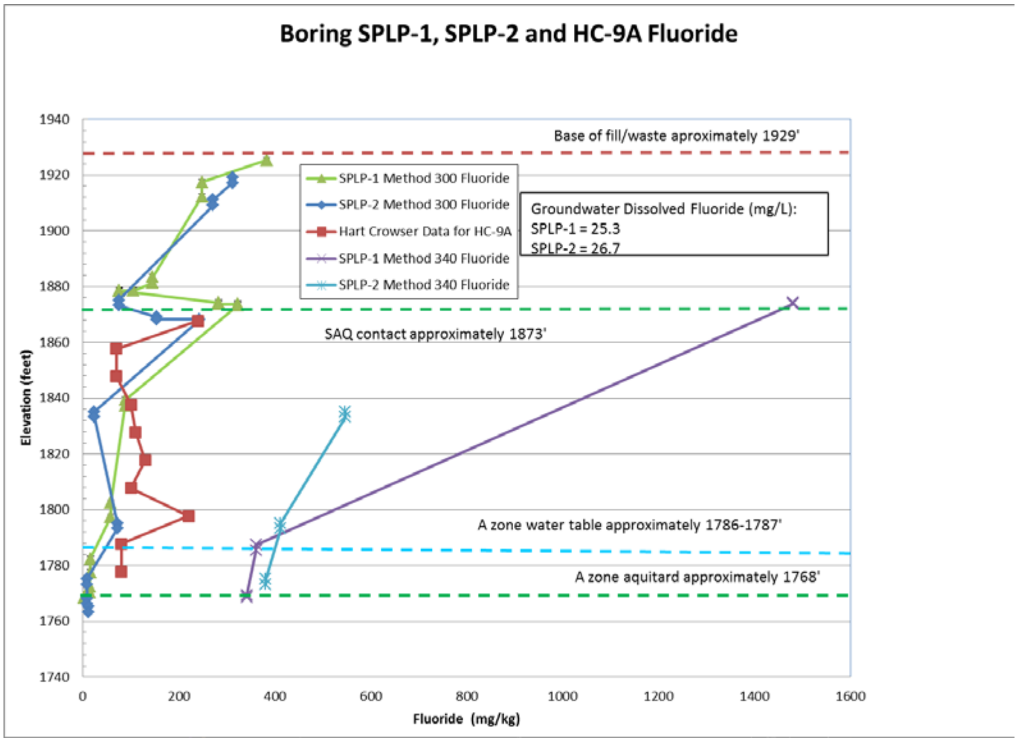


FIGURE 4-11. FLUORIDE IN SEDIMENT IMMEDIATELY DOWNGRADIENT OF SPL PILE



Notes: Sample elevations shown are the middle of the sampling interval (e.g., sample from 1780’ to 1785’ is shown as 1782.5’).

FIGURE 4-12. FLUORIDE IN SEDIMENT BENEATH SPL PILE



A few sediment samples were also collected and analyzed from test wells TW-1A and TW-1B that were constructed in January 2013, for aquifer testing purposes. Locations of these wells are shown on Figure 2-1 in Section 2 and results of sediment analyses are presented in Table 4-2. Well TW-1A is located within the center of the groundwater plume near well KM-6 while Well TW-1B is located near the line of Compliance Wells but on the edge of the contaminant plume where concentrations are relatively low. In both wells, water table occurs at approximately 147 feet bgs. From comparison with the cyanide and fluoride profiles for borings NPRB-1 and 2 (above) it appears that cyanide and fluoride levels in sediment from TW-1B may be near background levels while cyanide, and to a lesser extent fluoride levels, in TW-1A are elevated, suggesting that secondary cyanide and perhaps fluoride sources may exist in sediments in the plume center. The presence of these enrichment sediments was confirmed through additional testing of sediment samples collected from borings/monitoring wells that were installed in the plume center and Compliance Wells area in 2015 and 2016.

TABLE 4-2. CYANIDE AND FLUORIDE IN SEDIMENTS FROM TEST WELLS 1A AND 1B

Sediment Sample	Total Cyanide (mg/kg or ppm)	WAD Cyanide (mg/kg or ppm)	Method 300 Readily Water Soluble Fluoride (mg/kg or ppm)
TW-1A @ 140’	8.9	<0.5	4.9
TW-1A @ 145’	30.7	<0.5	16.3
TW-1A @ 155’	10.6	<0.5	5.7
TW-1B @ 155’	2.60	<0.5	4.8
TW-1B @ 160’	4.95	<0.5	6.2

4.3.2 Borings and Sediment Testing in Groundwater Plume in 2015-2016

In 2015 and 2016, eleven borings were installed downgradient of the SPL pile targeting the groundwater contaminant plume from the BPA powerline area to the Compliance Wells.

4.3.2.1 Total Fluoride and Cyanide

Concentrations of total fluoride (Method 340), soluble fluoride (Method 300), cumulative fluoride leached in modified SPLP leaching tests, and percent of total fluoride leachable (by sequential modified SPLP leaches with site groundwater) measured in sediment samples from site borings from 2013 through 2016, are shown in Figures 4-13 through 4-15. Sediments are enriched in total and leachable fluoride throughout the groundwater plume area. Highest percentage of leachable fluoride is found downgradient of the SPL pile in the BPA powerline area (e.g., 188 mg/kg F leached at KM-11) but significant levels of leachable fluoride persist further downgradient in the plume center area (e.g., 92 mg/kg fluoride leached at KM-12) and extending to the Compliance Wells area (e.g., 98 mg/kg F leached at KM-18).

Concentrations of total cyanide (Method 9012B acid extraction), cumulative total cyanide leached in modified SPLP leaching tests, and percent of total cyanide leachable (by sequential modified SPLP leaches with site groundwater) measured in sediment samples from site borings from 2013 through 2016, are shown in Figure 4-14. Highest total cyanide concentration and cumulative total cyanide leached are found downgradient of the SPL pile in the BPA powerline area (e.g., 571 mg/kg total cyanide leached at KM-8) but significant levels of leachable cyanide persist further downgradient in the plume center area (e.g., 43 mg/kg total cyanide leached at KM-12) with enriched, but low concentrations at the Compliance Wells area (e.g., 5 mg/kg total cyanide leached at KM-17).

FIGURE 4-13. TOTAL LEACHABLE FLUORIDE IN AQUIFER SEDIMENT

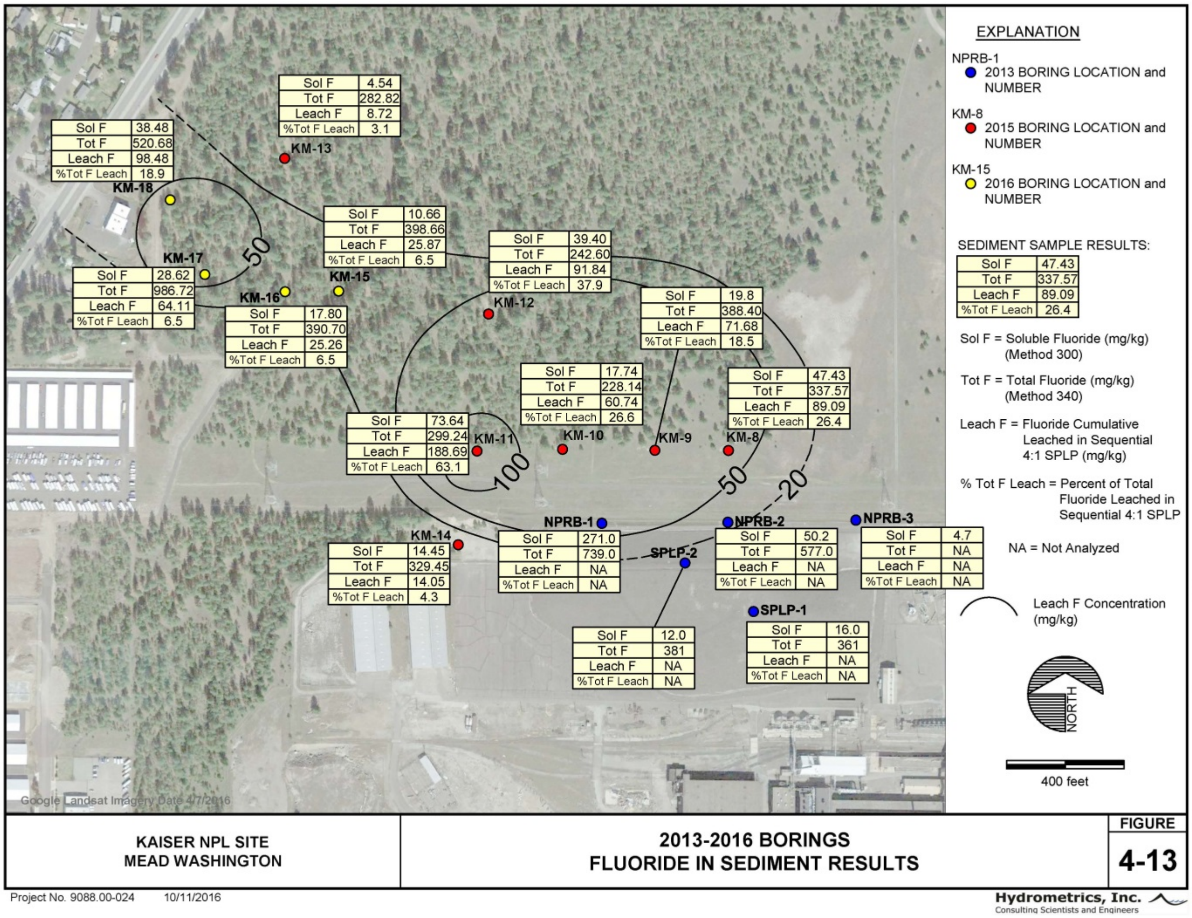


FIGURE 4-14. TOTAL CYANIDE IN AQUIFER SEDIMENT

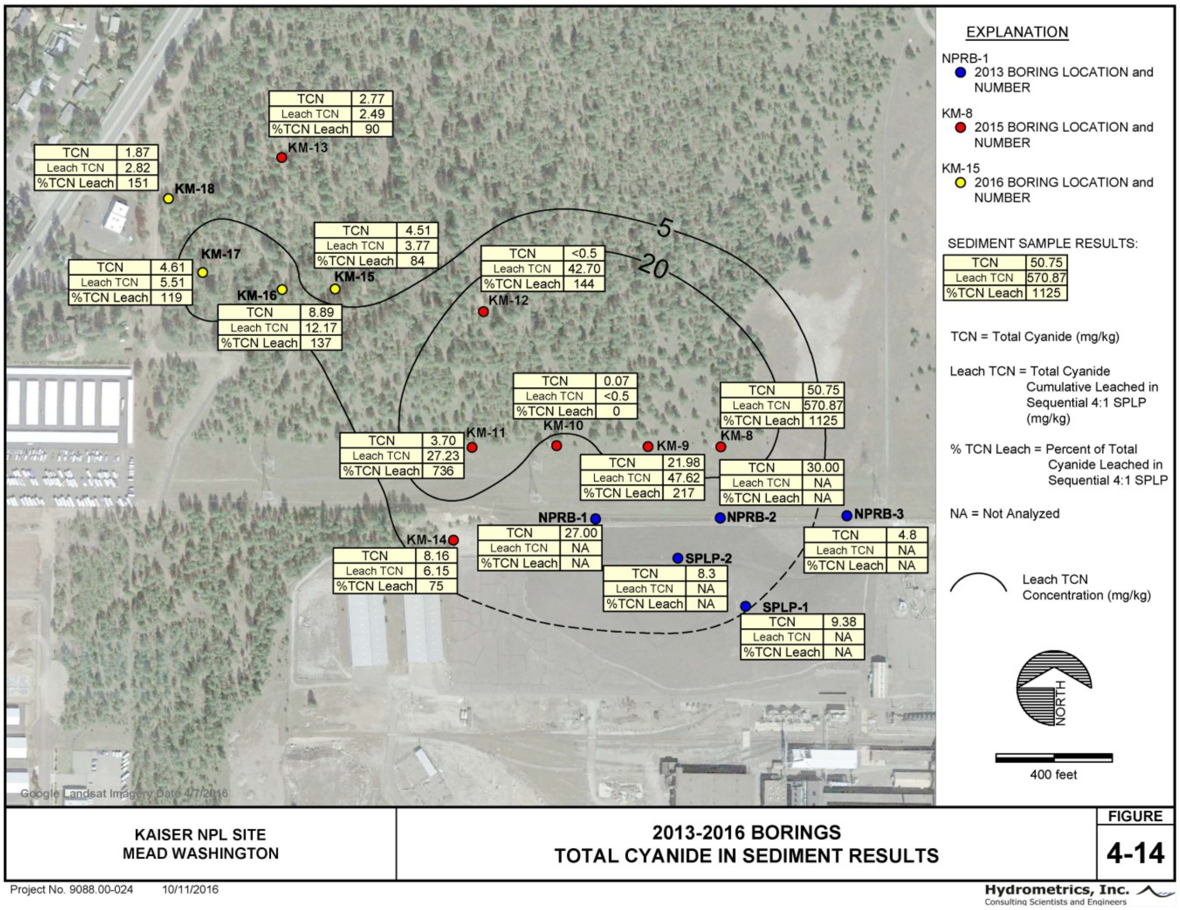
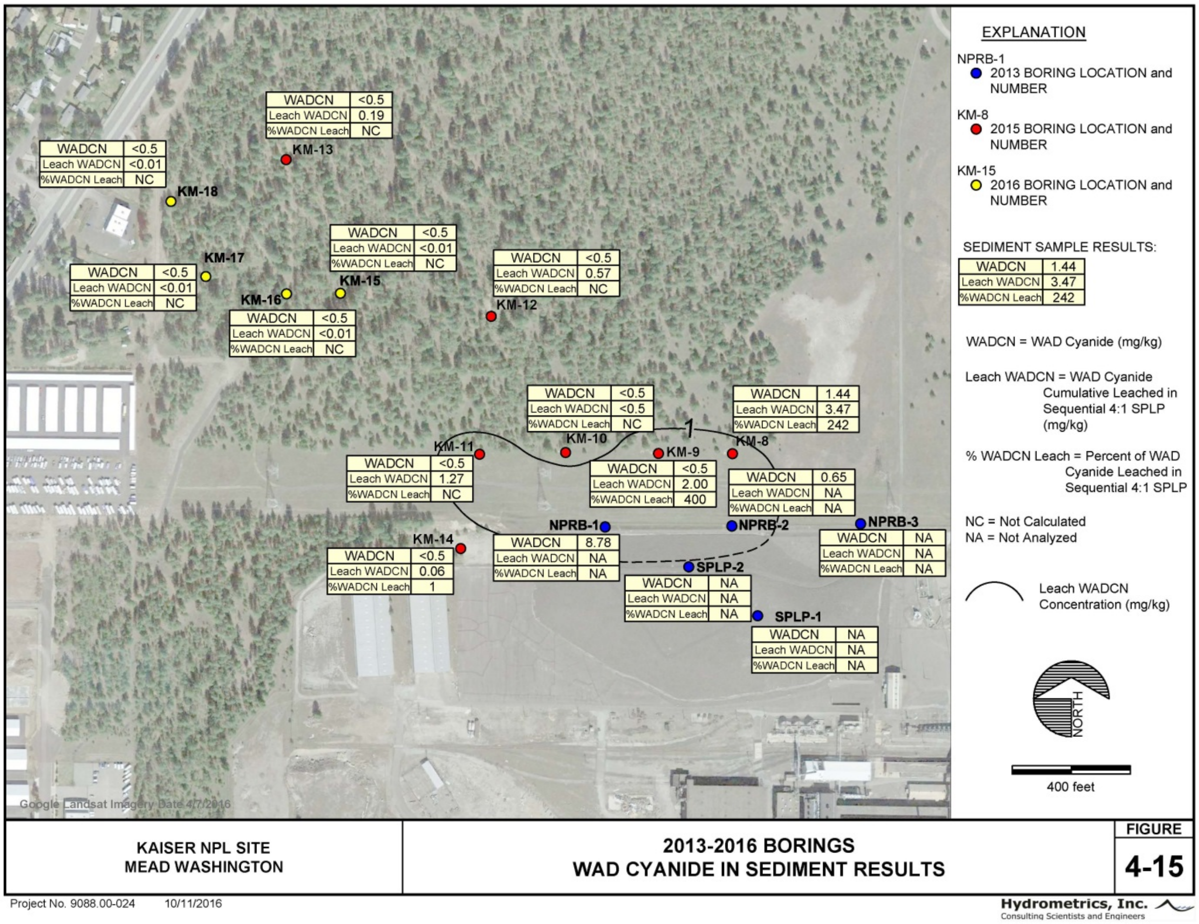


FIGURE 4-15. WAD CYANIDE IN AQUIFER SEDIMENT



Concentrations of WAD cyanide, cumulative WAD cyanide leached in modified SPLP leaching tests, and percent of WAD cyanide leachable (by sequential modified SPLP leaches with site groundwater) measured in sediment samples from site borings from 2013 through 2016, are shown in Figure 4-15. WAD cyanide concentrations were less than the analytical detection limit of 0.5 mg/kg in all borings with the exception of KM-8, the boring with the highest total cyanide concentration, located near the BPA powerline. Highest cumulative WAD cyanide leached was found near the BPA powerline (e.g., 3.5 mg/kg in KM-8), with low but measurable concentration near the plume center (e.g., 0.6 mg/kg at KM-12) and non-detectable concentration near the Compliance Wells.

4.3.2.2 Sediment Fluoride Leaching and Adsorption Characteristics

Sediment leaching (desorption and dissolution) and adsorption characteristics were determined by sequential modified SPLP leach testing and by batch adsorption testing as described in Section 4.1. In laboratory leach testing, leaching of fluoride from saturated zone sediments exhibited partitioning behavior where declines in leachate concentration were proportional to the cumulative amount of water to which the sediment was exposed (Figure 4-16) and proportional to the concentration of fluoride bound to, or contained in, the sediment (Figure 4-17). These leaching characteristics are consistent with chemical constituents that are adsorbed to sediment. Similar partitioning or adsorption behavior by fluoride has been observed in agricultural soils and aluminum smelter-impacted soils (Arnesen and Krogstad, 1998; Gupta et al, 1982; Bouwer and Hatcher, 1966; Anchor Environmental, 2014).

The relationship between fluoride in solution in contact and equilibrium with fluoride in sediment (Figure 4-17) can be described by a partition or distribution coefficient (Kd) defined as:

Kd= Concentration in sediment/ Concentration in solution.

Kd values determined for sediment samples collected in 2015-2016, by sequential leach testing are provided in The draft Sediment:Groundwater Partitioning Model Report (Hydrometrics,(2017c).

FIGURE 4-16. FLUORIDE LEACHING CONCENTRATION AS FUNCTION OF CUMULATIVE WATER APPLIED

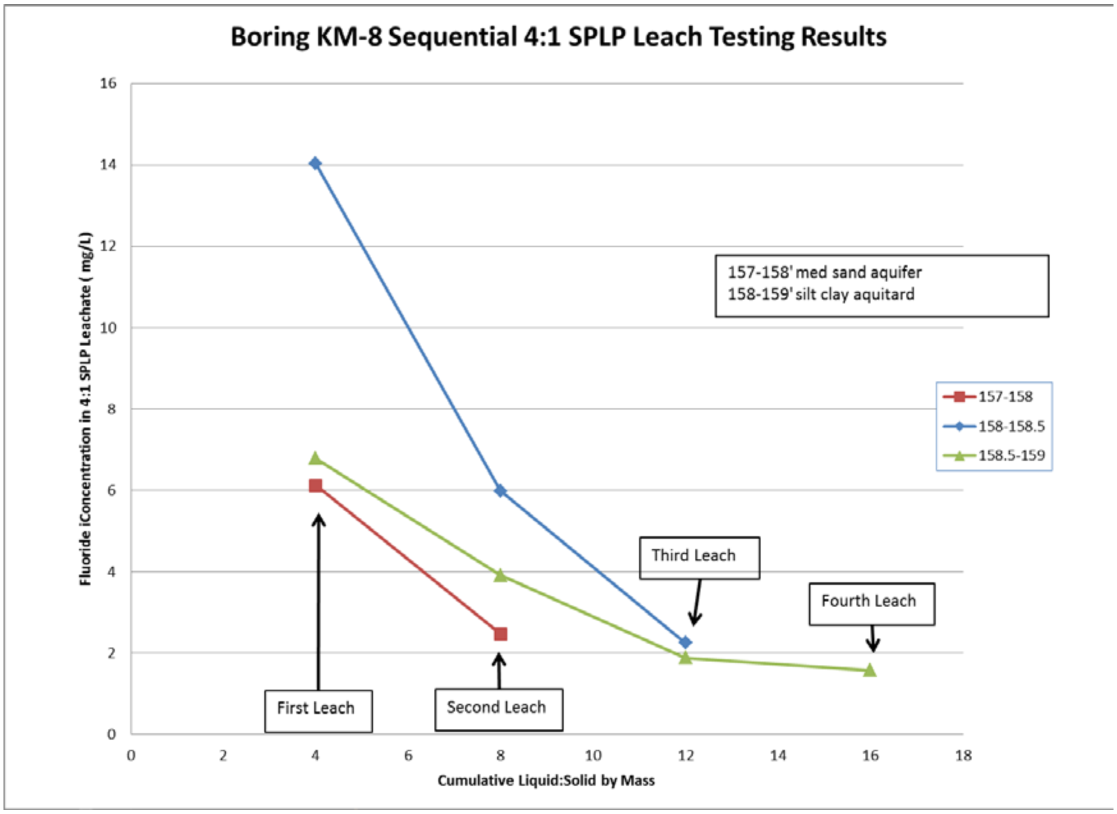
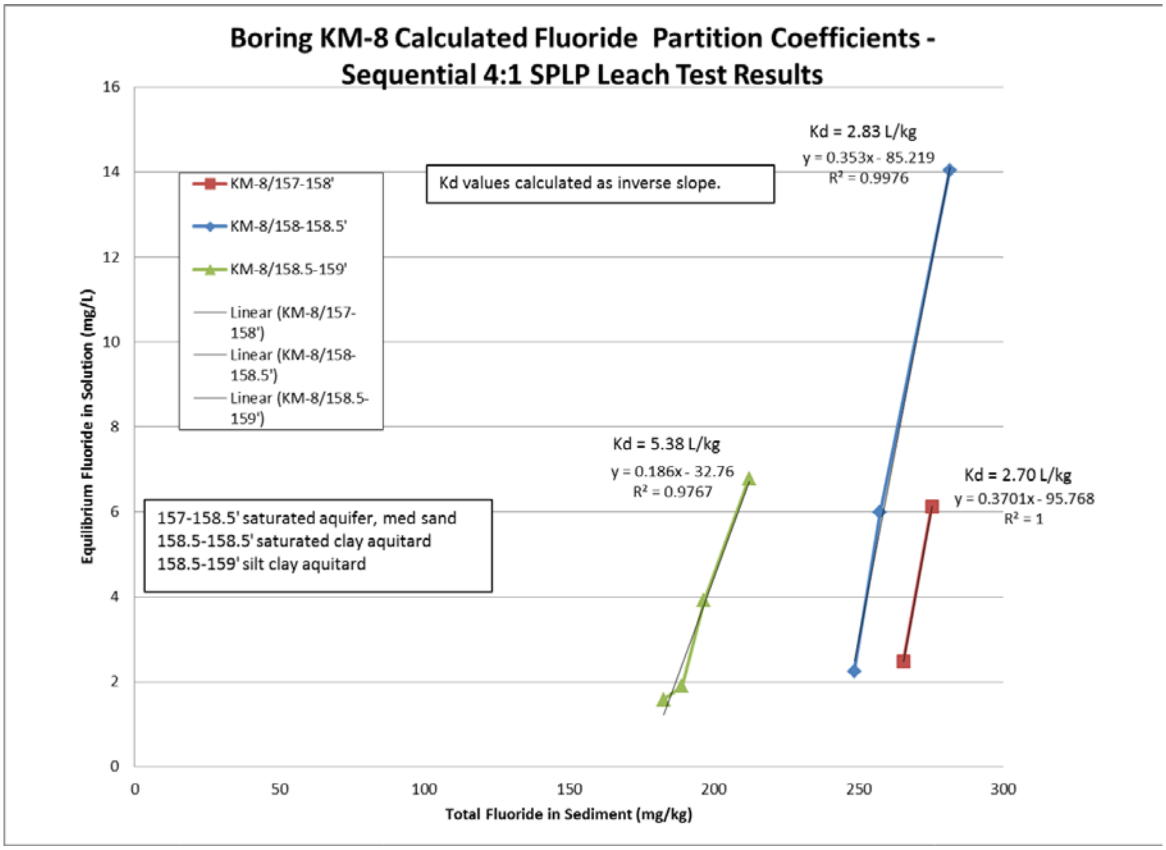


FIGURE 4-17. FLUORIDE LEACHING CONCENTRATION AS FUNCTION OF FLUORIDE IN SEDIMENT

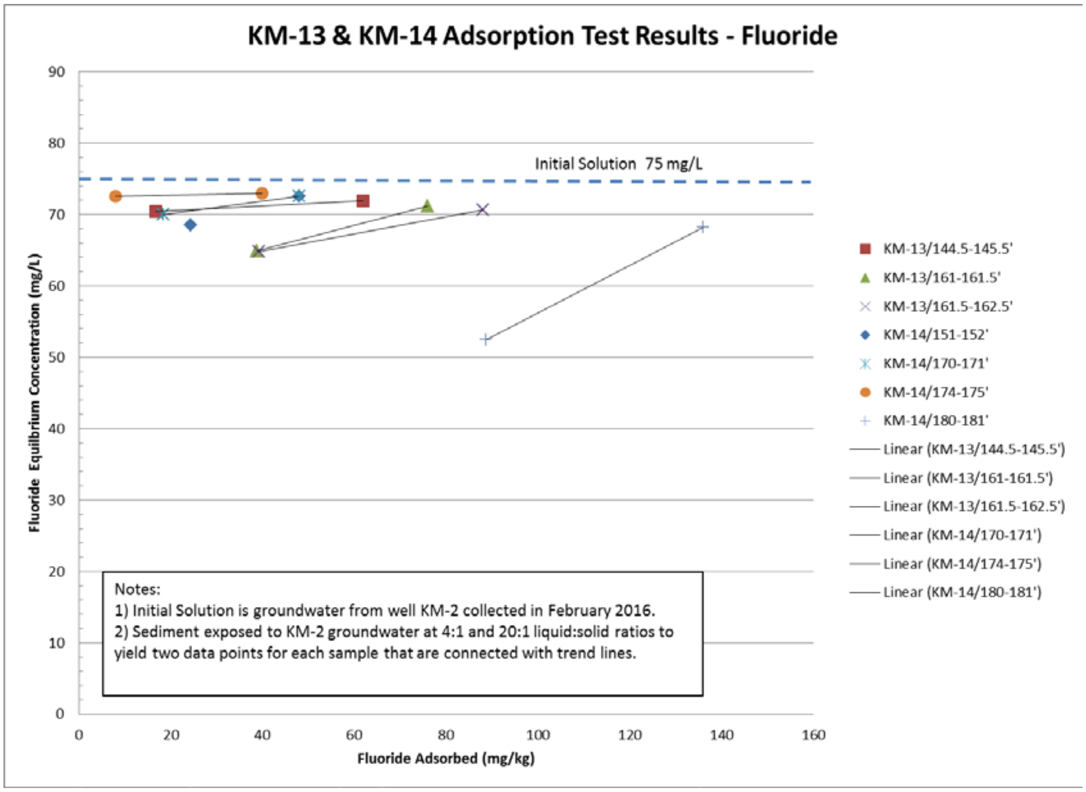


Results of batch adsorption testing of sediment samples collected in 2015, from borings KM-13 and KM-14 are shown in Figure 4-18. These samples were chosen because KM-13 and KM-14 are located outside of the primary groundwater fluoride plume and were found to have low leachable fluoride concentrations and thus would be expected to have the highest adsorption capacity available. In the adsorption tests, the sediment samples were exposed to groundwater from well KM-2 containing high concentrations of fluoride and cyanide (initial concentration of groundwater is shown by the horizontal line in Figure 4-18). The plotted points indicate the final groundwater concentration after exposure of the groundwater to the clean sediments, adsorption is indicated by decreases in fluoride concentration relative to initial groundwater concentration. In many of the tests, the change in fluoride concentration in solution was small relative to the initial solution concentration and therefore the data has a high uncertainty relative to the precision of the laboratory analysis. For samples that did show a significant change in solution concentration, the calculated Kd values are similar to Kd values calculated from leaching tests.

4.3.2.3 Sediment Cyanide Leaching and Adsorption Characteristics

Cyanide leaching (desorption and dissolution) and adsorption characteristics for sediment samples were determined by sequential modified SPLP leach testing and by batch adsorption testing as described in Section 4.2.2.3. Similar to fluoride, in sequential modified SPLP leachate testing in the laboratory, total cyanide leaching from saturated zone sediments appears to exhibit partitioning behavior where declines in leachate cyanide concentrations were proportional to the cumulative amount of water to which the sediment was exposed (Figure 4-19) and proportional to the concentration of cyanide bound to, or contained in, the sediment (Figure 4-20).

FIGURE 4-18. FLUORIDE ADSORPTION IN BATCH TESTS



Notes:
1) Initial Solution is groundwater from well KM-2 collected in February 2016.
2) Sediment exposed to KM-2 groundwater at 4:1 and 20:1 liquid:solid ratios to yield two data points for each sample that are connected with trend lines.

FIGURE 4-19. TOTAL CYANIDE LEACHING CONCENTRATION AS FUNCTION OF CUMULATIVE WATER APPLIED

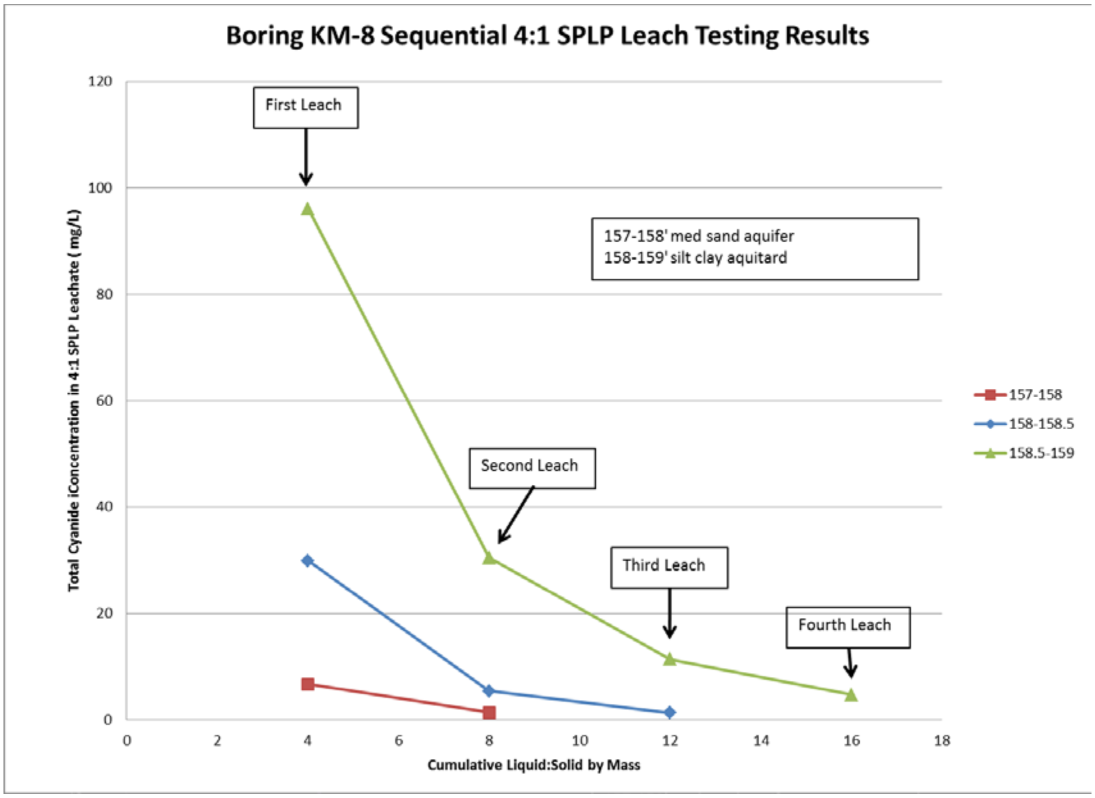
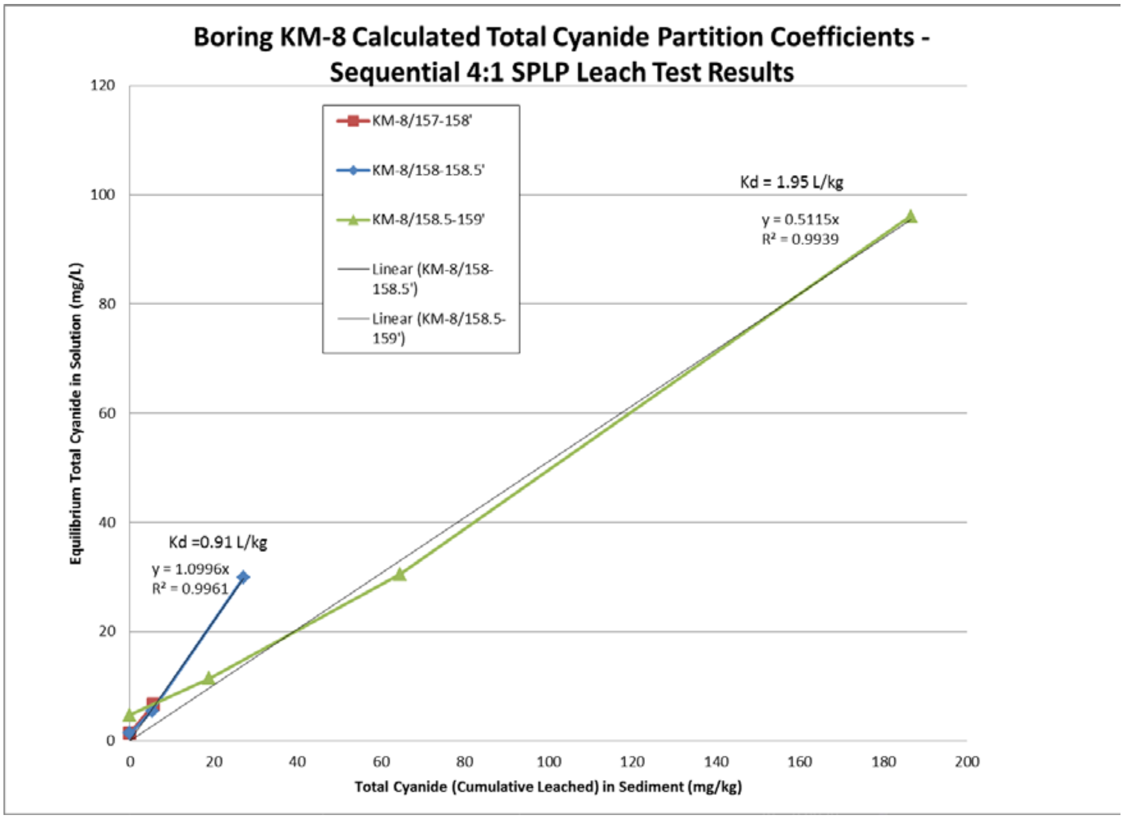
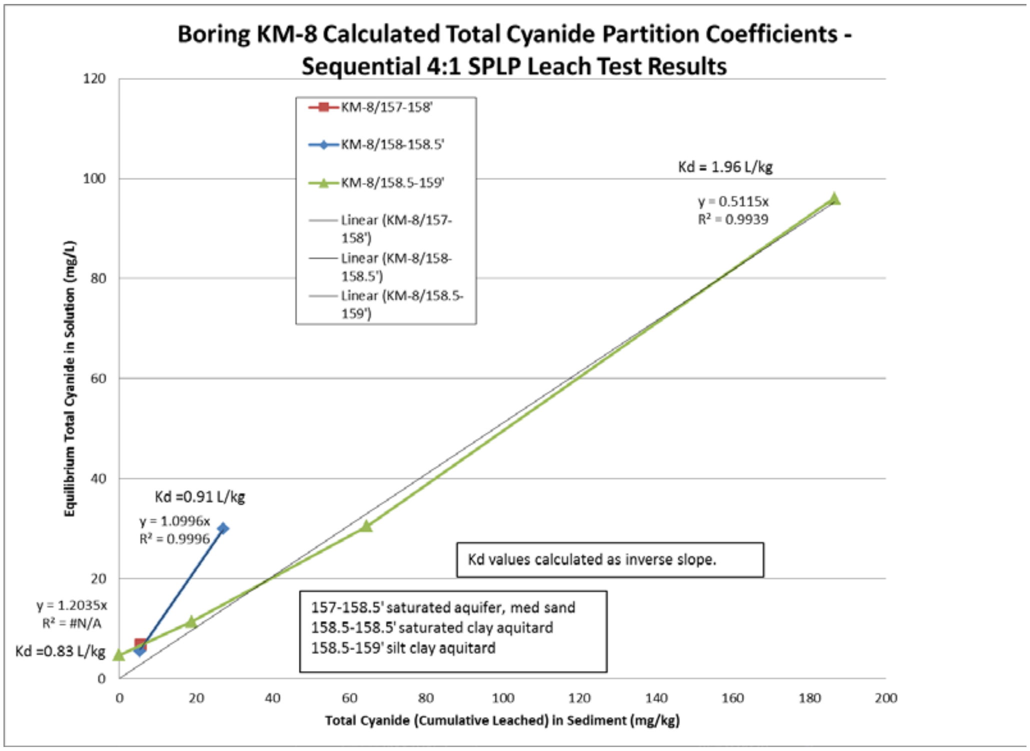


FIGURE 4-20. TOTAL CYANIDE LEACHING CONCENTRATION AS FUNCTION OF TOTAL CYANIDE IN SEDIMENT (BORING KM-8)





Results of batch adsorption testing of sediment samples collected in 2015, from borings KM-13 and KM-14 are shown in Figure 4-21. These samples were chosen because KM-13 and KM-14 are located outside of the primary groundwater cyanide plume and were found to have low leachable cyanide concentrations and thus would be expected to have the highest adsorption capacity available. In many of the tests, the change in cyanide concentration in solution was small relative to the initial solution concentration and therefore the data has a high uncertainty relative to the precision of the laboratory analysis. For samples that did show a significant change in solution concentration, the calculated Kd values are similar to Kd values calculated from leaching tests.

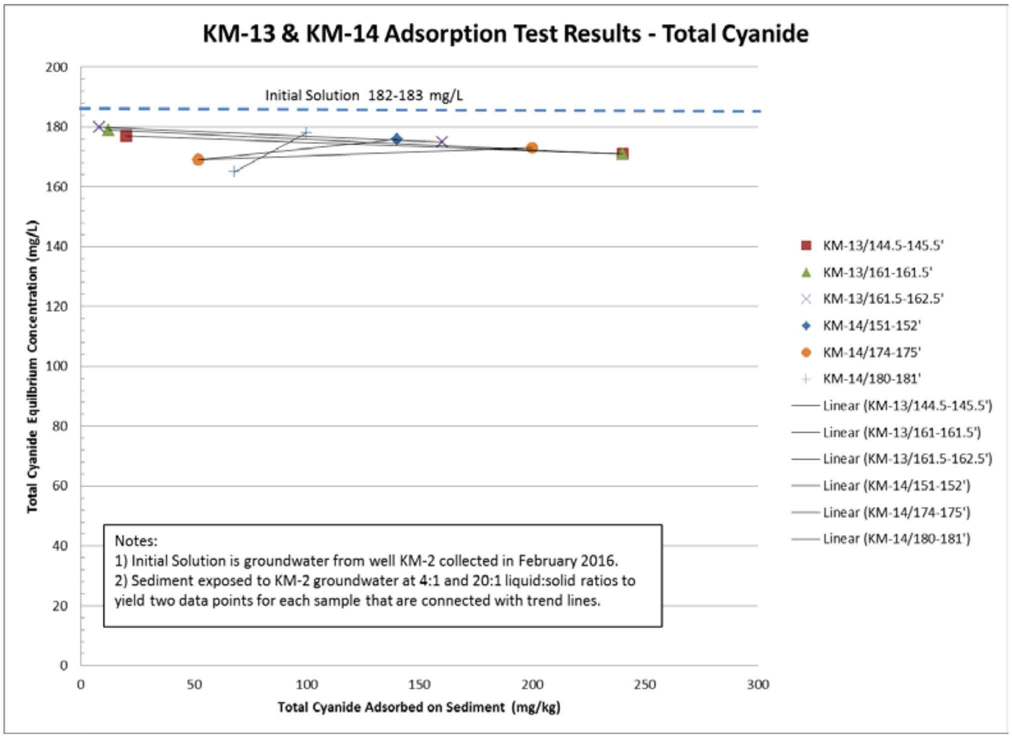
Laboratory leaching data suggest leaching of cyanide from sediments may contribute a significant proportion of cyanide to groundwater; however, the laboratory evidence is not as clear for cyanide as it is for fluoride for several reasons:

1. There is remaining uncertainty regarding sediment total cyanide results. Since most of the samples leached more cyanide than was measured by the total cyanide analysis the true total cyanide content is unknown. Note that for graphing purposes on the included figures, the cumulative total cyanide leached was assumed for the total cyanide concentration.
2. The source and nature of WAD and free cyanide that is leached from sediment is not completely understood. Free cyanide was not detected in any sediment solid samples and measurable concentrations of WAD cyanide were only reported in boring KM-8. This lack of free and WAD cyanide in the sediments is most likely an indication that the cyanide in the sediments is in the form of iron-cyanide (which is not part of WAD or free cyanide), either as iron-cyanide minerals and/or iron-cyanide complexes that are adsorbed to the sediment. The mechanism of the apparent release of WAD and free cyanide from sediment in leaching tests could be the dissolution of iron-cyanide minerals as described in laboratory experiments by Ghosh (1999). Ghosh (1999) noted the very slow formation of free/WAD cyanide forms in solution from dissolution of iron-cyanide minerals that required approximately 75 days to attain quasi-stead state or equilibrium conditions. This slow reaction rate for formation of

WAD/free cyanide could explain the observed increase in WAD and free cyanide concentrations upon aging of extraction mixtures in this study (Figures 4-5 and 4-6, above). If this were true, leach test WAD and free cyanide results may be biased low due to the relatively short duration of the sediment testing.

3. The literature evidence for cyanide adsorption behavior is also not as definitive as for fluoride and it is possible that other mechanisms such as cyanide mineral dissolution may be responsible for the apparent partitioning behavior. In contrast to fluoride, the scientific literature reports weak adsorption of cyanide by sediment, except in soils containing abundant organic matter (Rennert and Mansfeldt, 2002).

FIGURE 4-21. TOTAL CYANIDE ADSORPTION IN BATCH TESTS



In spite of these uncertainties, the sediment data clearly show enrichment of sediment in cyanide and that leaching of cyanide by groundwater can contribute a significant amount of cyanide to groundwater.

4.3.2.4 Sodium, Chloride and Alkalinity (pH)

As discussed in Section 2.5 and shown in Figures 2-8, 2-11, and 2-12, above, sodium, alkalinity, pH, and chloride concentrations in groundwater display similar patterns and trends to the contaminants fluoride and cyanide. The source or cause of high chloride in groundwater has not been identified but is assumed to be due to similar processes that cause high concentrations of the other parameters. High concentrations of, and correlations between, sodium, fluoride, cyanide, alkalinity and pH is due to two factors: the chemical composition of process water and SPL leachate that was released to groundwater; and the retention and subsequent ongoing release of these chemical constituents by aquifer sediments. Historical information indicates SPL and SPL leachate contains very high concentrations of sodium, fluoride and cyanide and is very alkaline. In laboratory leaching tests, high concentrations of sodium and alkalinity (signified by high pH) were leached from sediments along with fluoride and cyanide (Figures 4-22 through 4-25). Similar to fluoride, sodium exhibits partitioning behavior where groundwater concentration is proportional to sediment concentration. Calculated partitioning coefficients based on sequential leaching tests indicate sodium Kd values range from approximately 0.5 to 1.5 L/kg, or approximately one-third to one-half of the fluoride Kd. For the plume center wells immediately downgradient of the BPA powerline (KM-10 and KM -11) sediments have an leachable sodium concentrations of 700 to 820 mg/kg, assuming a Kd of 0.5, these sediments would be calculated to leach 1,400 to 1,640 mg/L of sodium, a concentration which matches observed groundwater concentrations in the wells.

FIGURE 4-22. CORRELATION BETWEEN SODIUM AND FLUORIDE CONCENTRATIONS IN SEQUENTIAL LEACHING TESTS

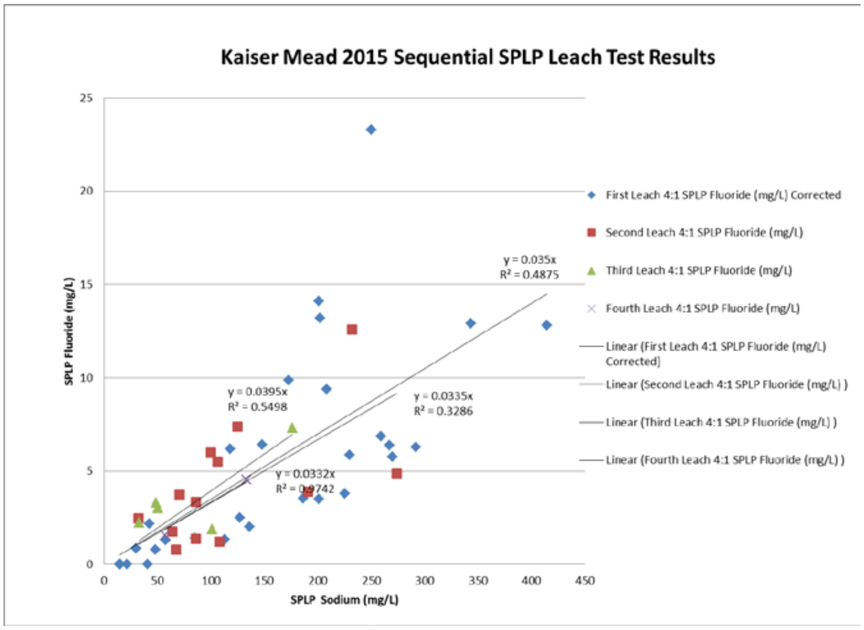


FIGURE 4-23. CORRELATION BETWEEN SODIUM AND FLUORIDE CONCENTRATIONS IN ADSORPTION TESTS

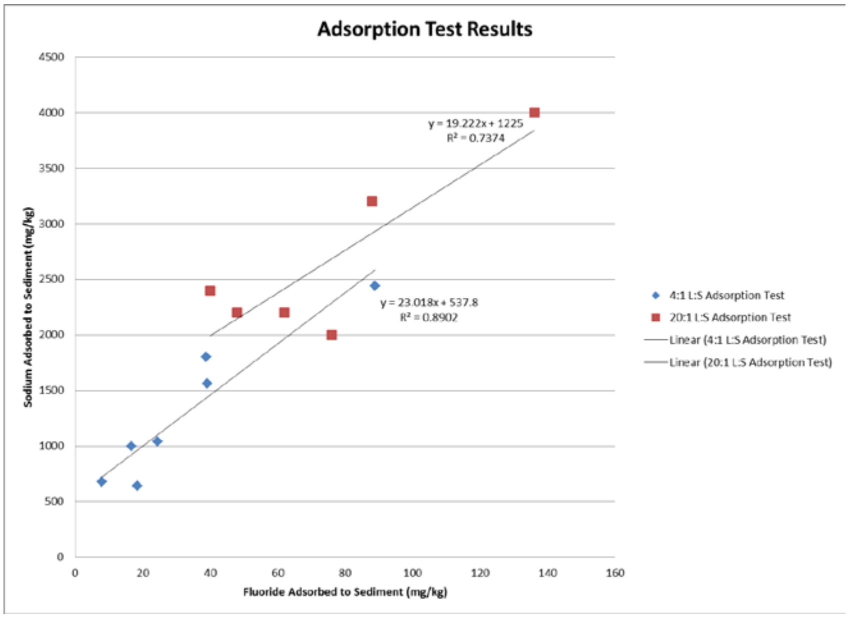


FIGURE 4-24. PH IN LEACHING TESTS

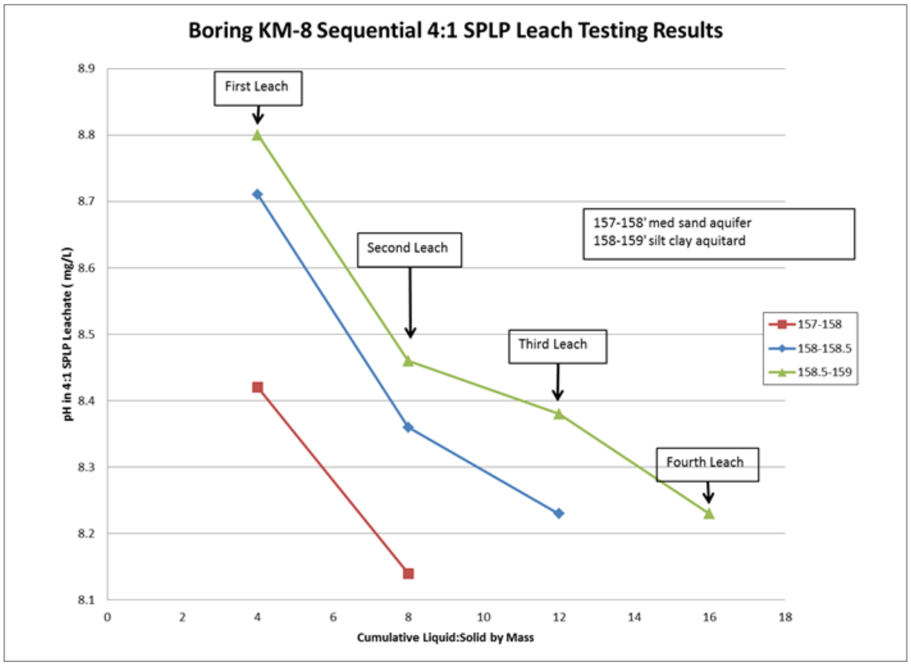
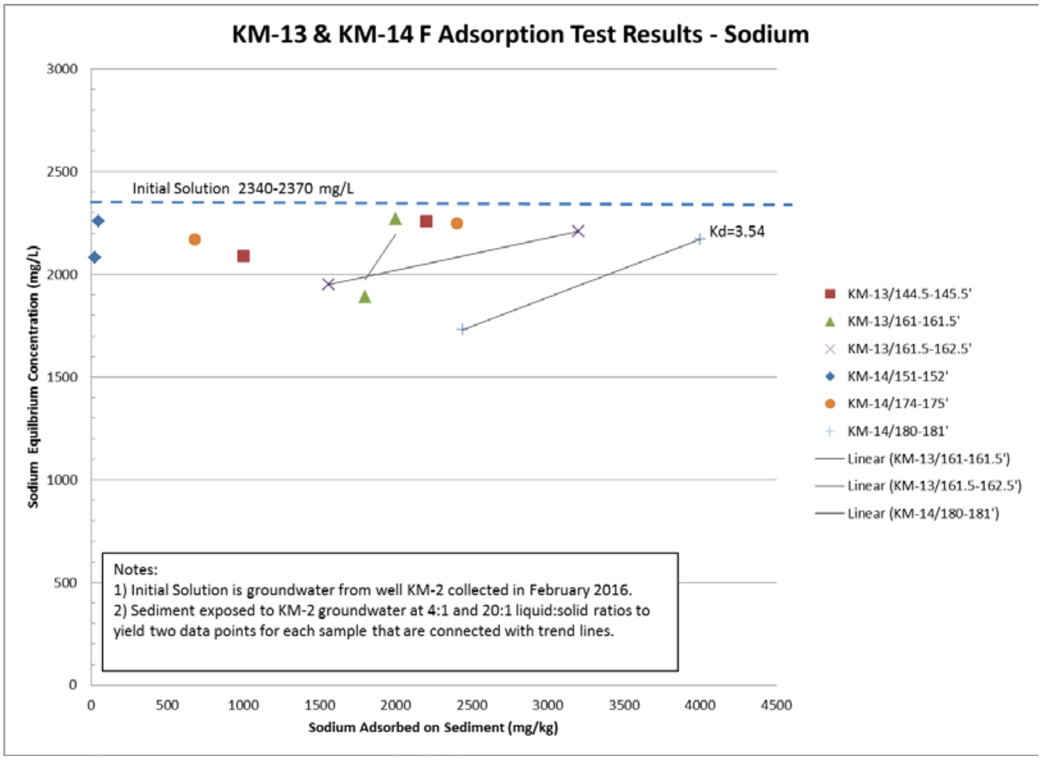


FIGURE 4-25. SODIUM ADSORPTION TEST RESULTS



Notes:
1) Initial Solution is groundwater from well KM-2 collected in February 2016.
2) Sediment exposed to KM-2 groundwater at 4:1 and 20:1 liquid:solid ratios to yield two data points for each sample that are connected with trend lines.

4.3.2.5 Sediment:Groundwater Partitioning and Mass Balance Models

Sediment leaching characteristics (leachable concentration and mass, partition coefficients) derived from testing of 2015/2016, sediments and groundwater flux estimates from the numeric groundwater model (Hydrometrics, 2017b) were used to develop a sediment:groundwater partitioning and mass balance models for fluoride and total cyanide. The fluoride and cyanide models are identical except for differences in sediment characteristics (e.g., Kd values and initial sediment concentrations) and initial groundwater concentrations Details regarding the models can be found in The draft Sediment:Groundwater Partitioning Model Report (Hydrometrics,(2017c) to this report. The conceptual model, rationale, assumptions and limitations of the model and model simulations for current conditions are summarized below, followed by a discussion of model simulations of “base case” or current conditions.

The purpose of the partitioning and mass balance model is to estimate the effects of leaching of fluoride and cyanide from saturated sediment on groundwater fluoride and cyanide concentrations. The model may also be used to evaluate the potential effects of other potential ongoing sources such as SPL pile leakage and the potential effects of corrective actions such as hydraulic controls and groundwater pumping and treating. Potential effects of SPL pile leakage is described in this report while potential effects of corrective actions will be described in the Supplemental Feasibility Study. The conceptual model that is the basis of the partitioning and mass balance model is that groundwater and sediment behave as observed in the sequential modified SPLP tests and that water and sediment concentrations are related through partition coefficients (Kd) for fluoride and total cyanide. In this conceptual model, as fluoride and cyanide-enriched sediment is exposed to cleaner groundwater (for instance in the SPL pile area where sediment is leached by clean groundwater from upgradient sources) the contaminants are leached from sediment into groundwater. Continuing flux of groundwater through the sediment carries contaminant mass out of the groundwater system and over time, contaminant concentrations in sediment and in groundwater in equilibrium with the sediment, decreases (as was observed in laboratory tests as shown in Figures above). Conversely, as sediment is exposed to more highly-impacted groundwater (for instance in the Compliance Wells area where sediments are exposed to upgradient groundwater with high fluoride and cyanide concentrations from the plume center) the contaminants are further enriched in sediment (as seen in laboratory adsorption tests) and over time groundwater concentrations in equilibrium with the sediments are increased.

The primary assumptions of the model are:

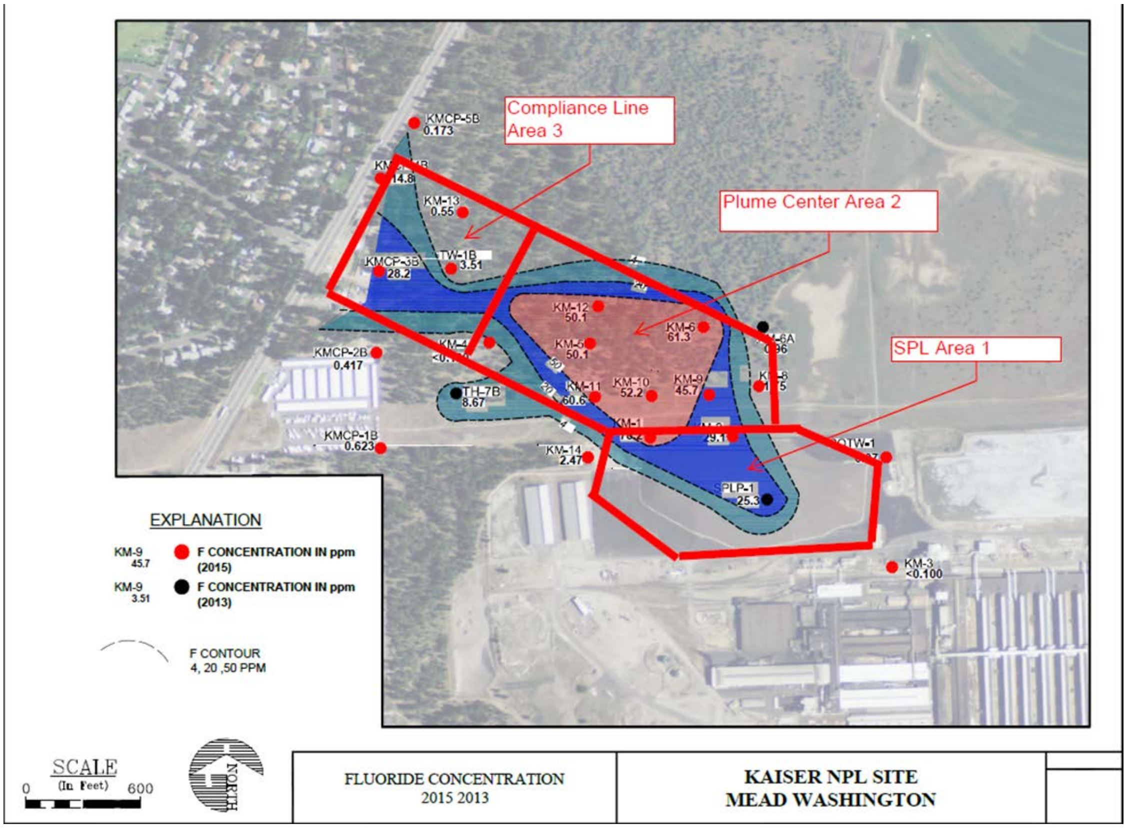
1. Sediment and groundwater partitioning in field conditions behave as observed in laboratory testing and are related through linear partition or distribution coefficients (Kd).
2. No other contaminant source except saturated sediment contributes to groundwater (sensitivity to the model to this assumption are evaluated and described below).
3. Instantaneous reaction and transport time for contaminants (i.e. the transport time from the SPL pile to Compliance Wells area of approximately 2 years is ignored).

The primary uncertainties/limitations of the model are:

1. Laboratory testing is likely not completely representative of field conditions. This uncertainty is partially addressed by calibration of the model to fit field observed groundwater.
2. Field data shows heterogeneity in sediment and groundwater concentrations, but the model is composed of three cells that are assumed to be homogenous and represented by average conditions within the cells. The ramification of this limitation is that the model is representative of average conditions in the cell but is not representative at every location within the cell and will over or under predict concentrations at specific points.

Model calculations are performed iteratively in a computer spreadsheet for the three model cells or areas – SPL Area, Plume Center Area, and Point of Compliance Area (Figure 4-26) for 100, 1-year time steps. Initial (Year 0) groundwater concentrations for each cell are set at the average groundwater concentration for the wells in each cell and initial sediment concentration is calculated based on the partition coefficient.

FIGURE 4-26. PARTITIONING MODEL CALCULATION AREAS



Model calibration for the partitioning model was achieved by adjusting and selecting initial input values for initial sediment fluoride and cyanide concentrations, fluoride leaching fraction, and Kd values within the observed ranges of measured values so that model base case simulations yielded predicted groundwater concentrations that approximated observed current and historic groundwater concentrations. Sensitivity of the model simulation results (outputs and predictions) to variations in input values was also evaluated during model development and calibration to identify key input parameters (parameters that most strongly affect model outputs; the parameters to which the results are most "sensitive") and to determine the amount of variations in output values caused by varying input values. Based on the sensitivity evaluation, leaching fraction (fluoride only) and Kd values were identified as the key input parameters and a range of input values for leaching fraction and Kd values were selected as representative of the potential uncertainty in input values to yield model output results that also reflect potential uncertainties.

Base case (i.e., assuming current conditions persist in the future with no further remedial actions) model predictions of future fluoride concentrations for the SPL, Plume Center, and Compliance Wells areas are shown on Figures 4-27 through 4-29. The model predicts that fluoride concentrations will decline slowly in all model calculation areas. Model estimates of the time to attain the fluoride cleanup level of 4 mg/L at the Compliance Wells range from 52 to 130 years. Base case model predictions of future total cyanide concentrations for the SPL, Plume Center, and Compliance Wells areas are shown in The draft Sediment:Groundwater Partitioning Model Report (Hydrometrics,(2017c). The model predicts that total cyanide concentrations will decline slowly in all model calculation areas. Model estimates of the time to attain the cleanup level of 0.2 mg/L free cyanide (6.6 mg/L total cyanide) at the Compliance Wells range from 33 to 80 years.

FIGURE 4-27. PARTITIONING MODEL ESTIMATES OF FUTURE FLUORIDE CONCENTRATIONS IN SPL AREA

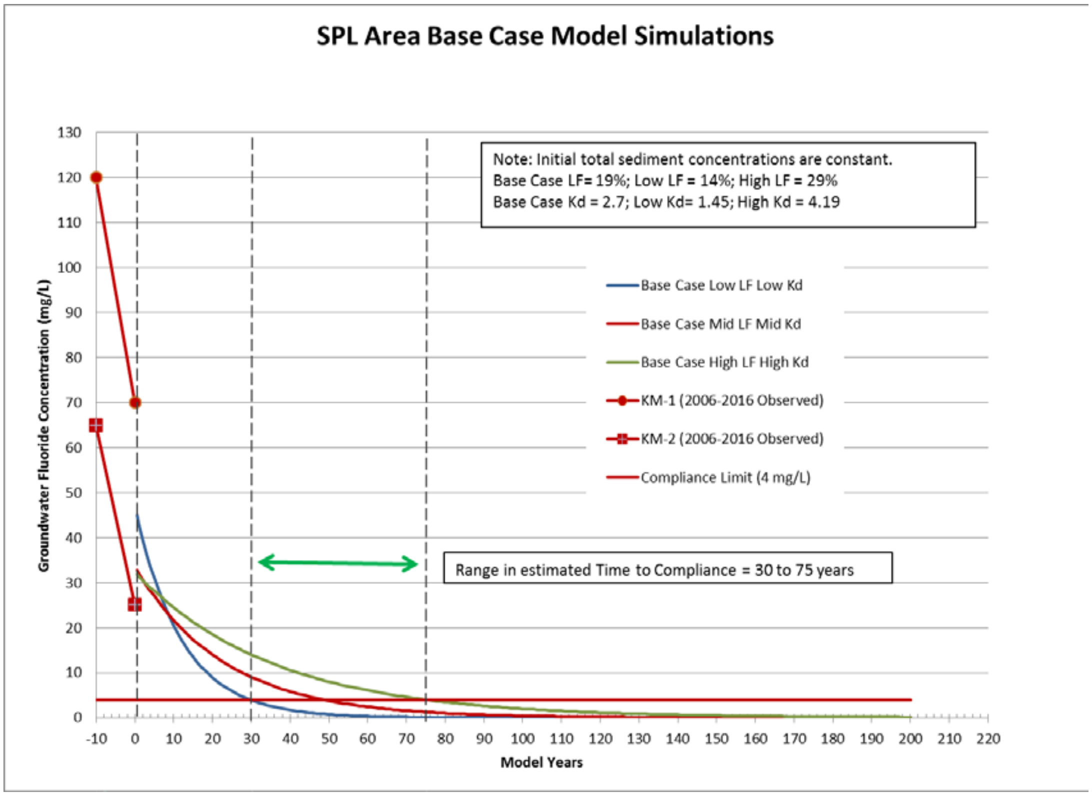
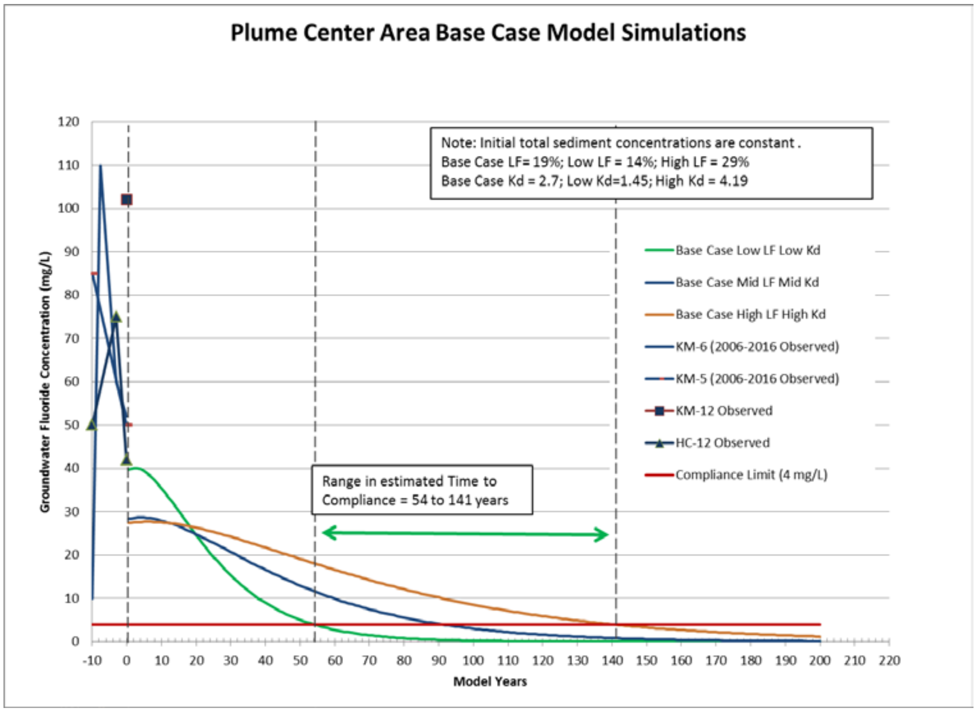


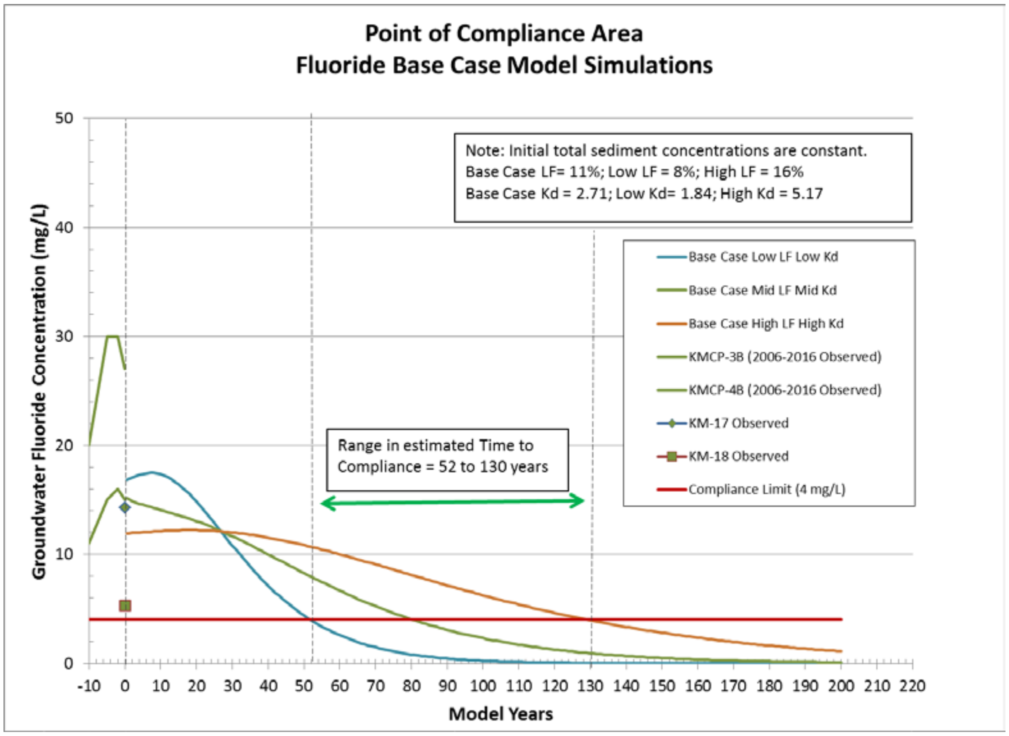
FIGURE 4-28. PARTITIONING MODEL ESTIMATES OF FUTURE FLUORIDE CONCENTRATIONS IN PLUME CENTER AREA



Note: Initial total sediment concentrations are constant.
Base Case LF= 19%; Low LF = 14%; High LF = 29%
Base Case Kd = 2.7; Low Kd=1.45; High Kd = 4.19

Range in estimated Time to Compliance = 54 to 141 years

FIGURE 4-29. PARTITIONING MODEL ESTIMATES OF FUTURE FLUORIDE CONCENTRATIONS IN COMPLIANCE WELLS AREA



One of the key model assumptions is that the sole source of fluoride and cyanide to groundwater is leaching from saturated aquifer sediment. If there were additional ongoing contributions of fluoride to groundwater from other sources, then the additional fluoride and cyanide would slow the leaching and flushing of contaminants from sediment, sustain higher groundwater concentrations in source area, and as a result the model would underestimate the time to cleanup levels at Compliance Wells. The sensitivity of the model to the assumption of no additional sources was evaluated by simulating additional source contributions in the vicinity of the SPL area. Base case model simulation results with and without assumed additional non-sediment sources are summarized in Table 4-3 and details of these evaluations are provided in The draft Sediment:Groundwater Partitioning Model Report (Hydrometrics,(2017c).

TABLE 4-3. SUMMARY OF BASE CASE SEDIMENT PARTITION MODEL SIMULATIONS AND ADDITIONAL SOURCE SENSITIVITY SIMULATIONS

	Estimated Range of Time to Cleanup Levels at Compliance Wells (Years)		
	Base Case Model (Sediment Source Only)	Base Case Model With Leaky SPL Cap	Base Case Model With No SPL Cap
Fluoride	52 to 130 years	54 to 132 years	68 to 180 years
Cyanide	33 to 80 years	35 to 81 years	38 to 94 years

1) Assumes the additional source is SPL in the capped SPL pile. SPL is present throughout the capped SPL pile (area of 10 acres). SPL leachate assumed to contain 925 mg/L fluoride and 700 mg/L total cyanide.

2) Leaky cap scenario: infiltration through the cap to groundwater is assumed to equal 0.1 inches/year over the 10-acre SPL pile (i.e., 27,152 gallons/year).

3)No Cap Scenario - Assuming the SPL Cap has catastrophically failed so that it performs as if there is no cap, infiltration through the cap to groundwater is assumed to equal 0.55 inches/year (2.8% of annual precipitation) over the 10-acre SPL pile (i.e., 149,388 gallons/year).

4.4 GROUNDWATER TO LINE OF COMPLIANCE WELLS

A mixed glacial outwash package of fine to coarse sands with minor gravel, and thin intervening layers of silt and clay underlie the Kaiser Mead site. In the lower portion of this sequence the sediments become coarser-grained and contain gravel, cobbles and boulders. The glacial outwash sequence is approximately 285 feet thick in the vicinity of the site and is underlain by a regional aquitard.

The stratigraphy in the area above the regional aquifer(s) is typically unsaturated and is predominantly made up of fine- to coarse-grained sand with intervening layers of thin/discontinuous silt/clay. Many boreholes and wells located in the vicinity of the SPL pile have encountered what has been historically described as a silt/clay lens between 50 and 60 feet below ground surface and referred to as the Shallow Aquitard or SAQ. See Figure 4-30 for locations of boreholes/wells used in developing cross-sections depicting the geology of the area. Cross-sections are shown in Figures 4-31, 4-32, and 4-33. Boreholes installed during 2011 and 2013, immediately to the north and east of the SPL pile encountered an interbedded layer of clay and very fine-grained sand ranging in thickness of about 1 to 4 feet. The clay/sand sequence typically consisted of thin (~0.2' thick), moist, low plasticity, stiff clays with very moist to saturated very fine sand and silts between the thin layers of clay. This leaky aquitard appears to be relatively continuous from east to west along the northern portion of the SPL pile and from north to south below the eastern portion of the pile, as shown in the F-F' and G-G' cross sections in Figures 4-31 and 4-33, respectively.

FIGURE 4-30. CROSS SECTION LOCATIONS

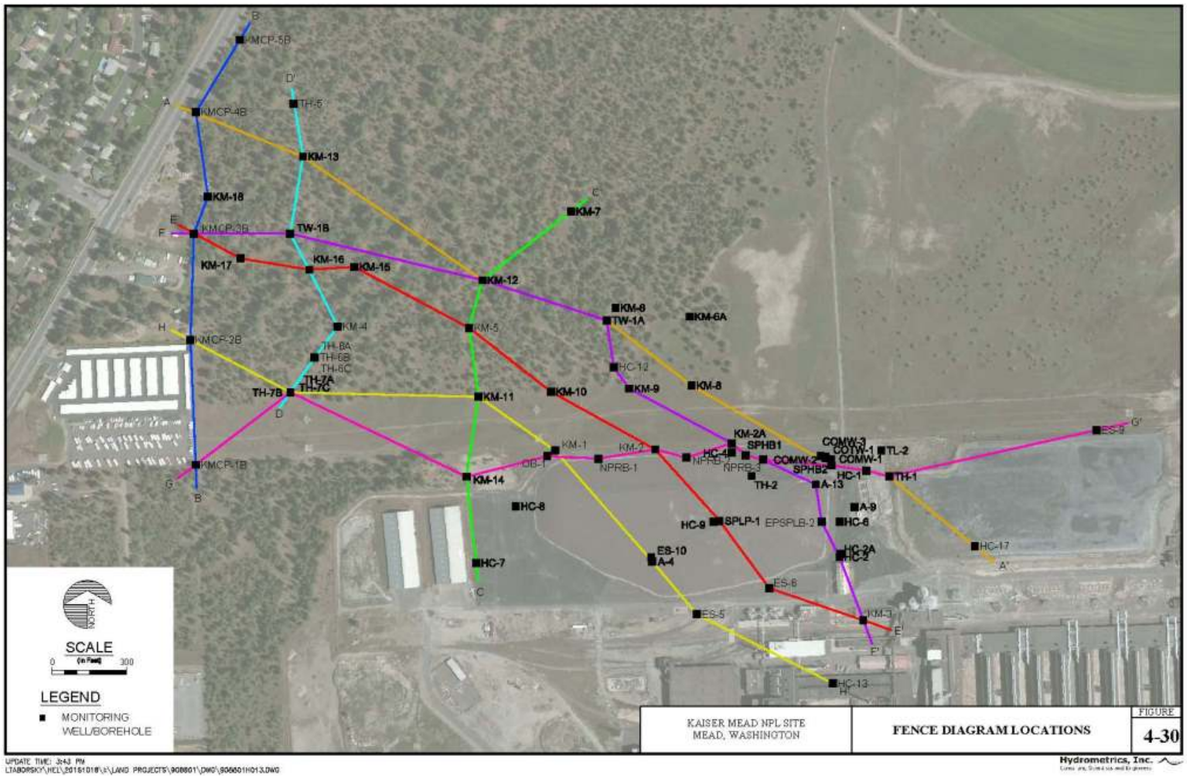


FIGURE 4-31. CROSS SECTIONS A-A’, B-B’, C-C’ AND D-D’

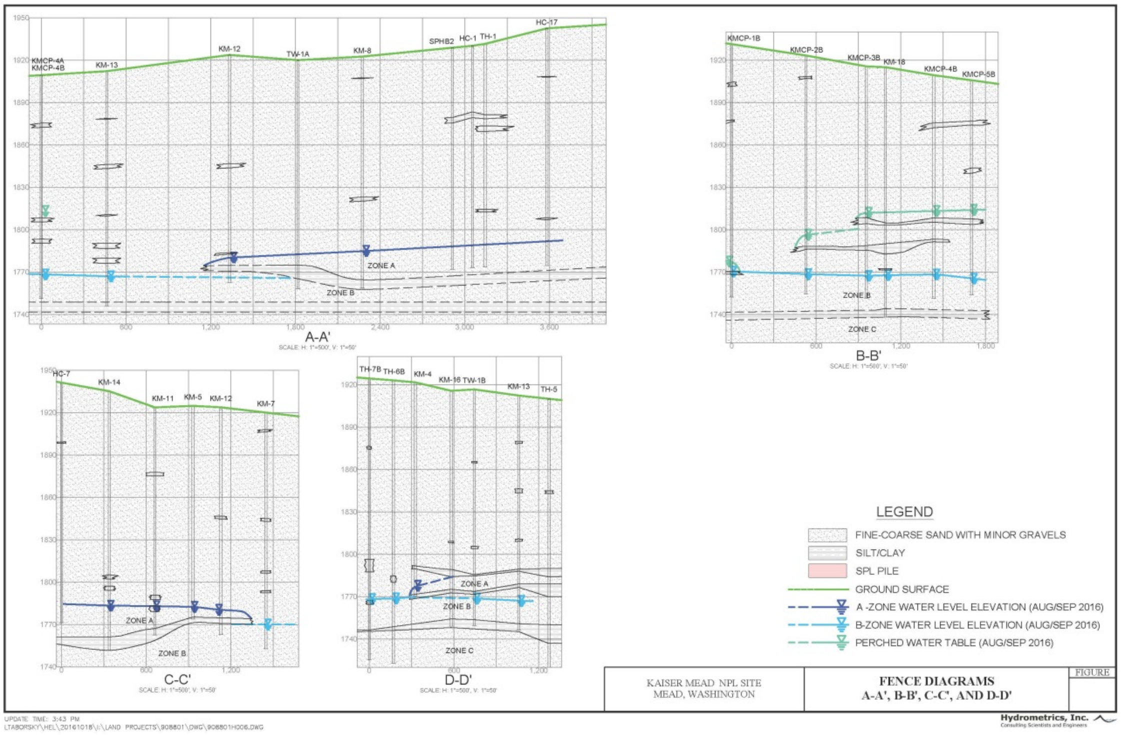


FIGURE 4-32. CROSS SECTIONS E-E’ AND F-F’

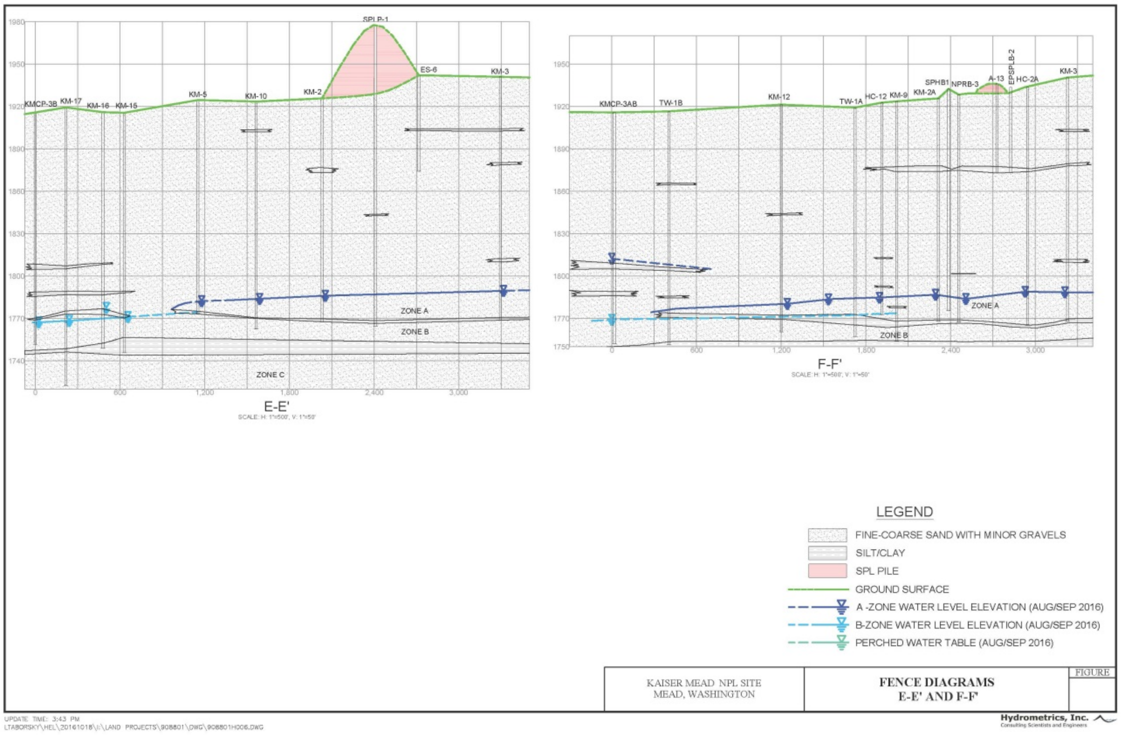
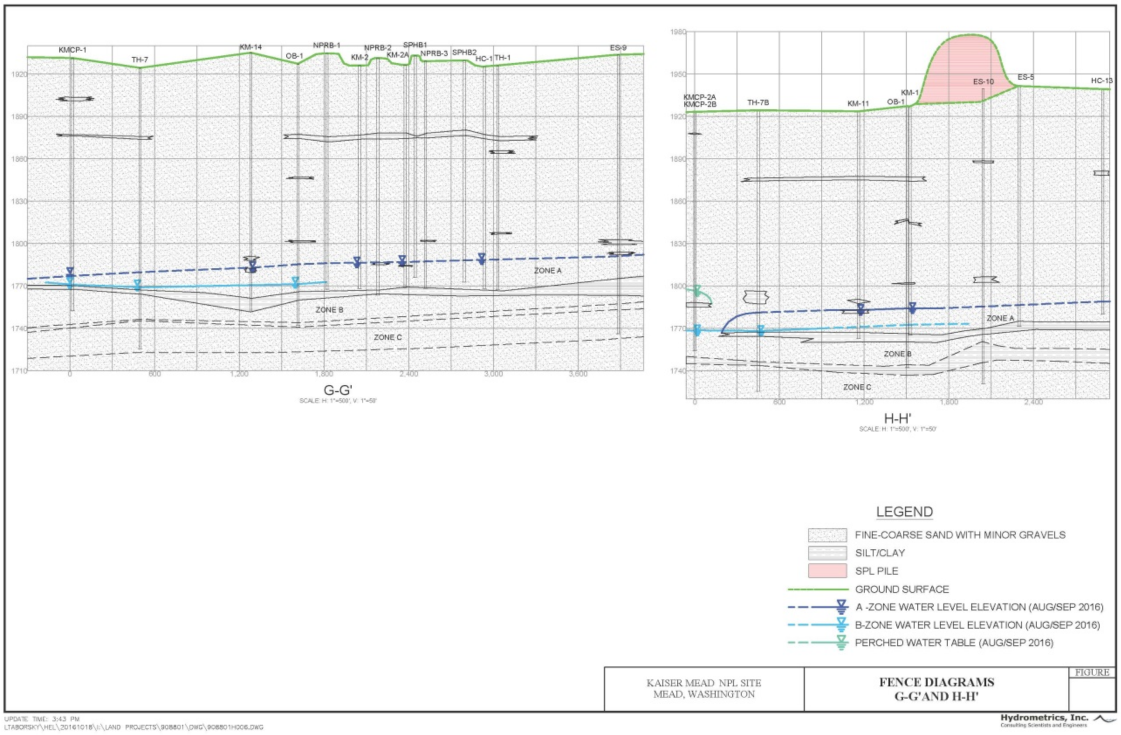


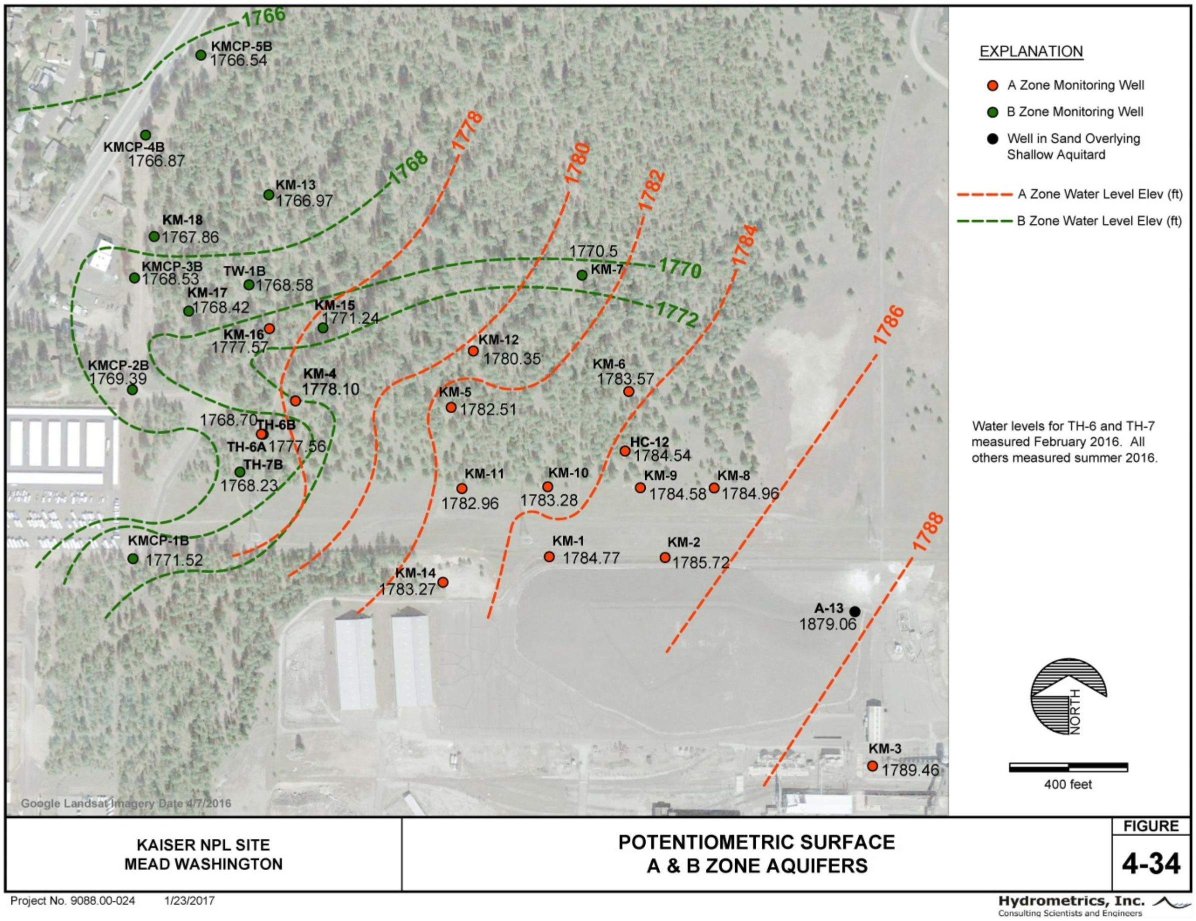
FIGURE 4-33. G-G’ AND H-H’



Previous investigators have divided the aquifer stratigraphy into three zones for purposes of defining contaminant transport at the site. The uppermost zone, A Zone, is composed of fine to coarse sand and/or medium to coarse sand with discrete zones of silt and very fine sand. A Zone is approximately 10 to 20 feet thick and underlain by a silt and clay layer (A/B aquitard) that is laterally discontinuous to the west. B Zone consists of fine sand, fine to medium sand, and/or medium to coarse sand, sometimes silty or with silt layers (MFG, 2000). The thickness of B Zone reported in boring logs ranges from 6 to 24 feet and is underlain by a silt/clay layer (B/C aquitard). C Zone consists of fine to medium sands or fine to coarse sands with some gravel. Sediments in the lower half of C Zone are cleaner and coarser-grained containing coarse sand and fine to coarse gravel with boulders. C Zone is reported to be up to 100 feet thick, however, the monitoring wells on the site typically only penetrate 10 to 25 feet into C Zone. To the northwest of the site, near the downgradient border, there is a perched groundwater system that appears to be a source of un-impacted groundwater to the A Zone aquifer near well KM-4.

Groundwater flows to the northwest in the A Zone aquifer as shown in Figure 4-34. There is a more northerly trend in the immediate vicinity of the SPL pile. The average gradient across the A Zone aquifer is approximately 0.005, the hydraulic gradient is more flat in the vicinity of the SPL pile (0.003) and more steep near KM-4 (0.01). The clay aquitard underlying the A Zone aquifer is discontinuous in the vicinity of KM-4, allowing A Zone water to infiltrate to the B Zone aquifer. General groundwater flow direction in the B Zone aquifer is to the west and northwest in the northeast portion of the facility and to the north in the western portion of the facility. Hydraulic gradient in the B Zone aquifer ranges from 0.003 to 0.007 with the highest hydraulic gradient near KMCP-1B and the lowest gradient near KMCP-3B. There is a general downward vertical hydraulic gradient between the A Zone and B Zone aquifers. Well TH-6C was the only C Zone aquifer well that was monitored in May 2013; data from this well shows a downward hydraulic gradient from the A Zone to the C Zone aquifer.

FIGURE 4-34. 2016 POTENTIOMETRIC SURFACE, A AND B ZONE AQUIFERS



Aquifer testing has been conducted on wells within all three aquifer zones. The range of hydraulic conductivities for each zone is summarized in Table 4-4. The hydraulic conductivity at HC-12 (0.5 ft/day) is much lower than other A Zone wells. Well HC-12 is completed in silty sand and illustrates that lower permeability zones are present in the A Zone aquifer. The higher permeability sands appear to make up a majority of the aquifer and are where most of the groundwater flow and contaminant transport takes place. The B Zone aquifer appears to be slightly more permeable than the A Zone aquifer.

TABLE 4-4. SUMMARY OF MEASURED HYDRAULIC CONDUCTIVITIES OF MAJOR AQUIFER ZONES

Aquifer Zone	Hydraulic Conductivity (ft/day) Range	Wells Tested
A Zone(1)	0.5[1]-300	ES-9, ES-10, KM-1, HC-2A, HC-12, KM-2, TH-8, & COTW-1
B Zone	270-640	KMCP-1B, OB-1, & TW-1B
C Zone	130	TH-6C

Note: Data sources: Aquifer Characterization and Groundwater Capture Analysis (Hydrometrics, 2013a)

1. HC-12 represents lower permeability heterogeneities in the aquifer and does not represent the aquifer properties most of the contaminants move through.

The groundwater flux and velocity through the plume area can be calculated based on the data presented above and an assumed porosity of 0.3. Table 4-5 summarizes the estimated flux and velocity for A and B Zone.

TABLE 4-5. SUMMARY OF GROUNDWATER FLUX AND VELOCITY ESTIMATES

Aquifer Zone	Thickness (ft)	Plume Width (ft)	K Range (ft/day)	Gradient	Flow Range (gpm)	Velocity (ft/day)
A Zone	12	1050	75-300	0.005	25-98	1.3-5
B Zone	18	750	270-640	0.005	95-224	4.5-10.7

5.0 REFERENCES

Anchor Environmental, 2014. Draft Remedial Investigation and Feasibility Study – Former Reynolds Metals Reduction Plant – Longview. Submitted by Anchor QEA, LLC on behalf of Northwest Alloys, Inc. and Millennium Bulk Terminals – Longview, LLC.

Arnesen and Krogstad, 1998. Sorption and Desorption of Fluoride in Soil Polluted from the Aluminum Smelter at Ardal in Western Norway. Water, Air and Soil Pollution 103:357-373. Gupta et al, 1982; Fluorine Adsorption Behavior in Alkali Soils: Relative Roles of pH and Sodicity. Soil Science Bulletin 133 No 6. Bouwer and Hatcher, 1966; Adsorption of fluoride by soils and minerals. Soil Sci 103:3.

Bouwer and Hatcher, 1966; Adsorption of fluoride by soils and minerals. Soil Sci 103:3.

Dzombak, DA, RS Ghosh, and GW Wong-Chong, 2006. Cyanide in Water and Soil – Chemistry, Risk, and Management. CRC Press, Boca Raton, 602 p.

EPA, 1978. US EPA Region X Laboratory, Kaiser Potlining Leachate Analysis, December 22, 1978; reported in March 12, 1979 letter from EPA to Spokane Health District and presented in Table 1 in Hart Crowser (1988).

Ecology, 2002. Washington Department of Ecology, Cleanup Action Plan, Kaiser Aluminum National Priorities List Site, Mead, Washington. May 1, 2002.

Ecology, 2016. Ecology Review of Measurement of Cyanide in Determining Compliance with Groundwater Cleanup Levels at Kaiser Mead Site, FSID #3. Letter from Guy Barret (Ecology Site Manager) to Dan Silver (Custodial Trustee, Mead Custodial Trust), October 31, 2016.

Ghosh, R.S., D.A. Dzombak, and R.G. Luthy, 1999. Equilibrium Precipitation and Dissolution of Iron Cyanide Solids in Water. Environmental Engineering Science, Vol. 16, Number 4, 1999.

Gupta et al, 1982; Fluorine Adsorption Behavior in Alkali Soils: Relative Roles of pH and Sodicity. Soil Science Bulletin 133 No 6.

Hart Crowser, 1988. Site Characterization Analysis, KACC – Mead Plant. Prepared for Kaiser Aluminum & Chemical Corporation, December, 1988.

Hydrometrics, Inc., 2011a. Kaiser Mead NPL Additional Site Investigations Project Report. Hydrometrics, Inc. June 2011.

Hydrometrics, Inc., 2011b. Kaiser Mead NPL Data Gap Investigation Project Report. December 2011.

Hydrometrics, Inc., 2013a. Aquifer Characterization and Groundwater Capture Analysis. June 2013.

Hydrometrics, Inc. 2013b. Data Report on Additional Field Characterization for the Kaiser Mead Facility. Draft. December 2013.

Hydrometrics, Inc., 2017a. Draft Data Report on Additional Field Characterization for the Kaiser Mead Facility. Hydrometrics, Inc. March 2017.

Hydrometrics, Inc. 2017b. Draft Groundwater Model Report, Kaiser Mead NPL Site, Mead, Washington. Prepared for Mead Custodial Trust. March 2017.

Hydrometrics, Inc. 2017c. Draft Sediment:Groundwater Partitioning and Mass Balance Model Report, Kaiser Mead NPL Site, Mead, Washington. Prepared for Mead Custodial Trust. March 2017.

MFG, Inc., 2000. SPL Remediation Engineering Design Report, Kaiser Aluminum & Chemical Corporation, Mead, Washington, November 30, 2000.

MFG, Inc., 2004. Supplemental Groundwater Modeling Report Kaiser Aluminum & Chemical Corp. Mead, Washington. Draft January 29, 2004.

Rennert, T and T Mansfeldt, 2002. Sorption of Iron-Cyanide Complexes in Soils. Soil Sci. Soc, Am. J. 66:437-444.

APPENDIX F

SEDIMENT:GROUNDWATER PARTITIONING AND MASS BALANCE MODEL

KAISER MEAD
SEDIMENT:GROUNDWATER PARTITIONING AND MASS BALANCE MODEL

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

KAISER MEAD
SEDIMENT:GROUNDWATER PARTITIONING
AND MASS BALANCE MODEL

1.0 INTRODUCTION

1.1 PURPOSE AND SCOPE OF REPORT

This report documents the Sediment:Groundwater Partitioning and Mass Balance Model (partitioning model or PM) developed to simulate behavior of fluoride (F), total cyanide ((TCN) and free cyanide through a conversion factor) in the aquifer sediment:groundwater system at the Kaiser Mead site. The conceptual model for the PM is based on the Conceptual Site Model (CSM) for the Kaiser Mead site and in particular results of laboratory-based testing of sediment:groundwater partitioning experiments (leach and desorption testing of sediments and site groundwater). The PM is a relatively simple spreadsheet-based model (Excel) that performs a series of partitioning and mass-balance calculations to simulate transfer of fluoride and total cyanide from groundwater to sediment, and vice versa, with removal of groundwater fluoride and total cyanide mass by groundwater flow. Although there are two separate models for fluoride and cyanide, the conceptual and mathematical formulations of the models are identical. The only differences between the models are the input variables (i.e., leachable fraction, partition coefficient, and sediment fluoride and cyanide concentration) which differ for fluoride and cyanide.

Primary input data to the model includes sediment total fluoride concentration, sediment leachable fluoride fraction, sediment leachable total cyanide concentration, sediment:groundwater partition coefficients (or distribution coefficient, Kd) for fluoride and total cyanide, volume and mass of aquifer sediment, and groundwater flux. The model was calibrated to observed current and historic groundwater fluoride and total cyanide concentrations. Primary model input sensitivities are sediment total and leachable fluoride and cyanide concentrations and partition coefficients. Principal model assumptions and uncertainties are that laboratory-measured sediment characteristics are representative of actual site conditions and that there are no additional contaminant sources other than sediment.

This report describes the base case models for fluoride and cyanide which describes existing conditions and include two user-selected variables (“fraction of ambient flux after hydraulic control” and “pumping rate”) that can be used to simulate conditions where groundwater flux through areas of the site is reduced through corrective actions such as a grout wall or pumping from areas within the contaminant plume. In addition to the base case scenarios, this report also describes model simulations of the effects of a grout wall surrounding the SPL and Plume Center (PC) areas and groundwater pumping from two locations, the Point of Compliance (POC) and PC areas.

1.2 PURPOSE OF MODEL

The partitioning model was developed to:

1. Evaluate and understand site data and observations, in particular fluoride and cyanide concentration patterns and trends in groundwater and sediment;
2. Predict future fluoride and cyanide concentration patterns and trends; and
3. Evaluate the effects of future changes to the sediment:groundwater system (e.g., various potential remedial actions that might change groundwater flux, such as grout wall barriers or other hydraulic controls and pumping and treatment of contaminated groundwater) on future groundwater and sediment fluoride and cyanide concentrations.

2.0 CONCEPTUAL MODEL

2.1 BASIS OF CONCEPTUAL MODEL

The conceptual model for the PM is based on the CSM for the Kaiser Mead site and in particular results of laboratory testing of sediment:groundwater partitioning experiments (leach and desorption testing of sediments with site groundwater). The foundational assumption of the PM conceptual model is that groundwater and sediment behave as observed in sequential batch leaching tests of sediment. Sequential batch leaching tests consisted of leaching of sediments with un-impacted groundwater collected upgradient of the site following a modified version of EPA Method 1312 (Synthetic Precipitation Leaching Procedure, or SPLP). The primary conclusions and observations from the lab testing are:

1. Fluoride/cyanide concentrations in groundwater were found to be related to, or a function of, the fluoride/cyanide concentration of the sediment with which the groundwater is in contact. Thus, fluoride and cyanide are found to partition between the sediment and groundwater as a function of sediment and groundwater concentrations. The factor relating sediment and groundwater concentrations is termed the partition or distribution coefficient commonly symbolized or referred to by the variable “Kd.” Figures 2-1 and 2-2 show the observed partitioning relationship curve and corresponding Kd values for sediment samples from one boring that are typical of the lab test results. Measured Kd values for aquifer sediment samples collected at Kaiser Mead are described in Section 4.3 of this report.
2. When exposed to clean (low F and TCN) groundwater collected from well KM-3 located upgradient of the historic primary source areas, impacted (high F and TCN) sediments were found to leach, or release fluoride and cyanide, to groundwater, thus raising the fluoride and cyanide concentrations in groundwater and reducing fluoride and cyanide concentrations in sediment. With repeated exposures of the sediment to clean groundwater, concentrations of fluoride and cyanide in both sediment and groundwater are further reduced as fluoride and cyanide mass is flushed from the sediment:groundwater system. These experiments mimic what is occurring in the groundwater system by the natural flux of clean groundwater through the impacted

sediments. Figures 2-3 and 2-4 show the observed leaching curves for one sediment sample that is typical of the lab test results.

3. When exposed to impacted (high F and CN) groundwater collected from well KM-2 located in the PC area, clean (low F and CN) sediments were found to adsorb, or remove fluoride, from groundwater, thus reducing the fluoride concentration in groundwater and increasing fluoride concentration in sediment. Figure 2-5 shows the observed adsorption curves for sediment samples collected in 2015. In the laboratory tests, sediment samples from borings KM-13 and KM-14 (located outside the groundwater fluoride plume) were exposed to groundwater from KM-2 that had 75 mg/L fluoride (represented by the initial groundwater concentration line shown on Figure 2-5) at two different liquid:solid ratios (4:1 and 20:1). After equilibration with sediment, groundwater fluoride concentrations (data points connected by lines) were decreased, indicating adsorption and removal of fluoride from solution by sediment. Adsorption test results for total cyanide are shown in Figure 2-6. Similar to fluoride, test results for total cyanide (Figure 2-6) indicate adsorption by sediment (i.e., exposure of high cyanide groundwater to sediment results in reduction in cyanide concentrations in groundwater).
4. Testing of site sediment samples indicates that only a portion of the total fluoride in sediment (typically 5% to 30%) is readily available for leaching or partitioning with groundwater. All un-impacted sediments, soil, and rocks contain some natural fluoride, typically from natural fluoride-bearing minerals, and normal mineral soils average 200 to 300 ppm (mg/kg) fluoride (EPA, 1980). The non-leachable fraction of the sediment fluoride is believed to be predominately composed of naturally-occurring fluoride minerals in the aquifer sediments, whereas the leachable fraction is composed of sorbed fluoride that is predominately the result of sorption of fluoride from contaminated groundwater.
5. Total cyanide concentration of sediment was measured by three methods, by analysis of sediment by EPA Method 9012B (acid extraction), by analysis of sediment by EPA Method 9013A (alkaline extraction followed by 9012B analysis of extract; 2016 sediment testing only) and by summation of the cumulative amount of total cyanide leached in the all of the sequential extractions. The Method 9013A and cumulative

leached total cyanide methods yielded similar sediment concentrations and both methods yielded significantly higher sediment concentrations than Method 9012B, indicating poor recovery by Method 9012B. For model purposes, the cumulative leached total cyanide concentrations were selected because there is more available data by this method (2015 and 2016 sediment data) than by Method 9013A. Since all of the cyanide measured by this method was leachable, the leaching fraction for total cyanide is assumed to be 1.

Because the cyanide partitioning model does not estimate free cyanide concentrations, a total cyanide:free cyanide conversion factor or ratio is needed in order to compare estimated concentrations to compliance levels. Throughout nearly all the period that monitoring has been conducted at the Site (2005-2014), free cyanide concentrations have not been measured in groundwater and WAD cyanide has been measured as a surrogate for free cyanide concentrations. Recent monitoring (2015-2016) indicates that groundwater free cyanide concentrations are slightly less than WAD cyanide concentrations. Ratios of total cyanide to WAD and free cyanide observed in POC monitoring wells KMCP-3 and KMCP-4 are shown in Table 2-1. The selected conversion factor is that free cyanide concentrations are 3% of total cyanide concentrations (1:33 free to total cyanide). This factor is calculated based on the ratios of free cyanide to total cyanide observed in groundwater in POC monitoring wells KMCP-3B and KMCP-4B during 2015-2016. As total cyanide to free cyanide ratios are variable with location in the groundwater contaminant plume and vary over time, the selected conversion factor may over- or under-estimate free cyanide concentrations at specific locations and times.

2.2 SUMMARY OF CONCEPTUAL MODEL

The conceptual model is:

1. Groundwater (aqueous phase) and sediment (solid phase) fluoride and cyanide concentrations are related by a partitioning relationship through a partition or distribution coefficient (Kd). The partitioning relationship is represented by the equation (Freeze and Cherry, 1979):

   $$Kd = \frac{\text{Concentration of fluoride in solid phase sediment}}{\text{Concentration of fluoride in liquid phase groundwater}}$$

2. The partitioning relationship is an equilibrium relationship whereby fluoride/cyanide concentrations of sediment and groundwater in contact with one another quickly and reversibly adjust or change to equalize with the partitioning coefficient (i.e., fluoride/cyanide is leached from, or sorbed to sediment to attain the ratio of sediment to groundwater concentrations equaling the Kd).
3. Sediment and groundwater comprise a closed system for fluoride/cyanide mass (i.e., leaching or loss of fluoride/cyanide from sediment is accompanied by an equal gain of fluoride/cyanide to groundwater; and conversely sorption of fluoride/cyanide to sediment is accompanied an equal loss of fluoride/cyanide from groundwater); with the exception that fluoride/cyanide is continually removed from the system by the groundwater into and flow out of the system.
4. Fluoride in sediment is composed of two fractions – a leachable fraction that readily partitions with groundwater and may be leached and removed from the sediment by groundwater flow through the aquifer; and a non-leachable fraction that does not partition and is not available for leaching and removal by groundwater flow. Total cyanide in sediment is assumed to be fully leachable.
5. Groundwater flows from the SPL area to the PC Area, from the PC to the POC area, and then flows out of the POC, removing fluoride and cyanide mass from the system (see Figure 2-7 and Figure 3-2 in Section 3.4).
6. The model does not predict the sediment:groundwater partitioning and contaminant concentrations downgradient of the POC.

Examples of how this partitioning relationship affects sediment and groundwater concentrations and transfer of fluoride between sediment and groundwater for three common scenarios are summarized in Table 2-2 and further described as follows (note that the example scenarios apply to cyanide as well as fluoride but discussion of cyanide is omitted for simplicity):

1. Equilibrium Scenario - When groundwater and sediment fluoride concentrations are at the ratio defined by the partition coefficient, groundwater and sediment are in equilibrium and there is no exchange of fluoride between the media. For example, for a Kd of 3 L/kg, sediment containing 3 mg/kg leachable fluoride would be at equilibrium with groundwater containing 1 mg/L. Equilibrium can also exist at higher or lower sediment concentrations (e.g., sediment 30 mg/kg and groundwater 10 mg/L) as long as the ratio equals the Kd value of 3. Under these equilibrium conditions there would be no partitioning exchange of fluoride between sediment and groundwater as long as the ratio equals the Kd value of 3.
2. Adsorption Scenario - As impacted groundwater (relatively high fluoride concentrations) flows through “cleaner” (relatively un-impacted sediment such that sediment F/groundwater F ratio is lower than Kd), fluoride is adsorbed onto sediment (F concentration and mass in sediment increases) to establish equilibrium with the groundwater per the Kd, resulting in some reduction of fluoride mass and concentration in the groundwater. This scenario likely describes conditions in the early history of the site where fluoride-rich process waters were released and allowed to infiltrate and flow through relatively clean sediments in the underlying vadose zone and saturated aquifer sediments. Over time, this process caused enrichment of the sediments in fluoride. This scenario is also occurring in areas of the Site that are distant from the primary historical contaminant sources in SPL pile area such as the POC area. Although sediments in the POC area are now impacted they may yet be exposed to ever increasing groundwater fluoride concentrations so that fluoride transfer from groundwater to sediment may still be occurring.
3. Leaching Scenario - As relatively clean groundwater flows through relatively impacted sediment (i.e., sediment F/groundwater F ratio is higher than Kd), fluoride

is leached from sediment into groundwater and as a result the fluoride concentration of groundwater is increased. This scenario describes conditions in the SPL and PC areas where impacted sediments are being rinsed by the flow of cleaner groundwater from upgradient areas. The fluoride leached from the sediment is removed by groundwater flow and with continued leaching and loss of fluoride over time, the mass and concentration of fluoride in sediment are gradually reduced. Over time with continued leaching, the groundwater concentration in equilibrium with the lower fluoride concentration sediment also decreases, so that both sediment and groundwater concentrations decrease over time and eventually will approach natural background levels.

3.0 MODEL INPUT DATA

3.1 PHYSICAL BOUNDARIES OF THE MODEL

The physical boundaries of the model were chosen to approximate the groundwater contaminant plume, areas of known contaminated sediments including the SPL, PC, and POC areas, and approximate boundaries of potential hydraulic controls such as grout walls. Fluoride concentrations in groundwater are shown in Figure 3-1. The selected model boundaries are shown on Figure 3-2. The model boundary was further divided into three model calculation areas (SPL Area, PC Area, and Point of Compliance or POC Area). In each calculation area, sediments are assumed to have the same characteristics (see description of input data for each area below). The model boundaries do not include off-Site areas downgradient of the POC. Fluoride that is transported past the POC likely partitions with sediment downgradient in much the same way as it does on-Site.

3.2 AQUIFER VOLUME AND MASS

Aquifer volume is defined as the volume of saturated sediment within the model boundary for each model calculation area. Aquifer saturated volumes for each model calculation area were derived from the Numeric Groundwater Model (Hydrometrics, 2017) and are summarized in Table 3-1. Aquifer sediment mass and the pore volume (i.e., volume of water in the saturated aquifer volume) of each area (Table 3-1) were calculated assuming a bulk dry density of 2,050 kg/m^3 and particle density of 2.65 g/cm^3 (typical for most mineral soils, Freeze and Cherry, 1979).

3.3 GROUNDWATER VOLUME AND FLUX

Total ambient groundwater flux values for each model calculation area were derived from the Numeric Groundwater Model (Hydrometrics, 2017) and are summarized in Table 3-2. The approximate doubling of flow between the PC and POC areas is due to the disappearance of the A and B zone aquitard between the two areas that allows the A and B zone aquifers to combine in the POC area (see Groundwater Model Report for further discussion).

3.4 INITIAL SEDIMENT CONCENTRATION AND MASS

Initial sediment concentrations for the three model calculation areas (summarized in Tables 3-3 and 3-4) are based on total fluoride (EPA Method 340) and cumulative sequential extraction leached total cyanide concentrations measured from aquifer sediment samples collected in 2013 through 2016 from borings in the SPL, PC and POC areas. No sequential extraction tests were run on SPL area sediments, therefore, SPL area total cyanide concentrations are assumed to be equal to the PC area.

During model development and calibration (see calibration discussion in Section 5), initial model simulations used average sediment fluoride and total cyanide concentrations for each boring, and averages of all borings in each calculation area to represent the three calculation areas. However, the fluoride model simulations did not match the calibration targets (observed groundwater concentrations) well. Moreover, it is recognized that there are relatively few (4 to 5) borings in each approximately 20-acre model calculation area and that data from the borings may not completely characterize sediment concentrations throughout the calculation areas. Therefore, initial sediment fluoride concentration values were shifted upward slightly from the calculated average values for the PC area to better match the calibration targets.

3.5 SEDIMENT LEACHABLE FLUORIDE FRACTION

Sediment leachable fluoride fractions for each model calculation area (Table 3-5) were derived from laboratory sequential leaching tests of sediment samples collected from borings within the fluoride plume in 2015 and 2016. Leaching fraction was calculated as the cumulative fluoride leached in the sequential leach tests (mg/kg) divided by the total fluoride concentration (i.e., Method 340 fluoride).

3.6 PARTITION COEFFICIENTS

Partition coefficients or Kd values for the three model calculation areas were derived from the laboratory sequential leach testing of sediment samples from borings completed in 2015 and 2016 in the PC and POC areas. Measured Kd values for sediment samples are provided in Tables 3-6 and 3-7. Kd values for each sediment sample were calculated by three different methods:

1. Slope (Adsorption Isotherm) of all sequential extraction test steps (i.e., ΔSediment concentration/Δwater concentration for all sequential extraction steps);
2. Kd of individual extraction test step (i.e., Sediment concentration/water concentration for individual extraction steps); and
3. In Situ Kd (Sediment concentration/groundwater concentration measured in monitoring well completed).

Multiple Kd calculation approaches were performed in order to consider the effect of calculation method on the Kd values and to derive as much information as possible from the available test data. The slope or isotherm method is appropriate and recommended in EPA guidance (EPA, 1992) when there are sufficient adsorption test data points (minimum of two, preferably more) to define an adsorption curve. The individual extraction test method is advantageous because it is not reliant on linear regression or curve fitting to define the adsorption relationship and can be used with as few as 1 data point, as was the case for cyanide in some leaching test results. The in situ Kd approach is not reliant on leach testing results and so provides a comparison for evaluation of leach test derived Kd values.

From the individual sample Kd values calculated by the various methods, median and average Kd values were then calculated for the each model area. From these statistical values, high, low, and mid-range values were then chosen for model calibration and sensitivity analyses (see Section 5).

3.6.1 Fluoride

Mid-range fluoride Kd values for the PC area and POC area were assumed to equal the median values for saturated sand intervals (shown in bold in Table 3-6) in the borings calculated by the slope method; 2.7 L/kg for both the PC and POC areas. Sand intervals were chosen as most representative because the majority of groundwater flow occurs through the more permeable intervals and selection of these Kd values resulted in better model calibration with observed groundwater concentrations. There is no available sequential leach test data for sediments in the SPL area; therefore, the Kd value for the SPL area is assumed to be equal to the PC area (mid-range of 2.7 L/kg).

High range Kd values were assumed to equal the overall median values for all samples (clay, silt, and sand) calculated by the slope method; 5.17 L/kg for the POC area and 4.19 L/kg for the PC and SPL areas. Since the high range Kd values include silt and clay samples as well as sand, the high case may represent a condition where contributions from the fine grained sediments more strongly controls groundwater concentration. Low range Kd values were assumed to equal the overall median values for sand interval samples calculated by the individual extraction step approach: 1.84 L/kg for the POC area and 1.45 L/kg for the PC and SPL areas.

3.6.2 Cyanide

Similar to fluoride, mid-range total cyanide Kd values for the PC area and POC area were assumed to equal the median values for saturated sand intervals (shown in bold in Table 3-7) in the borings; calculated by the slope method; 1.67 L/kg for the PC and 1.46 L/kg for the POC areas. There is no available sequential leach test data for sediments in the SPL area; therefore, the Kd value for the SPL area is assumed to be equal to the PC area (mid-range of 1.67 L/kg).

Unlike fluoride, for cyanide the high range Kd values were assumed to be equal to twice (2x) the mid-range values (2.92 L/kg for POC area, and 3.34 L/kg for PC and SPL areas). This approach was chosen because the overall median values for all samples (clay, silt, and sand) calculated by the slope method were very similar to the mid-range values and a larger spread in values was desired for sensitivity and calibration purposes. Similarly, Low range Kd values were assumed to equal one-half (0.5x) the mid-range: 0.73 L/kg for the POC area and 0.84 L/kg for the PC and SPL areas.

4.0 MATHEMATICAL FORMULATION OF MODEL

The PM is a relatively simple spreadsheet-based model in Excel software format that performs a series of partitioning and mass-balance calculations to simulate transfer of fluoride and total cyanide from groundwater to sediment, and vice versa, with removal of groundwater fluoride mass by groundwater flow.

As the terms are used in this report, “model” means the Excel spreadsheet that is a mathematical representation of the conceptual model. The term simulation means a specific version or run of the model that includes specific input data to represent a certain condition. The model can be used to generate numerous simulations that are named for the conditions that they represent. When the model is set up to represent current conditions at the site using the best estimate of input data, the model simulations are termed simply “base case” simulations throughout this report.

Although this section primarily discusses and displays the fluoride partitioning model, the mathematical formulation of the model is identical for total cyanide. The only differences between the fluoride and cyanide models is that for the cyanide model, the leachable fraction is set to 1 (i.e., all cyanide is leachable) and cyanide partition coefficients and sediment concentrations are used.

4.1 OVERVIEW AND ELEMENTS OF MODEL

The model consists of four input and calculation blocks:

1. Input Data Block;
2. SPL Area Calculation Block;
3. PC Calculation Block; and
4. POC Calculation Block.

The input data block contains initial input data for parameters described in Section 3 and also performs basic calculations to set initial values for the area calculation blocks. Input data block for the base case model is shown in Figure 4-1. Input data values can be varied to test the resulting variations in model outputs (i.e., model sensitivity). The input variable “Fraction of Ambient Flux after Remedial Action” can be varied to simulate reduction in flux from hydraulic controls such as a grout wall.

The SPL, PC, and POC area calculation blocks (Figures 4-2, 4-5, and 4-7) calculate the fluoride (and cyanide) concentrations and mass in sediment and groundwater for each time step of the model simulations. The model assumes that groundwater flows into and out of each calculation area, from SPL area to PC area to POC area, with no lag or transport time between the model calculation areas. For example, the groundwater concentration that is calculated to be in equilibrium with SPL area sediment in model year 1 (37.38 mg/L) also flows into the PC in model year 1. PC sediment equilibrates with this groundwater and the resulting groundwater (15.59 mg/L) flows into the POC area in model year 1 where it equilibrates with POC area sediment.

4.2 SPL AREA CALCULATIONS

SPL area calculations (Figure 4-3) are slightly different and simpler than the other calculation blocks as all groundwater flowing into the SPL area is assumed to be free of fluoride and cyanide (0 mg/L F and TCN) upgradient groundwater and therefore only leaching (transfer of fluoride/cyanide from sediment to groundwater) is modeled to occur in the SPL area. Actual upgradient fluoride concentrations are slightly higher, approximately 0.2 mg/L, but this difference is believed to be insignificant for the purposes of this model.

4.3 PLUME CENTER AREA CALCULATIONS

PC area calculations (Figures 4-4 and 4-5) are slightly modified from SPL area calculations because the PC receives fluoride and cyanide-containing groundwater from the SPL area rather than clean upgradient groundwater. At different time steps in the model, fluoride and cyanide concentrations in groundwater inflow from SPL area are higher or lower than the groundwater concentration that would be in equilibrium with PC sediment, thus model calculations allow and account for both fluoride and cyanide adsorption to, or leaching from, sediment in the PC (and also in the POC area) at different times.

Similar to the SPL area, initial groundwater concentration in the PC is calculated from PC initial sediment concentration and Kd. In subsequent model time steps, the equilibrium groundwater concentration in PC area is compared to the groundwater inflow concentration from SPL area. If the inflow concentration is greater than the PC equilibrium concentration, then the “excess” fluoride and cyanide (amount of inflow in excess of equilibrium) are assumed to be adsorbed to sediment and the excess amount is added to the sediment leachable fluoride and cyanide mass. Conversely, if the inflow concentrations are less than the PC equilibrium concentrations, then the “excess” fluoride and cyanide are negative values (a deficiency), fluoride and cyanide are assumed to be leached from sediment and the “excess” amount is added to the sediment leachable fluoride and cyanide masses (negative value reduces the mass). See Inflow GW Excess for years 3 and 4 in Figure 4-5 for an example of transition from excess F (adsorption conditions) to deficient F (leaching conditions).

4.4 POINT OF COMPLIANCE AREA CALCULATIONS

POC area calculations (Figures 4-6 and 4-7) are slightly modified from PC area calculations to account for an inflow of clean groundwater that is known to occur between the PC and POC areas (see Table 3-3). The additional inflow is assumed to be to be fluoride and cyanide-free, and thus the total inflow (combination of clean inflow and PC outflow) fluoride and cyanide concentrations are calculated as PC outflow concentration times the ratio of PC outflow to total POC inflow (i.e., 0.46 for the base case model).

4.5 SIMULATION OF REDUCED GROUNDWATER FLUX CONDITIONS

Potential remedies that might be introduced to the system (e.g., hydraulic controls such as grout walls) may cause reductions in groundwater flux. The model simulates reductions in groundwater flux from base case conditions through the input variable “Fraction of Ambient Flux after Remedial Actions.” Total flux after the remedy is calculated as “Total Ambient Flux” times the fraction. Under base case conditions the fraction is 1.0 and there is no reduction in ambient flux. For fractions less than 1, flux is reduced.

4.6 SIMULATION OF REMOVAL OF GROUNDWATER / SEDIMENT CONTAMINANT MASS

Potential remedies such as pumping and removal of contaminated water would cause removal of contaminant mass from the groundwater and sediment system. Input data block for the pumping scenario model is shown in Figure 4-8. The model simulates removal of contaminated groundwater and associated contaminant mass from base case conditions through the input variable “Assumed Pumping Rate (L/Day)” for two possible pumping locations, POC and PC. In PC pumping simulations, the amount of contaminant mass removed in each time step is calculated based on total volume of water pumped and groundwater concentration within the PC model cell. The mass of contaminant in sediments in the PC model cell is reduced by the contaminant mass pumped; thus reducing contaminant concentration in sediment; in turn reducing groundwater concentration in equilibrium with the sediment in the PC area (through the sediment:groundwater equilibrium defined by the partition coefficient); and finally reducing the concentration and mass of contaminants in groundwater flowing into the POC area.

POC pumping simulation is similar to PC pumping but also includes the division of the POC area cell into two sub-cells (Figure 4-9), one upgradient and one downgradient of the pumping wells. Sediment characteristics within both subcells are assumed to be identical and the same as described for the POC cell in Section 3. In the POC pumping simulation, the amount of contaminant mass removed in each time step is calculated based on total volume of water pumped and groundwater concentration within the upgradient POC model sub-cell. The mass of contaminant in sediments in the upgradient POC model sub-cell is reduced by the contaminant mass pumped; thus reducing contaminant concentration in sediment; in turn reducing groundwater concentration in equilibrium with the sediment in the upgradient POC sub-cell; and finally reducing the concentration and mass of contaminants in groundwater flowing into the downgradient POC sub-cell.

5.0 MODEL CALIBRATION AND SENSITIVITY EVALUATION

Model calibration "is the process of refining the model to achieve a desired degree of correspondence between the model output and actual observations of the environmental system or process the model is intended to represent" (EPA, 2002). Model calibration for the partitioning model was achieved by adjusting and selecting initial input values for initial sediment fluoride and cyanide concentration, fluoride leaching fraction, and Kd within the observed ranges of measured values so that model base case simulations yielded predicted groundwater concentrations that approximated observed current and historic groundwater concentrations.

Model sensitivity is the response in model outputs or predictions that result from variation in model structure or input values. Evaluation of model sensitivity was done during model development to verify that model structure and calculations were correct and reflected the conceptual model. Sensitivity of the model simulation results (outputs and predictions) to variations in input values was also evaluated during model development and calibration to identify key input parameters (parameters that most strongly affect model outputs; the parameters to which the results are most "sensitive") and to determine the amount of variations in output values caused by varying input values. Based on the sensitivity evaluation, fluoride leaching fraction, initial sediment total cyanide concentration, and Kd values were identified as the key input parameters. A range of input values for these four input parameters were selected as representative of the potential uncertainty in input values to yield model output results that also reflect potential uncertainties.

The overall process of model calibration and sensitivity analysis was as follows:

1. Observed historic and current groundwater concentrations were used to establish calibration targets;
2. Model simulations were run for mid-range values of key input parameters and compared to calibration targets and initial adjustments were made to mid-range values as needed (adjustments only to initial fluoride in sediment);

3. Multiple model simulations were run for a range of key input parameters and compared to calibration targets; and
4. The model simulation scenarios (combination of key parameters) that best exhibited good calibration (i.e., predicted concentrations values and trends similar to those observed in groundwater monitoring wells) and model uncertainty (range of predicted values) were selected as final “Base Case” model scenarios to represent potential current site conditions. Two additional simulations were run to determine sensitivity of the base case model scenarios to the potential presence of ongoing sources other than sediment (see Sections 5.3 and 5.5).

5.1 GROUNDWATER CALIBRATION TARGETS

Current groundwater concentrations and historic groundwater concentration trends were used as calibration targets for the model. Measured groundwater concentrations in monitoring wells for the period of record are shown in Figures 5-1 through 5-3. Monitoring wells and groundwater concentrations that were used in the calibration are summarized in Tables 5-1 and 5-2. Model year zero (0) is current conditions, thus historic and current groundwater concentrations for wells used in the calibration are for prior or negative model years (-10 to 0 years). Most wells exhibit short-term variations in concentrations. For model calibration purposes, values that approximated the mid-range of the observed short term variations were assumed rather than specific measured values.

5.2 FLUORIDE MODEL CALIBRATION AND SENSITIVITY SIMULATIONS

Model simulation results for the calibrated base case conditions and mid-range leaching fraction and Kd values are shown in Figure 5-4. Output from the model consists of calculated fluoride concentrations in groundwater for each time step of the simulation. These concentrations are plotted on graphs (Figure 5-4) with the model time steps in years on the horizontal axis and fluoride concentration on the vertical axis. Model year zero (0) represents current conditions, negative model years represent previous or historic conditions, and model years greater than zero represent model predictions of concentrations in the future. The concentration lines prior to model year zero (years -10 through 0) are actual observed groundwater concentrations for selected monitoring wells as described in Table 5-1.

Concentration lines after (to the right of) model year zero are model simulation output values.

For the SPL area, mid-range input values for initial sediment concentration, leaching fraction and Kd yield predicted concentration values that appear to calibrate very well with observed data calibration targets (Figure 5-4). Model predicted concentration for year 0 falls in the middle of the range of currently observed values for SPL area monitoring wells KM-1 and KM-2 and the future trend of predicted concentration values also appears to match an extrapolation of the observed data (i.e., observed and predicted values have similar slopes).

In the PC area, mid-range input values for initial sediment concentration, leaching fraction and Kd yielded predicted concentration values that were significantly lower than calibration targets. To achieve a better calibration, a higher value for initial sediment concentration (equal to highest observed value for PC area as shown in Table 3-3) was assumed and this yielded an acceptable calibration as shown in Figure 5-4. Although the model predicted concentration for year 0 is lower than the range of currently observed values for PC monitoring wells KM-5 and KM-6, the future trend of predicted concentration values appears to match an extrapolation of the observed data well.

For the POC area, mid-range input values for initial sediment concentration, leaching fraction and Kd, yield predicted concentration values that appear to calibrate well with observed data calibration targets (Figure 5-4). Model predicted concentration for year 0 falls in the middle of the range of currently observed values for SPL area monitoring wells KMCP-3B, KMCP-4B, KM-17, and KM-18 and the future trend of predicted concentration values also appears to match an extrapolation of the observed data (i.e., observed and predicted values have similar slopes).

Model simulation results to evaluate model sensitivity to the key parameters leaching fraction and Kd are shown in Figures 5-5, 5-6, and 5-7 for the individual model calculation areas. For leaching fraction (LF), values ranged from 75% to 150% of mid-range values. For Kd, values ranged from 50% to 150% of mid-range values. The combination of high, mid-range and low values for each parameter yields the following sensitivity cases:

1. Mid-range values (LF and Kd);
2. Low LF and Low Kd;
3. Low LF and High Kd;
4. High LF and Low Kd; and
5. High LF and High Kd.

Conclusions of the sensitivity evaluation are:

1. Variation or uncertainty in LF and Kd over the evaluated range of input values yields an approximately five-fold range in initial predicted concentrations in all model calculation areas. The range in concentrations decreases over time and by model year 30 is reduced to approximately two-fold.
2. The sensitivity cases that yield the greatest range in concentrations are Low LF High Kd and High LF Low Kd. These cases yield concentrations that appear to be well outside the calibration targets, which likely indicates that the cases are not very representative of typical conditions in the calculation areas and that these cases may not accurately represent potential model uncertainties.
3. Variation or uncertainty in LF and Kd over the evaluated range of input values yields an approximately three-fold range in predicted time to compliance (i.e., predicted number of years until concentration at POC is 4 mg/L or less = 53 to 132 years).
4. The sensitivity cases that yield the greatest range in time to compliance are the Low LF Low Kd and High LF High Kd cases. These cases yield concentrations that match calibration target concentrations; therefore, these base case simulations are believed to accurately represent potential model uncertainties and future consideration of these cases to evaluate and account for potential uncertainty in the model will be adopted. The Base Case model simulations with the recommended sensitivity case simulations for the POC area is shown in Figure 5-8.

5.3 FLUORIDE SENSITIVITY TO ASSUMPTION OF NO ADDITIONAL SOURCE

One of the key model assumptions is that the sole source of fluoride to groundwater is leaching of fluoride from sediment. If there were additional ongoing contributions of fluoride to groundwater from other sources, then the additional fluoride would slow the leaching and flushing of fluoride from sediment and the model would underestimate the time to compliance. The sensitivity of the model to the assumption of no additional sources was evaluated by simulating additional source contributions in the vicinity of the SPL area. Since there are no documented or quantified additional source(s), further assumptions regarding the fluoride contributions from the additional source(s) were required in order to evaluate model sensitivity to the assumption of no additional source. These sensitivity evaluation assumptions are:

1. It is assumed that the additional source is SPL in the capped SPL pile. This is a reasonable assumption since SPL is known to be the initial source of fluoride and SPL remains on site in the capped SPL pile.
2. SPL is assumed to be present throughout the capped SPL pile (area of 10 acres). This assumption is likely an overestimate as the pile also contains non-SPL waste that likely contains low fluoride concentrations.
3. SPL is assumed to contain 2,500 mg/kg fluoride based on data presented in Hart Crowser (1988). This assumption is likely an overestimate of the average concentration of the waste in the SPL pile as the pile also contains non-SPL waste that likely contains low fluoride concentrations.
4. Water that contacts SPL and infiltrates to groundwater is assumed to leach fluoride from SPL in equilibrium with a partitioning coefficient (Kd) of 2.7 L/kg (Kd used in base case for SPL and PC area groundwater), which yields a leachate/infiltration concentration of 925 mg/L fluoride. This concentration may overestimate SPL leachate concentrations. Singh et al. (1999) report fluoride concentrations in SPL leachate to range up to 575 mg/L.

5. The engineered SPL Cap is assumed to leak and allow rainfall/snowmelt to infiltrate through the Cap, contact SPL and percolate to groundwater at two different rates/scenarios:

    a. Leaky Cap Scenario - Assuming the SPL Cap is "leaky," infiltration through the cap to groundwater is assumed to equal 0.1 inches/year over the 10-acre SPL pile (i.e., 27,152 gallons/year). The leaky cap scenario is considered to be a possible condition, which could represent conditions that might occur on the Site if the Cap performed poorly.
    b. No Cap Scenario - Assuming the SPL Cap has catastrophically failed so that it performs as if there is no cap, infiltration through the cap to groundwater is assumed to equal 0.55 inches/year (2.7 percent of annual precipitation of 20.6 in/yr) over the 10-acre SPL pile (i.e., 149,388 gallons/year). This assumed infiltration rate for the failed cap is equal to approximately 40 percent of the areal recharge rate (1.44 in/yr) of the surrounding areas in the calibrated numeric groundwater model (Hydrometrics, 2017). Even without a functioning cap, the SPL pile is sloped to reduce ponding and infiltration, thus reducing infiltration somewhat compared to adjacent areas. The No Cap scenario is considered to be a highly unlikely condition that was simulated to investigate model response to an extreme assumption.

Results of the additional source sensitivity analysis are shown in Figure 5-9 (Leaky Cap scenario) and Figure 5-10 (No Cap scenario) for the POC area. In the Base Case Scenario compliance (decrease of groundwater fluoride concentration to 4 mg/L) is met in an estimated 53 to 132 years; while in the "leaky cap" scenario, compliance is met in estimated 56 to 137 years, while assuming "no cap" extends time to compliance to a range of 70 to 184 years. Under potential conditions of a leaky SPL cap, fluoride contributions from SPL have little effect (3 to 5 years or 5%) on estimated time to compliance; demonstrating that under expected conditions, the model is relatively insensitive to unknown additional sources, even with the many conservative assumptions regarding potential SPL fluoride contributions. Under the highly unlikely condition that SPL cap performance is so poor that it is no better than if the cap were absent, fluoride contributions from SPL have a moderate effect (20 to 50 years) on estimated time to compliance. However, even under the No Cap scenario, the effect is relatively minor compared to model sensitivity to leaching fraction (LF) and distribution coefficient (Kd) which causes a range of 80 years in time to compliance.

5.4 TOTAL CYANIDE MODEL CALIBRATION AND SENSITIVITY SIMULATIONS

Calibration and sensitivity analysis for the total cyanide model followed a similar approach as for the fluoride model described above but with slightly different outcome in the selection of Base Case scenarios. For cyanide, the leaching fraction is assumed to be 1 and constant and therefore the model was found to be most sensitive to initial total cyanide concentration (TCN, instead of leaching fraction as for fluoride) and Kd values. In further contrast to the fluoride model, most low and mid-range input simulations did not calibrate well; and three high TCN simulations were selected to be most representative for base case conditions.

Model simulation results for mid-range initial total cyanide in sediment concentration and Kd values are shown in Figure 5-11. For the SPL area, mid-range input values for initial sediment concentration and Kd yield predicted concentration values that appear to calibrate very well with observed data calibration targets (Figure 5-11). Model predicted concentration for year 0 falls within the range of currently observed values for SPL area monitoring wells KM-1 and KM-2 and the future trend of predicted concentration values also appears to match an extrapolation of the observed data (i.e., observed and predicted values have similar slopes).

In the PC area, mid-range input values for initial sediment concentration and Kd yielded predicted concentration values that were somewhat lower than calibration targets. For the POC area, mid-range input values yield predicted concentration values that appear to calibrate well with observed data from the 2016 borings (KM-17 and KM-18) but are low compared to compliance wells KMCP-3B and KMCP-4B.

Model simulation results to evaluate model sensitivity to the key parameters initial total cyanide sediment concentration (TCN) and Kd are shown in Figures 5-12, 5-13, and 5-14 for the individual model calculation areas. For TCN, values ranged from 50% to 150% of mid-range values. For Kd, values ranged from 50% to 200% of mid-range values. The combination of high, mid-range and low values for each parameter yields the following sensitivity cases:

1. Mid-range TCN and Mid Kd;
2. Mid-range TCN and Low Kd;
3. Mid-range TCN and High Kd;
4. Low TCN and Low Kd;
5. Low TCN and Mid Kd;
6. Low TCN and High Kd;
7. High TCN and Low Kd;
8. High TCN and Mid Kd; and
9. High TCN and High Kd.

Conclusions of the sensitivity evaluation are:

1. Variation or uncertainty in TCN and Kd over the evaluated range of input values yields very large ranges in initial predicted concentrations in all model calculation areas.
2. The sensitivity cases that yield the greatest range in concentrations are Low TCN High Kd and High TCN Low Kd.
3. The Low-TCN and Mid-TCN cases yield concentrations that are much lower than the compliance well calibration targets, which likely indicates that the cases are not very representative of typical conditions at the compliance line wells. Therefore, these cases will not be carried forward as base case conditions in future model simulations.
4. The sensitivity cases that match calibration target concentrations the best are the three High TCN cases (High KD, Mid Kd, Low Kd); therefore, these base case simulations are believed to accurately represent potential model uncertainties. These three cases plus the Mid-TCN Mid-KD case are selected as Base Case scenarios for future model

simulations. The final calibrated and selected Base Case model simulations for the POC area are shown in Figure 5-15.

5.5 TOTAL CYANIDE SENSITIVITY TO ASSUMPTION OF NO ADDITIONAL SOURCE

As was done for fluoride and described above, the sensitivity of the model to the assumption of no additional cyanide sources was evaluated by simulating additional source contributions in the vicinity of the SPL area. Since there are no documented or quantified additional source(s), further assumptions regarding the cyanide contributions from the additional source(s) were required in order to evaluate model sensitivity to the assumption of no additional source. These sensitivity evaluation assumptions are:

1. It is assumed that the additional source is SPL in the capped SPL pile.
2. SPL is assumed to be present throughout the capped SPL pile (area of 10 acres).
3. SPL leachate is assumed to contain 700 mg/L total cyanide based on data presented in Hart Crowser (1988).
4. The engineered SPL Cap is assumed to leak and allow rainfall/snowmelt to infiltrate through the Cap, contact SPL and percolate to groundwater at two different rates/scenarios:

    a. Leaky Cap Scenario - Assuming the SPL Cap is “leaky”, infiltration through the cap to groundwater is assumed to equal 0.1 inches/year over the 10-acre SPL pile (i.e., 27,152 gallons/year).
    b. No Cap Scenario - Assuming the SPL Cap has catastrophically failed so that it performs as if there is no cap, infiltration through the cap to groundwater is assumed to equal 0.55 inches/year (2.8% of annual precipitation) over the 10-acre SPL pile (i.e., 149,388 gallons/year).

Results of the additional source sensitivity analysis are shown in Figure 5-16 (Leaky Cap scenario) and Figure 5-17 (No Cap scenario) for the POC area. In the Base Case Scenario compliance (decrease of groundwater total cyanide concentration to 8 mg/L accompanied by a decrease in WAD and free cyanide to less than the compliance limit of 0.2 mg/L) is met in an estimated 32 to 69 years; while in the “leaky cap” scenario, compliance is met in an estimated 34 to 69 years. Assuming “no cap” increases time to compliance to a range of 36 to 80 years. Under both leaky and no cap scenarios there is little effect (2 to 4 years) on minimum predicted time to compliance and only moderate (0 to 11 years) effects on predicted maximum time to compliance.

6.0 REMEDIAL ACTION SIMULATIONS

One purpose of partition model development was to allow evaluation of the potential effects of various remedial options or alternatives. Model evaluation of remedial actions included simulation of hydraulic controls (e.g., grout wall encompassing areas of contaminated aquifer sediment) and pumping (removal) of contaminated groundwater from two locations, the PC and POC areas for treatment. The purpose of the remedial action simulations was to estimate or forecast groundwater concentrations at the POC, the time required for groundwater concentrations to decrease to compliance levels at the POC (time to compliance or TTC), and the contaminant mass flowing across the POC line under the various remedial action scenarios.

6.1 GROUT WALL SIMULATIONS

In grout wall model simulations, the flux of groundwater into and out of the area encircled by the grout wall was reduced. Grout wall simulation assumptions and input values were identical to base case simulations with the following exceptions:

1. The grout wall is assumed to encircle the SPL area and PC area model cells (shown on Figure 3-2).
2. The grout wall is assumed to have 0.7 percent defects initially and throughout the model simulations. This defect rate is based on the grout wall pilot scale test and the calibrated numeric groundwater model as described in Hydrometrics (2017).
3. The grout wall is assumed to reduce flux into the SPL and PC cells by 79 percent (i.e., fraction of flux remaining after grout wall installation equals 0.21) based on simulation of the grout wall by the numeric groundwater model (Hydrometrics, 2017).

Forecast or estimated fluoride and total cyanide concentrations at the POC line for grout wall simulation are shown in Figures 6-1 and 6-2.

6.2 PUMP AND TREAT SIMULATIONS

Simulation of pump and treat remedial actions included two pumping locations and three pumping rates for a total of six scenarios as follows:

1. PC pumping location at 25, 50, and 100 gpm pumping rates; and
2. POC pumping location at 25, 50, and 100 gpm pumping rates.

Pump and treat simulation assumptions and input values were identical to base case simulations with the following exceptions:

1. Groundwater removal rates assumed to equal 25, 50, and 100 gpm; and
2. Contaminant mass equal to pumping rate times groundwater concentration in the pumping model cell is removed.

Forecast or estimated fluoride and total cyanide concentrations at the POC line for pump and treat simulation are shown in Figures 6-3 through 6-14.

7.0 MODEL ASSUMPTIONS, UNCERTAINTIES, AND LIMITATIONS

7.1 ASSUMPTIONS

Key assumptions are:

1. Groundwater and sediment under site field conditions behave as observed in laboratory sequential batch leach tests. This assumption is supported by comparison of fluoride and cyanide behavior in the field with lab results.
2. Aqueous and sediment concentrations are related through a partition or distribution coefficient (Kd). This assumption appears to be well-supported by lab testing.
3. Partition coefficients are linear (i.e., do not vary with concentration). This assumption appears to be well-supported by lab testing which indicates approximate linearity over the concentration range observed in laboratory testing of approximately 2 to 25 mg/L fluoride and 10 to 100 mg/L total cyanide. Variation in Kd is incorporated in sensitivity evaluation and in selected base case scenarios.
4. Chemical reaction in groundwater (i.e., adsorption and desorption or leaching of F) is fast relative to groundwater transport and equilibrium partitioning between sediment and groundwater is attained. This assumption appears to be well-supported by lab testing which indicates reactions occur within a few days, much shorter than groundwater transport times at the Site.
5. Sediment characteristics are homogeneous throughout each model calculation area. This assumption is known to be invalid and therefore must be considered when interpreting model results (see Limitations below).
6. It is assumed that there are no sources of fluoride and cyanide to groundwater other than aquifer sediment. If additional sources exist, actual rates of decreases in groundwater concentrations would be slower, and time to compliance would be longer, than estimated by the model. However, the effects of these potential sources are estimated to be small (see Figures 5-9, 5-10, 5-16, and 5-17).

Secondary assumptions that were made to simplify the mathematical calculations in the model are:

1. Groundwater flow from SPL area to PC area to POC area is assumed to be instantaneous. This is known to be untrue as groundwater time of travel from SPL area to the POC is estimated to be on the order of a few years. Given that estimated time to compliance in the POC area is on the order of 50 to 130 years (Figure 5-8), the potential error from lack of consideration of transport time is not believed to be significant.
2. Fluoride and cyanide concentrations of groundwater flowing into the SPL area from upgradient areas is assumed to be zero. Given the low concentration of fluoride in background groundwater (0.2 mg/L) the error from this assumption is not believed to be significant.
3. Fluoride and cyanide concentrations of additional groundwater inflow that occurs between PC and POC area is assumed to be zero. Given the low concentration of fluoride in background groundwater (0.2 mg/L) the error from this assumption is not believed to be significant.

7.2 UNCERTAINTIES

The key uncertainty in the model is the degree to which the measured sediment characteristics from a small number of borings (four to five borings for each calculation area) accurately represent the entire calculation areas and site. This uncertainty is addressed to some extent by including base case conditions of high and low leaching fraction and Kd in model simulations. These high and low cases likely bracket the potential range of sediment characteristics.

As described above, lab testing of site groundwater and sediment and literature reports provide strong support of the conceptual model of fluoride adsorption The literature evidence for cyanide adsorption behavior is not as definitive as for fluoride and it is possible that other mechanisms such as cyanide mineral dissolution may be responsible for the apparent partitioning behavior. In contrast to fluoride, the scientific literature reports weak adsorption of cyanide by sediment, except in soils containing abundant organic matter (Rennert and Mansfeldt, 2002).

7.3 LIMITATIONS

The primary limitations of the model are:

1. The model is not capable of estimating concentrations for any specific locations (such as an individual well) but instead provides estimates of typical concentrations for three relatively large areas of the Site. Concentrations at any specific location are likely to be somewhat higher or lower than model predictions for the entire area.
2. The assumption of instantaneous groundwater flow may result in underestimation of time to compliance by an estimated 1 to 10 years.
3. The model does not address off-Site areas and conditions downgradient of the POC. Fluoride that is transported past the POC likely partitions with sediment downgradient in much the same way as it does on-Site.

8.0 REFERENCES

Freeze, RA and JA Cherry, 1979. Groundwater. Prentice-Hall, Inc. Englewood Cliffs. 603pp.

Hart Crowser, 1988. Site Characterization Analysis, KACC – Mead Plant. Prepared for Kaiser Aluminum & Chemical Corporation, December 1988.

Hydrometrics, Inc., 2017. Groundwater Model Report, Kaiser Mead NPL Site, Mead, WA. Prepared for Kaiser Mead Custodial Trust.

Rennert, T and T Mansfeldt, 2002. Sorption of Iron-Cyanide Complexes in Soils. Soil Sci. Soc, Am. J. 66:437-444.

Singh, G, B Kumar, PK Sen and J. Majumdar, 1999. Removal of Fluoride from Spent Pot Liner Leachate Using Ion Exchange. Water Environment Research Vol. 71, No. 1 (Jan. - Feb. 1999), pp. 36-42.

USEPA, 1980. Reviews of the Environmental Effects of Pollutants: IX. Fluoride. Office of Research and Development Health Effects Research Laboratory. EPA-600/1-78-050.

USEPA, 1992. Technical Resource Document Batch-Type Procedures For Estimating Soil Adsorption of Chemicals. Office of Solid Waste and Emergency Response. EPA/530/SW-87/006-F April 1992.

USEPA, 2002. Guidance for Quality Assurance Project Plans for Modeling. Office of Environmental Information. EPA/240/R-02/007. December 2002.

TABLES

TABLE 2-1. OBSERVED TOTAL CYANIDE TO WAD AND FREE CYANIDE RATIOS IN GROUNDWATER IN POC WELLS

	KMCP-3B	**KMCP-4B**	**Combined Data (KMCP-3B and KMCP-4)**
Total CN/WAD CN (Median for Period of 2005-2016)	47.9	32.9	39.7
Total CN/WAD CN (Median for Period of 2015-2016)	30.3	28.7	25.3
Total CN/Free CN (Median for Period of 2015-2016)	33.8	31.4	33.4

TABLE 2-2. EXAMPLES OF FLUORIDE TRANSFER FOR DIFFERENT SEDIMENT AND GROUNDWATER CONCENTRATION SCENARIOS

Scenario	**Example Partition Coefficient (Kd) (L/kg)**	**Example Sediment Concentration (mg/kg)**	**Example Groundwater Concentration (mg/L)**	**Fluoride Transfer**
1-Equilibrium	3	3	1	None
	3	30	10	None
2-Adsorption	3	3	100	From groundwater to sediment
3-Leaching or Desorption	3	30	1	From sediment to groundwater

TABLE 3-1. AQUIFER VOLUME AND MASS

Model Area	Aquifer Saturated Volume (m^3)	Aquifer Sediment Mass (kg)*	Pore Volume of Area (L)*
SPL Area	385,133	789,522,714	87,199,931.584
Plume Center Area	455,444	933,660,130	103,119,389
Point of Compliance Area	502,277	1,029,668,831	113,723,203

Assumes bulk dry density of 2,050 kg/m^3 and particle density of 2.65 g/cm^3.

TABLE 3-2. AMBIENT GROUNDWATER FLUX

Model Calculation Area	Ambient Groundwater Flux (L/day)	Ambient Groundwater Flux (gallons/minute)
SPL Area	249,210	46
Plume Center Area	249,210	46
Point of Compliance Area	544,813	100

TABLE 3-3. FLUORIDE INITIAL SEDIMENT CONCENTRATION AND MASS

Boring Location	Fluoride Sediment Concentration (mg/kg)	Mass of Total Fluoride in Sediment (kg)	Notes
SPL Area			
SPLP-1	352		Average of KMSB-1309-109 and -110; 190-192' and 208.1-208.8'
SPLP-2	381		KMSB-1309-119 190-192' depth satd A zone aquifer
NPRB-2	445		Average of 3 samples, 112', 137', 145-146.8’
NPRB-1	726		Average of 115-117’ and 146-147' samples; omit high value for 149'
Area Average	**476**	**375,812**	
Area Standard Deviation	171		
Plume Center Area			
KM-8	284		Average of boring KM-8 satd zone samples
KM-9	327		Average of boring KM-9 satd zone samples
KM-10	263		Average of boring KM-108 satd zone samples
KM-11	**402**	**375,331**	Average of boring KM-11 satd zone samples
KM-12	268		Average of boring KM-12 satd zone samples
Area Average	311		
Area Standard Deviation	58		
Point of Compliance Area			
KM-15	277		Average of boring KM-15 satd zone samples
KM-16	282		Average of boring KM-16 satd zone samples
KM-17	470		Average of boring KM-17 satd zone samples
KM-18	284		Average of boring KM-18 satd zone samples
KM-17 and 18 Average	**377**	**388,185**	
Area Average	328		
Area Standard Deviation	95		

Note: Values used in calibrated base case model shown in bold.

TABLE 3-4. TOTAL CYANIDE INITIAL SEDIMENT CONCENTRATION AND MASS

Boring (sample depth)	Sediment Description	Cumulative Leached Total Cyanide (mg/kg)	Mass of Total Cyanide in Sediment (kg)
Point of Compliance Area Sediment			
KM-15 (144-145')	Sat-clay	17.83	
KM-15 (145-146')	sat – aquifer, med sand	3.13	
KM-15 (159-160')	sat - aquifer, med sand	4.02	
KM-15 (160-161')	sat - aquitard, silty clay	3.77	
KM-16 (143-144')	sat - aquifer, fine to med sand	2.20	
KM-16 (161-162')	sat - aquifer, med sand	8.07	
KM-16 (162-163')	sat - aquitard, brown clay	12.17	
KM-17 (168-169')	sat - aquifer, fine silty sand	1.25	
KM-18 (170-171')	sat - aquifer, med sand	1.84	
KM-18 (171-172')	sat - aquitard, clayey silt	2.82	
Point of Compliance Area Average		**5.71**	5,879
Point of Compliance Area Median		3.45	
Plume Center Area Sediment			
KM-8 (157-158')	sat - aquifer, med sand	32.33	
KM-8 (158-158.5')	sat - aquitard, clay	146.68	
KM-8 (158.5-159')	sat - aquitard, clay	570.87	
KM-9 (144.5 - 145.5')	sat - aquitard, clay	33.77	
KM-9 (157-158')	sat - transition, sand with silt/clay lenses	47.62	
KM-10 (140-141')	water table - aquifer, silt	7.26	
KM-10 (152-153')	sat - aquifer, sand	41.25	
KM-10 (153-153.5')	sat - aquitard, clay	42.19	
KM-11 (143-144')	sat - aquitard, silty clay to clay	31.78	
KM-11 (155-156')	sat - aquifer, med sand	20.59	
KM-11 (156-156.5')	sat - aquifer, med sand	15.81	
Plume Center Area Average		**81.47**	76,065
Plume Center Area Median		32.33	

TABLE 3-5. SEDIMENT LEACHABLE FLUORIDE FRACTIONS FOR MODEL CALCULATION AREAS

Model Calculation Area	Leachable Fluoride Fraction (percentage)	Notes and Rationale
SPL Area	19%	No data – assumed equal to Plume Center
Plume Center Area	19%	Median of sediment samples from Plume Center borings KM-8 through KM-12
Point of Compliance Area	11%	Median of sediment samples from POC borings KM-17 and KM-18

TABLE 3-6. FLUORIDE PARTITION COEFFICIENTS

Boring (sample depth)	**Sediment Description**	**Kd (slope) from Sequential Leach Tests (L/kg)**	**Kd (median of individual tests) from Sequential Leach Tests (L/kg)**	**In Situ Kd (Total F/ Ground-water F (L/kg)**
Point of Compliance Area Sediment				
KM-15 (159-160')	sat - aquifer, med sand	**3.07**	**1.11**	**1.60**
KM-15 (160-161')	sat - aquitard, silty clay	7.39	4.86	4.16
KM-16 (161-162')	sat - aquifer, med sand	**2.18**	**1.73**	**0.34**
KM-16 (162-163')	sat - aquitard, brown clay	4.06	3.83	1.05
KM-17 (168-169')	sat - aquifer, fine silty sand	**2.34**	**1.96**	**0.48**
KM-17 (169-170')	sat - aquitard, silt to clay	19.01	7.11	4.48
KM-18 (170-171')	sat - aquifer, med sand	**6.28**	**4.61**	**3.97**
KM-18 (171-172')	sat - aquitard, clayey silt	7.7	5.10	18.65
	Point of Compliance Area Average	6.5	3.79	4.34
	Point of Compliance Area Median	**5.17**	4.22	2.78
	POC Sand Interval Average	3.47	2.35	1.6
	POC Sand Interval Median	**2.7**	**1.84**	1.04

TABLE 3-6. FLUORIDE PARTITION COEFFICIENTS (continued)

Boring (sample depth)	Sediment Description	Kd (slope) from Sequential Leach Tests (L/kg)	Kd (median of individual tests) from Sequential Leach Tests (L/kg)	In Situ Kd (Total F/ Ground-water F (L/kg)
Plume Center Area Sediment				
KM-8 (157-158')	sat - aquifer, med sand	**2.7**	**1.61**	**23.88**
KM-8 (158-158.5')	sat - aquitard, clay	2.83	1.93	61.87
KM-8 (158.5-159')	sat - aquitard, clay	5.38	3.55	39.34
KM-9 (142-142.5')	sat - aquifer, coarse sand	**3.96**	**3.42**	**0.31**
KM-9 (144.5 - 145.5')	sat - aquitard, clay	4.40	2.10	1.33
KM-9 (157.5 - 158')	sat - transition, sand with silt/clay lenses	**1.96**	**1.31**	**0.48**
KM-10 (140-141')	water table - aquifer, silt	8.63	2.63	0.16
KM-10 (152-153')	sat - aquifer, sand	**1.47**	1.07	0.47
KM-10 (153-153.5')	sat - aquitard, clay	3.54	1.88	1.24
KM-11 (143-144')	sat - aquitard, silty clay to clay	6.14	3.77	3.75
KM-11 (155-156')	sat - aquifer, med sand	**1.65**	**1.45**	**0.43**
KM-11 (156-156.5')	sat - aquifer, med sand	**4.19**	**2.05**	**0.44**
KM-11 (156.5-157')	sat - aquitard, clay	4.38	2.09	0.91
KM-12 (150-151')	sat - aquifer, sandy silt	9.08	3.38	1.14
KM-12 (151-152')	sat - aquitard, clay	13.18	3.99	0.85
	Plume Center Area Average	5.06	2.47	8.05
	Plume Center Area Median	**4.19**	2.09	0.91
	Plume Center Sand Interval Average	2.82	1.5	2.82
	Plume Center Sand Interval Median	**2.70**	**1.45**	3.96
Overall Average		5.58	2.95	6.7
Overall Median		4.19	2.10	1.14

Note: Sand intervals used in calculation of average and median values shown in bold.

TABLE 3-7. TOTAL CYANIDE PARTITION COEFFICIENTS

Boring (sample depth)	**Sediment Description**	**Kd (slope) from Sequential Leach Tests (L/kg)**	**Kd (median of individual tests) from Sequential Leach Tests (L/kg)**	**In Situ Kd (sediment cumulative leached TCN/ground water TCN) (L/kg)**
Point of Compliance Area Sediment				
KM-15 (144-145')	sat - clay	1.20	0.87	3.909
KM-15 (145-146')	sat - aquifer, med sand	**1.40**	**1.74**	**0.721**
KM-15 (159-160')	sat - aquifer, med sand	**1.25**	**1.33**	**0.898**
KM-15 (160-161')	sat - aquitard, silty clay	2.30	2.01	0.904
KM-16 (143-144')	sat - aquifer, fine to med sand	**1.52**	**1.82**	**0.195**
KM-16 (161-162')	sat - aquifer, med sand	**1.22**	**1.65**	**0.704**
KM-16 (162-163')	sat - aquitard, brown clay	0.99	1.05	1.036
KM-17 (168-169')	sat - aquifer, fine silty sand	**2.63**	**2.19**	**0.147**
KM-18 (170-171')	sat - aquifer, med sand	**1.62**	**1.80**	**0.651**
KM-18 (171-172')	sat - aquitard, clayey silt	1.09	2.18	0.997
Point of Compliance Area Average		1.52	1.74	1.02
Point of Compliance Area Median		1.33	1.77	0.81
Point of Compliance Sand Interval Average		1.61	1.76	0.62
Point of Compliance Sand Interval Median		**1.46**	1.77	0.70

TABLE 3-7. TOTAL CYANIDE PARTITION COEFFICIENTS (continued)

Plume Center Area Sediment				
Boring (sample depth)	**Sediment Description**	**Kd (slope) from Sequential Leach Tests (L/kg)**	**Kd (median of individual tests) from Sequential Leach Tests (L/kg)**	**In Situ Kd (sediment cumulative leached TCN/groundwater TCN) (L/kg)**
KM-8 (157-158')	sat - aquifer, med sand	NC	**0.83**	*143**
KM-8 (158-158.5')	sat - aquitard, clay	0.91	0.94	*649**
KM-8 (158.5-159')	sat - aquitard, clay	1.96	1.94	*2526**
KM-9 (144.5 -145.5')	sat - aquitard, clay	2.44	2.01	0.33
KM-9 (157-158')	sat - transition, sand with silt/clay lenses	NC	**0.84**	**0.46**
KM-10 (140-141')	water table - aquifer, silt	0.70	0.70	0.10
KM-10 (152-153')	sat - aquifer, sand	**0.58**	**0.58**	**0.57**
KM-10 (153-153.5')	sat - aquitard, clay	1.57	1.29	0.58
KM-11 (143-144')	sat - aquitard, silty clay to clay	NC	2.25	0.64
KM-11 (155-156')	sat - aquifer, med sand	NC	**0.86**	**0.41**
KM-11 (156-156.5')	sat - aquifer, med sand	**2.75**	**2.03**	**0.32**
Plume Center Area Average		1.56	1.34	0.43
Plume Center Area Median		1.57	0.94	0.44
Plume Center Sand Interval Average		1.67	1.03	0.44
Plume Center Sand Interval Median		**1.67**	**0.84**	0.44
Overall Average		1.54	1.56	0.71
Overall Median		1.40	1.65	0.64

Notes:
Bold values indicate sand intervals used in calculation of sand interval average and median values.
* In Situ Kd values for KM-8 not included in calculation of Plume Center and Overall average and median values.
NC = Slope Kd not calculated due to insufficient data points.

TABLE 5-1. GROUNDWATER FLUORIDE CONCENTRATION CALIBRATION TARGETS

Model Year	**Compliance Area Well Calibration Targets (mg/L F)**			
	KMCP-3B	**KMCP-4B**	**KM-17**	**KM-18**
-10	20	11	No data	No data
-5	30	15	No data	No data
-2	30	16	No data	No data
0	27	15	14.3	5.28
Model Year	**Plume Center Area Well Calibration Targets (mg/L F)**			
	KM-5	**KM-6**	**KM-12**	**HC-12**
-10	85	10	--	50
-7.5	--	110	--	--
-3	--	60	--	75
0	50	52	102	42
Model Year	**SPL Area Well Calibration Targets (mg/L F)**			
	KM-1	**KM-2**		
-10	120	65		
0	70	25		

TABLE 5-2. GROUNDWATER TOTAL CYANIDE CONCENTRATION CALIBRATION TARGETS

Model Year	Compliance Area Well Calibration Targets (mg/L TCN)			
	KMCP-3B	KMCP-4B	KM-17	KM-18
-10	20	11	No data	No data
-5	30	15	No data	No data
-2	30	16	No data	No data
0	27	15	9.9	3.18
Model Year	Plume Center Area Well Calibration Targets (mg/L TCN)			
	KM-5	KM-6	KM-12	HC-12
-10	175	275	No data	120
-7.5	--		No data	190
-3	--		No data	139
0	60	75	102	76
Model Year	SPL Area Well Calibration Targets (mg/L TCN)			
	KM-1	KM-2		
-10	95	140		
0	40	60		

FIGURES

FIGURE 2-1. FLUORIDE SEDIMENT:GROUNDWATER PARTITIONING CURVE OBSERVED IN LAB TESTING OF SITE SEDIMENT

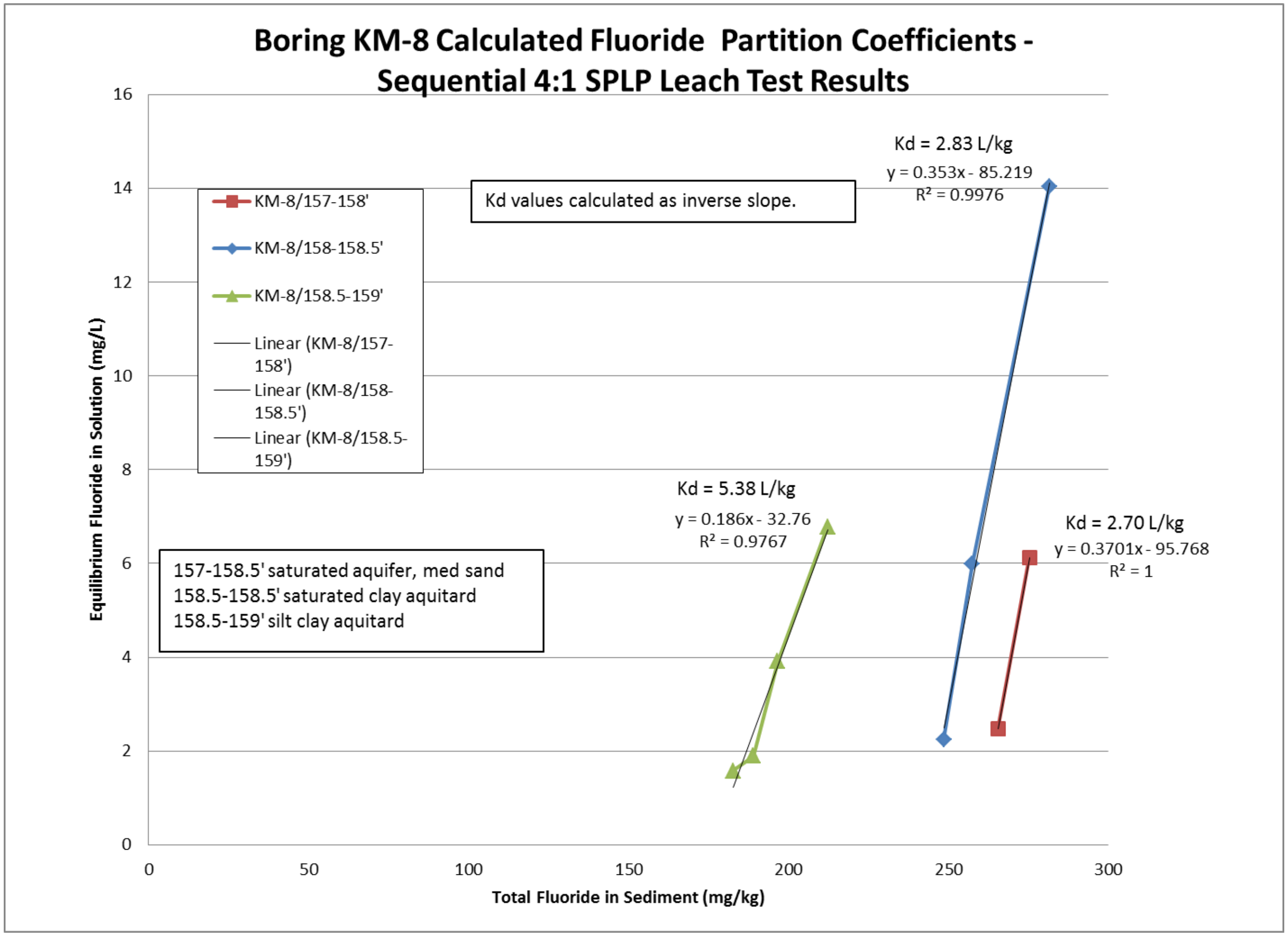


FIGURE 2-2. CYANIDE SEDIMENT:GROUNDWATER PARTITIONING CURVE OBSERVED IN LAB TESTING OF SITE SEDIMENT

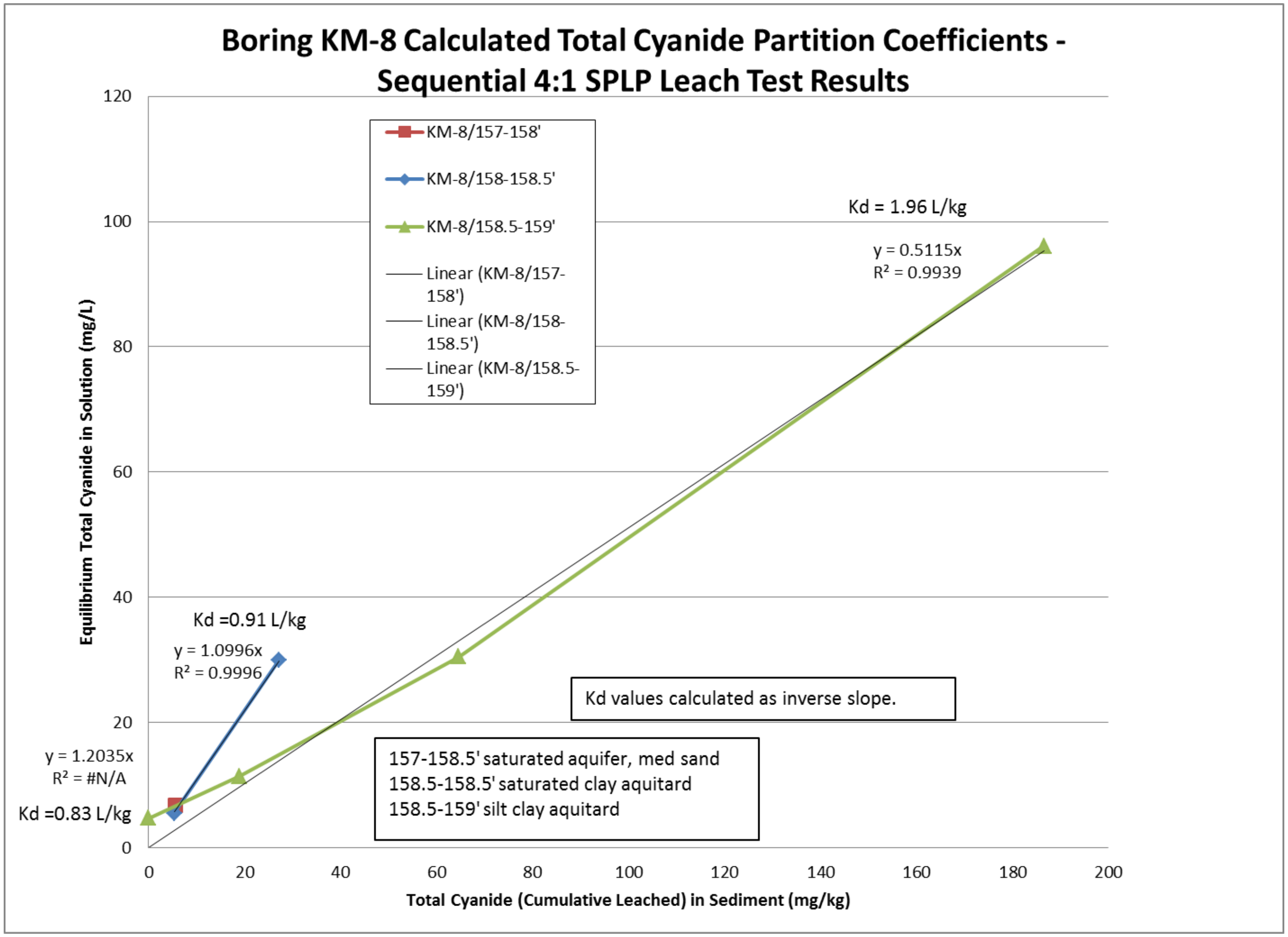


FIGURE 2-3. FLUORIDE LEACHING CURVE OBSERVED IN LAB TESTING OF SITE SEDIMENT

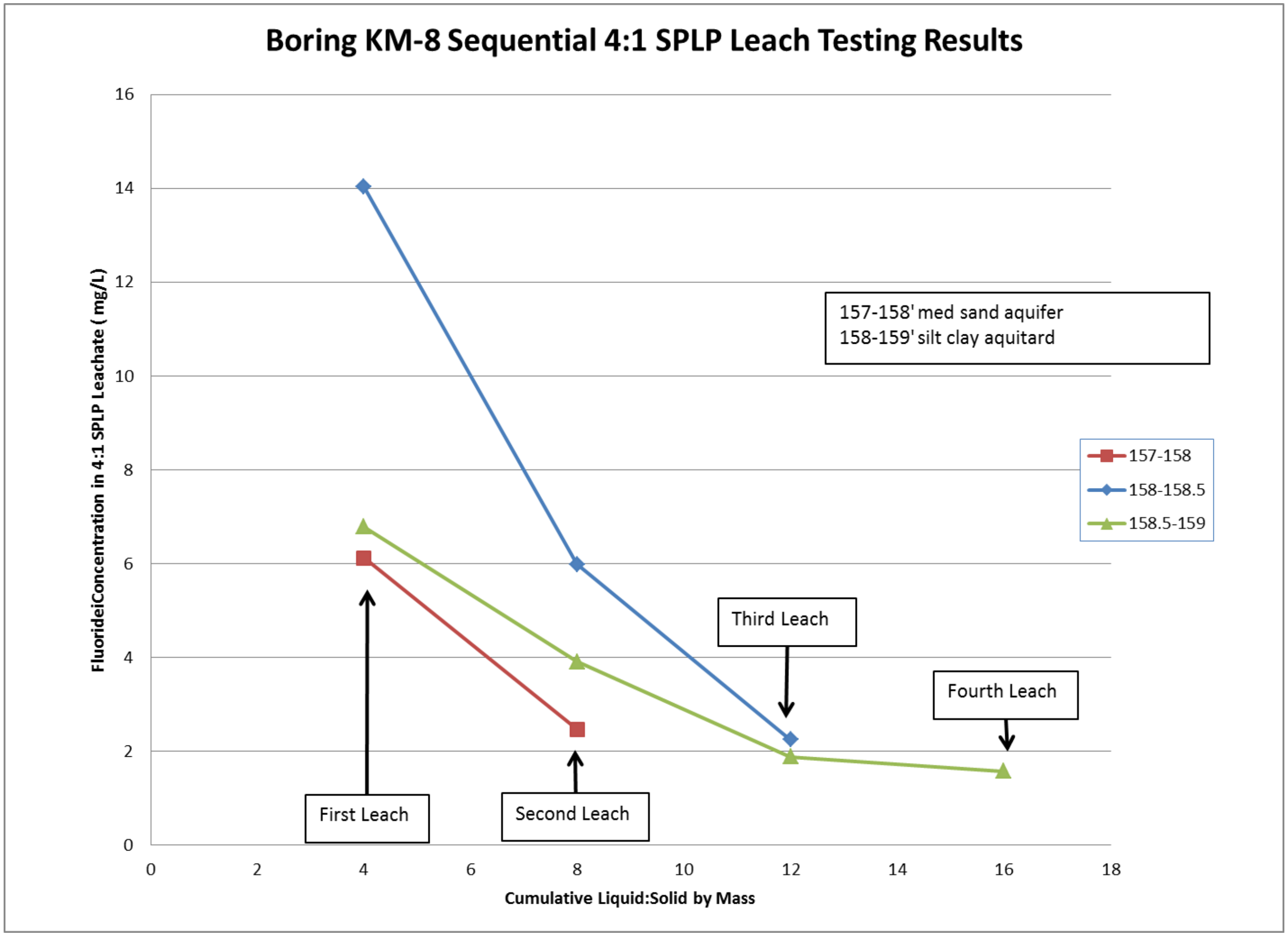


FIGURE 2-4. CYANIDE LEACHING CURVE
OBSERVED IN LAB TESTING OF SITE SEDIMENT

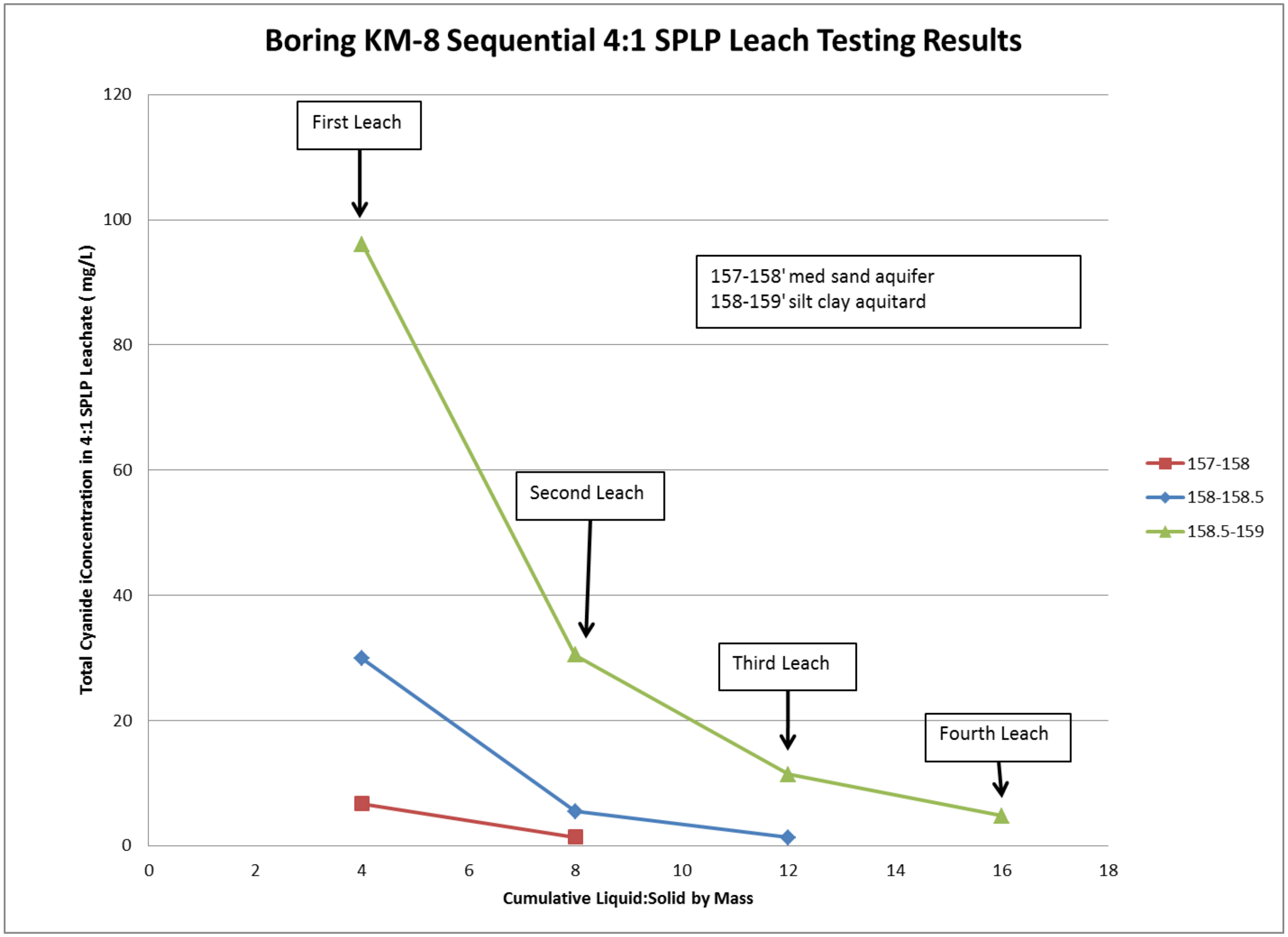
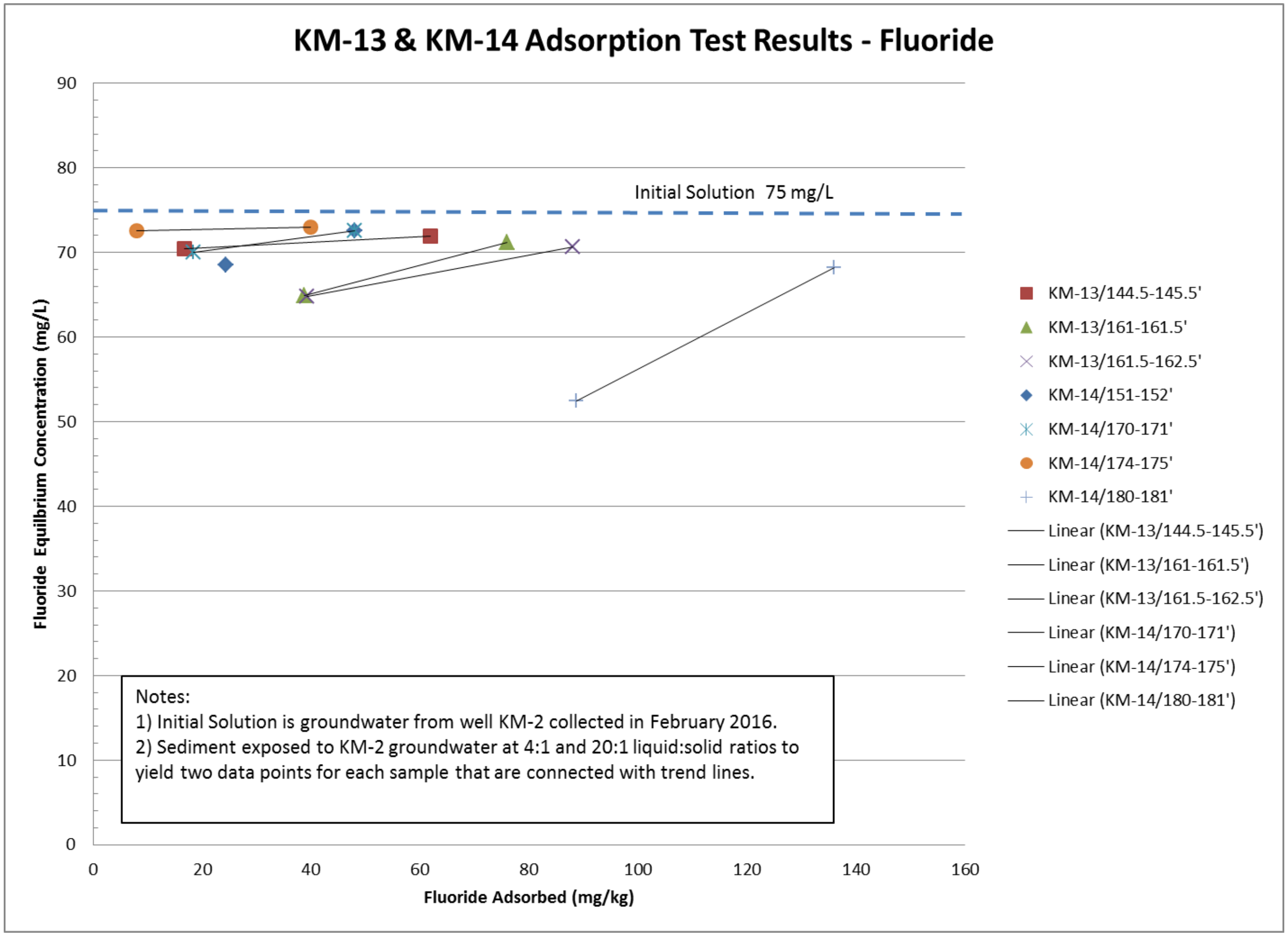
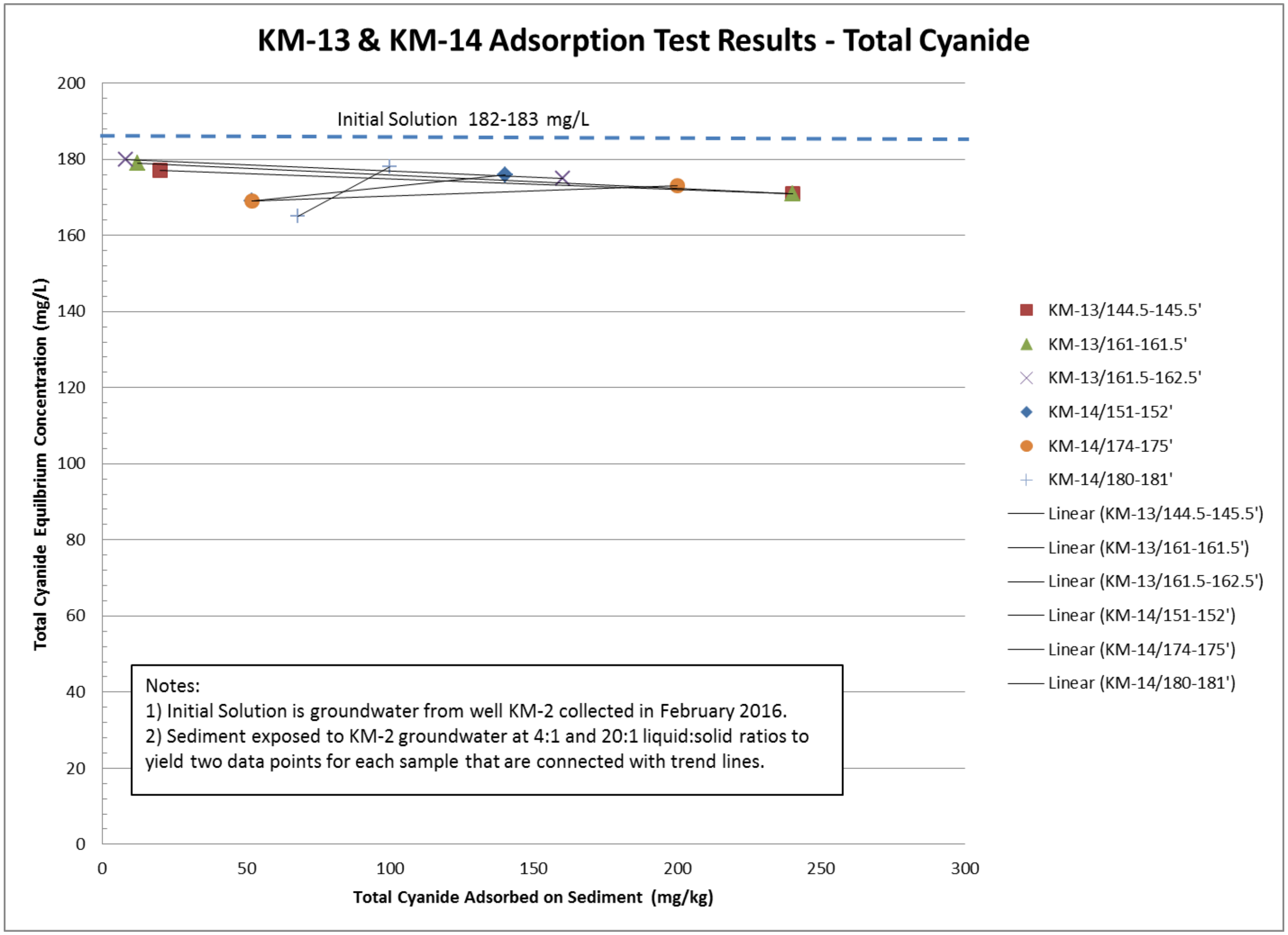


FIGURE 2-5. FLUORIDE ADSORPTION
OBSERVED IN LAB TESTING OF SITE SEDIMENT



Notes:
1) Initial Solution is groundwater from well KM-2 collected in February 2016.
2) Sediment exposed to KM-2 groundwater at 4:1 and 20:1 liquid:solid ratios to yield two data points for each sample that are connected with trend lines.

FIGURE 2-6. TOTAL CYANIDE ADSORPTION OBSERVED IN LAB TESTING OF SITE SEDIMENT



Notes:
1) Initial Solution is groundwater from well KM-2 collected in February 2016.
2) Sediment exposed to KM-2 groundwater at 4:1 and 20:1 liquid:solid ratios to yield two data points for each sample that are connected with trend lines.

FIGURE 2-7. DIRECTION OF GROUNDWATER FLOW

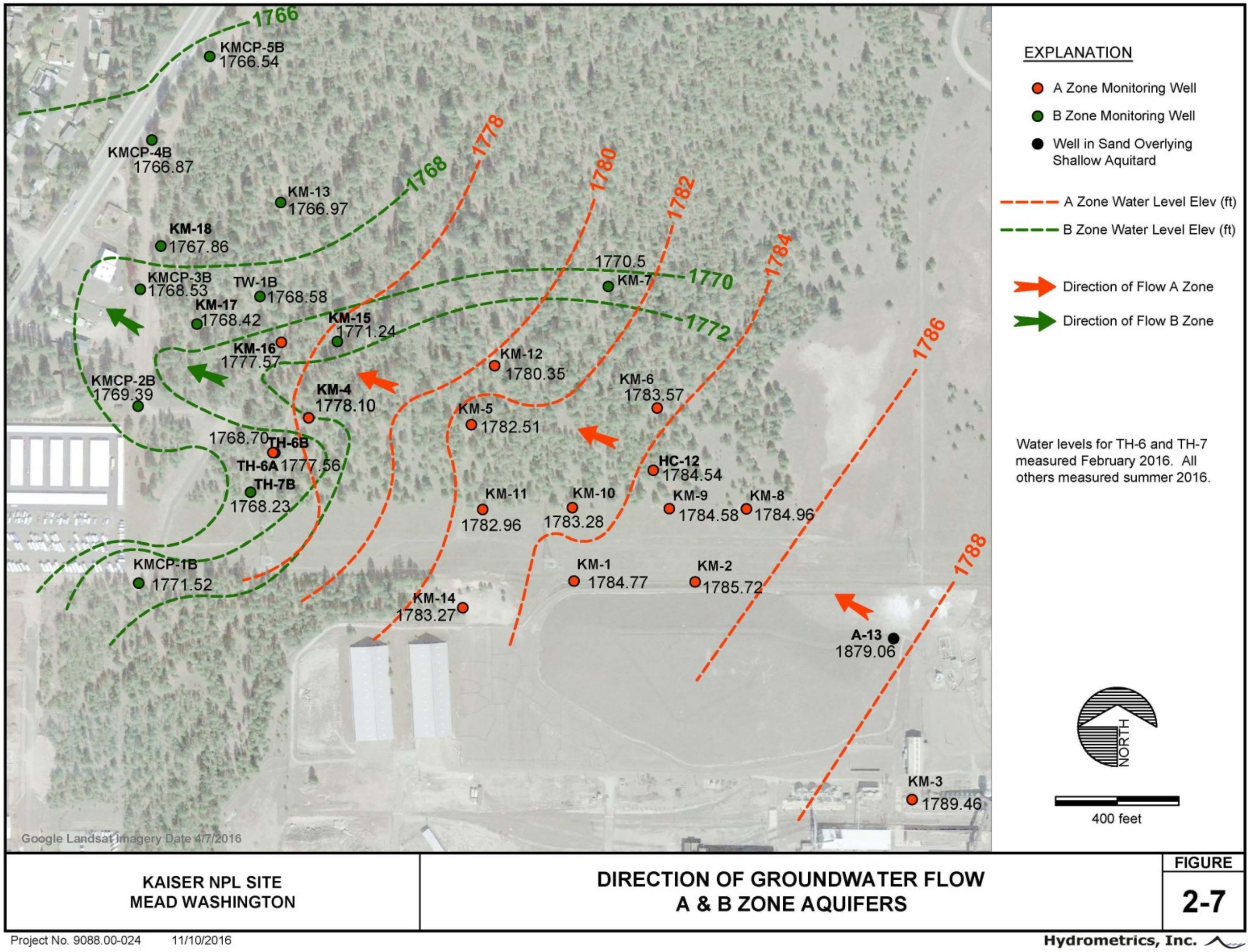
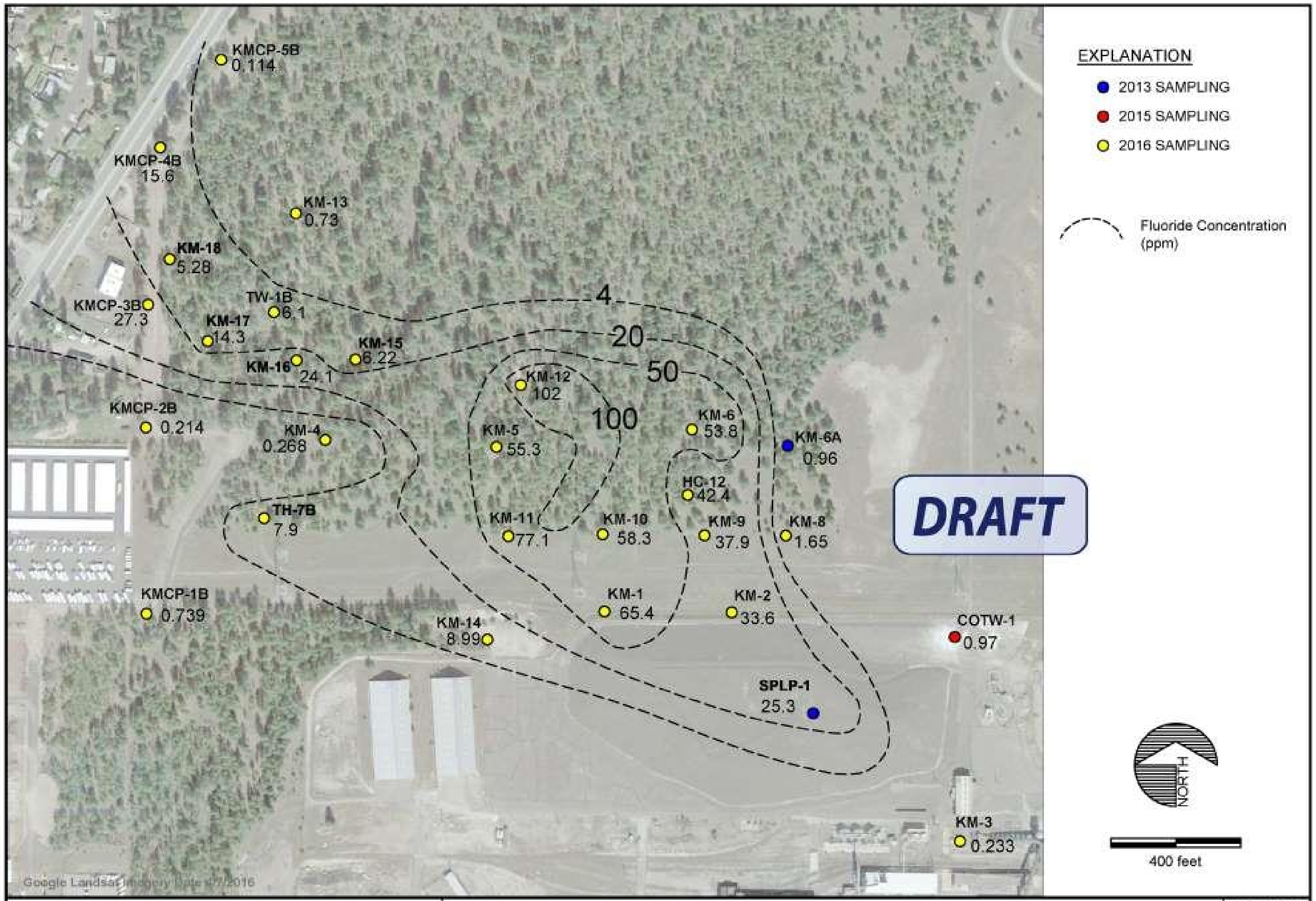


FIGURE 3-1. FLUORIDE CONCENTRATIONS IN GROUNDWATER



KAISER NPL SITE
MEAD WASHINGTON

FLUORIDE CONCENTRATION
IN GROUNDWATER RESULTS

FIGURE
3-1

Project No. 9088.00-024 10/6/2016

Hydrometrics, Inc.
Consulting Scientists and Engineers

FIGURE 3-2. BOUNDARIES AND CALCULATION AREAS OF THE MODEL

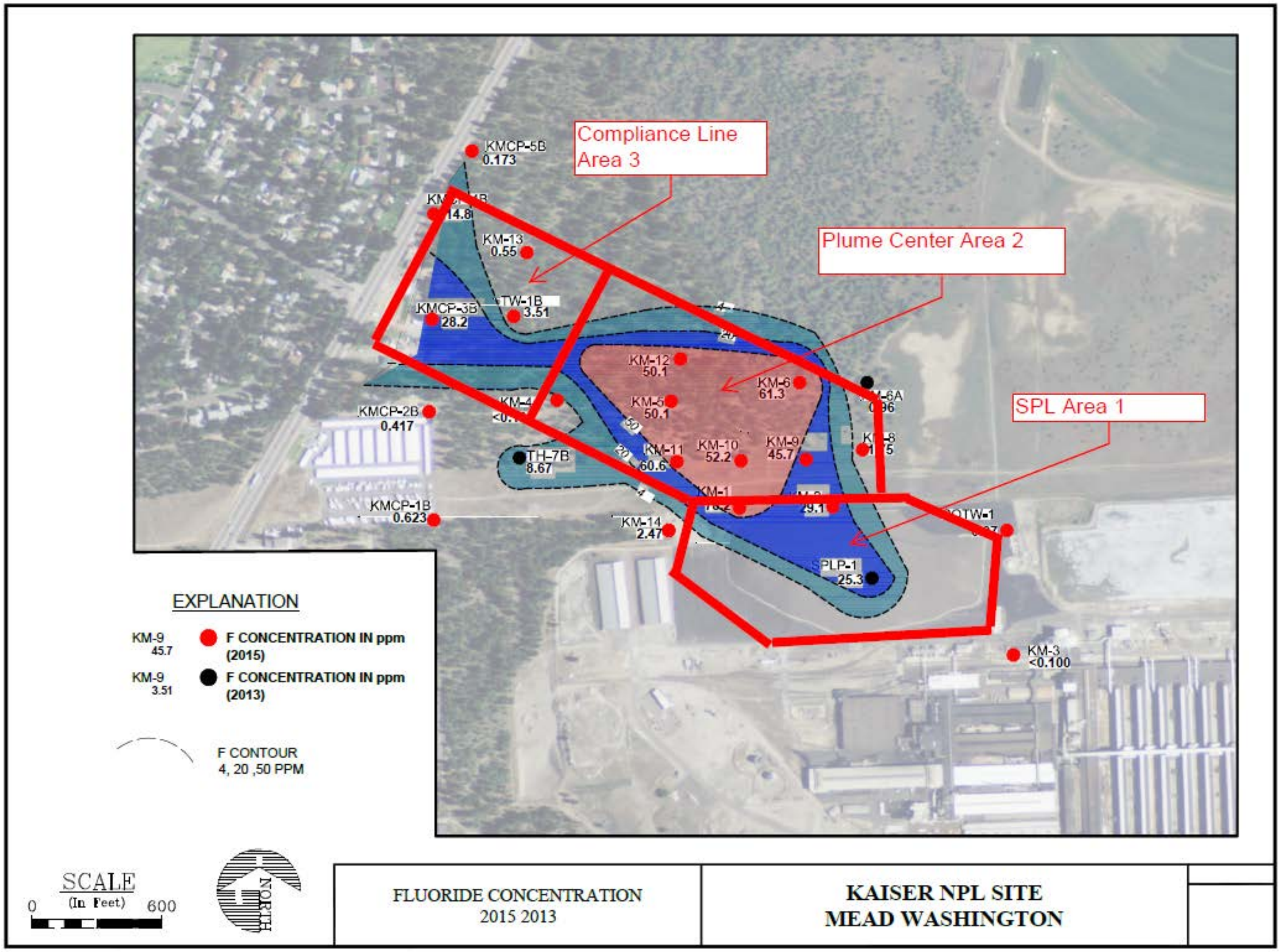
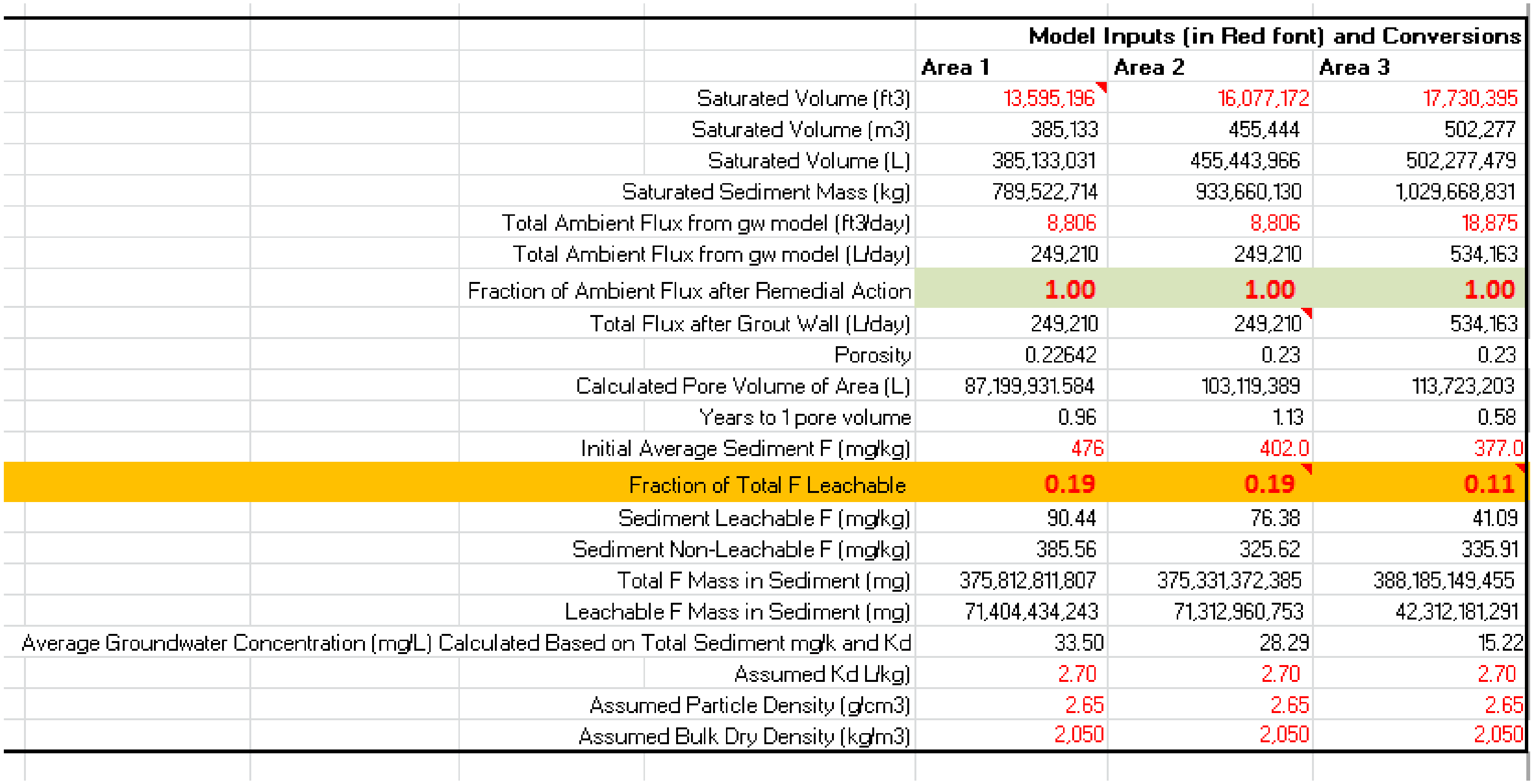
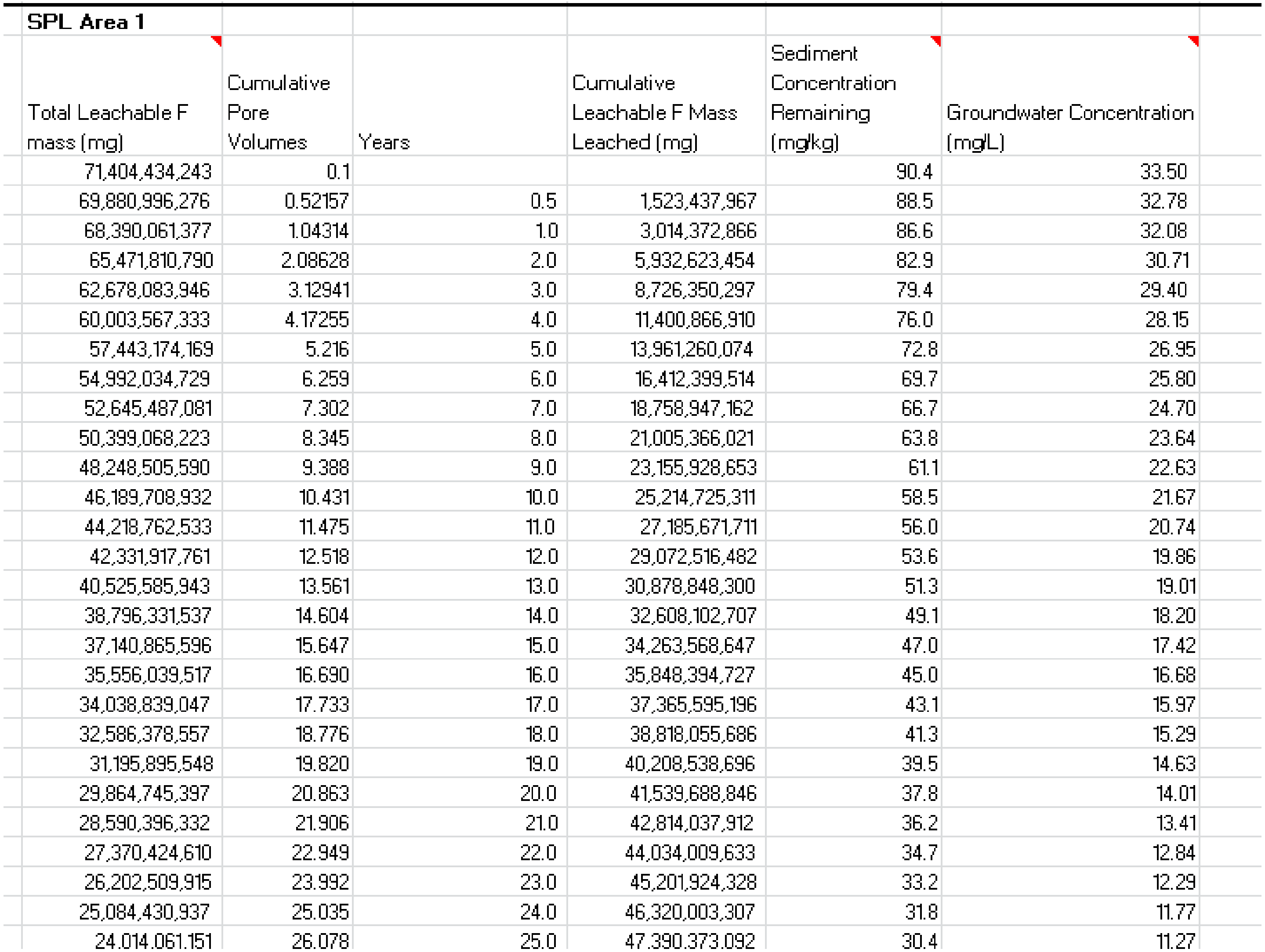


FIGURE 4-1. INPUT DATA BLOCK



	Model Inputs (in Red font) and Conversions		
	Area 1	**Area 2**	**Area 3**
Saturated Volume (ft3)	13,595,196	16,077,172	17,730,395
Saturated Volume (m3)	385,133	455,444	502,277
Saturated Volume (L)	385,133,031	455,443,966	502,277,479
Saturated Sediment Mass (kg)	789,522,714	933,660,130	1,029,668,831
Total Ambient Flux from gw model (ft3/day)	8,806	8,806	18,875
Total Ambient Flux from gw model (L/day)	249,210	249,210	534,163
Fraction of Ambient Flux after Remedial Action	**1.00**	**1.00**	**1.00**
Total Flux after Grout Wall (L/day)	249,210	249,210	534,163
Porosity	0.22642	0.23	0.23
Calculated Pore Volume of Area (L)	87,199,931.584	103,119,389	113,723,203
Years to 1 pore volume	0.96	1.13	0.58
Initial Average Sediment F (mg/kg)	476	402.0	377.0
Fraction of Total F Leachable	**0.19**	**0.19**	**0.11**
Sediment Leachable F (mg/kg)	90.44	76.38	41.09
Sediment Non-Leachable F (mg/kg)	385.56	325.62	335.91
Total F Mass in Sediment (mg)	375,812,811,807	375,331,372,385	388,185,149,455
Leachable F Mass in Sediment (mg)	71,404,434,243	71,312,960,753	42,312,181,291
Average Groundwater Concentration (mg/L) Calculated Based on Total Sediment mg/k and Kd	33.50	28.29	15.22
Assumed Kd L/kg)	2.70	2.70	2.70
Assumed Particle Density (g/cm3)	2.65	2.65	2.65
Assumed Bulk Dry Density (kg/m3)	2,050	2,050	2,050

FIGURE 4-2. SPL AREA CALCULATION BLOCK



SPL Area 1					
Total Leachable F mass (mg)	Cumulative Pore Volumes	Years	Cumulative Leachable F Mass Leached (mg)	Sediment Concentration Remaining (mg/kg)	Groundwater Concentration (mg/L)
71,404,434,243	0.1			90.4	33.50
69,880,996,276	0.52157	0.5	1,523,437,967	88.5	32.78
68,390,061,377	1.04314	1.0	3,014,372,866	86.6	32.08
65,471,810,790	2.08628	2.0	5,932,623,454	82.9	30.71
62,678,083,946	3.12941	3.0	8,726,350,297	79.4	29.40
60,003,567,333	4.17255	4.0	11,400,866,910	76.0	28.15
57,443,174,169	5.216	5.0	13,961,260,074	72.8	26.95
54,992,034,729	6.259	6.0	16,412,399,514	69.7	25.80
52,645,487,081	7.302	7.0	18,758,947,162	66.7	24.70
50,399,068,223	8.345	8.0	21,005,366,021	63.8	23.64
48,248,505,590	9.388	9.0	23,155,928,653	61.1	22.63
46,189,708,932	10.431	10.0	25,214,725,311	58.5	21.67
44,218,762,533	11.475	11.0	27,185,671,711	56.0	20.74
42,331,917,761	12.518	12.0	29,072,516,482	53.6	19.86
40,525,585,943	13.561	13.0	30,878,848,300	51.3	19.01
38,796,331,537	14.604	14.0	32,608,102,707	49.1	18.20
37,140,865,596	15.647	15.0	34,263,568,647	47.0	17.42
35,556,039,517	16.690	16.0	35,848,394,727	45.0	16.68
34,038,839,047	17.733	17.0	37,365,595,196	43.1	15.97
32,586,378,557	18.776	18.0	38,818,055,686	41.3	15.29
31,195,895,548	19.820	19.0	40,208,538,696	39.5	14.63
29,864,745,397	20.863	20.0	41,539,688,846	37.8	14.01
28,590,396,332	21.906	21.0	42,814,037,912	36.2	13.41
27,370,424,610	22.949	22.0	44,034,009,633	34.7	12.84
26,202,509,915	23.992	23.0	45,201,924,328	33.2	12.29
25,084,430,937	25.035	24.0	46,320,003,307	31.8	11.77
24,014,061,151	26.078	25.0	47,390,373,092	30.4	11.27

FIGURE 4-3. SPL AREA CALCULATION FLOW DIAGRAM

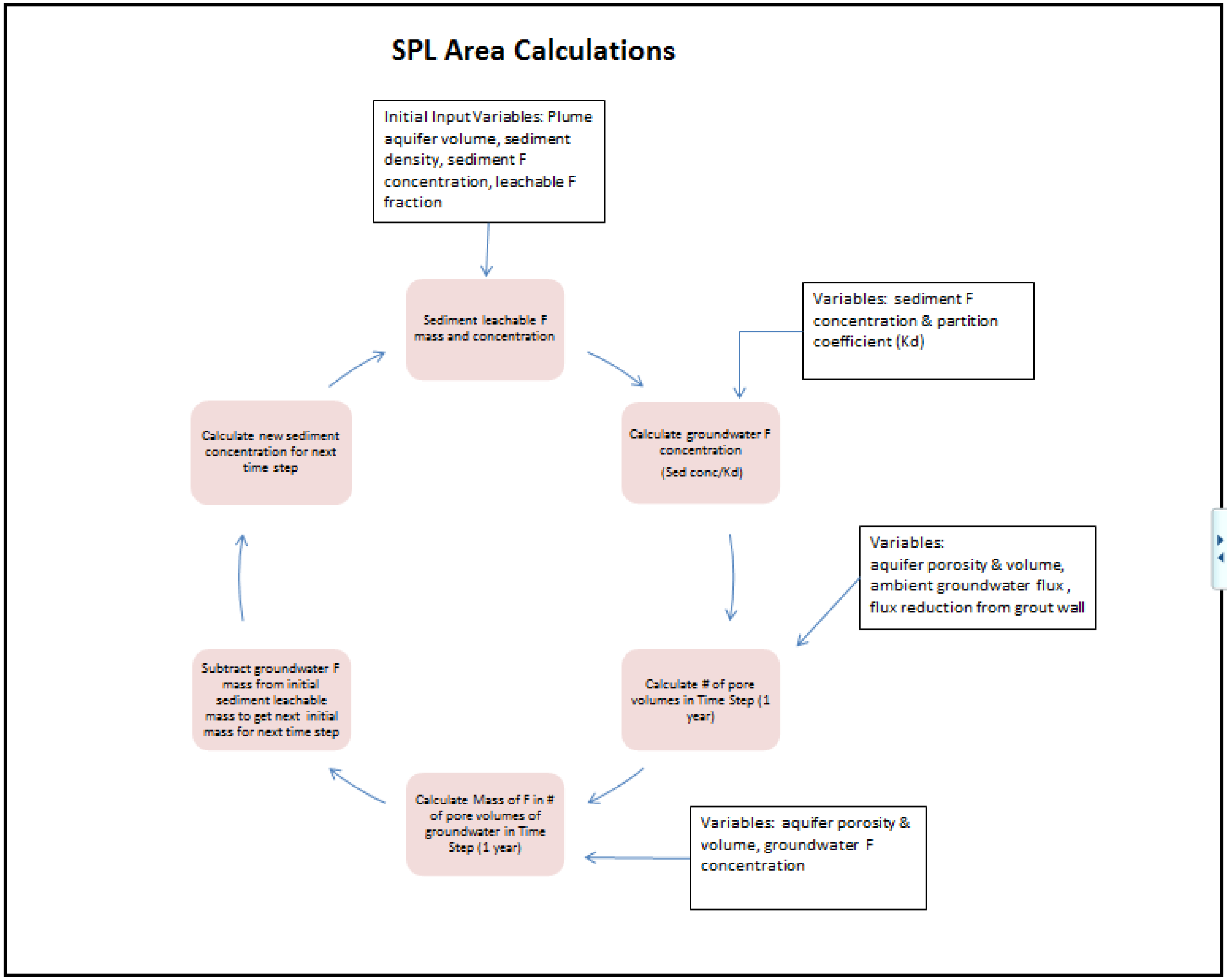
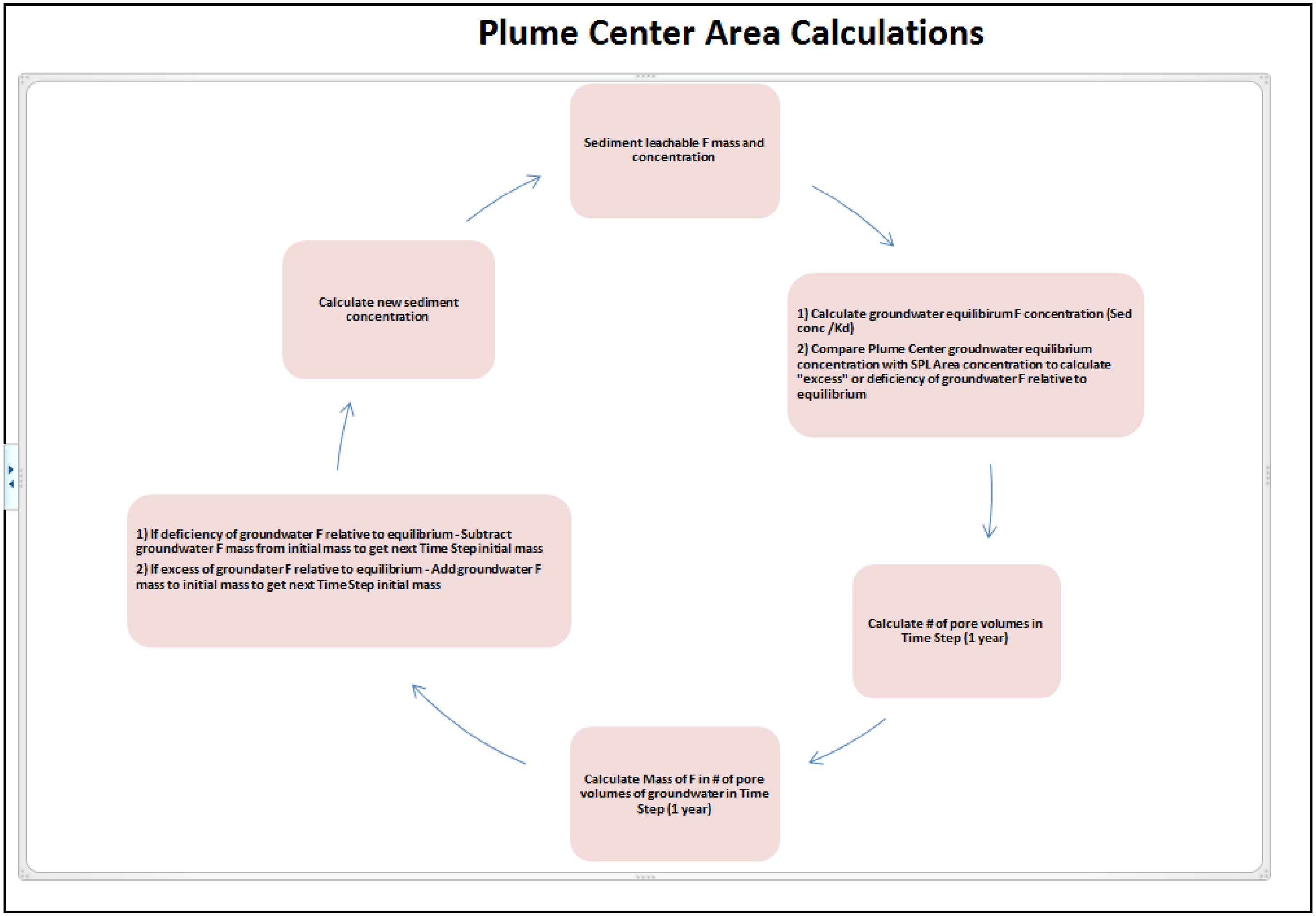


FIGURE 4-4. PLUME CENTER AREA CALCULATION FLOW DIAGRAM



Plume Center Area Calculations

Sediment leachable F mass and concentration

1) Calculate groundwater equilibirum F concentration (Sed conc /Kd)

2) Compare Plume Center groudnwater equilibrium concentration with SPL Area concentration to calculate "excess" or deficiency of groundwater F relative to equilibrium

Calculate # of pore volumes in Time Step (1 year)

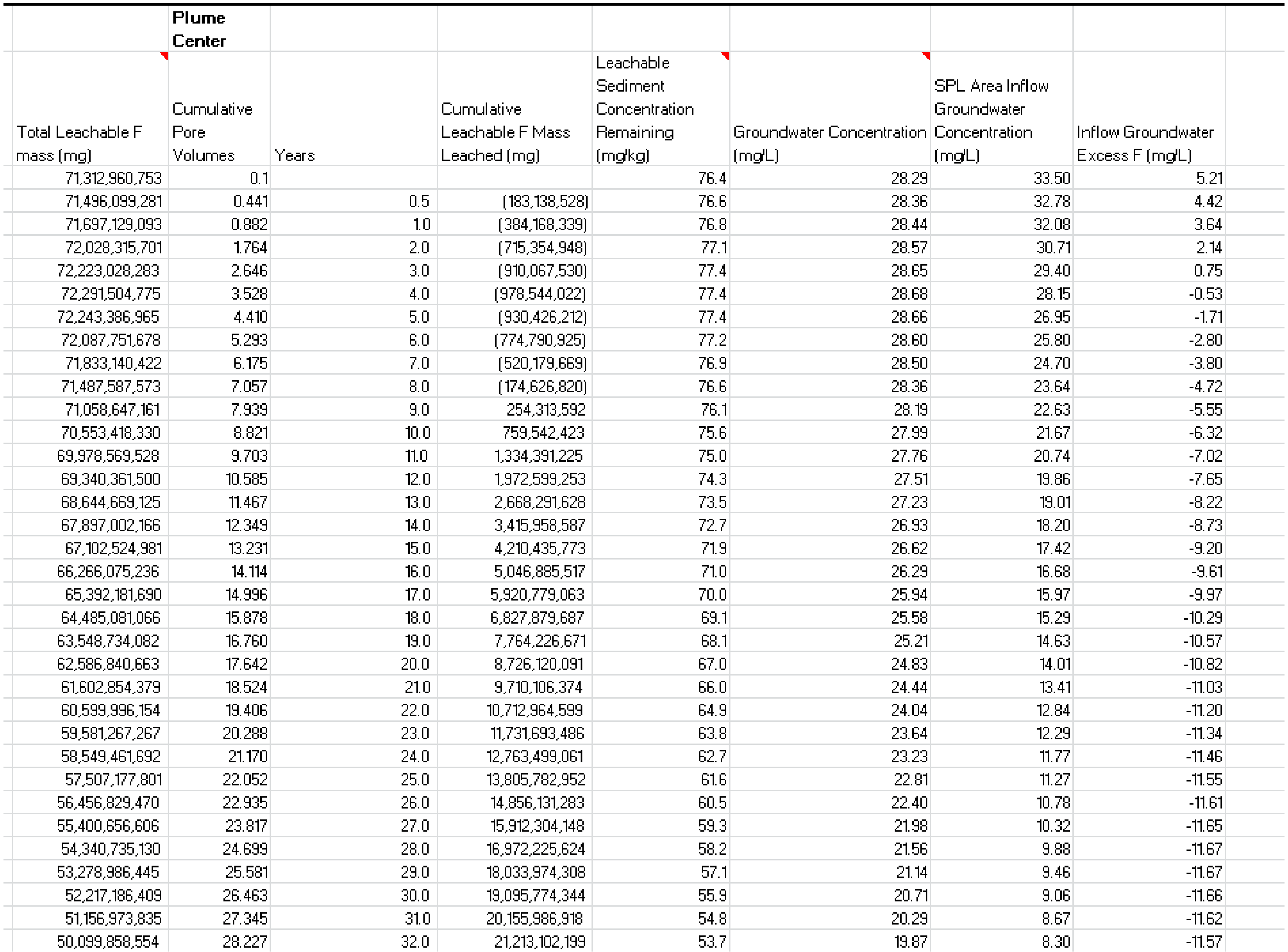
Calculate Mass of F in # of pore volumes of groundwater in Time Step (1 year)

1) If deficiency of groundwater F relative to equilibrium - Subtract groundwater F mass from initial mass to get next Time Step initial mass

2) If excess of groundater F relative to equilibrium - Add groundwater F mass to initial mass to get next Time Step initial mass

Calculate new sediment concentration

FIGURE 4-5. PLUME CENTER AREA CALCULATION BLOCK



	Plume Center						
Total Leachable F mass (mg)	Cumulative Pore Volumes	Years	Cumulative Leachable F Mass Leached (mg)	Leachable Sediment Concentration Remaining (mg/kg)	Groundwater Concentration (mg/L)	SPL Area Inflow Groundwater Concentration (mg/L)	Inflow Groundwater Excess F (mg/L)
71,312,960,753	0.1			76.4	28.29	33.50	5.21
71,496,099,281	0.441	0.5	(183,138,528)	76.6	28.36	32.78	4.42
71,697,129,093	0.882	1.0	(384,168,339)	76.8	28.44	32.08	3.64
72,028,315,701	1.764	2.0	(715,354,948)	77.1	28.57	30.71	2.14
72,223,028,283	2.646	3.0	(910,067,530)	77.4	28.65	29.40	0.75
72,291,504,775	3.528	4.0	(978,544,022)	77.4	28.68	28.15	-0.53
72,243,386,965	4.410	5.0	(930,426,212)	77.4	28.66	26.95	-1.71
72,087,751,678	5.293	6.0	(774,790,925)	77.2	28.60	25.80	-2.80
71,833,140,422	6.175	7.0	(520,179,669)	76.9	28.50	24.70	-3.80
71,487,587,573	7.057	8.0	(174,626,820)	76.6	28.36	23.64	-4.72
71,058,647,161	7.939	9.0	254,313,592	76.1	28.19	22.63	-5.55
70,553,418,330	8.821	10.0	759,542,423	75.6	27.99	21.67	-6.32
69,978,569,528	9.703	11.0	1,334,391,225	75.0	27.76	20.74	-7.02
69,340,361,500	10.585	12.0	1,972,599,253	74.3	27.51	19.86	-7.65
68,644,669,125	11.467	13.0	2,668,291,628	73.5	27.23	19.01	-8.22
67,897,002,166	12.349	14.0	3,415,958,587	72.7	26.93	18.20	-8.73
67,102,524,981	13.231	15.0	4,210,435,773	71.9	26.62	17.42	-9.20
66,266,075,236	14.114	16.0	5,046,885,517	71.0	26.29	16.68	-9.61
65,392,181,690	14.996	17.0	5,920,779,063	70.0	25.94	15.97	-9.97
64,485,081,066	15.878	18.0	6,827,879,687	69.1	25.58	15.29	-10.29
63,548,734,082	16.760	19.0	7,764,226,671	68.1	25.21	14.63	-10.57
62,586,840,663	17.642	20.0	8,726,120,091	67.0	24.83	14.01	-10.82
61,602,854,379	18.524	21.0	9,710,106,374	66.0	24.44	13.41	-11.03
60,599,996,154	19.406	22.0	10,712,964,599	64.9	24.04	12.84	-11.20
59,581,267,267	20.288	23.0	11,731,693,486	63.8	23.64	12.29	-11.34
58,549,461,692	21.170	24.0	12,763,499,061	62.7	23.23	11.77	-11.46
57,507,177,801	22.052	25.0	13,805,782,952	61.6	22.81	11.27	-11.55
56,456,829,470	22.935	26.0	14,856,131,283	60.5	22.40	10.78	-11.61
55,400,656,606	23.817	27.0	15,912,304,148	59.3	21.98	10.32	-11.65
54,340,735,130	24.699	28.0	16,972,225,624	58.2	21.56	9.88	-11.67
53,278,986,445	25.581	29.0	18,033,974,308	57.1	21.14	9.46	-11.67
52,217,186,409	26.463	30.0	19,095,774,344	55.9	20.71	9.06	-11.66
51,156,973,835	27.345	31.0	20,155,986,918	54.8	20.29	8.67	-11.62
50,099,858,554	28.227	32.0	21,213,102,199	53.7	19.87	8.30	-11.57

FIGURE 4-6. POINT OF COMPLIANCE AREA CALCULATION FLOW DIAGRAM

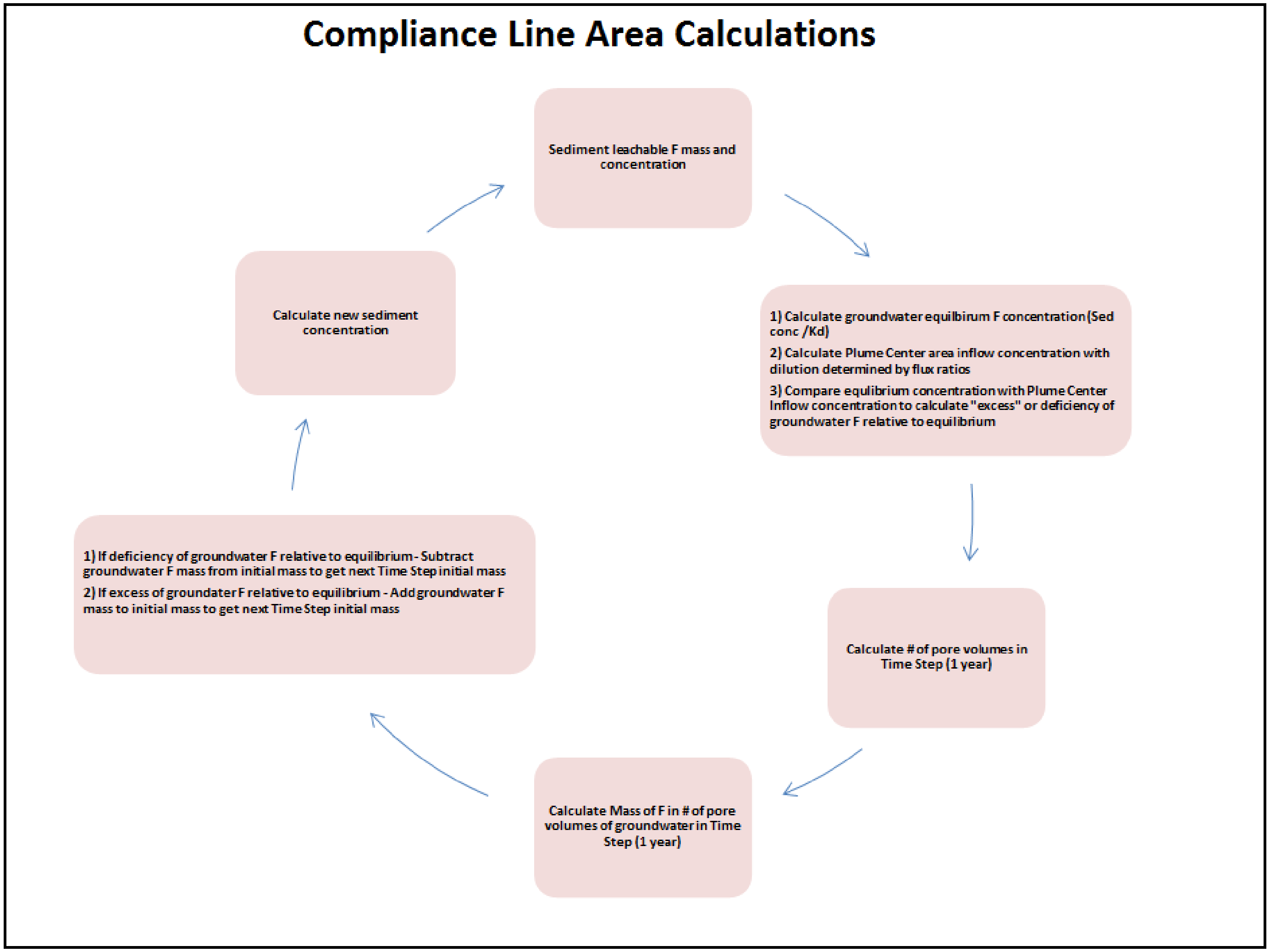
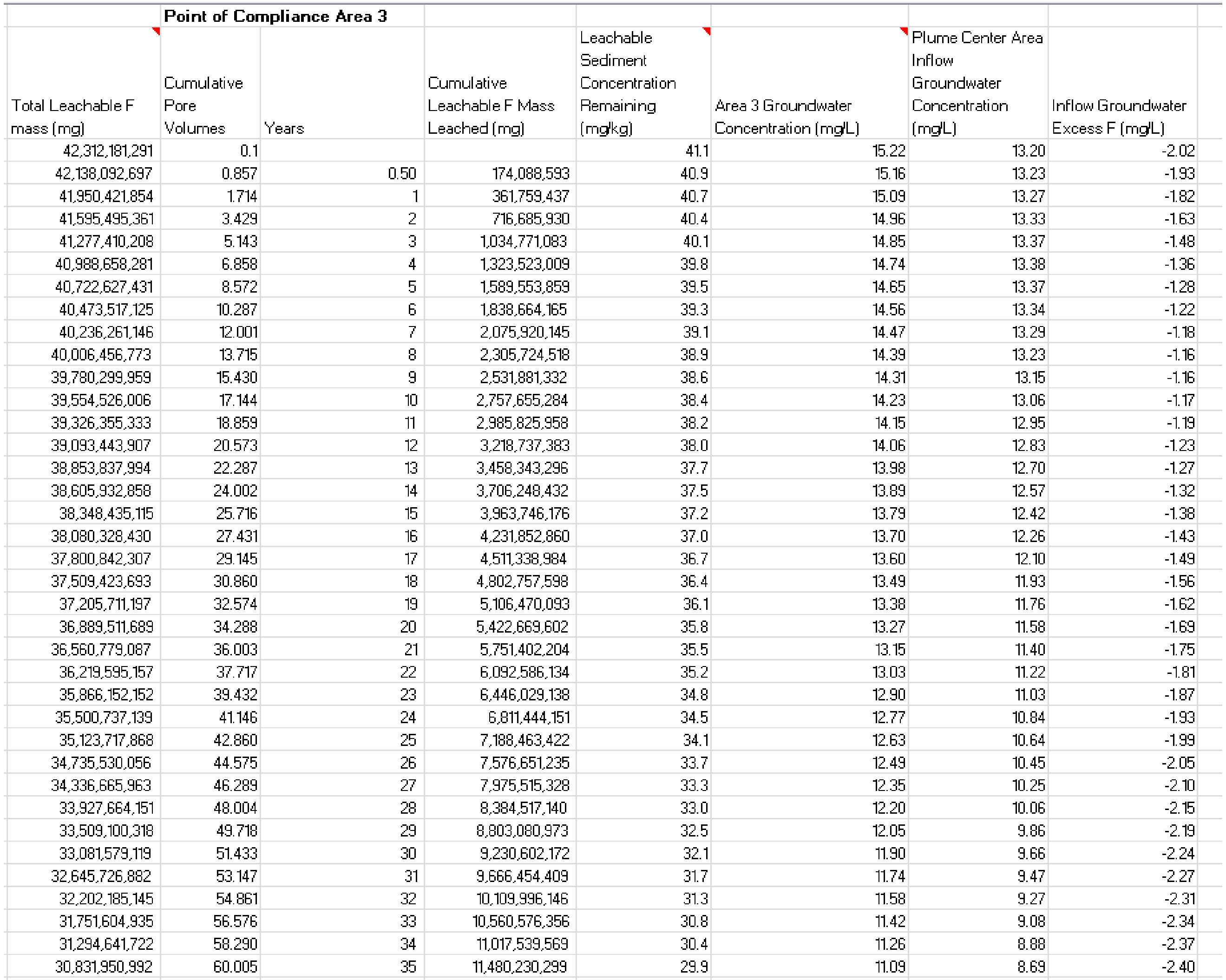
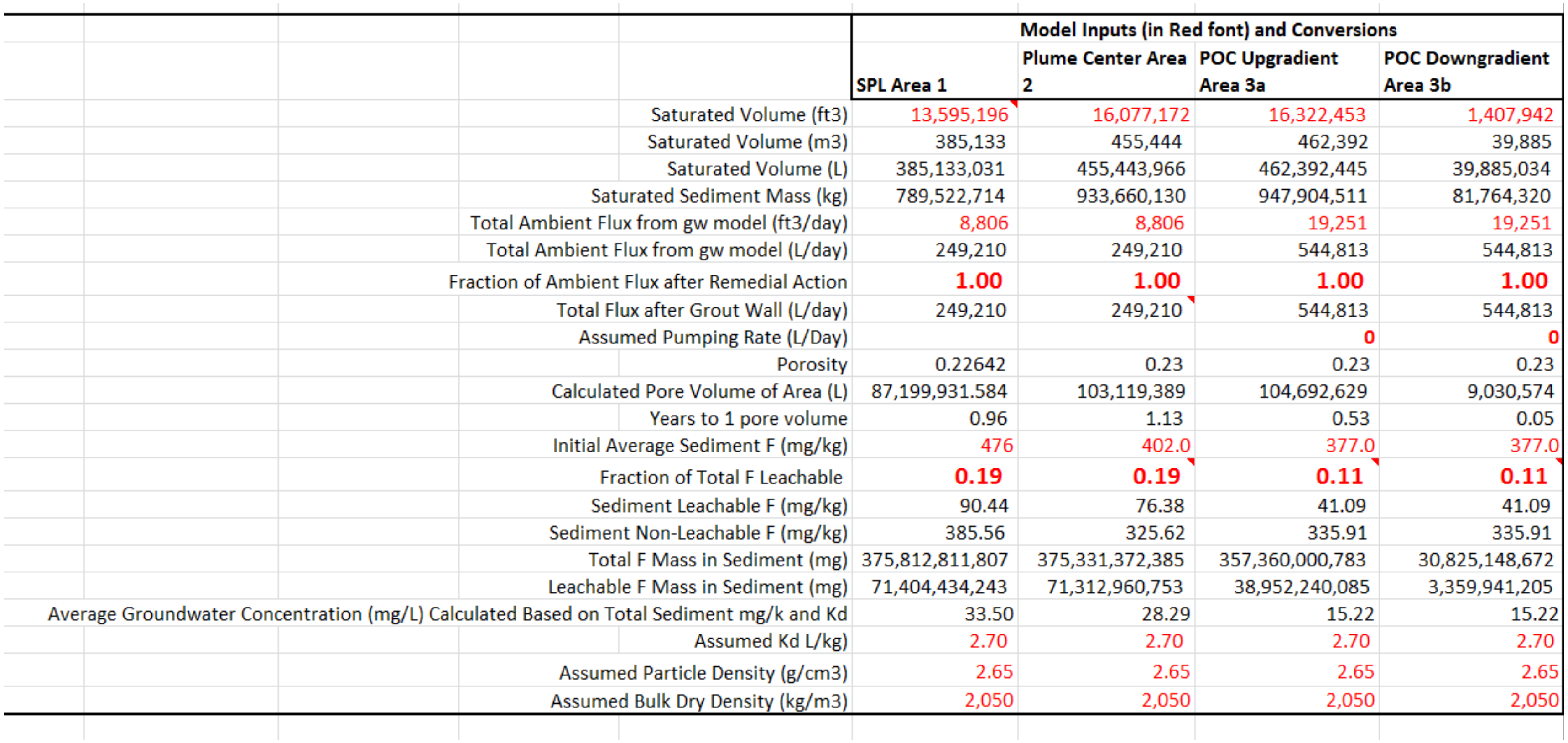


FIGURE 4-7. POINT OF COMPLIANCE AREA CALCULATION BLOCK



	Point of Compliance Area 3						
Total Leachable F mass (mg)	Cumulative Pore Volumes	Years	Cumulative Leachable F Mass Leached (mg)	Leachable Sediment Concentration Remaining (mg/kg)	Area 3 Groundwater Concentration (mg/L)	Plume Center Area Inflow Groundwater Concentration (mg/L)	Inflow Groundwater Excess F (mg/L)
42,312,181,291	0.1			41.1	15.22	13.20	-2.02
42,138,092,697	0.857	0.50	174,088,593	40.9	15.16	13.23	-1.93
41,950,421,854	1.714	1	361,759,437	40.7	15.09	13.27	-1.82
41,595,495,361	3.429	2	716,685,930	40.4	14.96	13.33	-1.63
41,277,410,208	5.143	3	1,034,771,083	40.1	14.85	13.37	-1.48
40,988,658,281	6.858	4	1,323,523,009	39.8	14.74	13.38	-1.36
40,722,627,431	8.572	5	1,589,553,859	39.5	14.65	13.37	-1.28
40,473,517,125	10.287	6	1,838,664,165	39.3	14.56	13.34	-1.22
40,236,261,146	12.001	7	2,075,920,145	39.1	14.47	13.29	-1.18
40,006,456,773	13.715	8	2,305,724,518	38.9	14.39	13.23	-1.16
39,780,299,959	15.430	9	2,531,881,332	38.6	14.31	13.15	-1.16
39,554,526,006	17.144	10	2,757,655,284	38.4	14.23	13.06	-1.17
39,326,355,333	18.859	11	2,985,825,958	38.2	14.15	12.95	-1.19
39,093,443,907	20.573	12	3,218,737,383	38.0	14.06	12.83	-1.23
38,853,837,994	22.287	13	3,458,343,296	37.7	13.98	12.70	-1.27
38,605,932,858	24.002	14	3,706,248,432	37.5	13.89	12.57	-1.32
38,348,435,115	25.716	15	3,963,746,176	37.2	13.79	12.42	-1.38
38,080,328,430	27.431	16	4,231,852,860	37.0	13.70	12.26	-1.43
37,800,842,307	29.145	17	4,511,338,984	36.7	13.60	12.10	-1.49
37,509,423,693	30.860	18	4,802,757,598	36.4	13.49	11.93	-1.56
37,205,711,197	32.574	19	5,106,470,093	36.1	13.38	11.76	-1.62
36,889,511,689	34.288	20	5,422,669,602	35.8	13.27	11.58	-1.69
36,560,779,087	36.003	21	5,751,402,204	35.5	13.15	11.40	-1.75
36,219,595,157	37.717	22	6,092,586,134	35.2	13.03	11.22	-1.81
35,866,152,152	39.432	23	6,446,029,138	34.8	12.90	11.03	-1.87
35,500,737,139	41.146	24	6,811,444,151	34.5	12.77	10.84	-1.93
35,123,717,868	42.860	25	7,188,463,422	34.1	12.63	10.64	-1.99
34,735,530,056	44.575	26	7,576,651,235	33.7	12.49	10.45	-2.05
34,336,665,963	46.289	27	7,975,515,328	33.3	12.35	10.25	-2.10
33,927,664,151	48.004	28	8,384,517,140	33.0	12.20	10.06	-2.15
33,509,100,318	49.718	29	8,803,080,973	32.5	12.05	9.86	-2.19
33,081,579,119	51.433	30	9,230,602,172	32.1	11.90	9.66	-2.24
32,645,726,882	53.147	31	9,666,454,409	31.7	11.74	9.47	-2.27
32,202,185,145	54.861	32	10,109,996,146	31.3	11.58	9.27	-2.31
31,751,604,935	56.576	33	10,560,576,356	30.8	11.42	9.08	-2.34
31,294,641,722	58.290	34	11,017,539,569	30.4	11.26	8.88	-2.37
30,831,950,992	60.005	35	11,480,230,299	29.9	11.09	8.69	-2.40

FIGURE 4-8. INPUT DATA BLOCK FOR PUMPING SIMULATIONS



	Model Inputs (in Red font) and Conversions			
	SPL Area 1	Plume Center Area 2	POC Upgradient Area 3a	POC Downgradient Area 3b
Saturated Volume (ft3)	13,595,196	16,077,172	16,322,453	1,407,942
Saturated Volume (m3)	385,133	455,444	462,392	39,885
Saturated Volume (L)	385,133,031	455,443,966	462,392,445	39,885,034
Saturated Sediment Mass (kg)	789,522,714	933,660,130	947,904,511	81,764,320
Total Ambient Flux from gw model (ft3/day)	8,806	8,806	19,251	19,251
Total Ambient Flux from gw model (L/day)	249,210	249,210	544,813	544,813
Fraction of Ambient Flux after Remedial Action	**1.00**	**1.00**	**1.00**	**1.00**
Total Flux after Grout Wall (L/day)	249,210	249,210	544,813	544,813
Assumed Pumping Rate (L/Day)			**0**	**0**
Porosity	0.22642	0.23	0.23	0.23
Calculated Pore Volume of Area (L)	87,199,931.584	103,119,389	104,692,629	9,030,574
Years to 1 pore volume	0.96	1.13	0.53	0.05
Initial Average Sediment F (mg/kg)	476	402.0	377.0	377.0
Fraction of Total F Leachable	**0.19**	**0.19**	**0.11**	**0.11**
Sediment Leachable F (mg/kg)	90.44	76.38	41.09	41.09
Sediment Non-Leachable F (mg/kg)	385.56	325.62	335.91	335.91
Total F Mass in Sediment (mg)	375,812,811,807	375,331,372,385	357,360,000,783	30,825,148,672
Leachable F Mass in Sediment (mg)	71,404,434,243	71,312,960,753	38,952,240,085	3,359,941,205
Average Groundwater Concentration (mg/L) Calculated Based on Total Sediment mg/k and Kd	33.50	28.29	15.22	15.22
Assumed Kd L/kg)	2.70	2.70	2.70	2.70
Assumed Particle Density (g/cm3)	2.65	2.65	2.65	2.65
Assumed Bulk Dry Density (kg/m3)	2,050	2,050	2,050	2,050

FIGURE 4-9. MODEL CELLS WITH POINT OF COMPLIANCE AREA MODEL SUB-CELLS

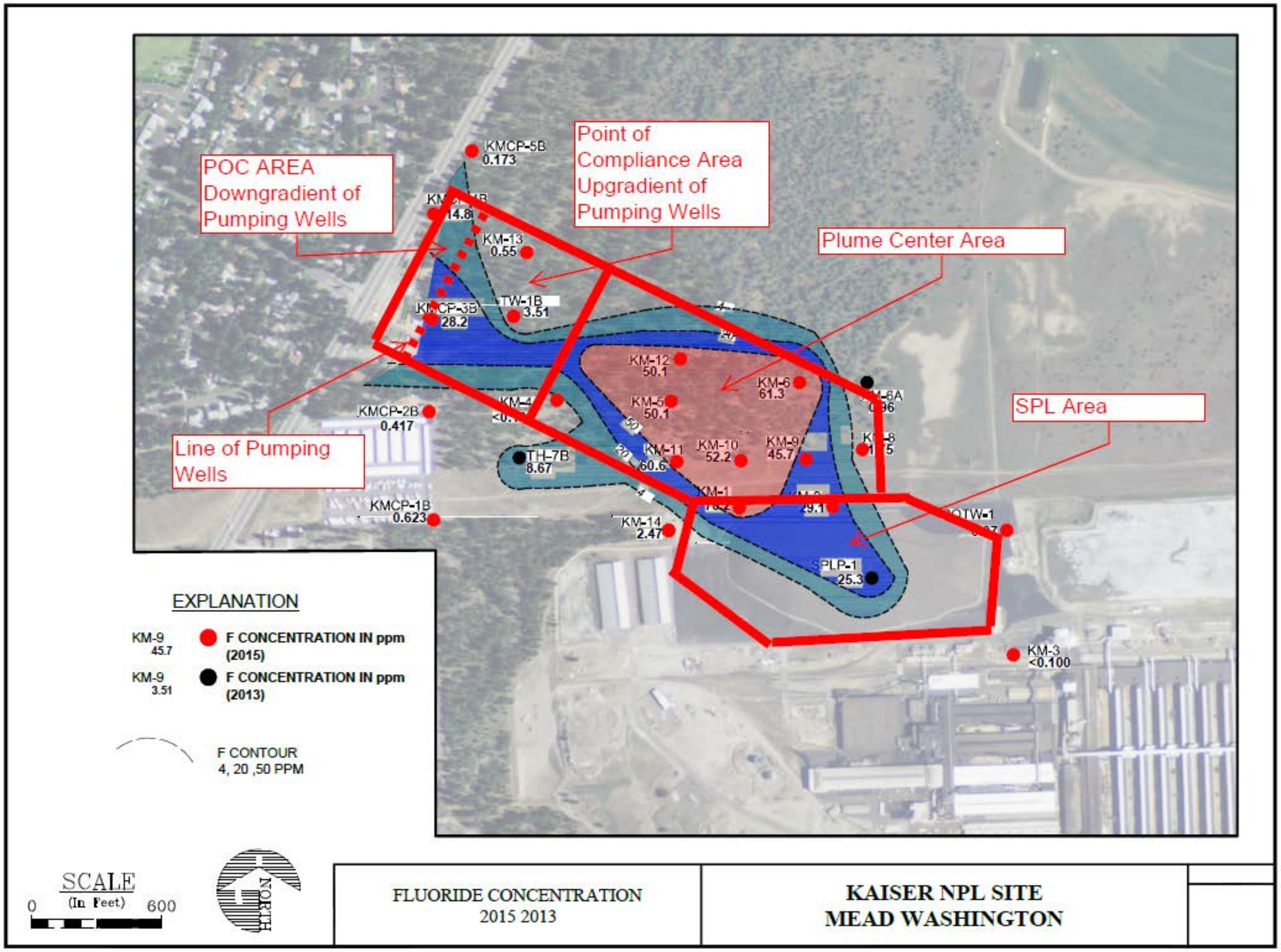


FIGURE 5-1. GROUNDWATER CONCENTRATION TRENDS IN SPL AREA MONITORING WELLS

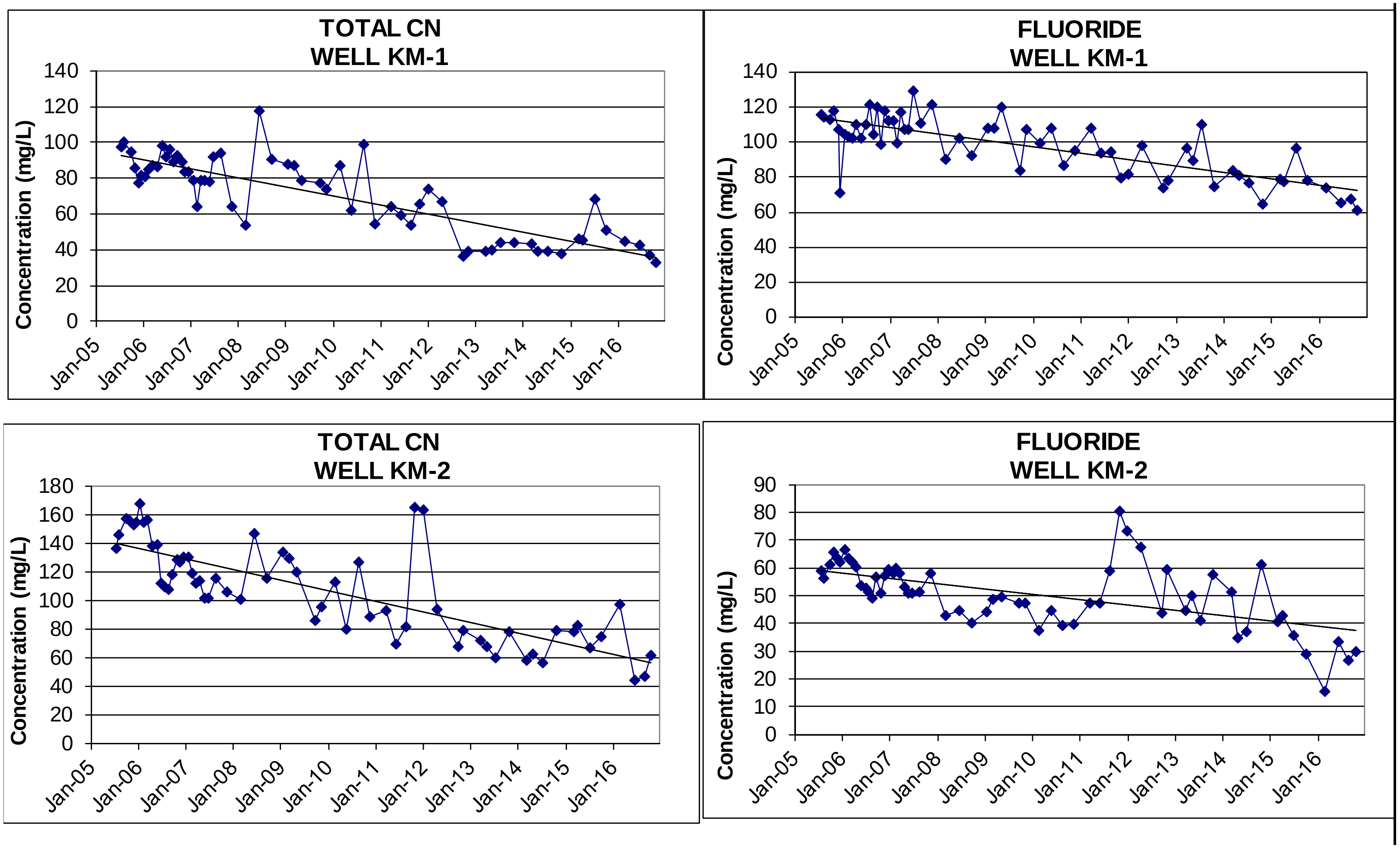


FIGURE 5-2. GROUNDWATER CONCENTRATION TRENDS IN PLUME CENTER AREA MONITORING WELLS

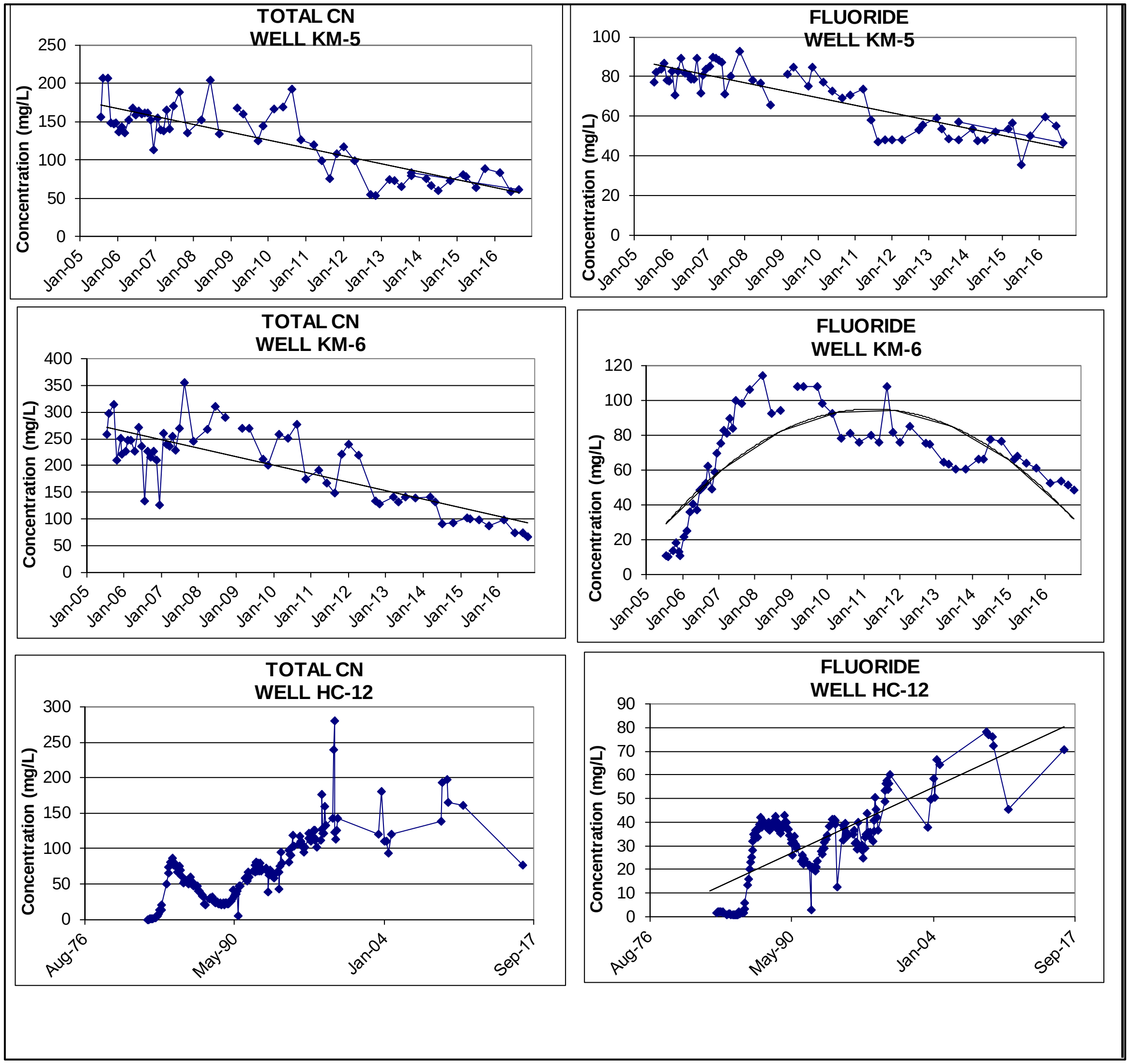


FIGURE 5-3. GROUNDWATER CONCENTRATION TRENDS IN POC AREA MONITORING WELLS

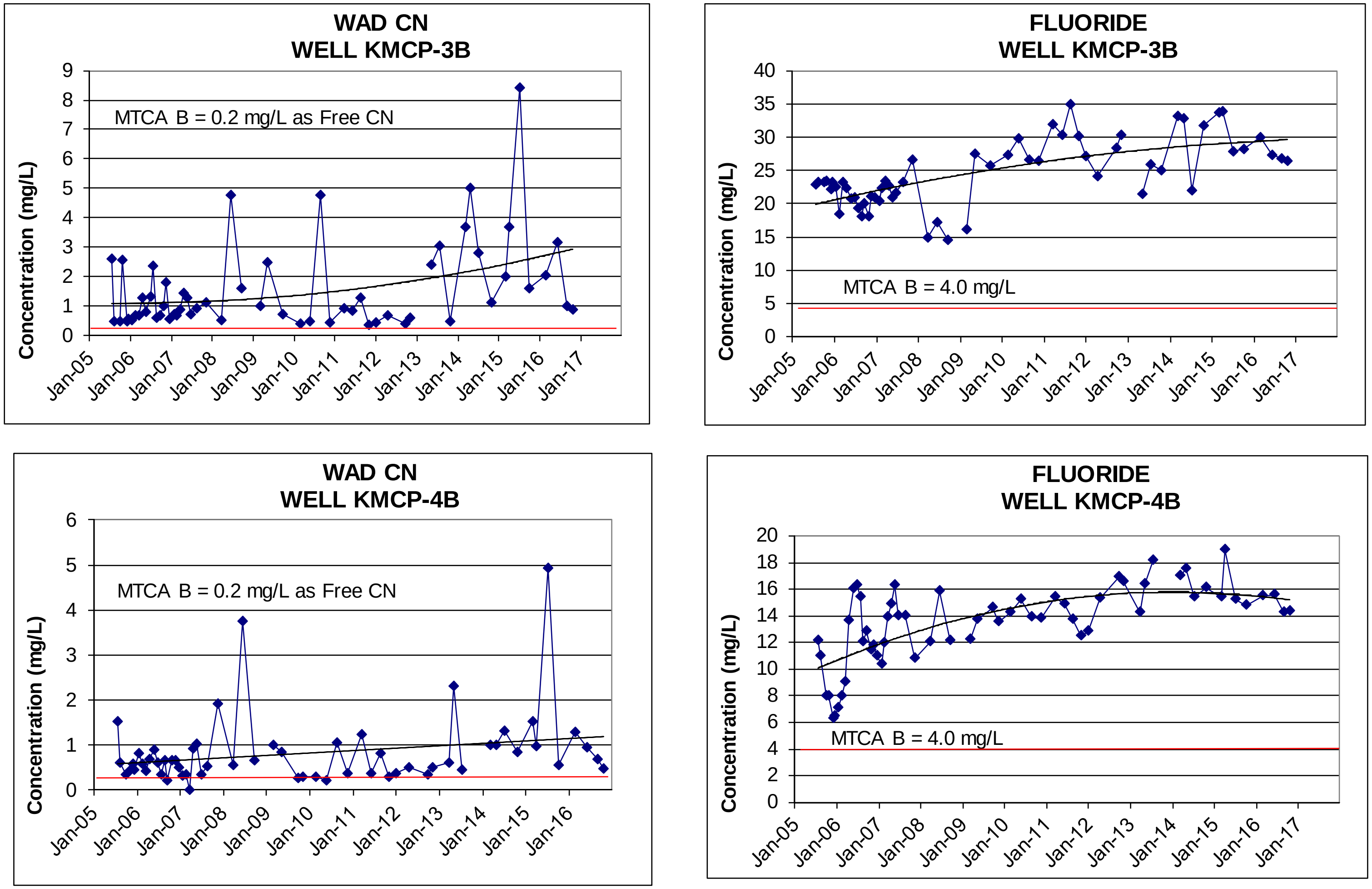


FIGURE 5-4. FLUORIDE MODEL – MID RANGE INPUTS

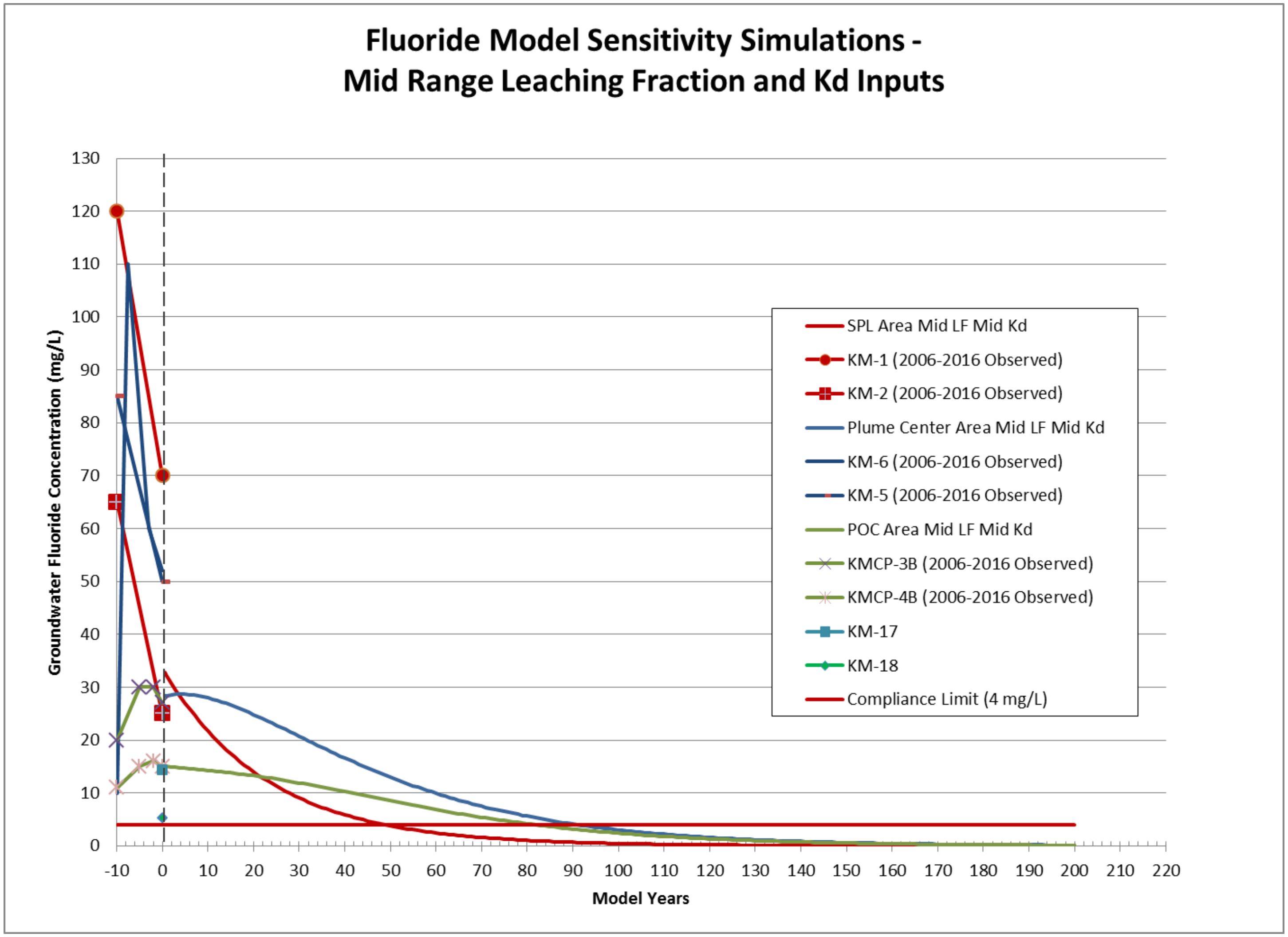
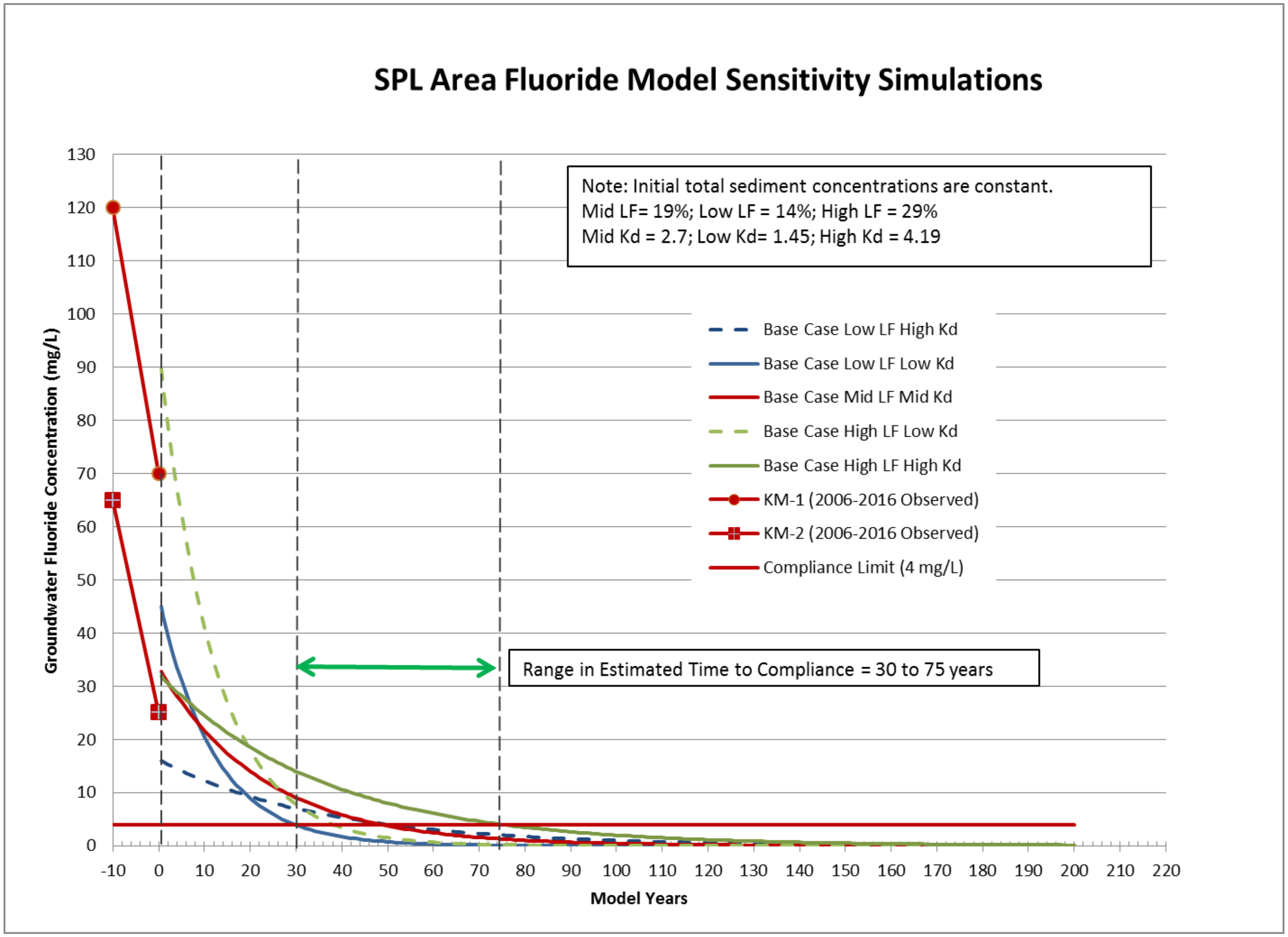


FIGURE 5-5. SPL AREA; FLUORIDE CALIBRATION AND SENSITIVITY ANALYSIS SIMULATIONS WITH VARYING LEACHABLE FRACTION AND KD



Note: Initial total sediment concentrations are constant.
Mid LF= 19%; Low LF = 14%; High LF = 29%
Mid Kd = 2.7; Low Kd= 1.45; High Kd = 4.19

Range in Estimated Time to Compliance = 30 to 75 years

FIGURE 5-6. PLUME CENTER AREA; FLUORIDE CALIBRATION AND SENSITIVITY ANALYSIS SIMULATIONS WITH VARYING LEACHABLE FRACTION AND KD

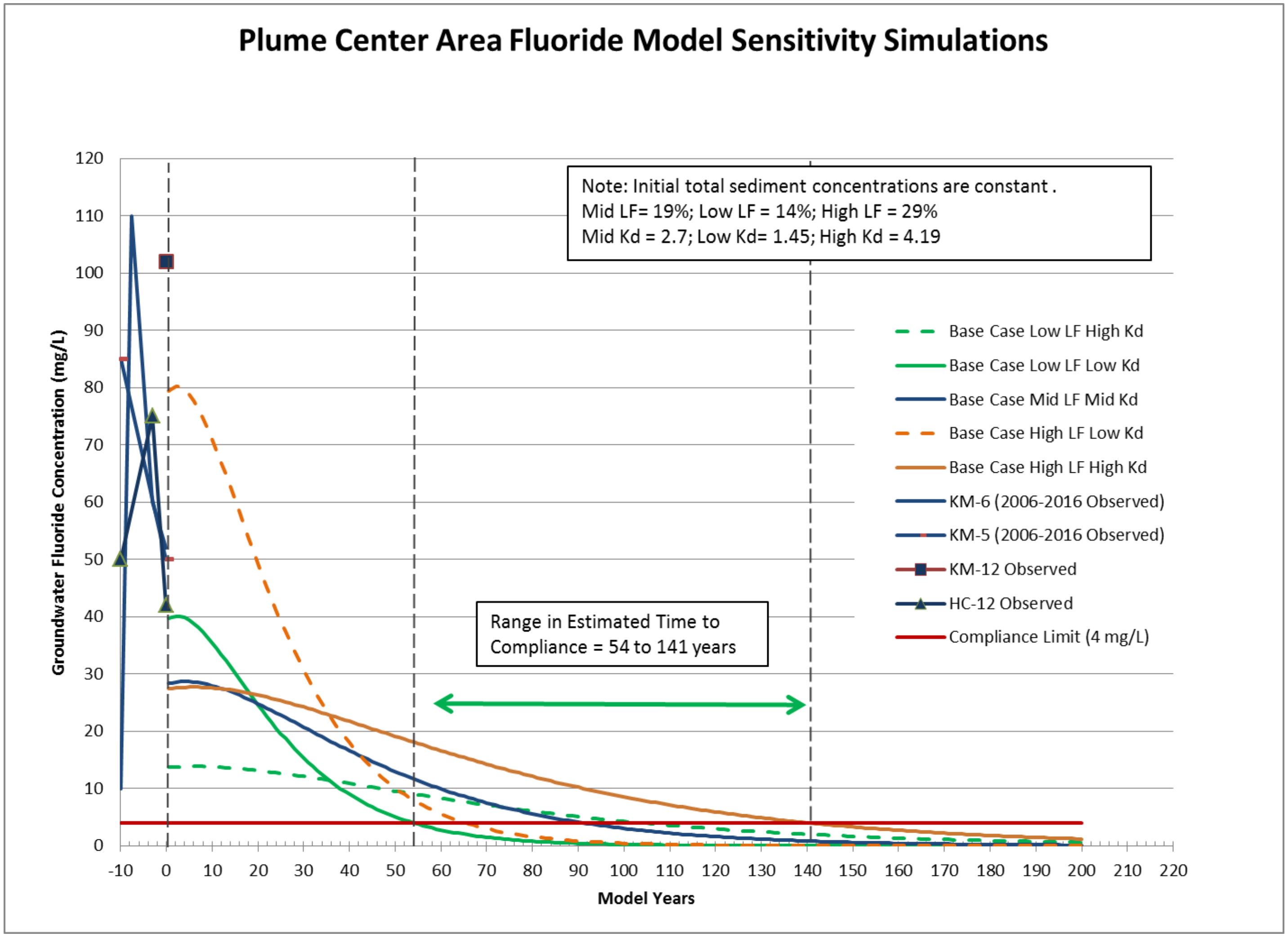


FIGURE 5-7. POC AREA; FLUORIDE CALIBRATION AND SENSITIVITY ANALYSIS SIMULATIONS WITH VARYING LEACHABLE FRACTION AND KD

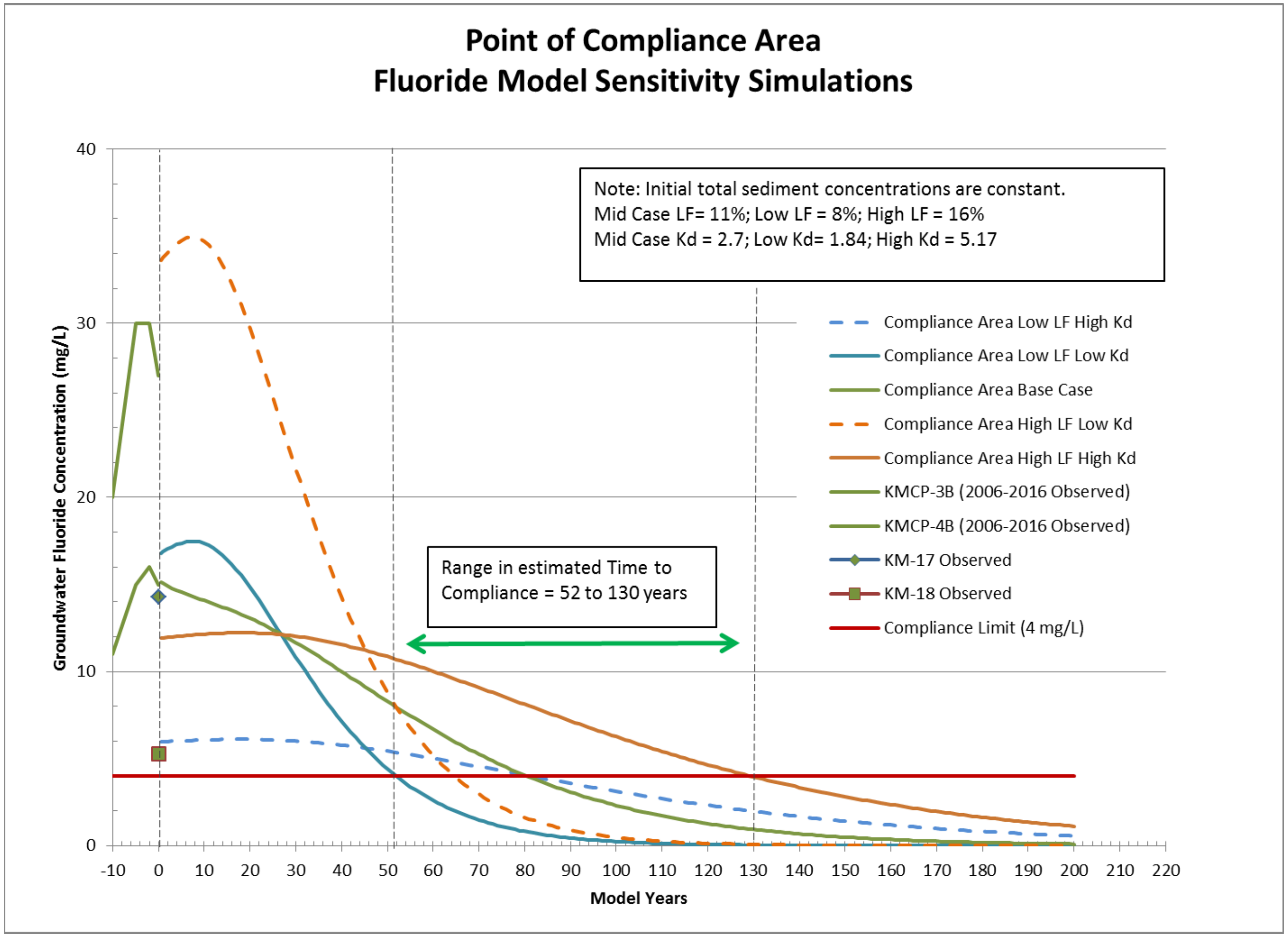


FIGURE 5-8. POC AREA; FLUORIDE SELECTED BASE CASE SIMULATIONS

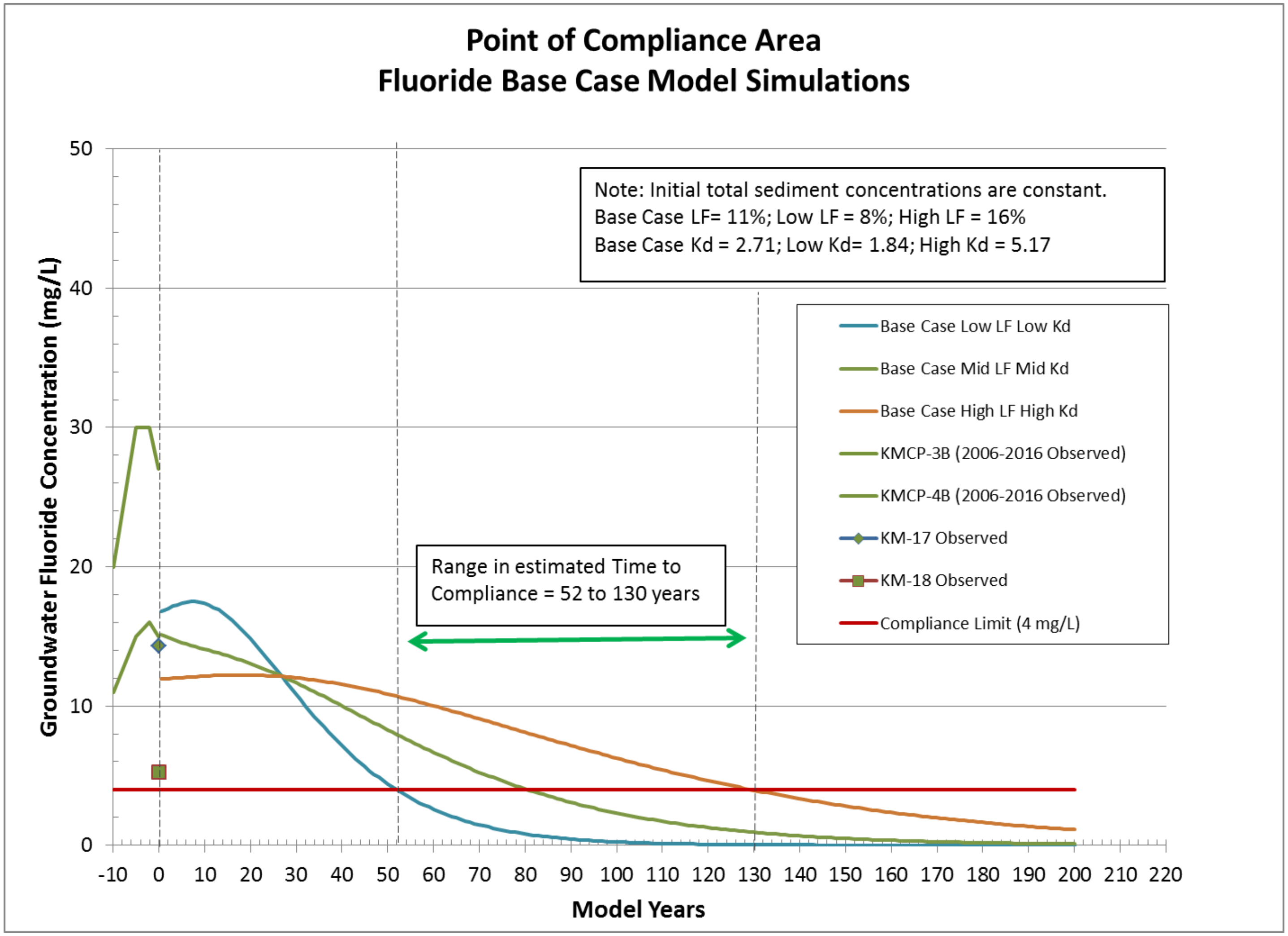


FIGURE 5-9. POC AREA FLUORIDE BASE CASE SENSITIVITY ANALYSIS SIMULATION FOR LEAKY CAP SPL SOURCE SCENARIO

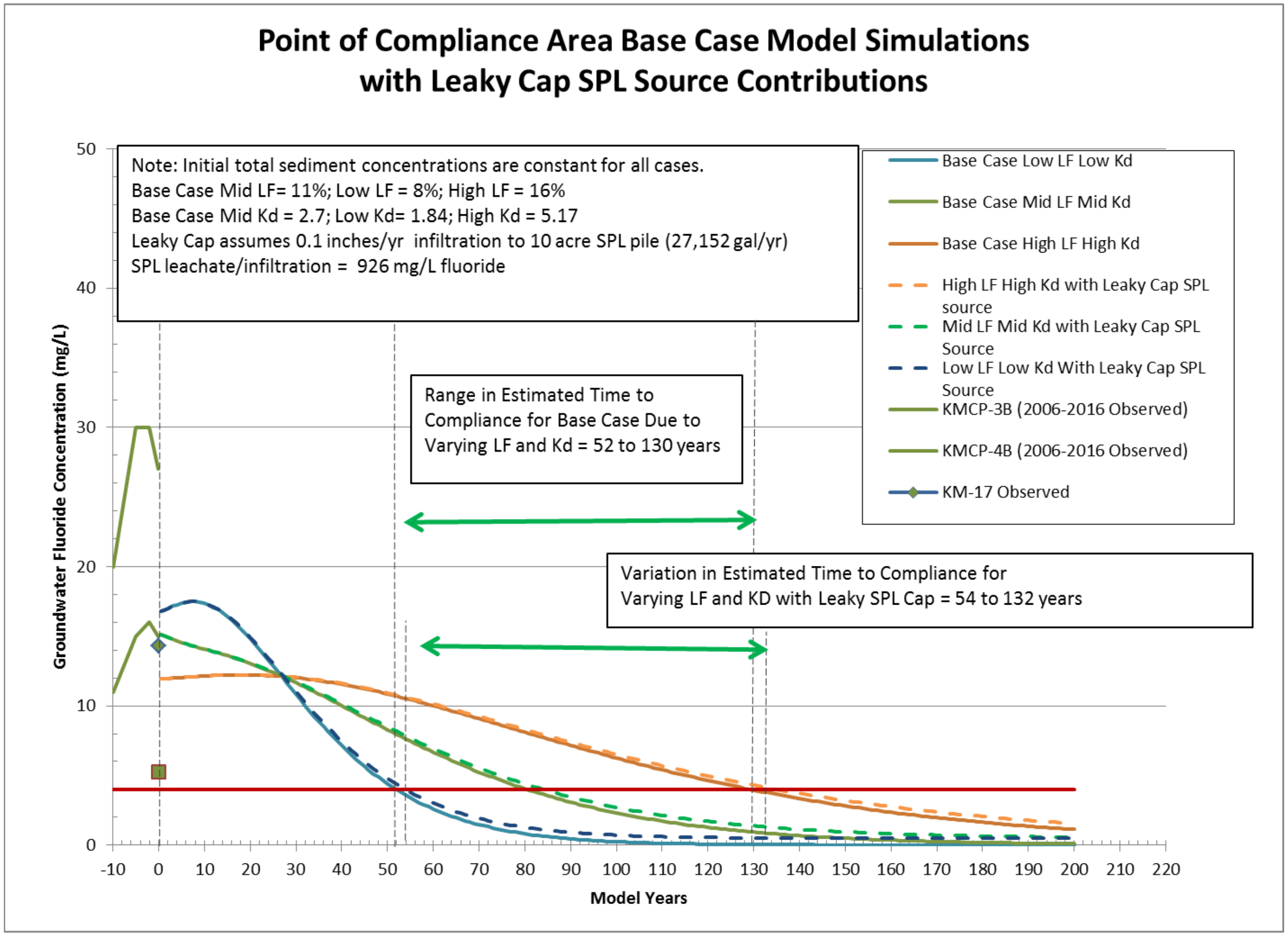


FIGURE 5-10. POC AREA FLUORIDE BASE CASE SENSITIVITY ANALYSIS SIMULATION FOR NO CAP SPL SOURCE SCENARIO

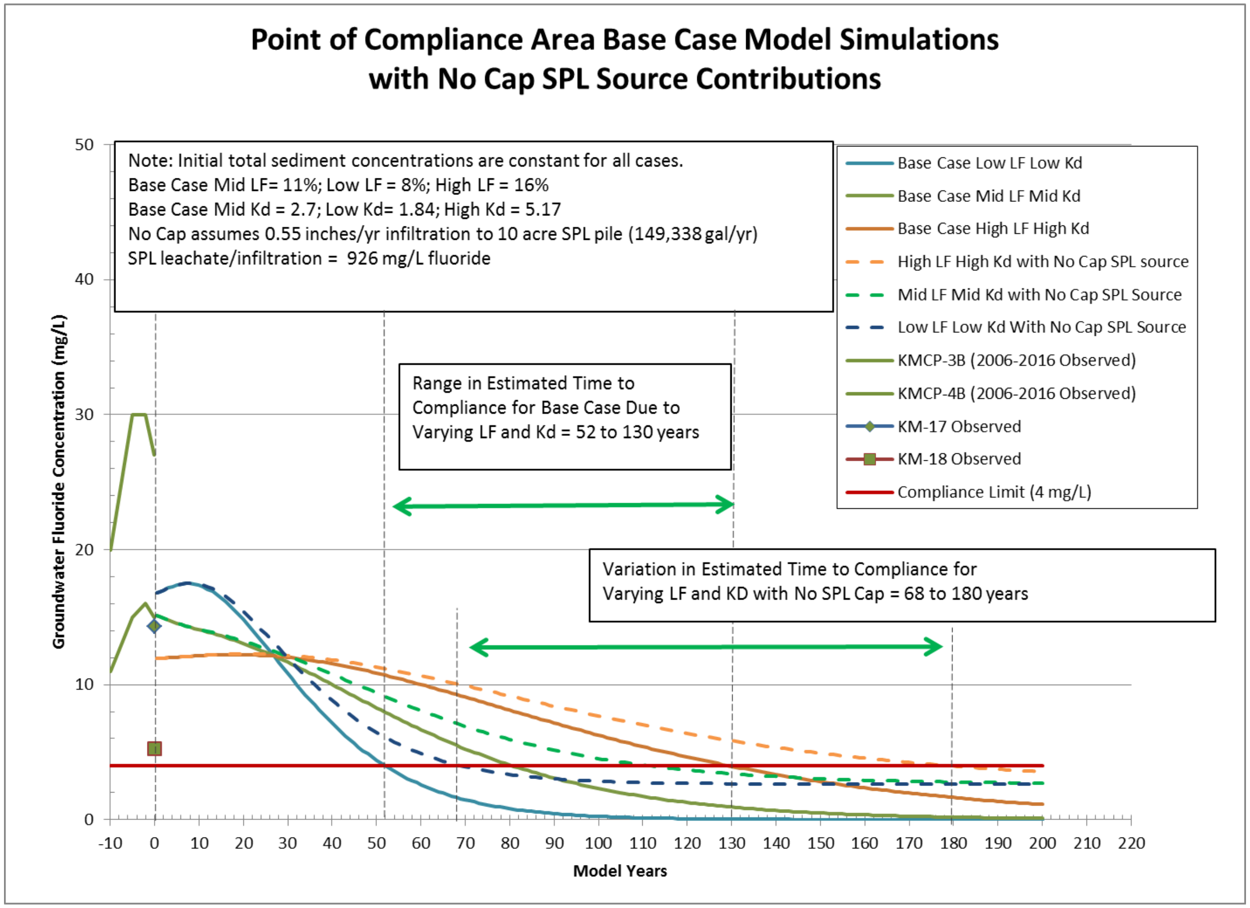


FIGURE 5-11. TOTAL CYANIDE MODEL – MID RANGE INPUTS

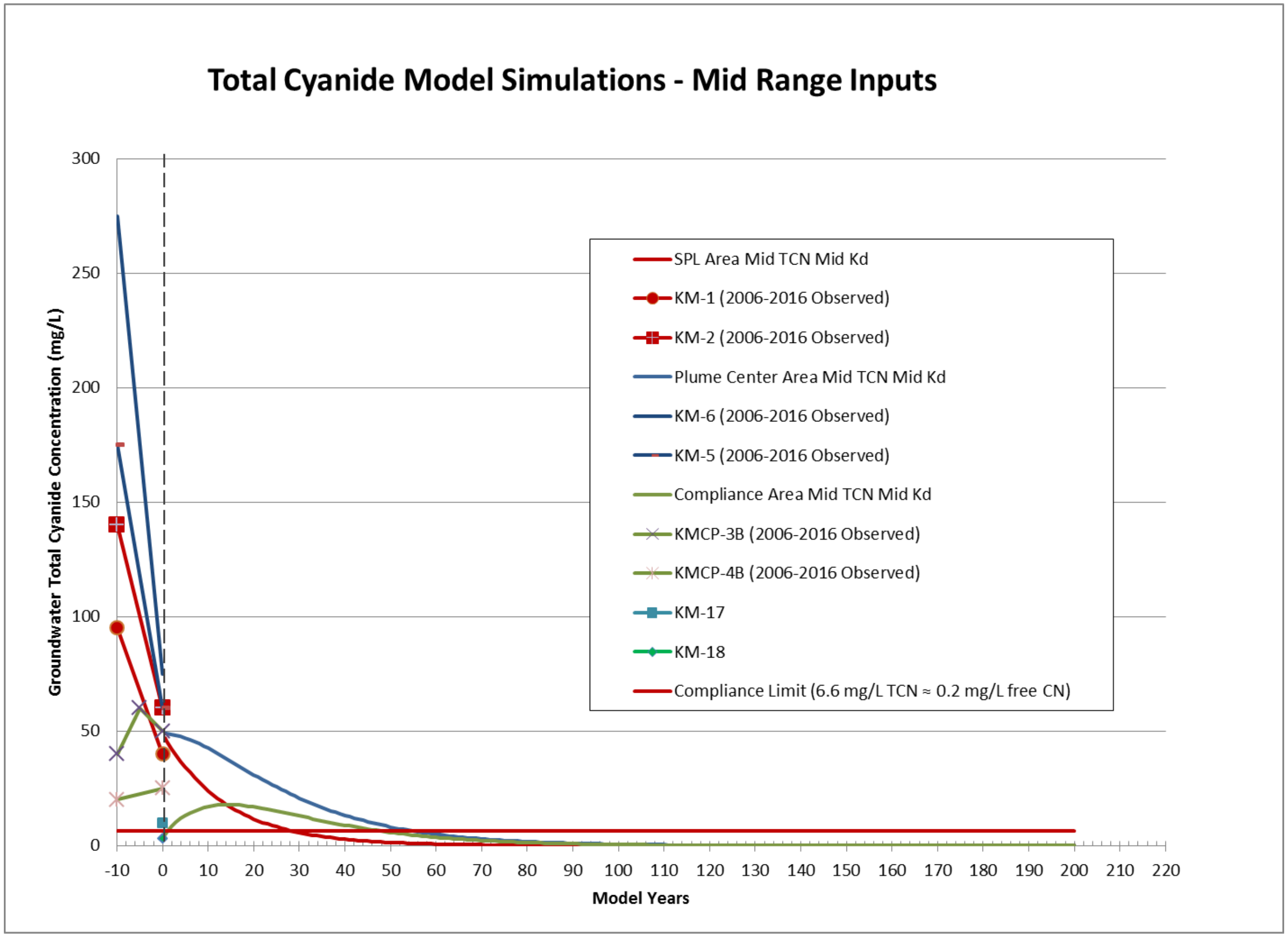


FIGURE 5-12. SPL AREA; TOTAL CYANIDE CALIBRATION AND SENSITIVITY ANALYSIS SIMULATIONS WITH VARING TCN AND KD

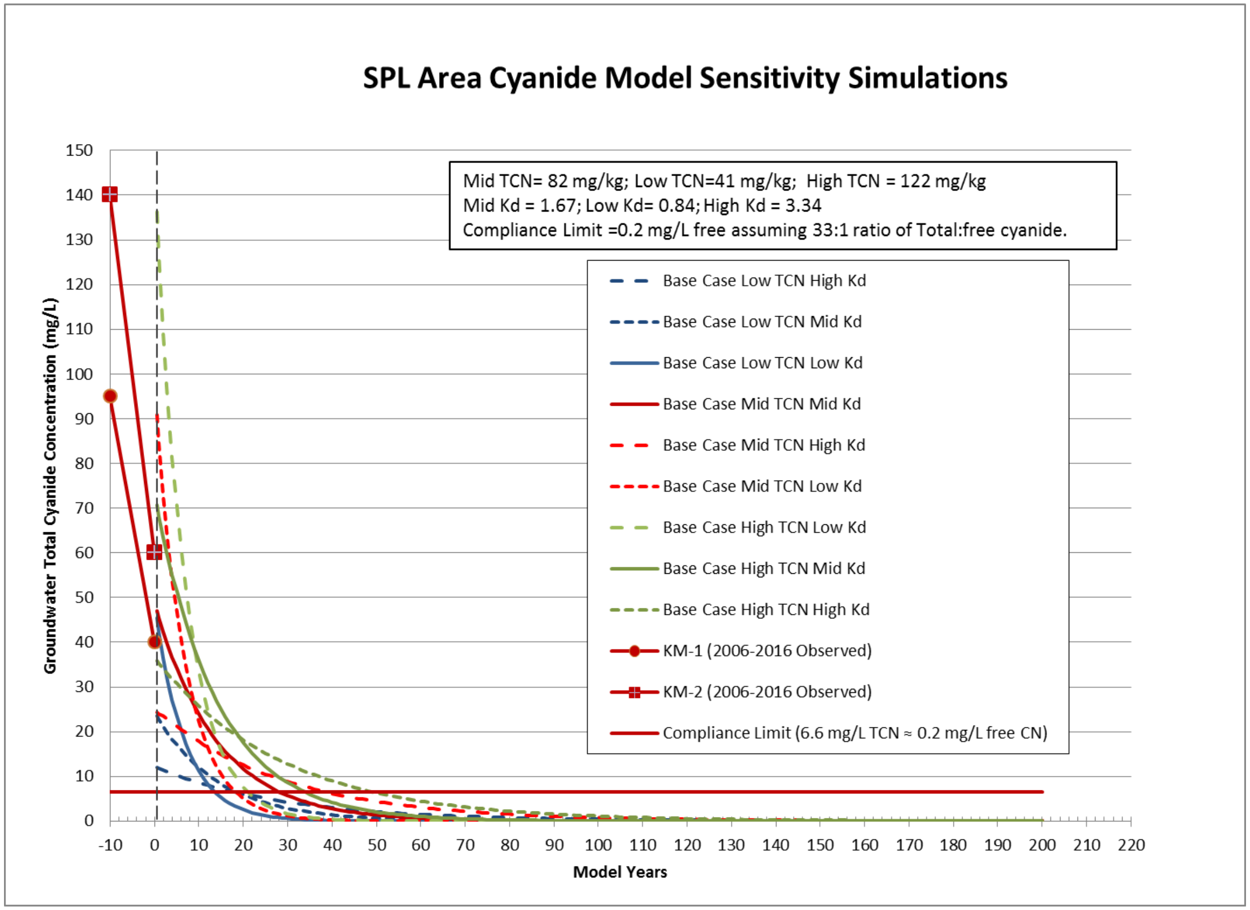


FIGURE 5-13. PLUME CENTER AREA; CYANIDE MODEL CALIBRATION AND SENSITIVITY ANALYSIS SIMULATIONS WITH VARYING TCN AND KD

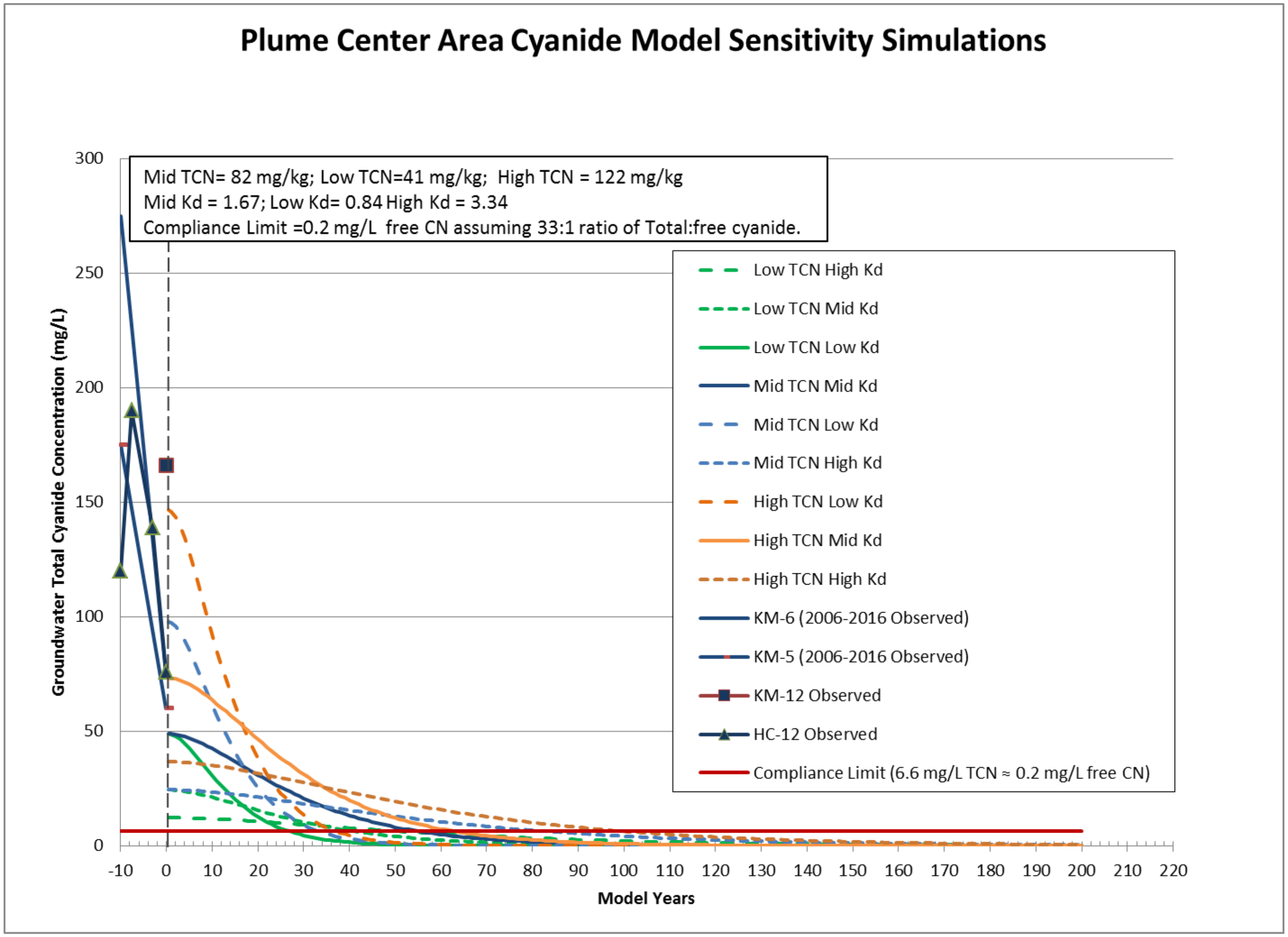


FIGURE 5-14. POC; CYANIDE MODEL CALIBRATION AND SENSITIVITY ANALYSIS SIMULATIONS WITH VARYING TCN AND KD

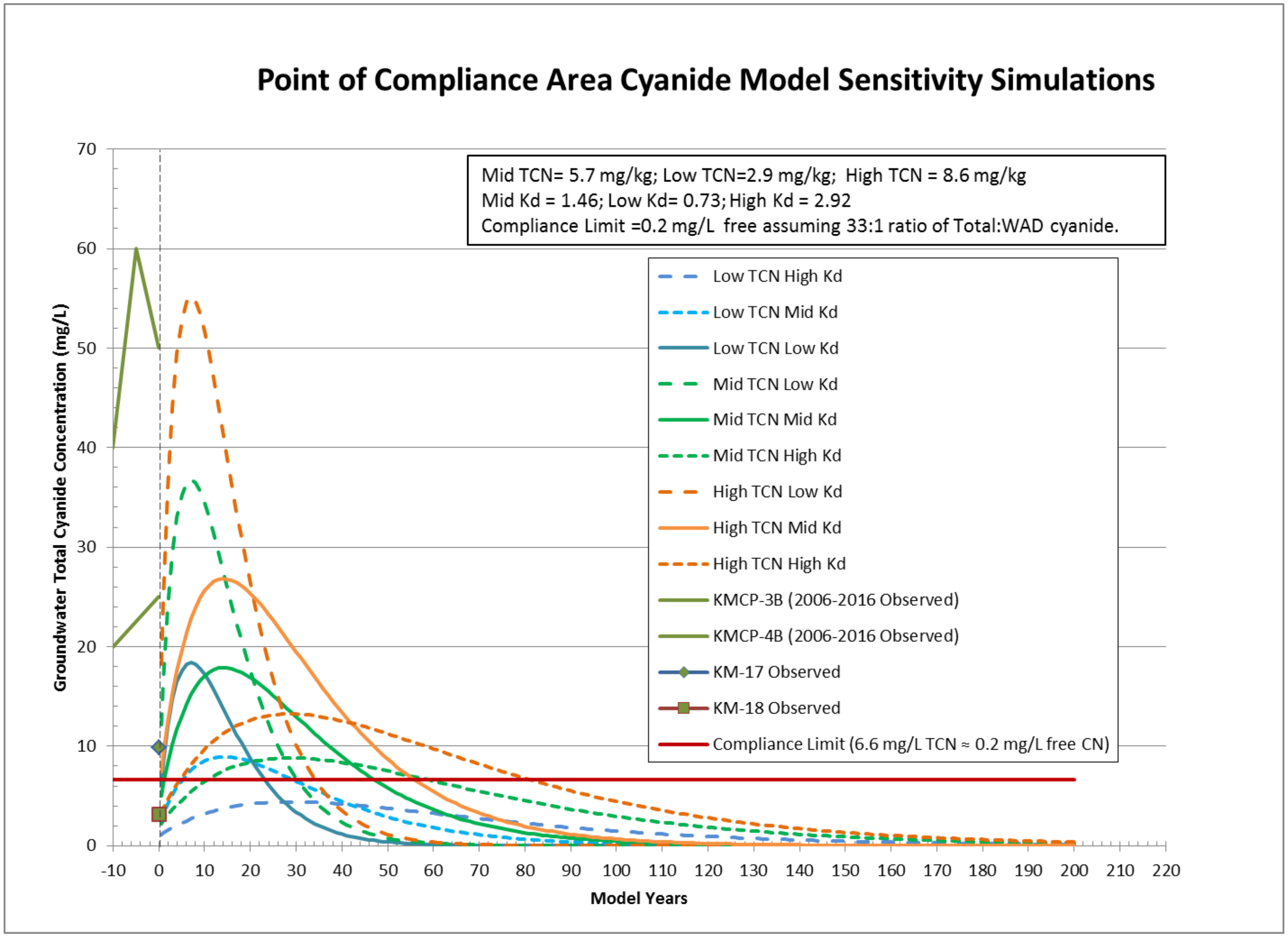


FIGURE 5-15. POC AREA; CYANIDE MODEL SELECTED BASE CASE SIMULATIONS

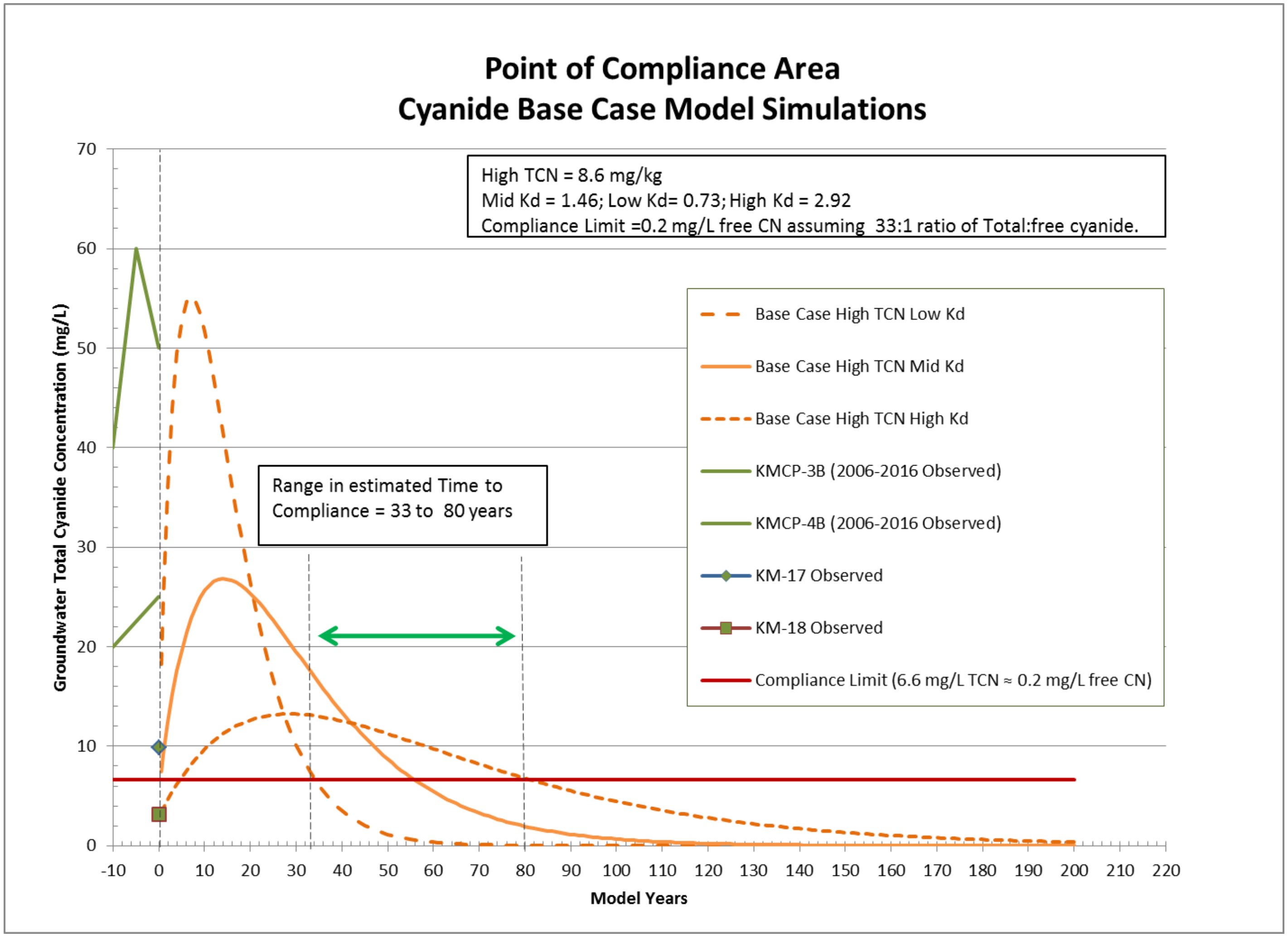
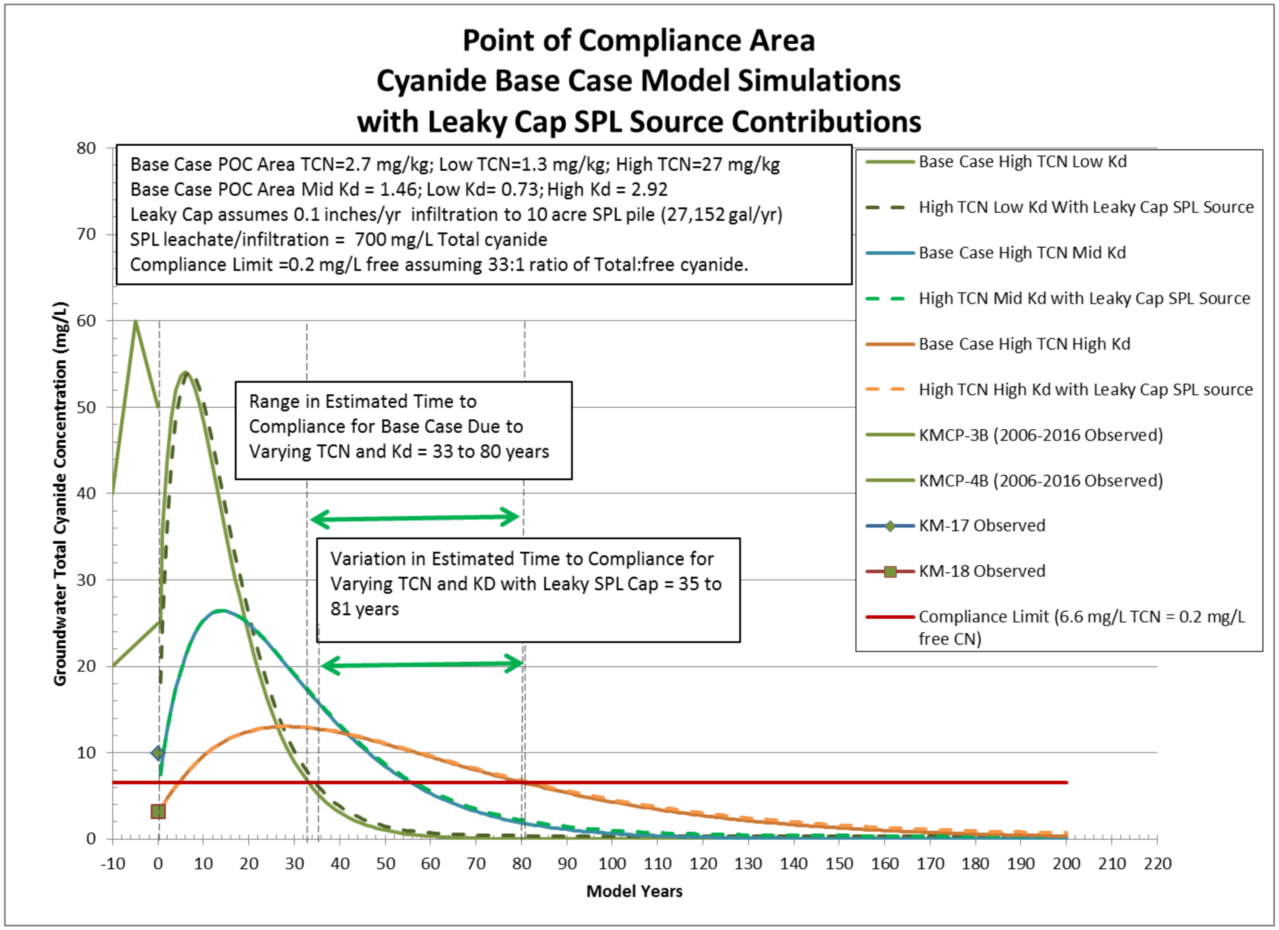


FIGURE 5-16. POC AREA TOTAL CYANIDE BASE CASE SENSITIVITY ANALYSIS SIMULATION FOR LEAKY CAP SPL SOURCE SCENARIO



Point of Compliance Area
Cyanide Base Case Model Simulations
with Leaky Cap SPL Source Contributions

Base Case POC Area TCN=2.7 mg/kg; Low TCN=1.3 mg/kg; High TCN=27 mg/kg
Base Case POC Area Mid Kd = 1.46; Low Kd= 0.73; High Kd = 2.92
Leaky Cap assumes 0.1 inches/yr infiltration to 10 acre SPL pile (27,152 gal/yr)
SPL leachate/infiltration = 700 mg/L Total cyanide
Compliance Limit =0.2 mg/L free assuming 33:1 ratio of Total:free cyanide.

Range in Estimated Time to Compliance for Base Case Due to Varying TCN and Kd = 33 to 80 years

Variation in Estimated Time to Compliance for Varying TCN and KD with Leaky SPL Cap = 35 to 81 years

FIGURE 5-17. POC AREA TOTAL CYANIDE BASE CASE SENSITIVITY ANALYSIS SIMULATION FOR NO CAP SPL SOURCE SCENARIO

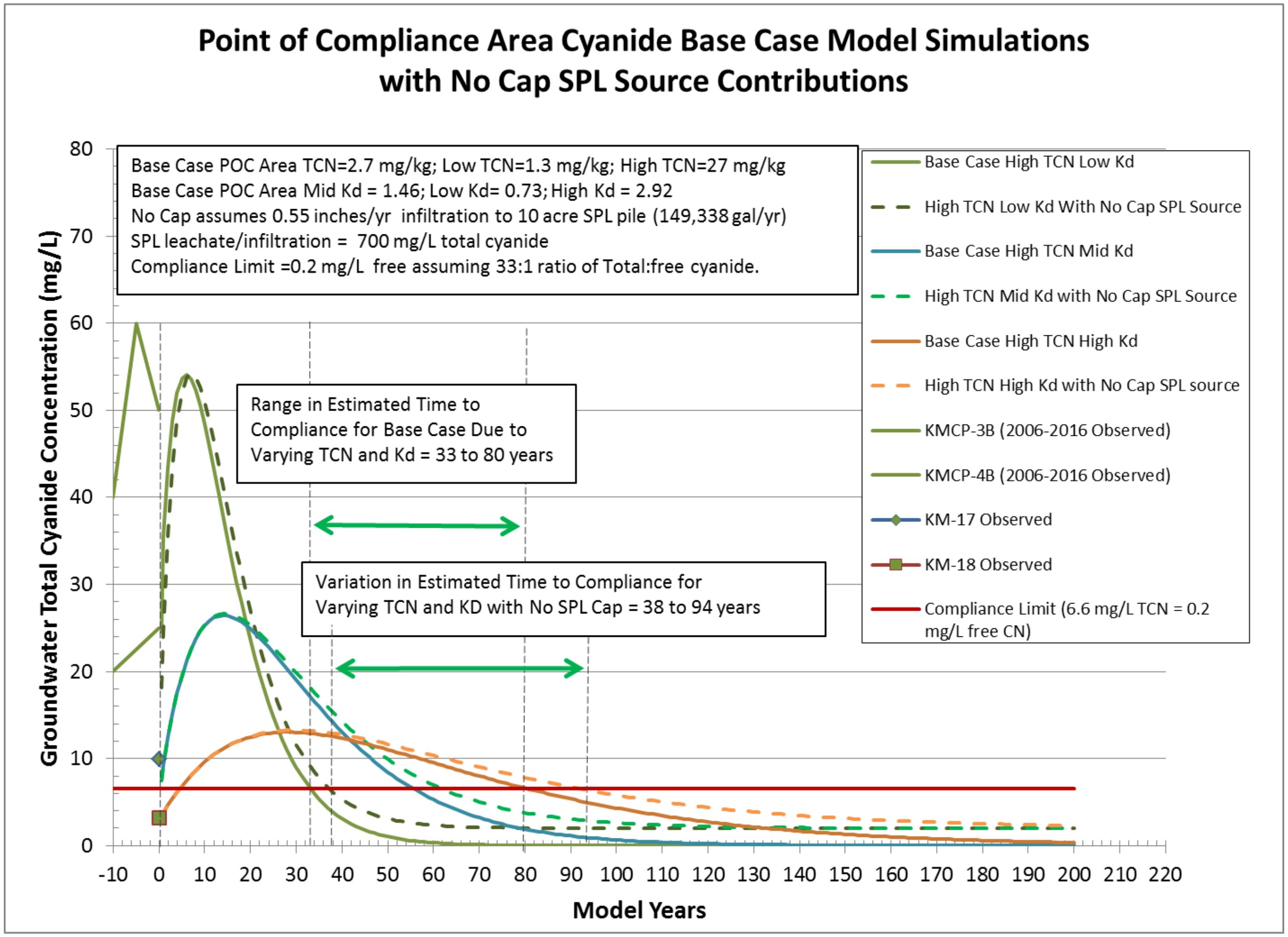


FIGURE 6-1. POC AREA FLUORIDE CONCENTRATIONS – SIMULATED GROUT WALL

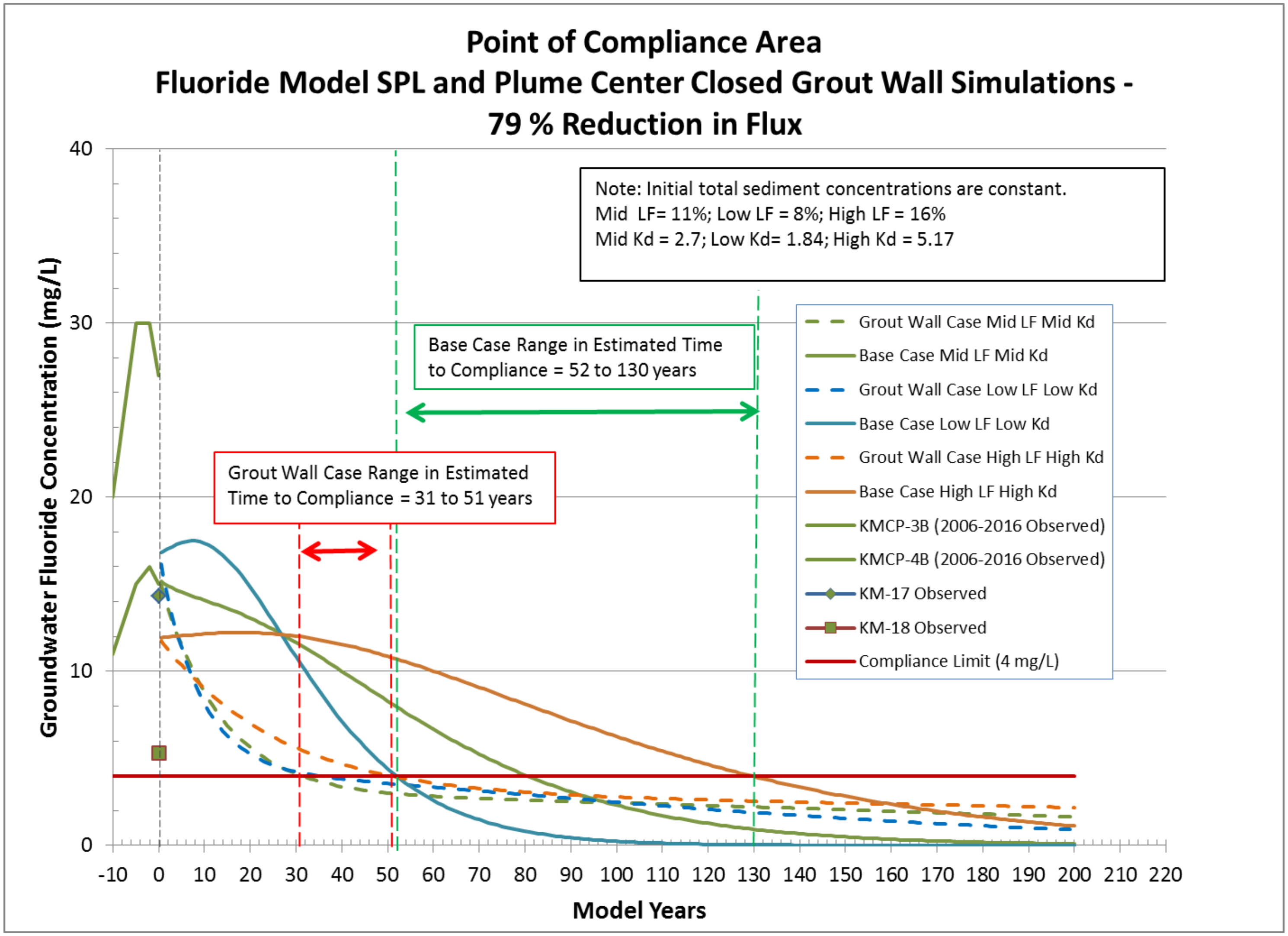


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FIGURE 6-2. POC AREA TOTAL CYANIDE CONCENTRATIONS – SIMULATED GROUT WALL

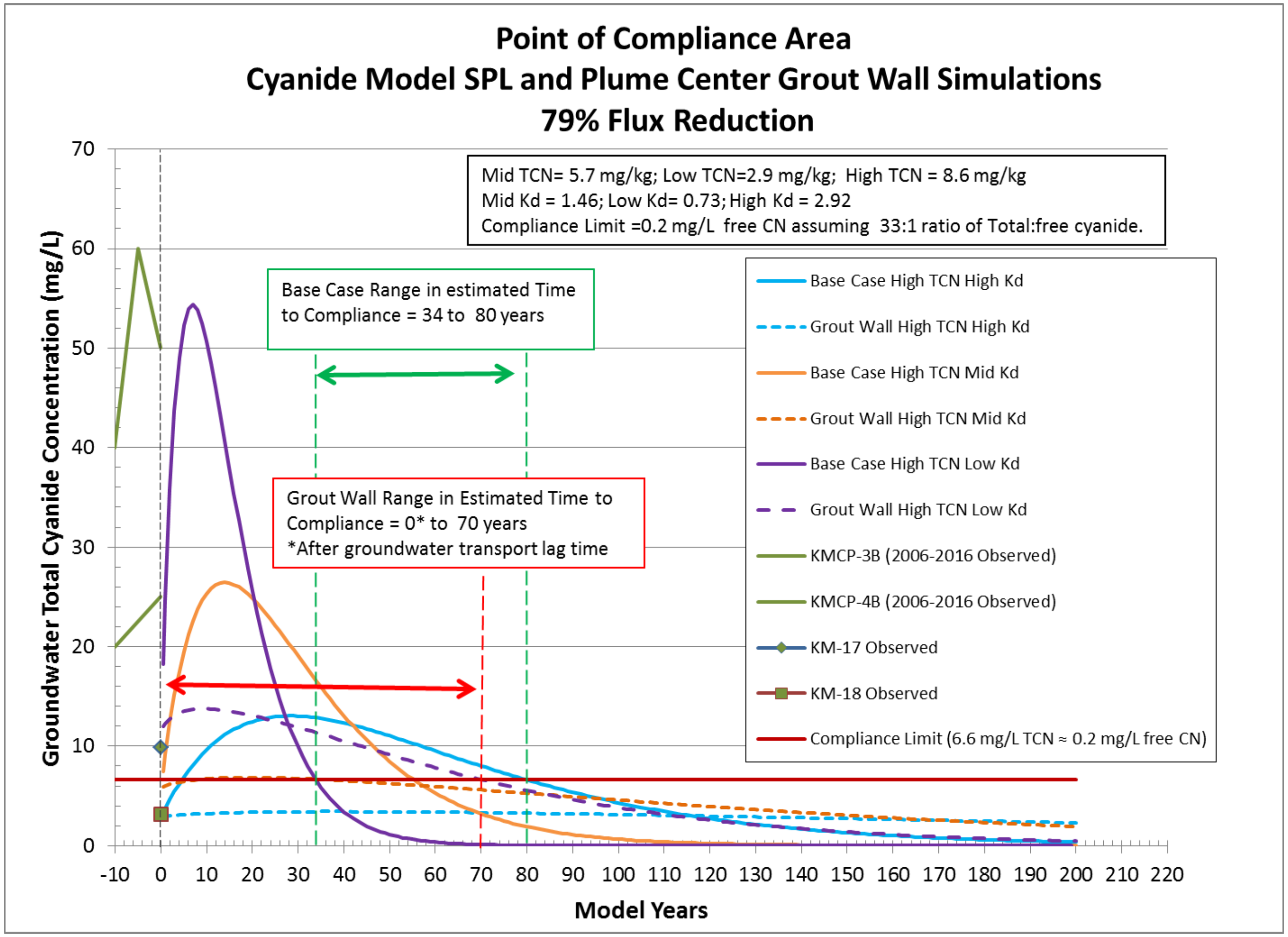


FIGURE 6-3. POC AREA FLUORIDE CONCENTRATIONS – SIMULATED PLUME CENTER PUMPING (25 GPM)

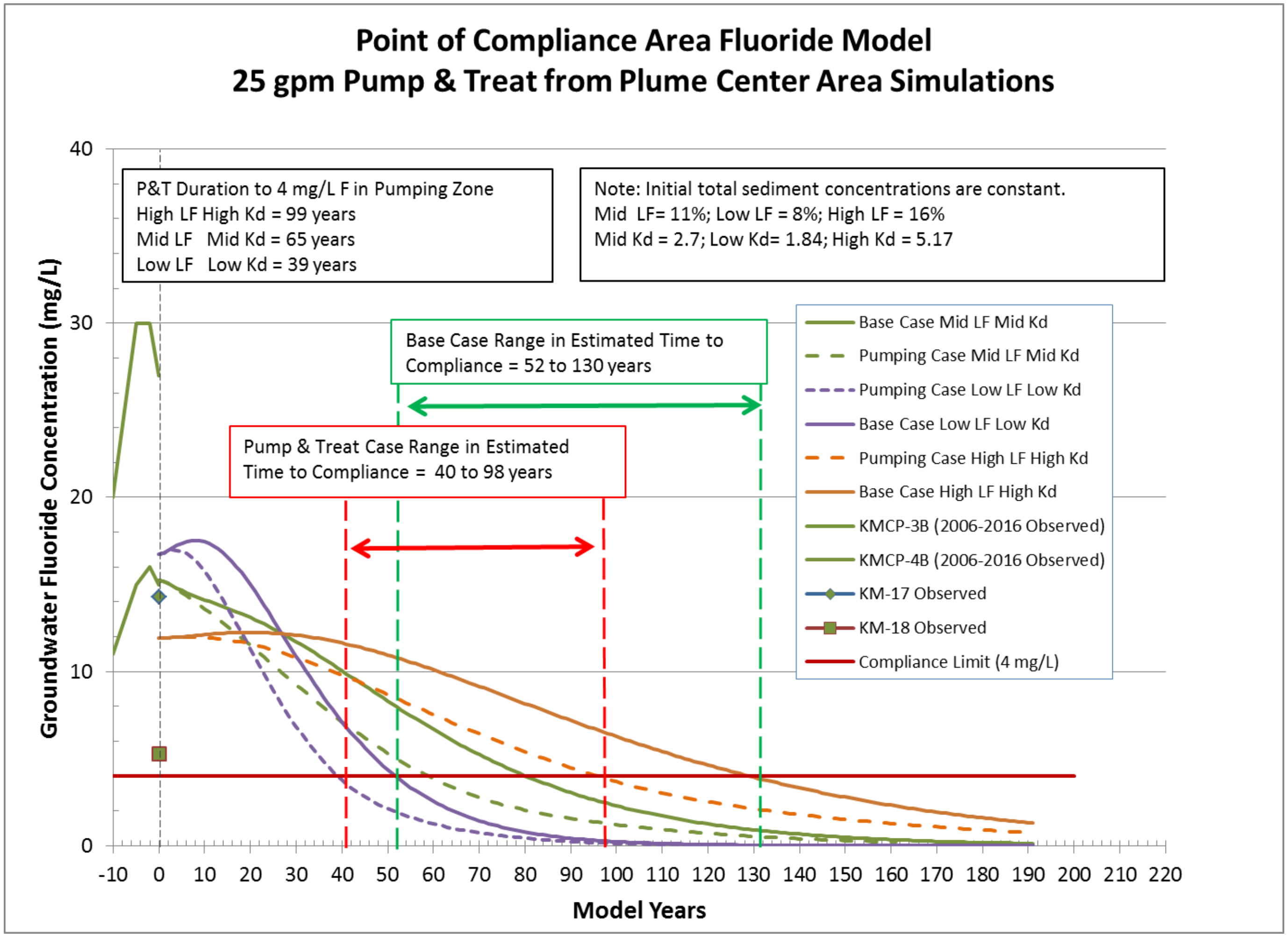


FIGURE 6-4. POC AREA FLUORIDE CONCENTRATIONS – SIMULATED PLUME CENTER PUMPING (50 GPM)

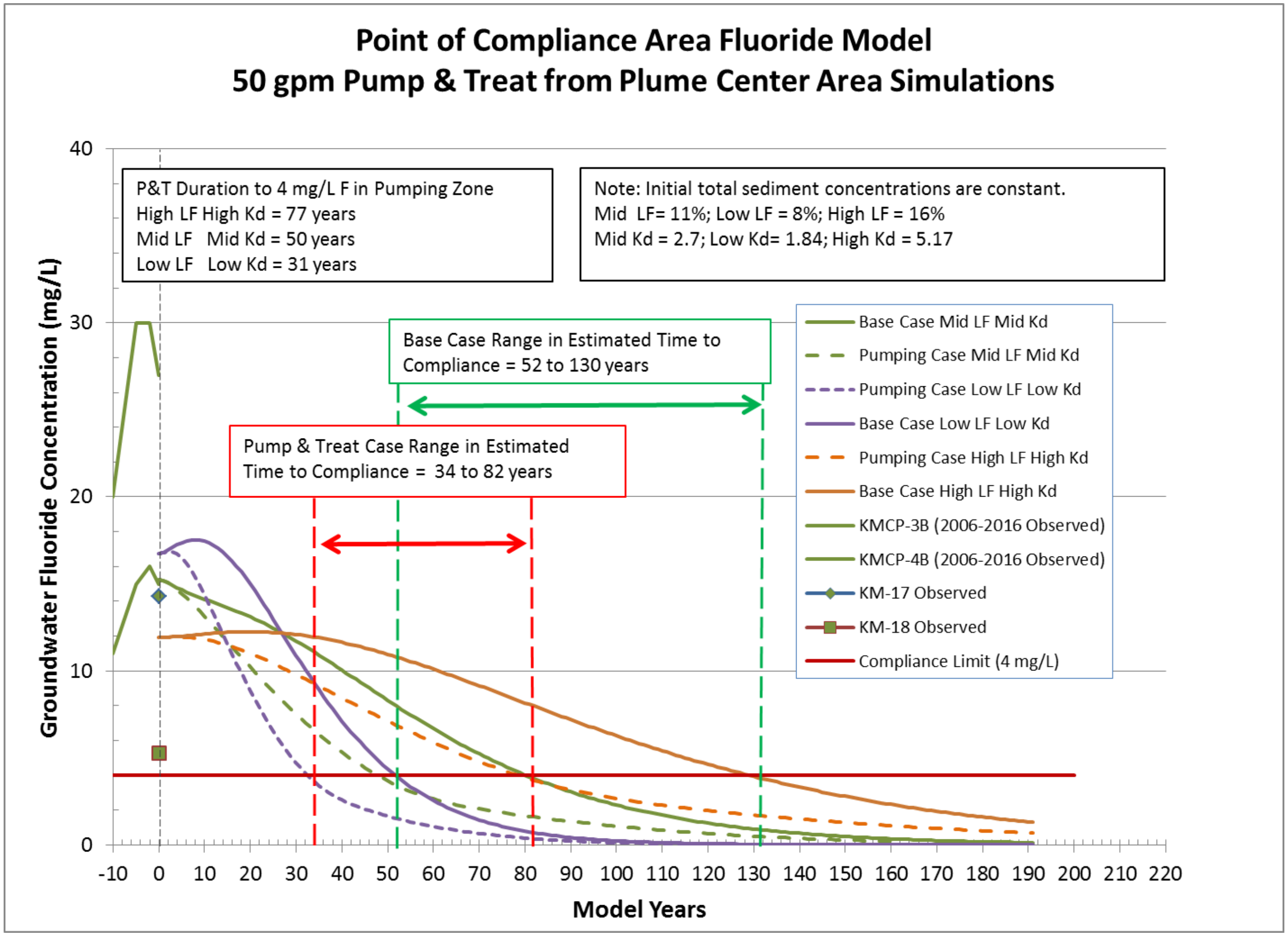
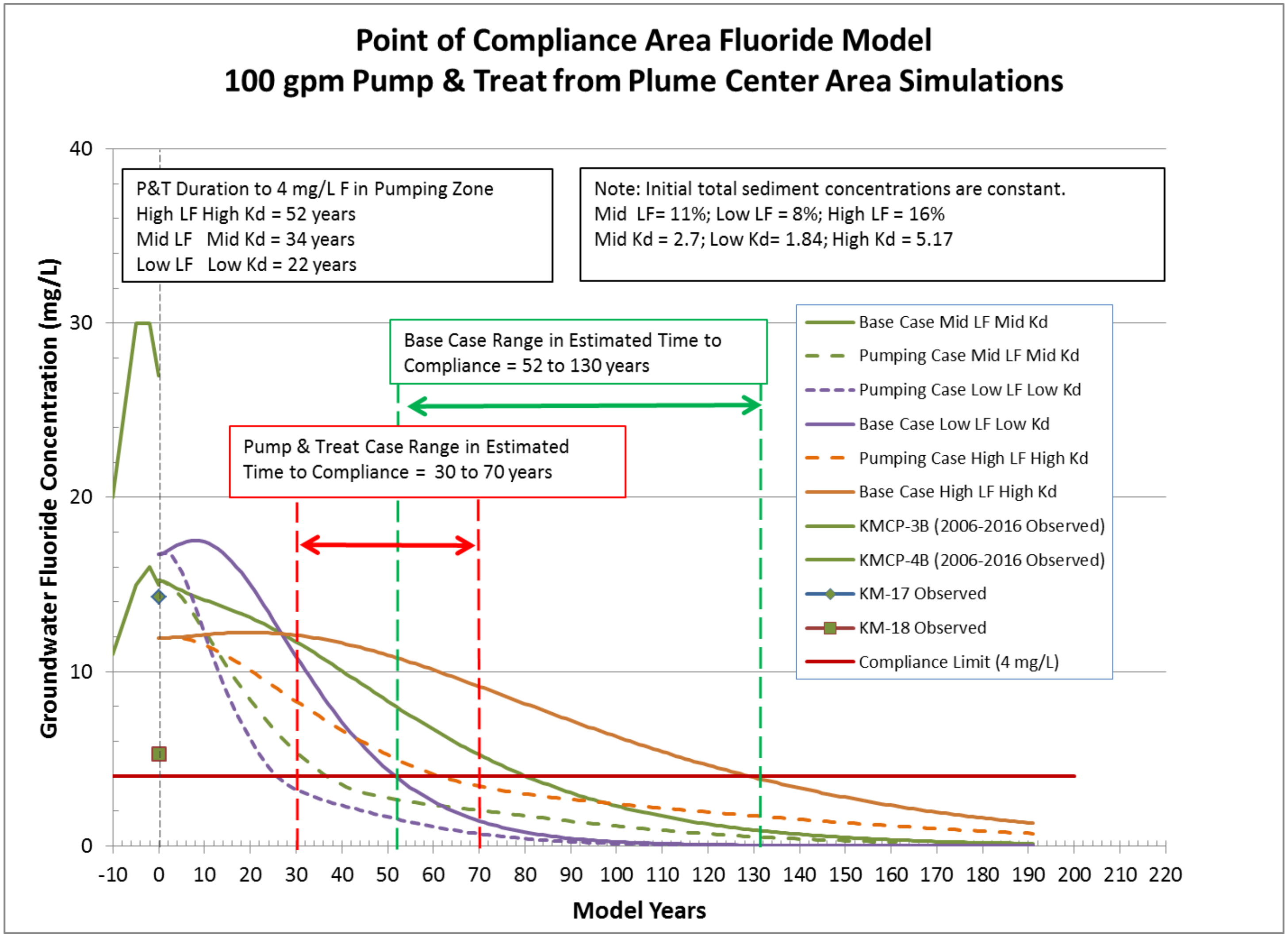


FIGURE 6-5. POC AREA FLUORIDE CONCENTRATIONS –
SIMULATED PLUME CENTER PUMPING (100 GPM)


Point of Compliance Area Fluoride Model
100 gpm Pump & Treat from Plume Center Area Simulations

P&T Duration to 4 mg/L F in Pumping Zone
High LF High Kd = 52 years
Mid LF Mid Kd = 34 years
Low LF Low Kd = 22 years

Note: Initial total sediment concentrations are constant.
Mid LF= 11%; Low LF = 8%; High LF = 16%
Mid Kd = 2.7; Low Kd= 1.84; High Kd = 5.17

Base Case Range in Estimated Time to Compliance = 52 to 130 years

Pump & Treat Case Range in Estimated Time to Compliance = 30 to 70 years

FIGURE 6-6. POC AREA TOTAL CYANIDE CONCENTRATIONS –
SIMULATED PLUME CENTER PUMPING (25 GPM)

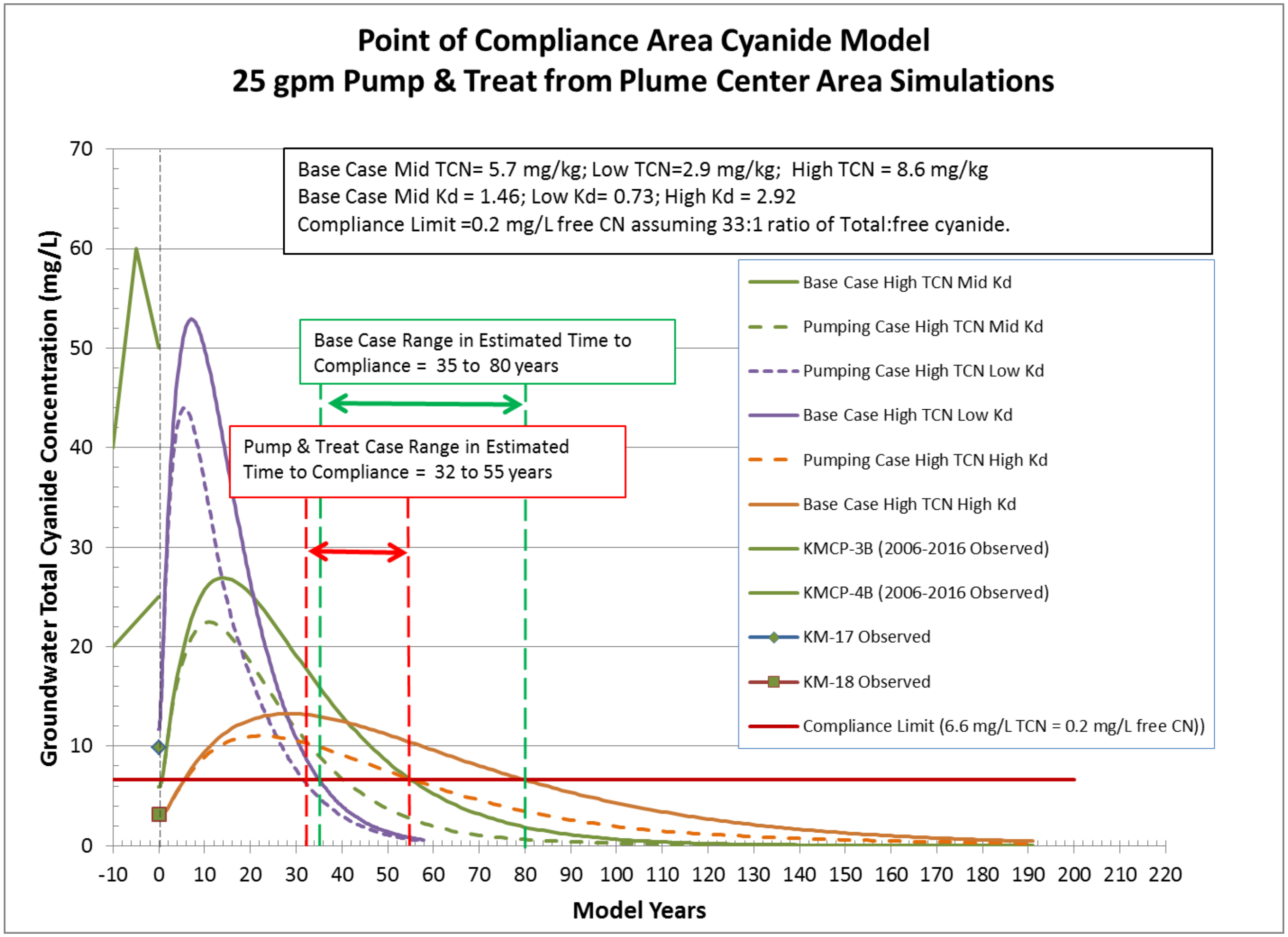


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FIGURE 6-7. POC AREA TOTAL CYANIDE CONCENTRATIONS – SIMULATED PLUME CENTER PUMPING (50 GPM)

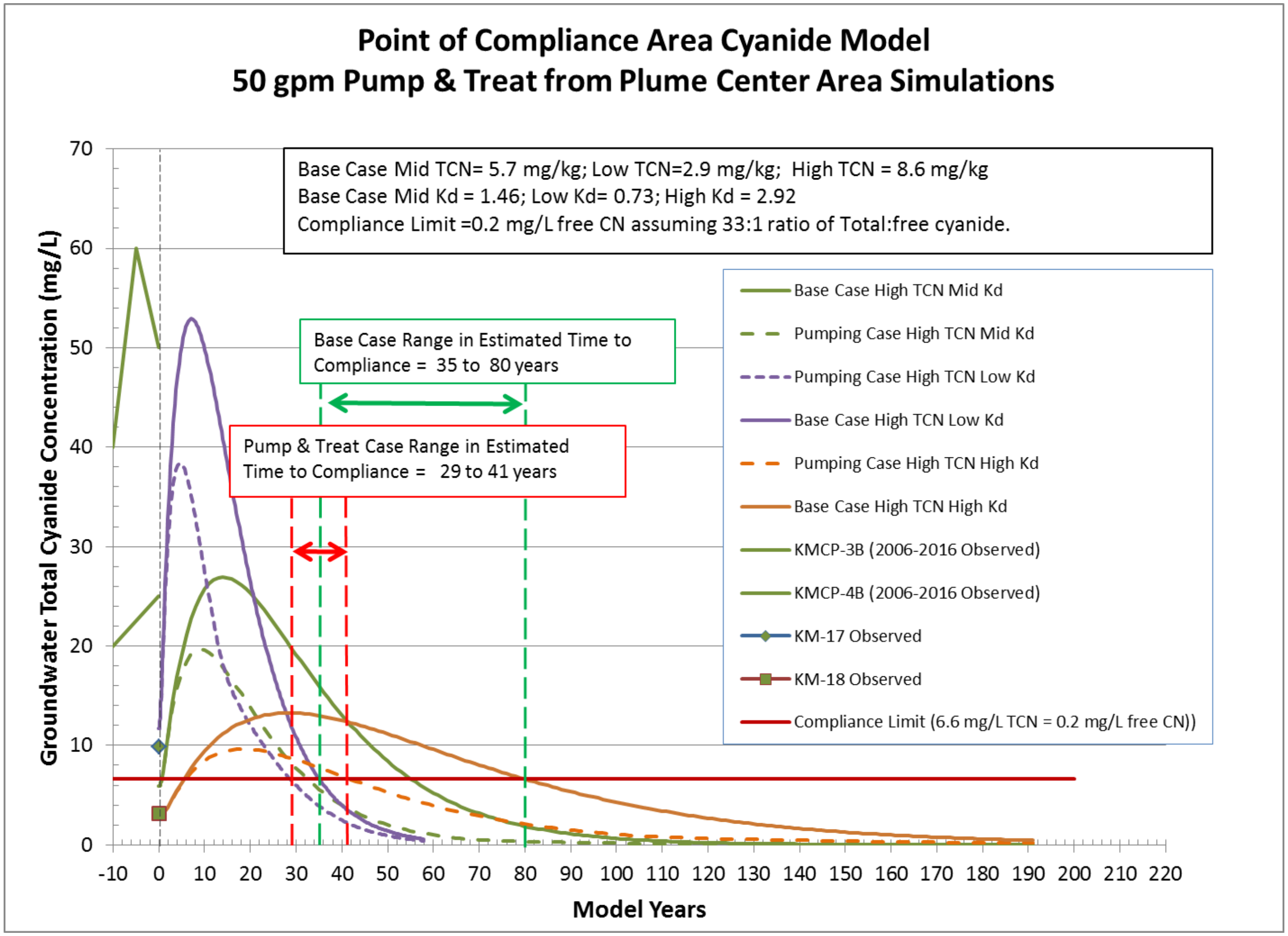


FIGURE 6-8. POC AREA TOTAL CYANIDE CONCENTRATIONS – SIMULATED PLUME CENTER PUMPING (100 GPM)

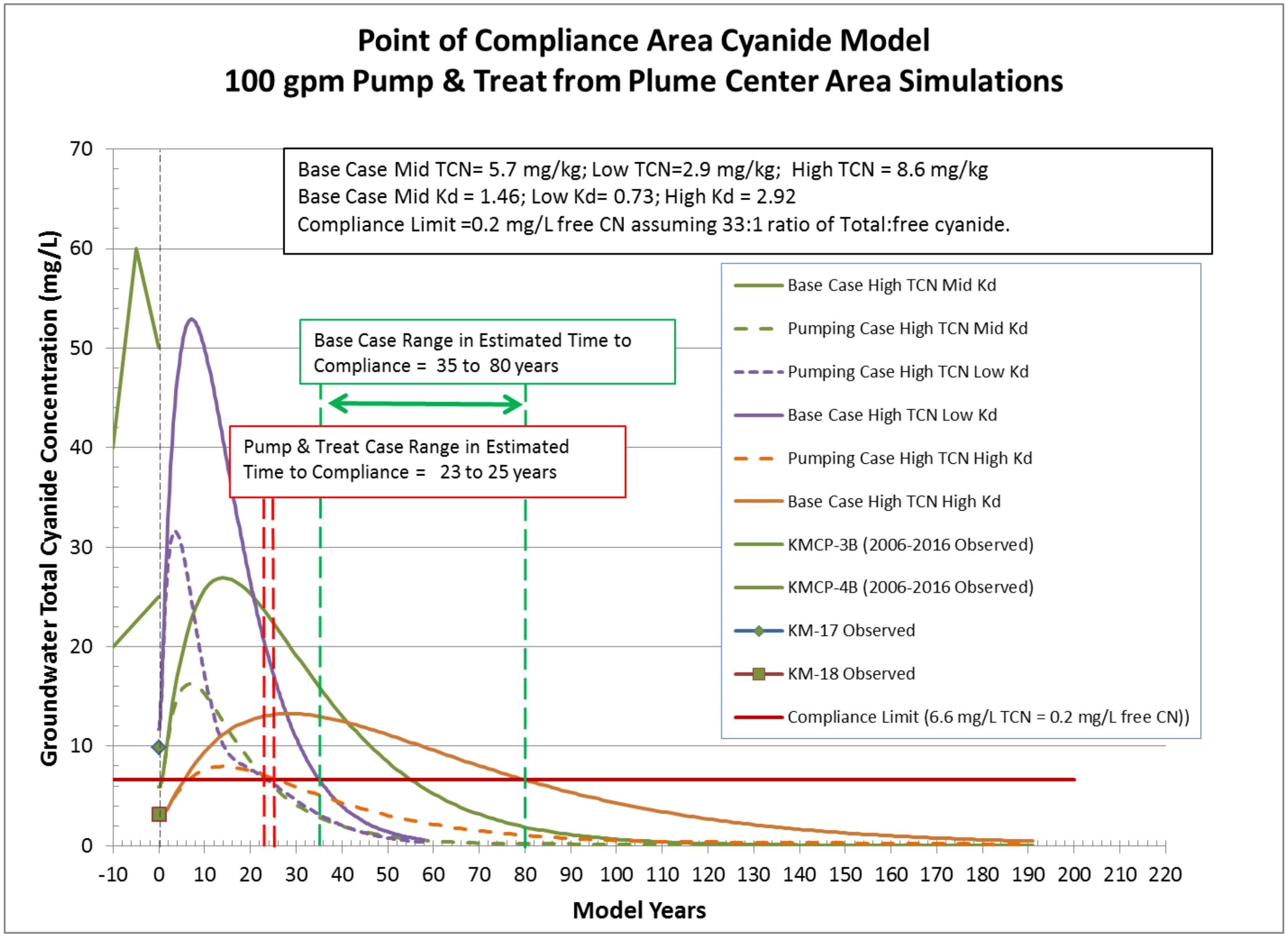
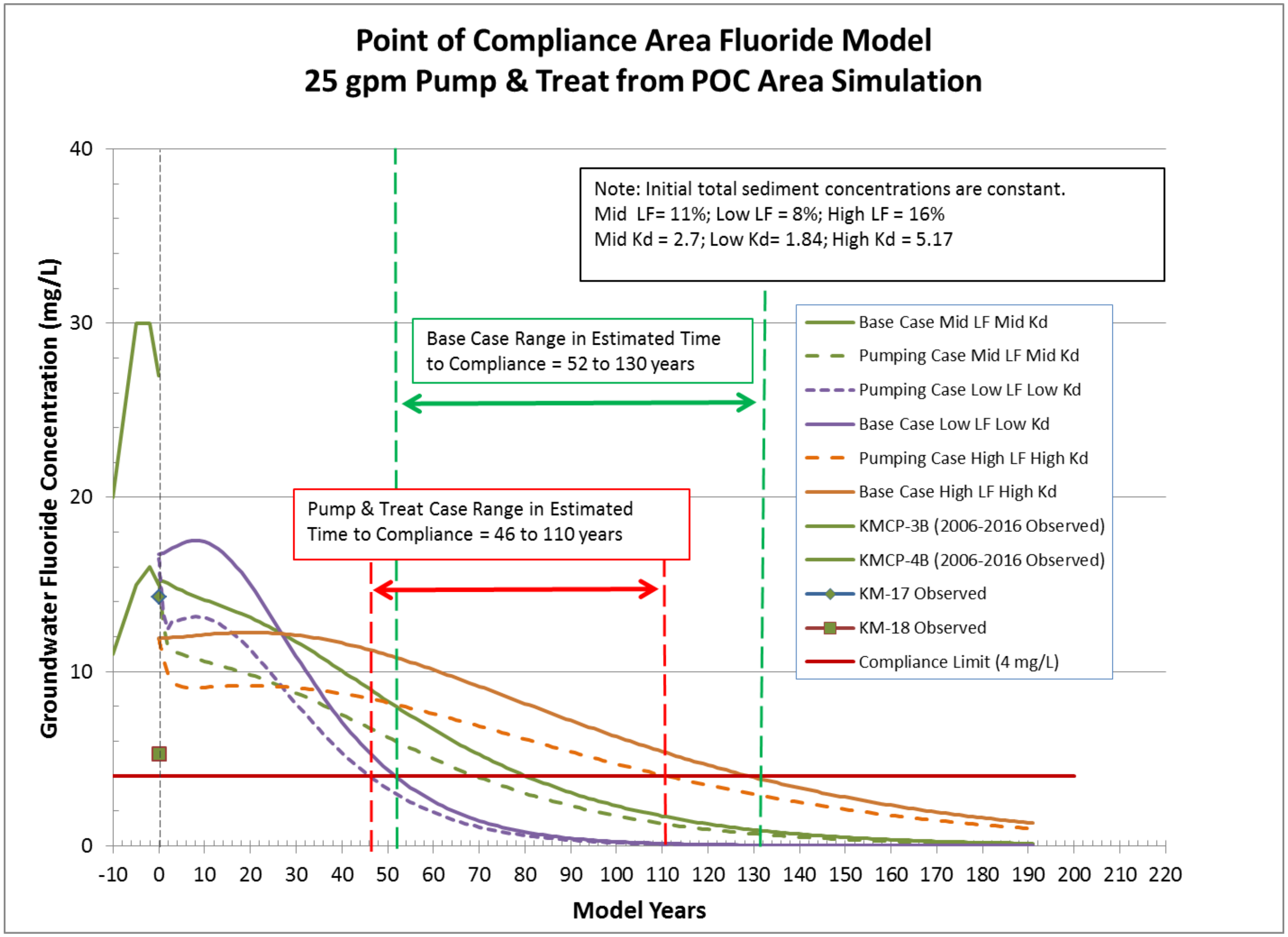


FIGURE 6-9. POC AREA FLUORIDE CONCENTRATIONS –
SIMULATED POC AREA PUMPING (25 GPM)



Note: Initial total sediment concentrations are constant.
Mid LF= 11%; Low LF = 8%; High LF = 16%
Mid Kd = 2.7; Low Kd= 1.84; High Kd = 5.17

Base Case Range in Estimated Time to Compliance = 52 to 130 years

Pump & Treat Case Range in Estimated Time to Compliance = 46 to 110 years

FIGURE 6-10. POC AREA FLUORIDE CONCENTRATIONS – SIMULATED POC AREA PUMPING (50 GPM)

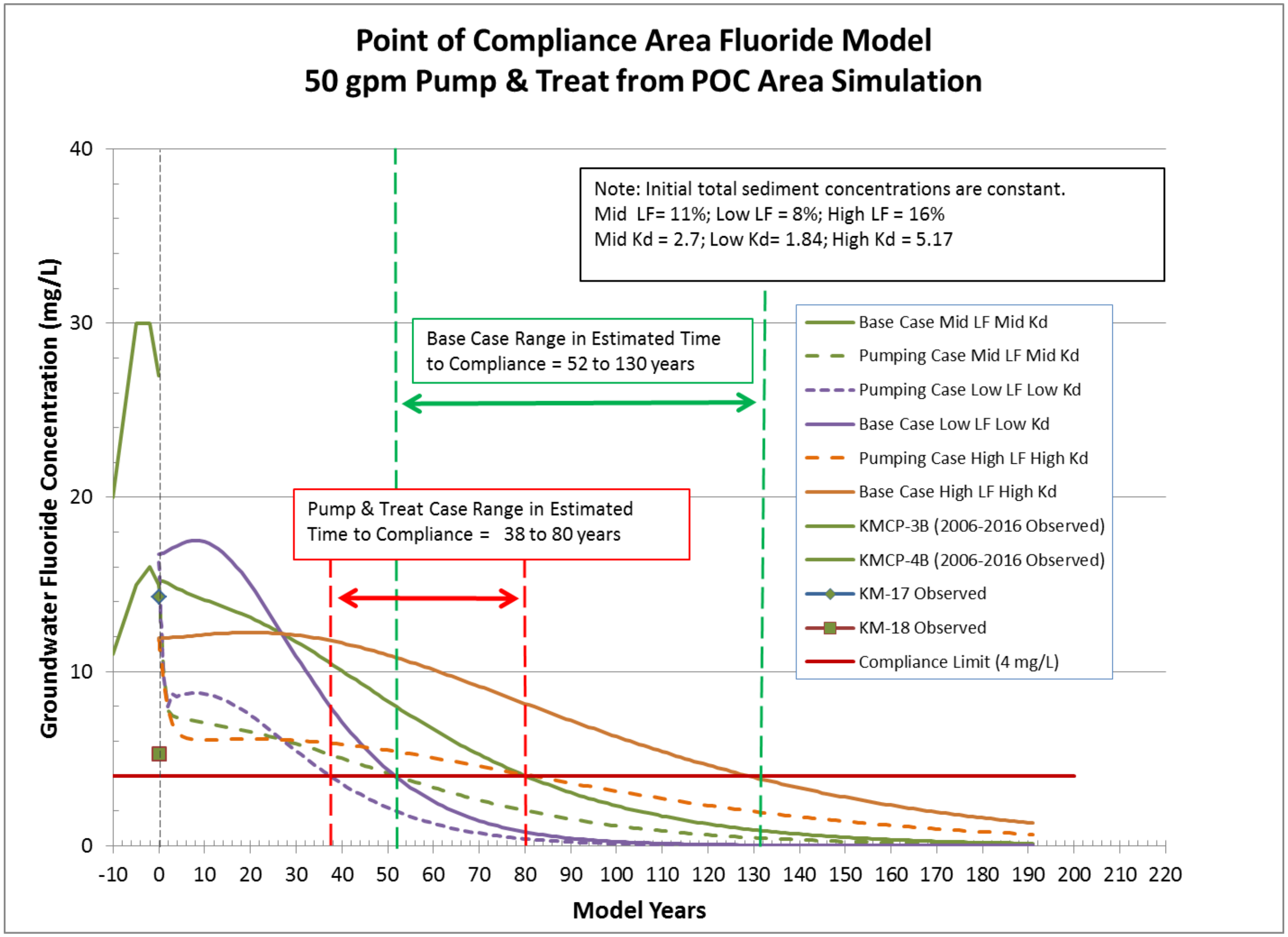


FIGURE 6-11. POC AREA FLUORIDE CONCENTRATIONS – SIMULATED POC AREA PUMPING (100 GPM)

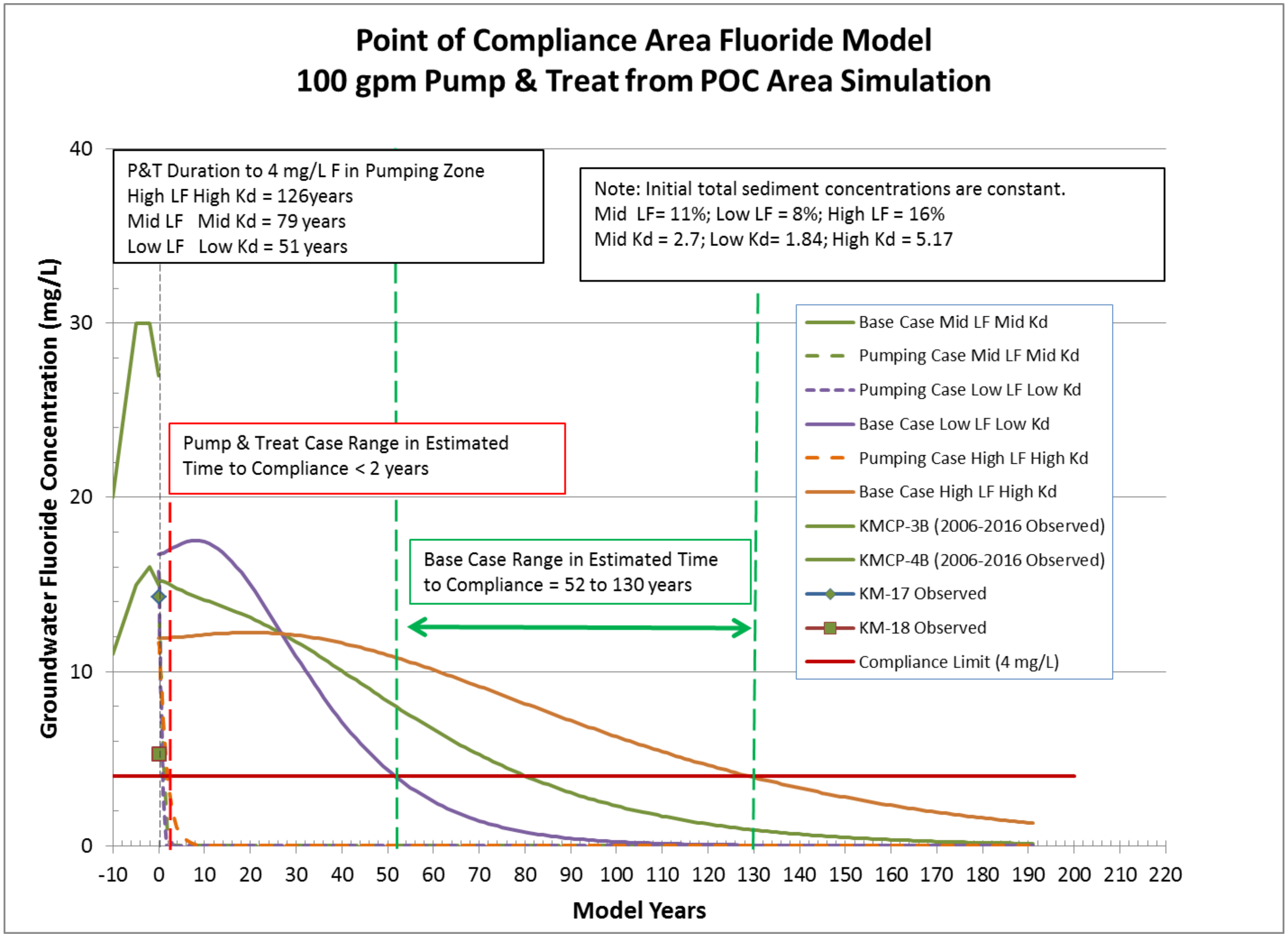


FIGURE 6-12. POC AREA TOTAL CYANIDE CONCENTRATIONS – SIMULATED POC AREA PUMPING (25 GPM)

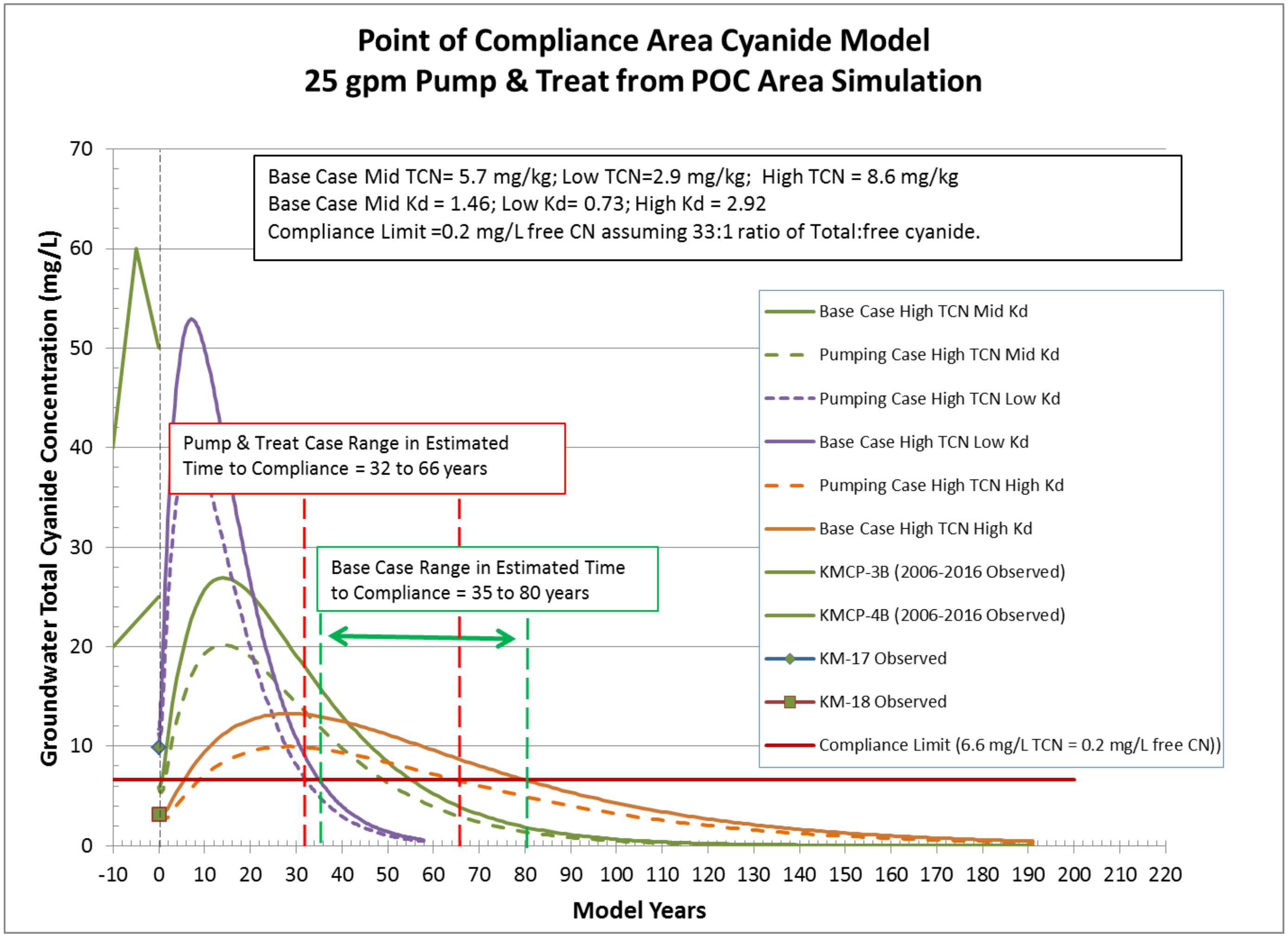


FIGURE 6-13. POC AREA TOTAL CYANIDE CONCENTRATIONS – SIMULATED POC AREA PUMPING (50 GPM)

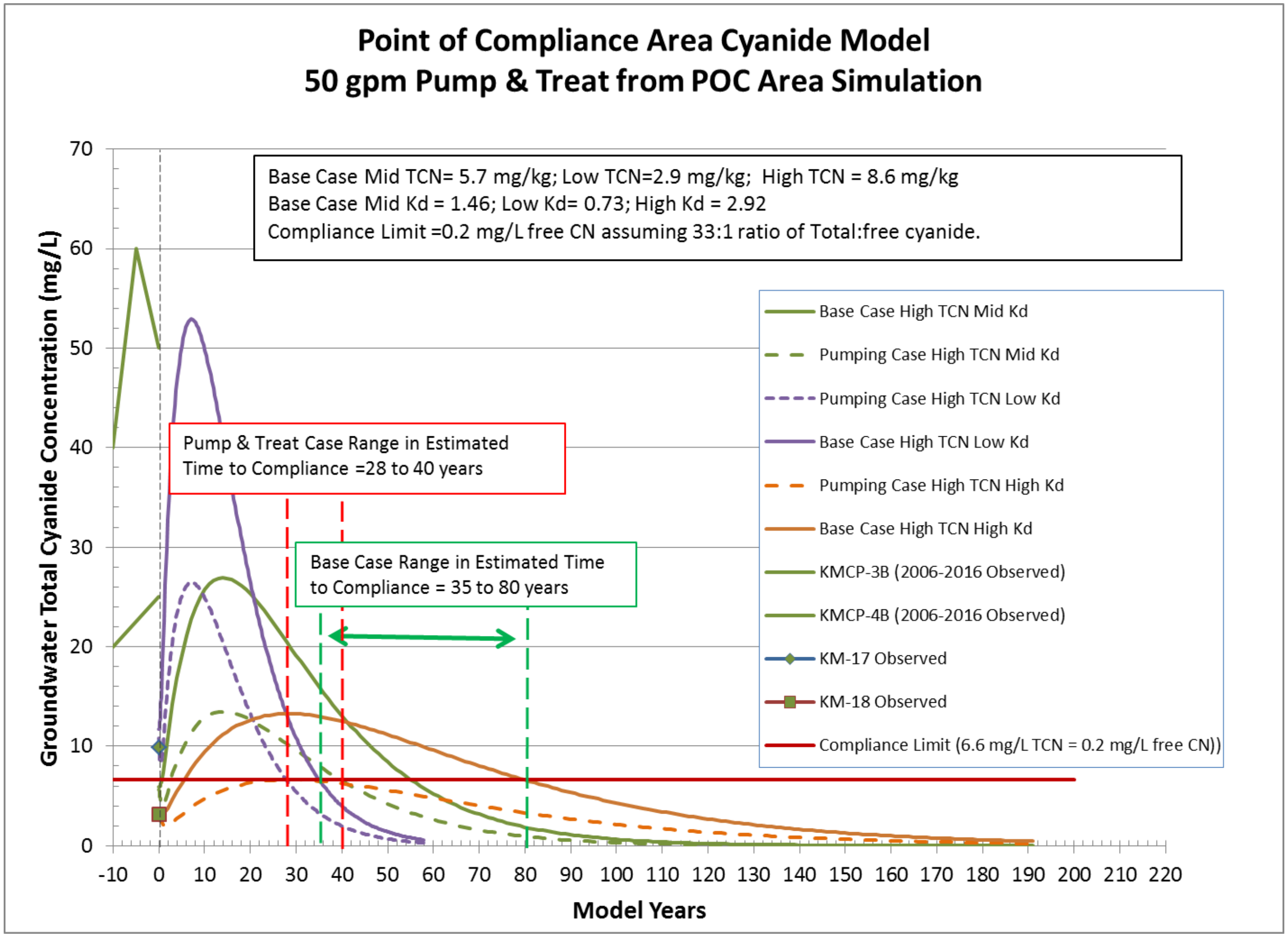
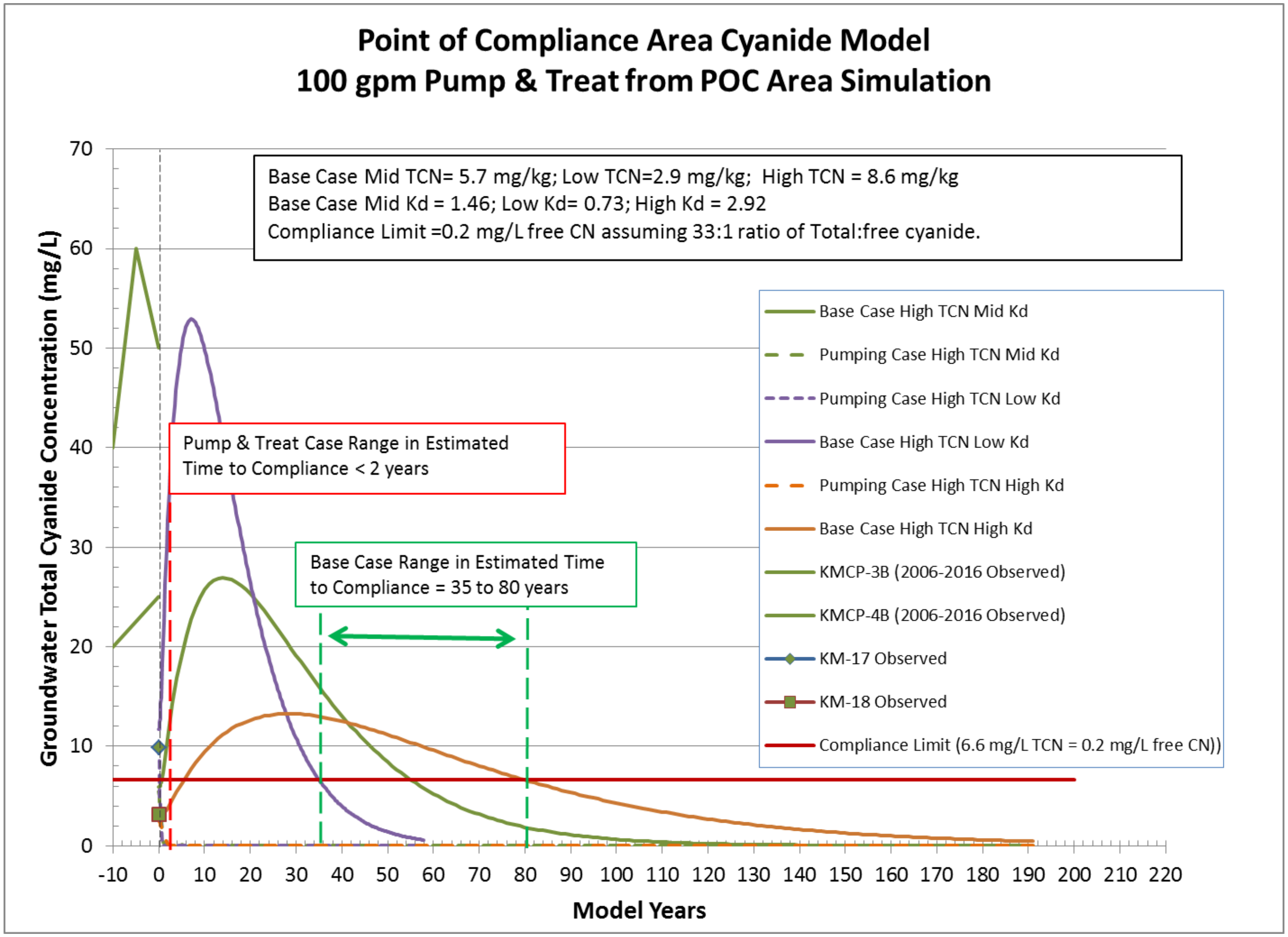


FIGURE 6-14. POC AREA TOTAL CYANIDE CONCENTRATIONS – SIMULATED POC AREA PUMPING (100 GPM)



APPENDIX G

GROUT WALL PILOT TEST

SUPPLEMENTAL FEASIBILITY STUDY
GROUT WALL PILOT TEST REPORT
FOR THE KAISER MEAD FACILITY

Prepared for:

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Prepared by:

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3020 Bozeman Avenue
Helena, MT 50601

October 2016 (Revised September 2018)

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

APPENDIX A	TEST WELL LOGS AND PRE-WALL PUMP TEST DISCUSSION
APPENDIX B	HAYWARD BAKER FINAL CONSTRUCTION REPORT
APPENDIX C	GROUT SAMPLE PERMEABILITY TEST RESULTS
APPENDIX D	HAYWARD BAKER FULL SCALE COST ESTIMATE

KEY TERMS

bar	pressure unit (1 bar = 14.5 psi)
bgs	below ground surface
cm/min	centimeters per second
cm/s	centimeters per second
Ecology	Washington Department of Ecology
ft	feet
ft/day	feet per day
gpm	gallons per minute
HBI	Hayward Baker, Inc.
K	hydraulic conductivity
Kaiser	Kaiser Aluminum and Chemical Corporation
m	minute
mm	millimeter
psi	pounds per square inch
RPM	revolutions per minute
S	storativity
SPL	Spent Potliner
Sy	specific yield
T	transmissivity

SUPPLEMENTAL FEASIBILITY STUDY
GROUT WALL PILOT TEST REPORT
FOR THE KAISER MEAD FACILITY

1.0 INTRODUCTION

This report describes the results of a pilot test conducted in 2015 at the former Kaiser Mead Works Facility to further assess the constructability of a deep grout wall within the Zone A aquifer near the Spent Pot Liner (SPL) pile. The data from this pilot test will be used to update the potential remedy evaluation as part of the Supplemental Feasibility Study for the site.

In 2015, the Washington Department of Ecology (Ecology) approved the scope to conduct a pilot test to evaluate the feasibility and effectiveness of constructing a grout wall to a depth of approximately 160 feet for the purposes of reducing the groundwater flux through an area of the A zone aquifer that has been impacted by potential secondary sources of both cyanide and fluoride.

This report documents the construction activities, quality control/quality assurance program implemented, and permeability evaluation of the grout wall. The contractor's construction completion report is also included as an appendix to this report.

2.0 SCOPE OF WORK

The pilot test scope included construction of the grout wall in the shape of a box with four equal sides measuring approximately 22.5 feet in length. The design height of the walls is approximately 25 feet, extending from the top of the aquitard that separates the A zone aquifer from the underlying B zone aquifer. At this height the top of the grout wall is seven to ten feet above the saturated zone. The grout wall was located upgradient or cross-gradient to the SPL pile, in an area of the A zone not impacted by contaminants.

The scope also included two pump tests to evaluate the effectiveness of the completed grout wall. The pump test scope included the drilling of four wells; three 2-inch monitoring wells and one 6-inch pumping well. The first test was performed prior to construction of the grout wall and the second test occurred approximately 60 days following completion of the grout wall.

2.1.1 Contractors

The contractor selection process for construction of the grout wall included pre-bid screening and competitive bidding. Hayward Baker, Inc. (HBI) of Tukwila, Washington was selected and they developed the grout wall construction parameters and construction quality control plan. The contractors for drilling of the pump test wells included Environmental West Exploration (Spokane Valley, WA) for installation of the three 2-inch monitoring wells and H2O Well Service, Inc. (Hayden, ID) for installation of the 6-inch pumping well. Both drilling contractors are considered local to the area and were selected based on their previous experience at the Site and qualifications.

2.2 GROUT WALL DESIGN

The basic design of the grout wall called for high pressure injection of a grout mix to form a double panel wall section at each injection point. The double panels from subsequent injection points intersect with adjacent panels to form a continuous wall. Grout injection parameters were developed by HBI based on their experience in construction of jet grout walls and considering the characteristics of the local geology. HBI performed pre-construction tests of the injection parameters by injecting two shallow double panels from four feet below ground surface (bgs) down to approximately 15 feet bgs in native sands. After allowing for cure time the test panels were exposed by excavation for examination. A detailed discussion of the pre-construction test is presented in Section 5.1 of Appendix B. The injection parameters selected for the pilot test are shown in Table 2-1 below.

TABLE 2-1. PRELIMINARY GROUT WALL INJECTION PARAMETERS

Test Panel Parameters	
Pull Speed [cm/min]	30
RPM	0
Grout Flow [GPM]	125
Grout Pressure [bar]	400
Nozzle Size [mm]	5.0x2

3.0 GROUT WALL PILOT TEST INVESTIGATION

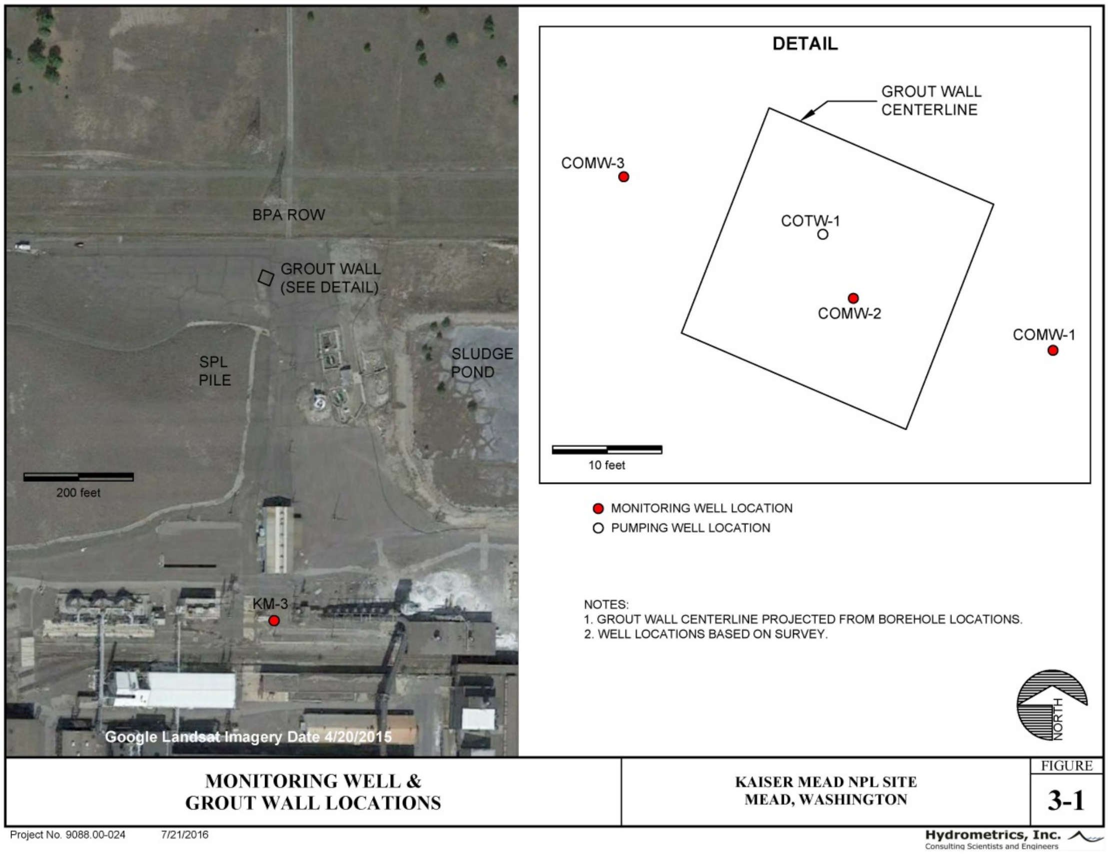
3.1 PUMP TEST WELL INSTALLATION

Three 2-inch test wells (COMW-1, COMW-2, and COMW-3) and one 6-inch pumping well (COTW-1) were installed at the site prior to construction of the grout wall between July13 and July 24, 2016. The pumping well, COTW-1, was installed inside the planned box area, along with one monitoring well, COMW-2. The other two monitoring wells, COMW-1 and COMW-3, were installed outside of the planned box area in order to collect data on water levels outside of the box in response to pumping. The configuration of the pumping and monitoring wells in relation to the test wall is show below in Figure 3-1. The cuttings from each hole were logged by an onsite Hydrometrics geologist to determine the local geology and the level of the A zone aquitard to determine the depth of the bottom of the grout wall panels. Logs of each of these wells are included in Appendix A.

The three monitoring wells and the pumping well were installed in close proximity to each other, resulting in very similar lithology. The lithologic log for COTW-1 is a general log of the cuttings and detailed lithology was recorded from the COMW wells. The wells were drilled through asphalt and fill to a depth of one to three feet bgs. Natural sediments beneath the fill consisted of poorly sorted medium to coarse sand with minor silt and intermittent gravel to a depth of 26 to 29 feet. A thin layer (0.3 to 1 foot thick) of silt underlays the poorly sorted sand followed by well sorted medium sand with few silt seams to a depth of 49 to 50 feet. The shallow aquitard (SAQ) was encountered beneath the well sorted sand to a depth of 52 to 54 feet and ranged in thickness of 1.5 to 5 feet. The silts and clays associated with the SAQ were saturated to moist; the sands beneath this unit were dry. A thick unit of moderately sorted dry sands was encountered below the SAQ to depth of 141 to 142 feet bgs. Saturated medium sand with minor gravel was present to a depth of approximately 160 feet bgs, where the Zone A aquitard was encountered.

COMW-1 was drilled first and was drilled into the top of the Zone A aquitard between 160 and 165 feet bgs; the remaining wells were drilled and completed between 157 and 159 feet bgs to limit the number of boreholes that penetrated the Zone A aquitard. The monitoring wells were completed with 20 feet of 0.010-inch slot screen and COTW-1 was completed with five feet of 0.018-inch slot stainless steel screen to allow for maximum amount of drawdown in the test well during the pumping tests.

FIGURE 3-1. MONITORING WELL AND GROUT WALL LOCATIONS



NOTES:
1. GROUT WALL CENTERLINE PROJECTED FROM BOREHOLE LOCATIONS.
2. WELL LOCATIONS BASED ON SURVEY.

3.1.1 Deviation from Plan

Wells were drilled according to plan, there was no deviation.

3.2 PRE-WALL PUMP TEST

A 24-hour pump test was performed during the week of July 27, 2015, by Hydrometrics to determine the aquifer reaction to pumping prior to construction of the grout wall. Pressure transducers were deployed in the pumping well (COTW-1) and four monitoring wells (COMW-1, COMW-2, COMW-3, KM-3). The transducers were installed and began collecting data approximately 36 hours prior to commencing pumping. Prior to starting the

24-hour constant rate test, a step-drawdown test was completed in order to determine the maximum sustainable pumping rate for the constant rate test. A detailed description of the step-drawdown test procedure, findings, and conclusions is included in Appendix A.

Pumping from COTW-1 for the 24-hour constant rate test began on July 30, 2015 at 18:00 with water being discharged to TW-1A (approximately 1,100 feet to the northwest of COTW-1). The flow rate was adjusted within the first six minutes of pumping to the target rate of 25 gpm and remained constant throughout the remainder of the pumping period. The pump was shut off on July 31, 2015 at 18:02 after 1,442 minutes of pumping. The average pumping rate for the 1,442-minute test was 25.2 gpm based on the totalizing flow meter attached to the discharge pipeline. Maximum drawdown measured in the pumping well was 11.5 feet (Table 3-1).

TABLE 3-1. PUMP TEST WELL DRAWDOWN

Well	Max Drawdown (feet)
COTW-1	4.7*
COMW-1	0.66
COMW-2	1.3
COMW-3	1.1

*Drawdown adjusted based on well efficiency (41%) from step-drawdown test; actual drawdown measured in well = 11.5 feet.

Data obtained from the pre-wall aquifer test were analyzed with analytical aquifer test solutions within AQTESOLV aquifer test analysis software. Analytical analysis resulted in a potential range of A Zone hydraulic conductivity from approximately 75 to 175 feet per day (Table 3-2). A detailed description of the constant rate test procedure, findings, and conclusions is included in Appendix A.

TABLE 3-2. AQUIFER COEFFICIENTS OBTAINED FROM PRE-WALL AQUIFER TEST ANALYSES

Well	Solution	b (feet)	T (ft^2/day)	K (ft/day)	Sy	S	Notes
COTW-1	Theis	18	1410	78	NA	NA	Drawdown adjusted based on well efficiency (41%) from step test
	Neuman	18	1360	76	NA	NA	
	Moench	18	1490	83	NA	NA	
COMW-1	Theis	18	2610	145	NA	0.16	
	Neuman	18	2428	135	0.25	NA	
	Moench	18	2880	160	0.22	NA	
COMW-2	Theis	18	3070	171	NA	0.009	Recovery Fit
	Neuman	18	1760	98	0.01	NA	
	Moench	18	2240	124	0.11	NA	
COMW-3	Theis	18	2810	156	NA	0.01	Recovery Fit
	Neuman	18	1380	77	0.25	NA	
	Moench	18	1880	104	0.14	NA	

Additionally, the data were input into the numerical groundwater flow model and a transient simulation of the test was completed. Further details on calibration of the groundwater flow model to the observed pre-wall test data are included in the Groundwater Model Report (Hydrometrics, 2016).

3.3 GROUT WALL CONSTRUCTION

3.3.1 Contractor Mobilization

Hayward Baker arrived onsite August 24, 2015 to begin mobilizing their equipment. They hired local laborers to assist with construction. Before beginning construction, the cement batch plant was assembled, and a vacuum system was put in place. The vacuum system would remove soilcrete spoils from the drilling area and relocate them into the existing sludge pond in the northeast corner of the site. HBI used water tapped from a fire hydrant on the southeast corner of the site to create the grout mix.

3.3.2 Grout Wall Construction

Grout wall construction began on August 27, 2016, and was completed on September 15, 2016. Prior to each panel being grouted, a shorter pilot hole was drilled by a portable drill rig to a maximum of 142 feet below ground surface. After the pilot hole was completed, the grout drill rig would continue drilling down to the target depth of approximately 160 feet below ground surface. When the drilling was complete, alignment of the hole was verified using a Shape Accel Array. Then the grout drill rig injection nozzle was oriented to 15 degrees from the center line, and the first panel was jet grouted from the bottom of the hole to a height of 25 feet. Following completion of the first panel, the injection nozzle is oriented 15 degrees in the opposite direction and positioned at the bottom of the hole before grouting the second panel to the same height as the previous panel. The remainder of the pilot hole was then filled with grout mixture to the ground surface. The total volume of grout injected to form the box shape was approximately 14,600 cubic feet. Due to the grout mixture displacing an equivalent amount of soilcrete spoils, roughly 14,600 cubic feet of material was placed in to the sludge pond as spoils. See Appendix B for HBI's complete construction report.

3.3.3 Grout Wall Quality Assurance

A Hydrometrics geologist was onsite during construction to perform quality assurance. The parameters recorded by the geologist are detailed in the work plan and are shown below in Table 3-3. Following jet grout drilling the Shape Accel Array (SAA) tool was lowered to measure vertical alignment. The SAA measured deviation from vertical in excess of 1% in 7 of 13 borings. Six of the deviations were 1.60% or less and adjustments were made during the grouting procedure if the alignments were considered significant relative to adjacent panels.

The geologist also collected four samples of the grout mixture (splits from the contractor's sampling) to be used for permeability testing. These samples were cured and taken to a third party lab to undergo permeability testing to ensure that the grout mixture was within the parameters detailed in the work plan. Results of the tests show that the grout mixture was within the margins set in the work plan, and are listed in Appendix C.

3.3.4 Deviation from Plan

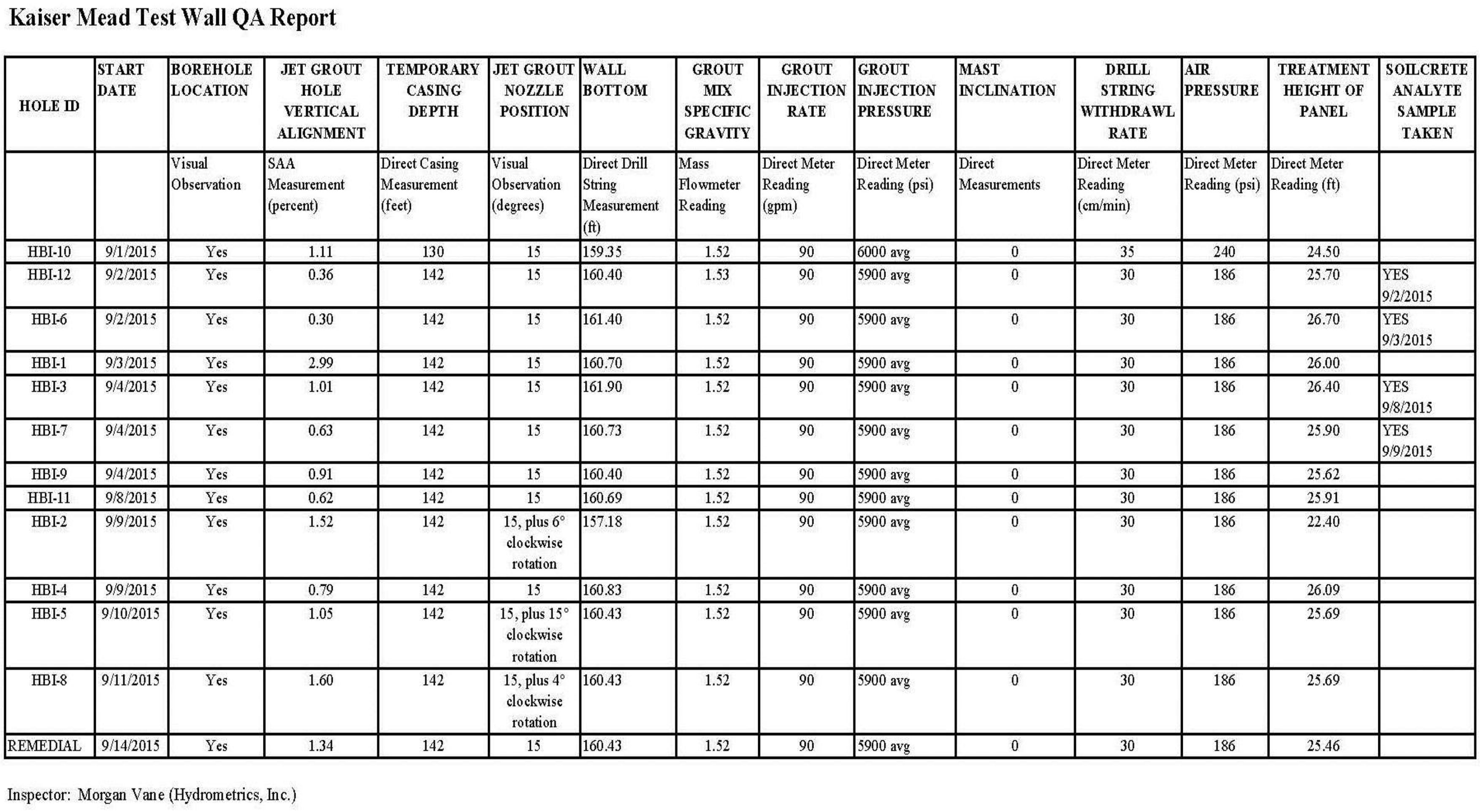
Panel HBI-1 encountered an obstruction near-surface which caused the drill hole to deviate 3% from vertical. This deviation led HBI to install a remedial panel to ensure that all panels were interlocking. Panel HBI-2 was completed roughly three feet short of the predicted aquitard depth due to an obstruction that appeared to be grout material, presumably from the adjacent panel HBI-3. Due to the shorter depth of panel HBI-2, there is the potential for a gap at the intersection of HBI-1 and HBI-2, where the panel may not reach the aquitard surface. The remedial panel installed (HBI-R) was designed to extend to fill the gap left by the deviation of HBI-1 and the potential gap above the aquitard at HBI-2. The pull rate on the remedial panel was slowed from 30cm/min to 20cm/min in order to achieve a longer panel and a better interlock.

3.4 POST-WALL PUMP TEST

The post-wall pump test was performed during the week of November 16, 2015, by Hydrometrics to determine the aquifer reaction to pumping with the grout wall in place. The time between completion of the wall and performing the pump test was approximately 60 days which was within the estimated time required for the wall to fully cure. Pressure transducers were deployed in the pumping well (COTW-1) and the same monitoring wells observed during the pre-wall aquifer test (COMW-1, COMW-2, COMW-3, KM-3). The transducers were in place and collecting data approximately 48 hours prior to commencing pump test activities.

Pumping from COTW-1 began on November 18, 2015 at 14:00 with water being discharged to KM-1 (approximately 1,000 feet to the west of COTW-1). The initial pumping rate was at 2.6 gpm and was changed throughout the test as shown in Table 3-4. It became evident while pumping at 2.6 gpm that the water level in the pumping well was stabilizing, which indicated that the grout wall and/or underlying aquitard was leaking (see Figure 3-2). The remainder of the test was targeted at slowly increasing the pumping rate in order to find the rate (if any) at which extraction exceeded inflow (leakage). A secondary goal was to dewater the interior of the grout wall as fully as possible.

TABLE 3-3. GROUT WALL QA SHEET



Kaiser Mead Test Wall QA Report

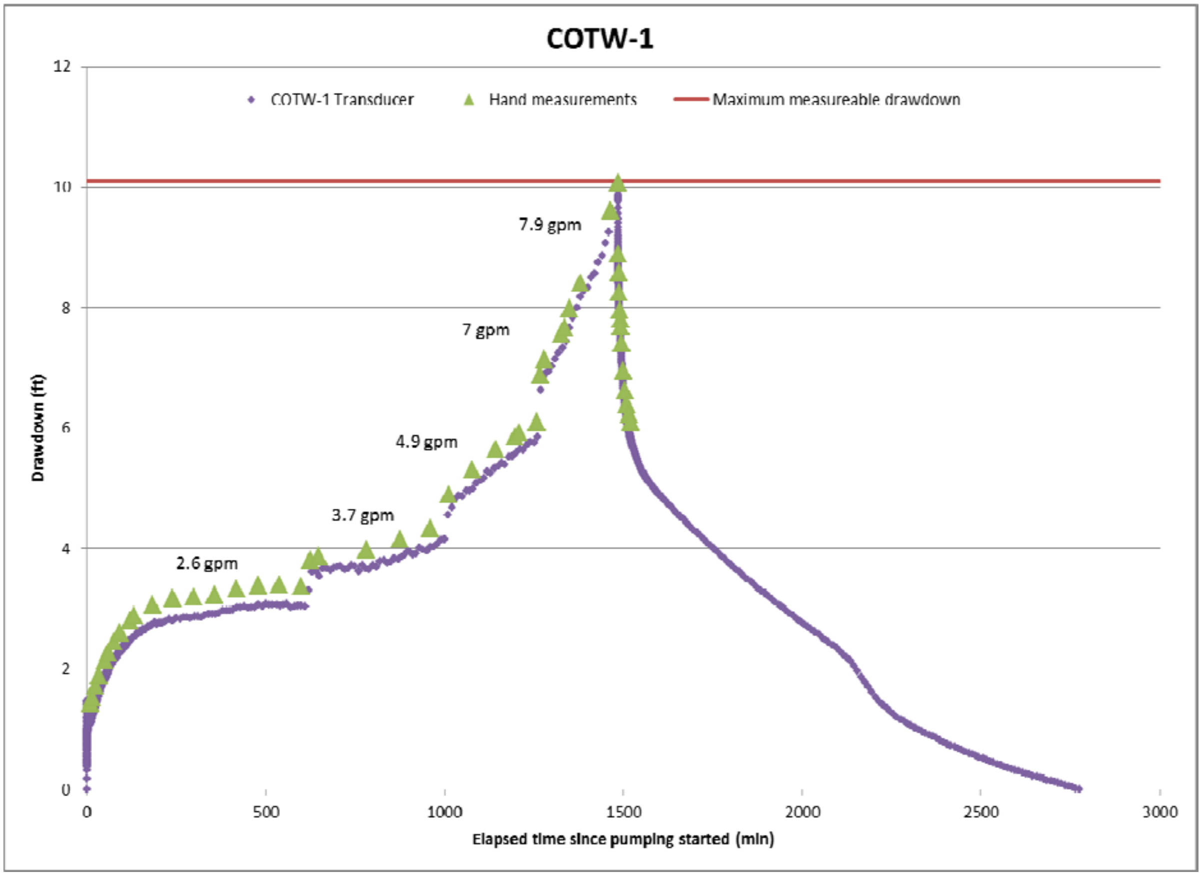
HOLE ID	START DATE	BOREHOLE LOCATION	JET GROUT HOLE VERTICAL ALIGNMENT	TEMPORARY CASING DEPTH	JET GROUT NOZZLE POSITION	WALL BOTTOM	GROUT MIX SPECIFIC GRAVITY	GROUT INJECTION RATE	GROUT INJECTION PRESSURE	MAST INCLINATION	DRILL STRING WITHDRAWL RATE	AIR PRESSURE	TREATMENT HEIGHT OF PANEL	SOILCRETE ANALYTE SAMPLE TAKEN
		Visual Observation	SAA Measurement (percent)	Direct Casing Measurement (feet)	Visual Observation (degrees)	Direct Drill String Measurement (ft)	Mass Flowmeter Reading	Direct Meter Reading (gpm)	Direct Meter Reading (psi)	Direct Measurements	Direct Meter Reading (cm/min)	Direct Meter Reading (psi)	Direct Meter Reading (ft)	
HBI-10	9/1/2015	Yes	1.11	130	15	159.35	1.52	90	6000 avg	0	35	240	24.50	
HBI-12	9/2/2015	Yes	0.36	142	15	160.40	1.53	90	5900 avg	0	30	186	25.70	YES 9/2/2015
HBI-6	9/2/2015	Yes	0.30	142	15	161.40	1.52	90	5900 avg	0	30	186	26.70	YES 9/3/2015
HBI-1	9/3/2015	Yes	2.99	142	15	160.70	1.52	90	5900 avg	0	30	186	26.00	
HBI-3	9/4/2015	Yes	1.01	142	15	161.90	1.52	90	5900 avg	0	30	186	26.40	YES 9/8/2015
HBI-7	9/4/2015	Yes	0.63	142	15	160.73	1.52	90	5900 avg	0	30	186	25.90	YES 9/9/2015
HBI-9	9/4/2015	Yes	0.91	142	15	160.40	1.52	90	5900 avg	0	30	186	25.62	
HBI-11	9/8/2015	Yes	0.62	142	15	160.69	1.52	90	5900 avg	0	30	186	25.91	
HBI-2	9/9/2015	Yes	1.52	142	15, plus 6° clockwise rotation	157.18	1.52	90	5900 avg	0	30	186	22.40	
HBI-4	9/9/2015	Yes	0.79	142	15	160.83	1.52	90	5900 avg	0	30	186	26.09	
HBI-5	9/10/2015	Yes	1.05	142	15, plus 15° clockwise rotation	160.43	1.52	90	5900 avg	0	30	186	25.69	
HBI-8	9/11/2015	Yes	1.60	142	15, plus 4° clockwise rotation	160.43	1.52	90	5900 avg	0	30	186	25.69	
REMEDIAL	9/14/2015	Yes	1.34	142	15	160.43	1.52	90	5900 avg	0	30	186	25.46	

Inspector: Morgan Vane (Hydrometrics, Inc.)

TABLE 3-4. PUMPING RATES AND DURATION

Pumping Rate (gpm)	Duration (minutes)
2.6	617
3.7	384
4.9	261
7.0	80
7.9	143

FIGURE 3-2. POST WALL PUMP TEST CURVE



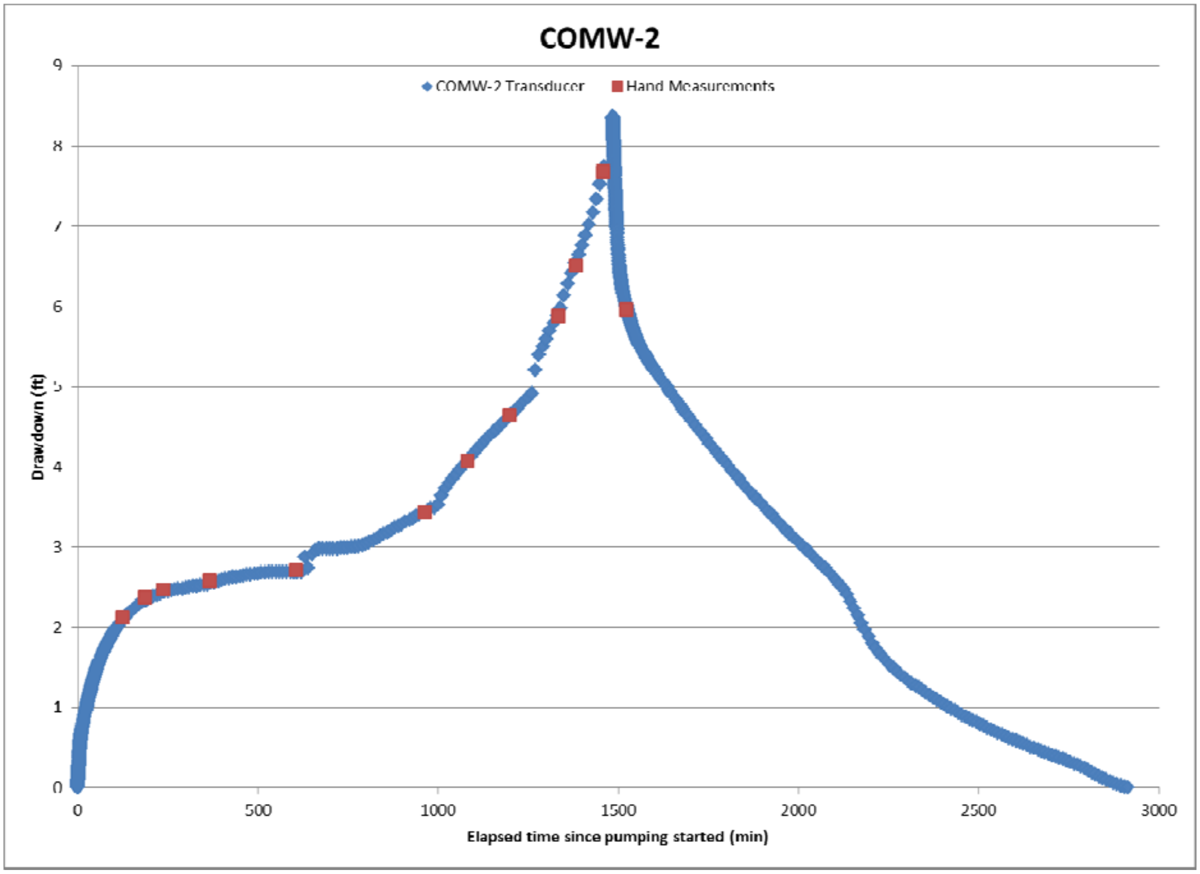
Pumping was stopped on November 19, 2015 at 14:45 after pumping approximately 5,955 gallons from COTW-1. Maximum drawdown in the pumping well after 1,485 minutes of pumping was 9.9 feet with 8.4 feet of drawdown in the observation well within the grout wall box (COMW-2). The two observation wells outside of the grout wall had a maximum drawdown of 0.1 feet, which may or may not be attributable to pumping in COTW-1. Water level in the pumping well returned to pre-pumping level within 21 hours and 35 minutes of the end of pumping. Transducers were removed from the wells on the afternoon of November 21, 2015, approximately 48 hours after pumping was stopped.

3.5 EVALUATION OF GROUT WALL

Data from the pre and post-wall pump tests were compared with output from the groundwater model in order to calibrate the aquifer properties and estimate the permeability of the completed grout wall. Drawdown data from the post-wall pump test is represented in the water level drawdown and recovery chart (see Figure 3-3) for monitoring well COMW-2, the well adjacent to the pumping well and located within the area enclosed by the grout wall box.

As stated earlier, drawdown in the pumping well (COTW-1) stabilized while pumping at the initial rate (2.6 gpm), which indicated that the grout wall and/or underlying aquitard was leaking at least 2.6 gpm into the box. Visual analysis of the water level recovery data from observation well COMW-2 provides another method for estimating the leakage into the grout wall box. The slope seen in Figure 3-3 between approximately 1,600 and 2,100 minutes indicates a water recovery rate in the box of 7.56 feet per day. Making some assumptions about the volume within the grout box and the porosity of the aquifer material, allows calculation of the volumetric flow into the box. Assuming porosity between 0.2 and 0.3, results in a flow rate into the box of 3.5 to 5.2 gpm.

FIGURE 3-3. COMW-2 DRAWDOWN AND RECOVERY



A review of the data collected during injection of the panels comprising the north wall of the box indicated a defect in the completed grout wall box developed during injection of the north wall. Two incidents during north wall injection have been identified as likely resulting in one or more defects.

1) Pre-drilling of injection hole HBI-1 encountered an obstruction at approximately 15 feet below ground surface causing deviation of drill string verticality of 3%; and
2) Injection drilling of hole HBI-2 encountered what was perceived to be grout from an adjacent panel approximately 3 feet from the planned bottom of the hole and stopping the drilling at that point.

The first incident, encountering unmapped buried material (quite possibly an abandoned culvert), is a potential risk when drilling within the fenced industrial complex, but not likely to occur north of the complex in the undeveloped area. The second incident was exacerbated by the sequencing (timing) of the grouting (as a result of the close quarters operation) that allowed the grout from the adjacent hole to harden resulting in refusal of the grout drill. These two incidents resulted in a misaligned panel and a shortened panel that could not be adequately joined with a remedial panel that was injected in an effort to bridge the perceived gap.

Results of the construction QA/QC program where soilcrete samples collected during grout wall injection returned laboratory permeabilities ranging from 10^{-6} cm/sec to 10^{-8} cm/sec it is likely the injected grout wall material did achieve the goal of 10^{-6} cm/sec permeability. Based on the laboratory permeability results and discussion with the Hayward Baker (pers. comm., Adam Gerondale, Hayward Baker), the most likely scenario for a leaking grout wall is a defect of unknown size (most likely at the remedial panel area discussed above and in Section 3.3.4) with the remainder of the wall having a hydraulic conductivity of the target value ($1x10^{-6}$ cm/s) or less. Initial modeling included a defect with a hydraulic conductivity between the native sand (100 ft/day) and the competent grout wall. The more accurate scenario is likely a defect of equal hydraulic conductivity to the native sand.

Modeling the grout wall at a hydraulic conductivity of $1x10^{-6}$ cm/sec with a 10.8 square foot defect in the northwest corner of the wall with a hydraulic conductivity equal to the native sand produced the best fit to the data observed during the post-wall aquifer test. While this defect was in large part due to difficulties associated with the construction of a small box configuration (necessitating unconventional sequencing of the pre-drilling and grouting operation), the modeled effect can be used as a basis for the full scale grout wall evaluation and assessment of other defect scenarios.

Utilizing the same ratio of defect to intact wall with a full scale wall scenario resulted in an estimated 79% reduction in effectiveness when compared to a wall with no flaws. A detailed discussion of the groundwater model is presented in the Groundwater Model Report (Hydrometrics, 2017). This scenario will be included in the evaluation of full scale wall configurations during the remedy evaluation phase of the ongoing Supplemental Feasibility Study.

3.6 COST ESTIMATE OF FULL SCALE GROUT WALL

As part of their scope on this project Hayward Baker prepared a cost estimate for a full scale grout wall. The alignment of the grout wall is similar to the outline of the Plume Center area that was modeled for groundwater flow and sediment leaching effects (see Figure 3-4). The total wall length in the Hayward Baker estimate is 3,950 feet and crosses beneath the Bonneville Power Administration overhead transmission lines in two areas. The alignment is one of several that will be evaluated and the cost developed by Hayward Baker will be converted to a unit cost for evaluating alignments of different lengths. The cost estimate totals $14,285,000 and includes $500,000 for additional geotechnical investigation along the alignment to reduce the possibility of encountering subsurface issues that could cause construction problems. The additional geotechnical investigation consists primarily of using a cone penetrometer test probe every 100 feet along the proposed wall alignment to identify changes in saturated sediment densities that may prompt adjustments to the grouting parameters and also to verify the top of the confining layer (aquitard). The Hayward Baker estimate is included in Appendix D.

FIGURE 3-4. GROUT WALL COST ESTIMATE ALIGNMENT

GROUT WALL
COST ESTIMATE ALIGNMENT

KAISER MEAD NPL SITE
MEAD, WASHINGTON

FIGURE
3-4

Project No. 9088.00-024 7/5/2016

Hydrometrics, Inc.
Consulting Scientists and Engineers

4.0 REFERENCES

Hydrometrics, 2017. Groundwater Model Report for the Kaiser Mead Facility. Draft February 2017.

Hydrometrics, 2016a. Data Report on Additional Field Characterization for the Kaiser Mead Facility. Draft 2016.

APPENDIX A

TEST WELL LOGS
AND PRE-WALL PUMP TEST DISCUSSION

Hydrometrics, Inc.
Consulting Scientists and Engineers
Helena, Montana

Monitoring Well Log

Hole Name: COMW-1

Date Hole Started: 7/13/2015 Date Hole Finished: 7/14/2015

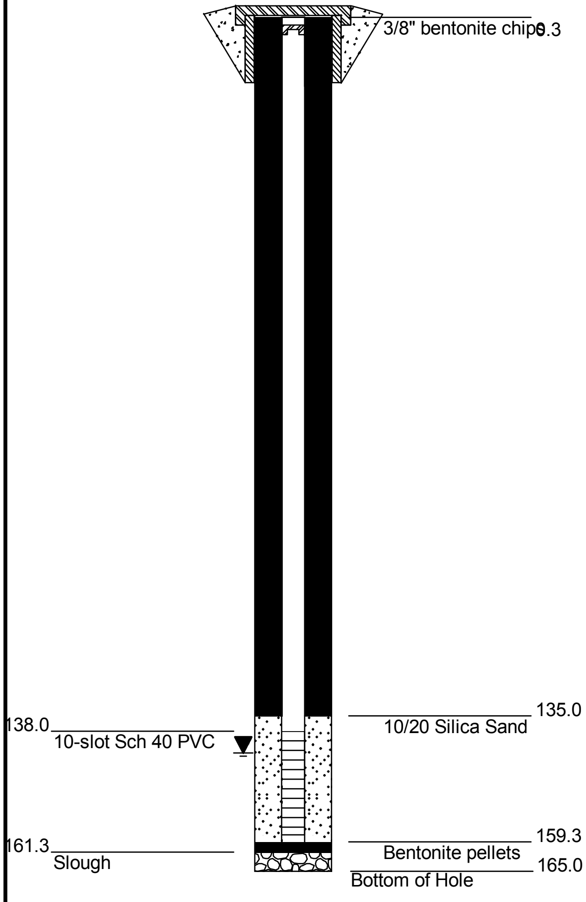
Client: Mead Custodial Trust
Project: Kaiser Mead NPL
County: Spokane State: Washington
Property Owner: Mead Custodial Trust
Legal Description: NW,NE S16 T26 R43
Location Description: NE Corner of SPL Pile, immediately east of test grout box
Recorded By: M. Vane/G. Davis
Drilling Company: Environmental West
Driller: Randy
Drilling Method: Air Rotary: Mobile B-90 with DHH
Drilling Fluids Used: Air/Water
Purpose of Hole: Aquifer Testing Monitoring Well
Target Aquifer: "A" Zone
Hole Diameter (in): 8: 0-52' and 6: 52-161.33'
Total Depth Drilled (ft): 165

WELL COMPLETION	Y/N	DESCRIPTION	INTERVAL
Well Installed?	Y	2-inch PVC	0 - 158.6'
Surface Casing Used?	Y	Steel Flush Mount	0 - 2'
Screen/Perforations?	Y	0.010" slot	138 - 158
Sand Pack?	Y	10/20 Sand	135 - 159.33
Annular Seal?	Y	Bentonite Pellets & 3/8" Chips	2 - 135'
Surface Seal?	Y	Flush mount cover & concrete pad	0 - 2'
DEVELOPMENT/SAMPLING			
Well Developed?	Y	Submersible pump	
Water Samples Taken?	Y	Sampled at end of development	
Boring Samples Taken?	Y	Split Spoon	See Remarks

Northing: 295565.3
Easting: 2489676.1
Static Water Level Below MP: 141.87
Surface Casing Height (ft): 0.0
Date: 10/8/2015
Riser Height (ft): -0.3
MP Description: Top of 2" PVC Casing
Ground Surface Elevation (ft): 1929.71
MP Height Above or Below Ground (ft): -0.31
MP Elevation (ft): 1929.4

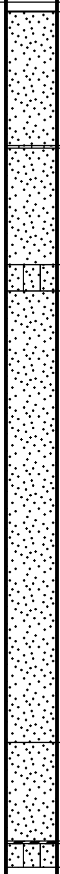
Remarks: Split spoons collected continuous from 40-55' and 154-165' and from 148.5-150'.

WELL CONSTRUCTION



SAMPLE NOTES

GRAPHICS



GEOLOGICAL DESCRIPTION

0.0 - 0.3' **Asphalt**
Pavement

0.3 - 26.0' **SAND**
Unknown thickness of fill between asphalt and native sand. Dry, SAND, coarse with minor silt, brown, rounded, trace gravel.

26.0 - 26.5' **SILT**
Approximate location of a saturated silt seam of unknown thickness.

26.5 - 49.0' **SAND**
Moist, SAND, medium, brown, clean, subrounded, minor gravel.

49.0 - 54.0' **SILTY SAND with CLAY**
SAQ: Saturated, sandy SILT, brown, silt with 1/4" - 1" thick fine sand layers. 7" thick brown CLAY layer at base.

54.0 - 141.0' **SAND**
Dry to damp, SAND, fine to medium and medium to coarse, brown to brown-grey, mostly clean, minor silt

141.0 - 160.0' **SAND**
A-Zone Aquifer: Saturated, SAND, medium, brown-grey, trace gravel near base, minor thin clay/silt seams.

160.0 - 160.5' **CLAY**
A-Zone Aquitard: CLAY, grey-blue, highly plastic, thin very fine sand seams, fragment of silt, 3"x2" cobble at base.

160.5 - 165.0' **SILTY SAND**
A-Zone Aquitard grading into B-Zone Aquifer: Saturated, silty very fine SAND, 1/8" thick clay seam near base.

STANDARD_REV4 K:\GINT\PROJECTS\9088.GPJ HYDHLN2.GDT 1/12/16

Hydrometrics, Inc.
Consulting Scientists and Engineers
Helena, Montana

Monitoring Well Log

Hole Name: COMW-2

Date Hole Started: 7/14/2015 Date Hole Finished: 7/16/2015

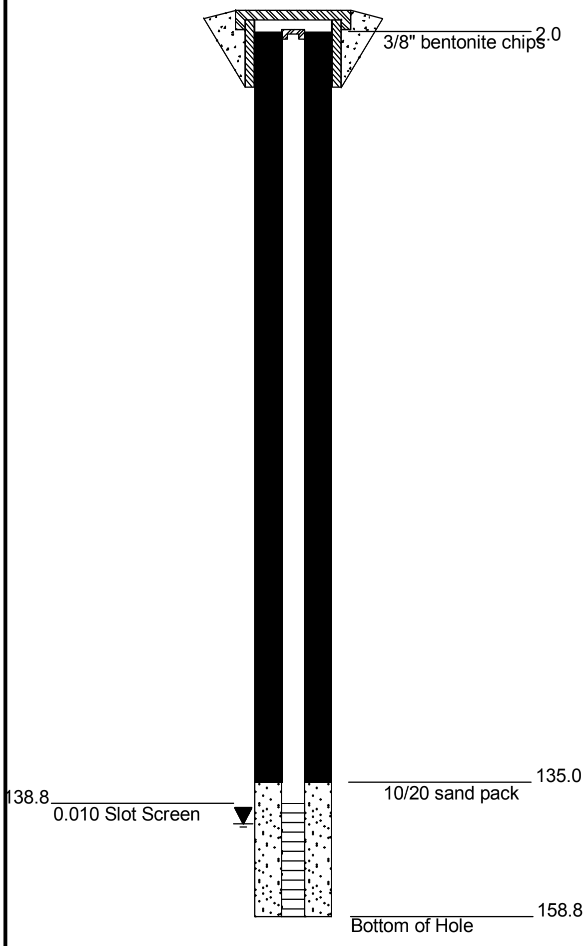
Client: Mead Custodial Trust
Project: Kaiser Mead NPL
County: Spokane State: Washington
Property Owner: Mead Custodial Trust
Legal Description: NW,NE S16 T26 R43
Location Description: NE Corner of SPL Pile, inside grout box
Recorded By: M.Vane/G. Davis
Drilling Company: Environmental West
Driller: Randy
Drilling Method: Air Rotary: Mobile B-90 with DHH
Drilling Fluids Used: Air/Water
Purpose of Hole: Aquifer Testing Monitoring Well
Target Aquifer: "A" Zone
Hole Diameter (in): 8: 0-49' and 6: 49-158.75'
Total Depth Drilled (ft): 158.75

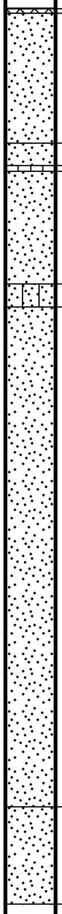
WELL COMPLETION	Y/N	DESCRIPTION	INTERVAL
Well Installed?	Y	2-inch PVC	0 - 158.75
Surface Casing Used?	Y	Steel Flush Mount	0 - 2'
Screen/Perforations?	Y	0.010" slot	138.75 - 158.75
Sand Pack?	Y	10/20 Sand	135 - 158.75
Annular Seal?	Y	3/8" Bentonite Chips	2 - 135'
Surface Seal?	Y	Flush mount cover & concrete pad	0 - 2'
DEVELOPMENT/SAMPLING			
Well Developed?	Y	Submersible pump	
Water Samples Taken?	Y	None	
Boring Samples Taken?	Y	Split Spoon	141 - 142.5' & 149.5 - 151'

Northing: 295569.15 Easting: 2489657.58
Static Water Level Below MP: 142.08 Surface Casing Height (ft): 0.0
Date: 10/8/2015 Riser Height (ft): -0.3
MP Description: Top of 2" PVC Casing Ground Surface Elevation (ft): 1929.82
MP Height Above or Below Ground (ft): -0.27 MP Elevation (ft): 1929.55

Remarks:

WELL CONSTRUCTION	SAMPLE NOTES	GRAPHICS	GEOLOGICAL DESCRIPTION





0.0 - 0.3' **ASPHALT**
Pavement

0.3 - 1.0' **FILL**
Gravely, dark brown

1.0 - 24.0' **SAND**
Damp to dry, SAND, coarse to medium, brown, subrounded, slightly silty, minor gravel (8-12' depth) and few silt/clay seams (8-12' depth)

24.0 - 28.0' **SAND**
Damp, SAND, fine, brown, slightly silty

28.0 - 29.0' **SILT/CLAY**
Saturated, SILT/CLAY, brown, slightly plastic

29.0 - 49.0' **SAND**
Damp to dry, SAND, medium to coarse in layers, brown, clean, thin SILT layer at 39', thin fine sand layer at 46'

49.0 - 53.0' **SILTY SAND, SANDY SILT**
SAQ: Moist, sandy SILT, with CLAY seams

53.0 - 141.5' **SAND**
Dry to moist, SAND, fine to coarse (mostly medium to coarse), brown to grey-brown, 20% fine gravel to 67',

141.5 - 158.8' **SAND**
A-Zone Aquifer: Saturated, SAND, fine to coarse (mostly medium to coarse), grey-brown, clean, few SILT/CLAY seams, minor gravel to 149.5'

Hydrometrics, Inc.
Consulting Scientists and Engineers
Helena, Montana

Monitoring Well Log

Hole Name: COMW-3

Date Hole Started: 7/16/2015 Date Hole Finished: 7/17/2015

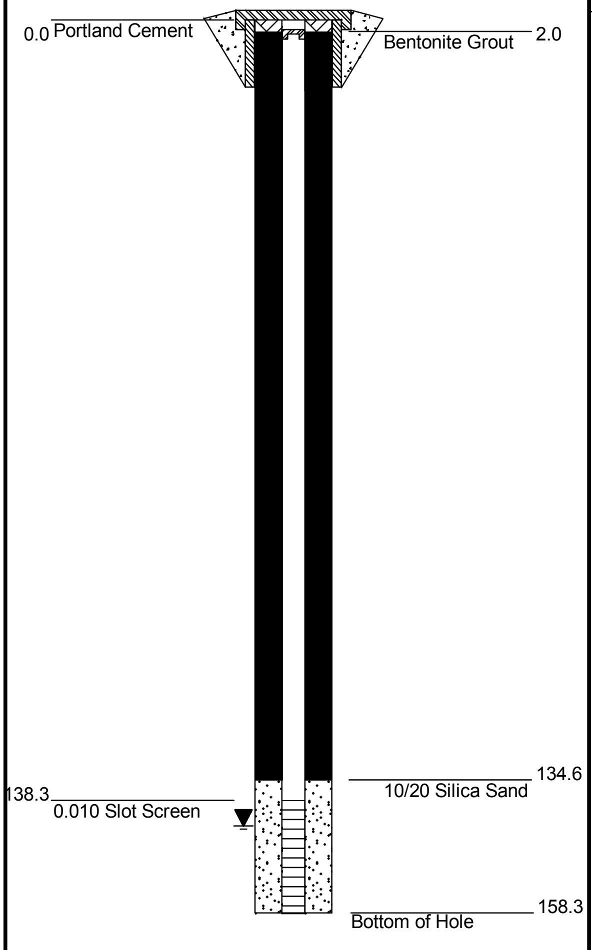
Client: Mead Custodial Trust
Project: Kaiser Mead NPL
County: Spokane State: Washington
Property Owner: Mead Custodial Trust
Legal Description: NW,NE S16 T26 R43
Location Description: NE Corner of SPL Pile, immediately west of test grout box
Recorded By: M. Vane/G. Davis
Drilling Company: Environmental West
Driller: Randy
Drilling Method: Air Rotary: Mobile B-90 with DHH
Drilling Fluids Used: Air/Water
Purpose of Hole: Aquifer Testing Monitoring Well
Target Aquifer: "A" Zone
Hole Diameter (in): 8: 0-50.5' and 6: 50.5-158.25'
Total Depth Drilled (ft): 158.25

WELL COMPLETION	Y/N	DESCRIPTION	INTERVAL
Well Installed?	Y	2-inch PVC	0 - 158.3
Surface Casing Used?	Y	Steel Flush Mount	0 - 2'
Screen/Perforations?	Y	0.010" slot	138.3 - 158.3'
Sand Pack?	Y	10/20 Sand	134.6 - 158.3'
Annular Seal?	Y	3/8" Bentonite Chips	2 - 134.6'
Surface Seal?	Y	Flush mount cover & concrete pad	0 - 2'
DEVELOPMENT/SAMPLING			
Well Developed?	Y	Submersible pump	
Water Samples Taken?	Y	None	
Boring Samples Taken?	Y	Split Spoon	50.5 - 52' & 150 - 151.5'

Northing: 295579.22 Easting: 2489635.99
Static Water Level Below MP: 142.54 Surface Casing Height (ft): 0.0
Date: 10/8/2015 Riser Height (ft): -0.3
MP Description: Top of 2" PVC Casing Ground Surface Elevation (ft): 1930.20
MP Height Above or Below Ground (ft): -0.26 MP Elevation (ft): 1929.94

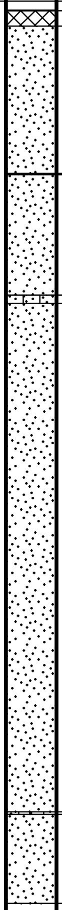
Remarks:

WELL CONSTRUCTION



SAMPLE NOTES

GRAPHICS



GEOLOGICAL DESCRIPTION

0.0 - 0.3' **ASPHALT**
Pavement

0.3 - 3.0' **FILL**
Gravelly fill, dark grey

3.0 - 29.0' **SAND**
Damp to dry, gravelly SAND, medium to coarse, minor silt

29.0 - 29.3' **SILT**
Saturated, SILT, unknown thickness, estimated as a couple of inches

29.3 - 50.5' **SAND**
Moist to dry, SAND, medium, clean, few thin SILT seams around 37'

50.5 - 52.0' **SILTY SAND, SANDY SILT, SILTY CLAY**
SAQ: Saturated, SILTY SAND, SANDY SILT, and SILTY CLAY, brown, layered

52.0 - 142.0' **SAND**
Dry to damp, SAND, medium to coarse, brown, up to 15% gravel near top

142.0 - 142.5' **SANDY SILT**
Sandy SILT layer of unknown thickness

142.5 - 158.3' **SAND**
A-Zone Aquifer: Saturated, SAND, medium to coarse, brown, minor gravel, few thin SILT seams

Hydrometrics, Inc.
Consulting Scientists and Engineers
Helena, Montana

Hole Name: COTW-1

Date Hole Started: 7/23/2015 Date Hole Finished: 7/24/2015

Client: Mead Custodial Trust
Project: Kaiser Mead NPL
County: Spokane State: Washington
Property Owner: Mead Custodial Trust
Legal Description: NW,NE S16 T26 R43
Location Description: NE Corner of SPL Pile, within test grout box
Recorded By: M. Vane
Drilling Company: H2O Well Service
Driller: Jim
Drilling Method: Air Rotary: Star 30K-DH
Drilling Fluids Used: Air/Water
Purpose of Hole: Aquifer Testing
Target Aquifer: "A" Zone
Hole Diameter (in): 6-inch
Total Depth Drilled (ft): 157

WELL COMPLETION	Y/N	DESCRIPTION	INTERVAL
Well Installed?	Y	6 inch Steel Casing	-2.08 - 157'
Surface Casing Used?	Y	6-inch Steel	-2 - 0'
Screen/Perforations?	Y	0.018" slot continuous stainless	152 -157'
Sand Pack?	N		
Annular Seal?	Y	Bentonite Grout	Driven with Casing
Surface Seal?	Y	Bentonite Grout	0 - 18'
DEVELOPMENT/SAMPLING			
Well Developed?	Y	Air development	0.5 hour
Water Samples Taken?	Y	Beginning & end of 24-hr test	
Boring Samples Taken?	Y	None	

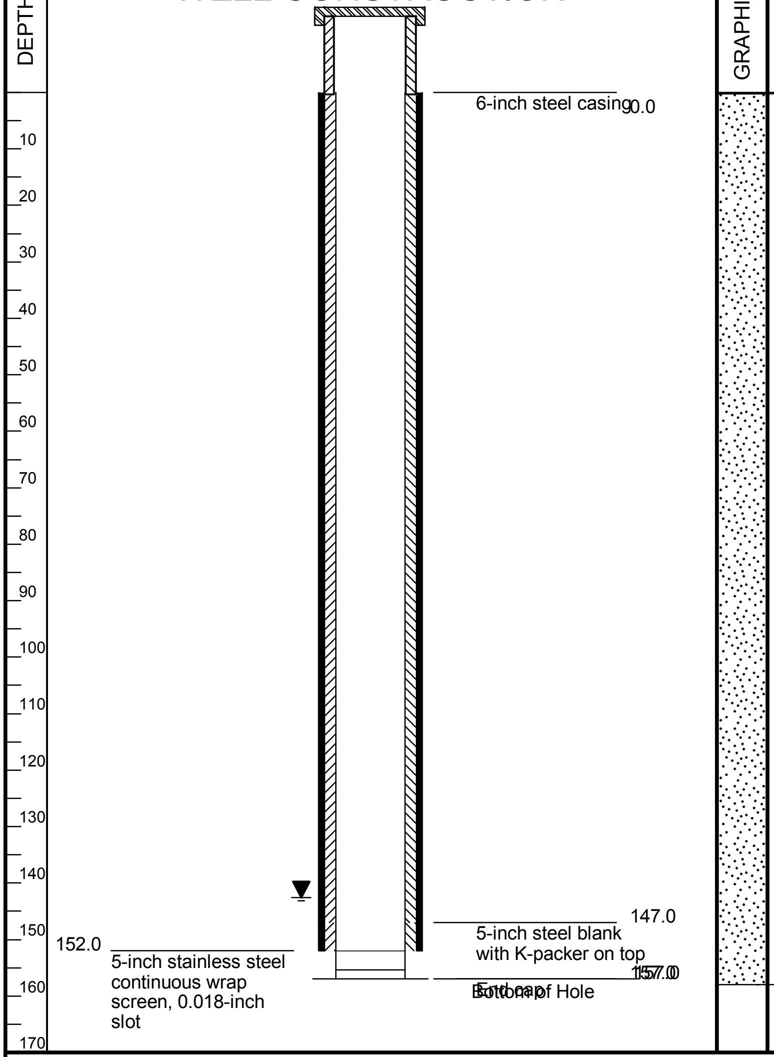
Northing: 295574.87 Easting: 2489654.49
Static Water Level Below MP: 144.60 Surface Casing Height (ft): 2.2'
Date: 10/8/2015 Ground Surface Elevation (ft): 1930.00
MP Description: Top of Steel Casing MP Elevation (ft): 1932.08
MP Height Above or Below Ground (ft): 2.08

Remarks: Difficult to log as cuttings were discharged directly into a roll-off container. See COMW series of wells for better geologic descriptions.

DEPTH

WELL CONSTRUCTION

GRAPHICS



GEOLOGICAL DESCRIPTION

0.0 - 0.3' **ASPHALT**
Pavement

0.3 - 158.0' **SAND**
Thin FILL overlying dry to saturated SAND, fine to coarse, brown-grey, notable SILT/CLAY layers at around 36', 50', 77', 143'.

1.0 PRE-WALL PUMP TEST DISCUSSION

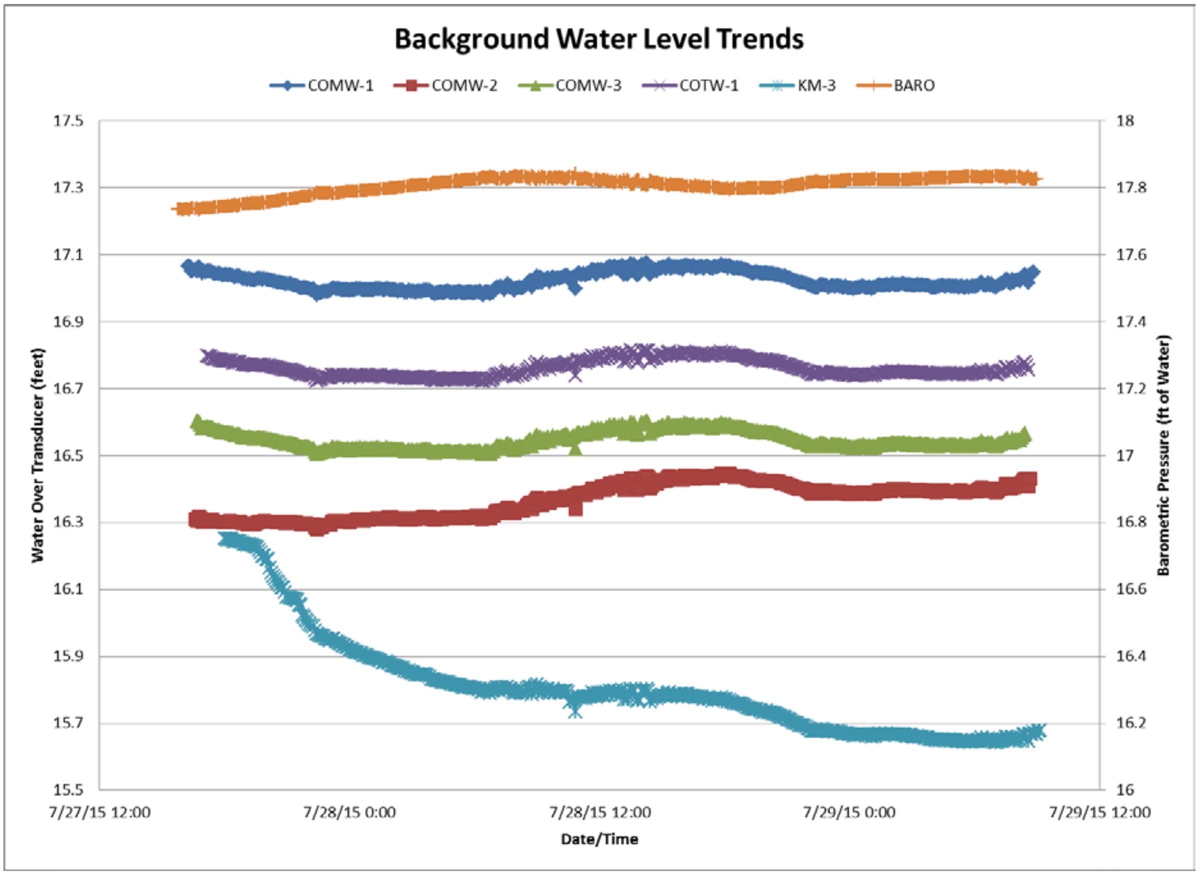
1.1 PRE-WALL PUMPING TEST

The pre-wall pumping test was performed during the week of July 27, 2015, by Hydrometrics to determine the aquifer characteristics and provide a pre-wall pumping curve to compare to the post-wall pumping test data. The pre-wall aquifer test consisted of four phases; background, step-drawdown, 24-hour pumping phase, and recovery phase. A summary of the three phases of the aquifer test are described below.

1.1.1 Background Monitoring

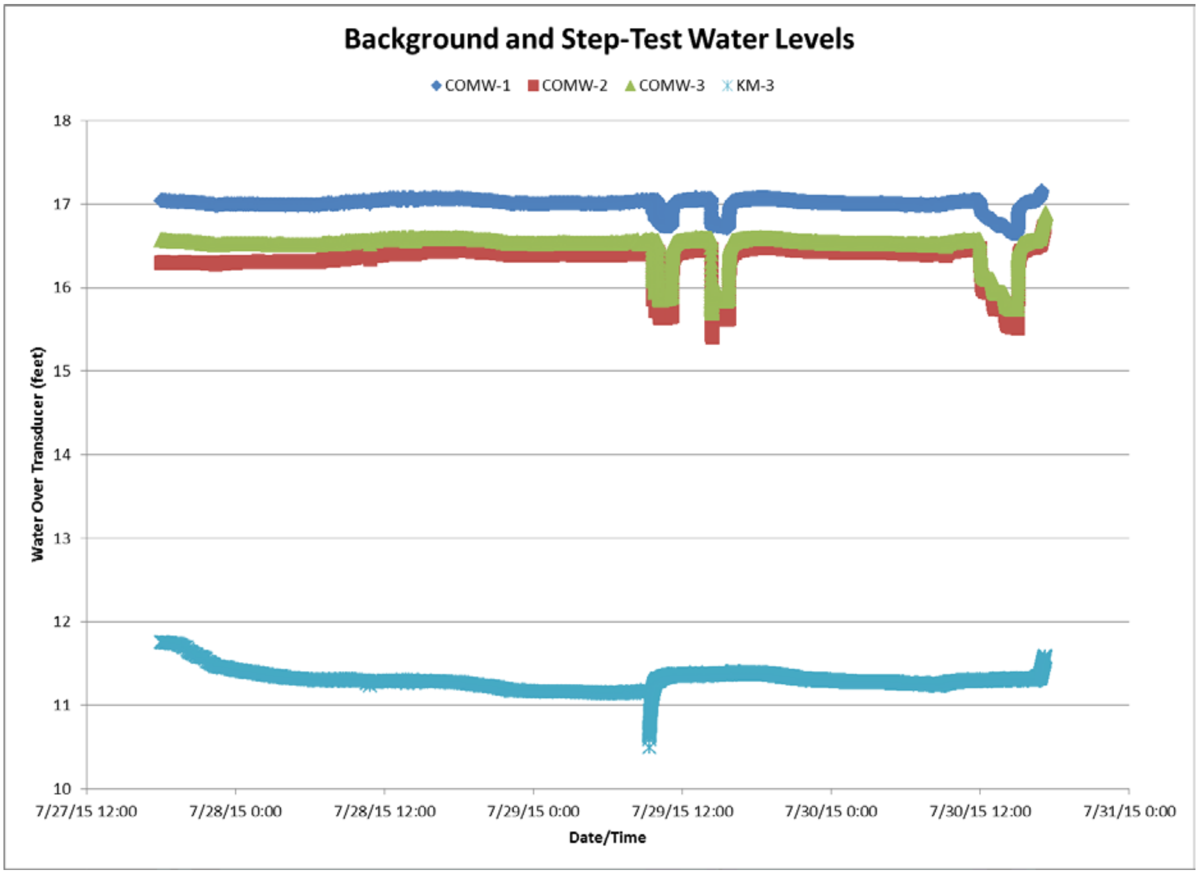
Datalogger pressure transducers were installed in wells COMW-1, COMW-2, COMW-3, COTW-1, and KM-3 on July 27, 2016 to collect background water level trends for approximately 36 hours prior to the step-drawdown test. Barometric pressure was recorded throughout the background monitoring period and throughout the drawdown and recovery phase of the aquifer test. With the exception of well KM-3, background water level data showed inverse trends to barometric pressure trends; therefore the barometric pressure trends were removed from the water level trends for the background, step test, pumping test and recovery test. Background water level corrected for barometric trends are shown in Figure 3-2.

FIGURE 1-1. BACKGROUND WATER LEVEL DATA



The background data appears to show a steady upward trend during the latter part of the background period; however the water levels return to within 0.1 feet of the initial background water level prior to starting the 24-hour test (Figure 3-3). The groundwater levels fluctuated within 0.1 to 0.3 feet during the background period and there was no discernable trend. Background water levels at well KM-3 did not show similar trends to the test well or other observation wells.

FIGURE 1-2. BACKGROUND AND STEP-TEST WATER LEVEL DATA



1.1.2 Step-Drawdown Test

Hydrometrics conducted a step-drawdown test on COTW-1 on July 30, 2015. The purpose of the test was to establish water level drawdown characteristics in the well under a range of pumping rates. The data from the test were used to estimate the maximum flow rate the well was capable of sustaining for the proposed 24-hour test. The step-drawdown data can also be used to estimate well loss (well efficiency). In theory, in an ideal aquifer with 100% efficient well, drawdown increases linearly with increases in discharge (e.g., doubling the discharge rate should double the drawdown). However, aquifers are rarely ideal and well construction typically does not allow for an ideal connection between the well and aquifer, which can cause non-linear drawdown effects due to friction losses or turbulent flow conditions in the well or formation. These effects can be assessed by conducting a step-test and are crucial to assure a long-term aquifer test will properly stress an aquifer.

A previous onsite aquifer test indicated that a pumping rate of 40 gpm was insufficient to significantly stress the A-Zone aquifer. Therefore, a pump was requested that would be able to pump approximately 100 gpm. The step-drawdown test began on the morning of July 29 at a rate between 25 and 30 gpm. It quickly became evident that the pump and transducer in the pumping well would have to be lowered to provide sufficient water column to pump at that rate. The pump and transducer were lowered approximately 5 feet and pumping resumed at approximately 23 gpm during the afternoon of July 29. Results analyzed in the field indicated that a lower pumping rate was desired in order to continue the step-drawdown test, which was not possible with the existing pump. Therefore, a smaller pump was planned for installation on the morning of July 30.

A Goulds 18GS30 pump was installed on the morning of July 30th with the intake set at 155 feet bgs, which provided approximately 12 feet of available drawdown. The step test consisted of three steps (changes in pumping rate) with each step running for one hour. The first step was started at 12:00 at a pumping rate of approximately 16 gpm and maximum drawdown of 4.6 feet. Water levels in all of the wells were monitored on a 10-second interval. The pumping rate was increased to 20 gpm (25% increase), which resulted in an increase in drawdown (6.83 feet, ~48% increase in drawdown from first step). The third and last step had a pumping rate of 25 gpm (25% increase from second step), which resulted in an increase in drawdown to 9.32 feet (36% increase from second step)

FIGURE 1-3. COTW-1 STEP-DRAWDOWN TEST EVALUATION

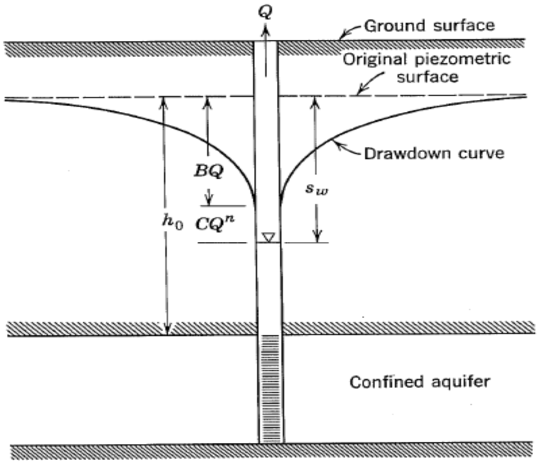
Worksheet for Evaluation of Well Loss and Well Efficiency

Total drawdown in a pumping well is a function of the drawdown in the formation (formation loss) plus any additional loss in head that occurs in the well (well loss) due to any frictional resistance as water flows from the formation to the pump intake. Jacob (1947) developed the following equation describing the drawdown components to a well at a given pumping rate:

eqn 1 $s_w = B*Q + C*Q^2$

where:

s_w = Total Drawdown
Q = Pumping Rate (gpm)
B = Formation Loss Coefficient
C = Well Loss Coefficient



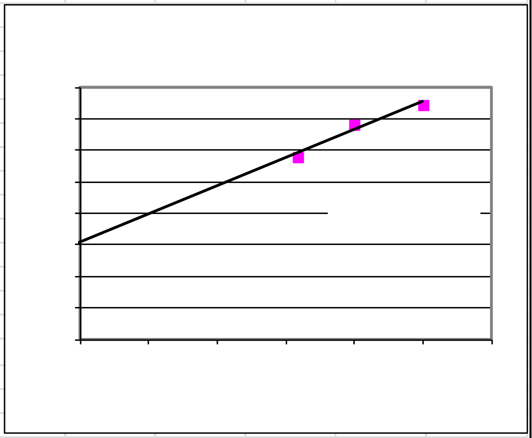
Well loss and well efficiency can be calculated from step drawdown pumping test results by plotting s/Q versus discharge and fitting a straight line through the observed data. The slope of the best fit line is equal to C (well loss) and the intercept of this line with Q = 0 is B (aquifer drawdown).

KAISER MEAD COTW-1 STEP TEST EVALUATION

Test Date: 7/30/2015

Test Results

Q (gpm)	s(ft)	s/Q
15.85	4.6	0.290
20	6.83	0.342
25	9.32	0.373



Loss Coefficients

drawdown B = 0.1537
well loss C = 0.0089

Calculated Losses

discharge rate Q = 25 gpm
aquifer drawdown BQ = 3.8 ft
well/formation loss CQ^2 = 5.6 ft

Well Efficiency

Well efficiency is a comparison of the total drawdown in a well versus the drawdown in the formation immediately outside the well. The efficiency of a well can be calculated at a given pumping rate using the following equation:

eqn. 2 $E_w = 100 * (B*Q)/s_w$

B = 0.1537
Q = 25 gpm
(from eqn 1) sw = 9.4 ft

E_w = 41%

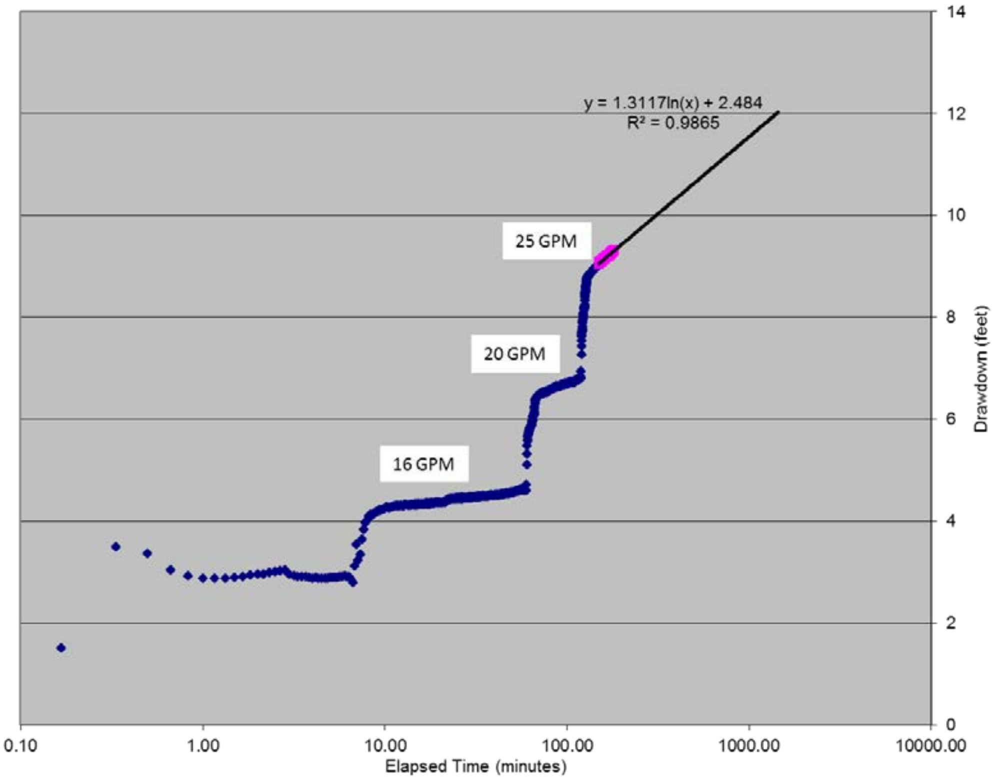
REFERENCES

Jacob C.E., 1947. Drawdown test to determine effective radius of artesian well, Trans. Amer. Soc. Civil Engrs. v. 112 pp.1047-1070
Todd, D.K, 1980. Groundwater Hydrology 2nd Edition. p.153.

The step test results show non-linear drawdown effects are evident in the pumping well with increases in discharge rate (i.e., specific capacity decreased at the pumping rate increased). Based on equation 1 on Figure 3-4, the drawdown in the aquifer at 25 gpm is 3.8 feet and the drawdown due to well/formation loss is 5.6 feet. Well efficiency was calculated at 41% within the range of discharge rates in the step test.

The estimated total drawdown after 24 hours of pumping was evaluated by extending the observed drawdown data on a semi-log drawdown versus time plot as shown in Figure 3-5. A straight-line extension of the drawdown from the final 32 minutes of the 25 gpm step out to 24 hours (1,440 minutes) results in an estimated 12 feet of drawdown in COTW-1. This method, more likely than not, overestimates the total drawdown as the drawdown rate will likely decrease as the cone of depression extends further and the flux moving into the cone of depression approaches the discharge of the well. Assuming the straight-line analysis over estimates the drawdown over longer pumping periods it was determined that the 24 hour test could sustain a flow rate of 25 gpm with sufficient water over the pump intake and transducer.

FIGURE 1-4. COTW-1 STEP-DRAWDOWN TEST STRAIGHT LINE EXTENSION



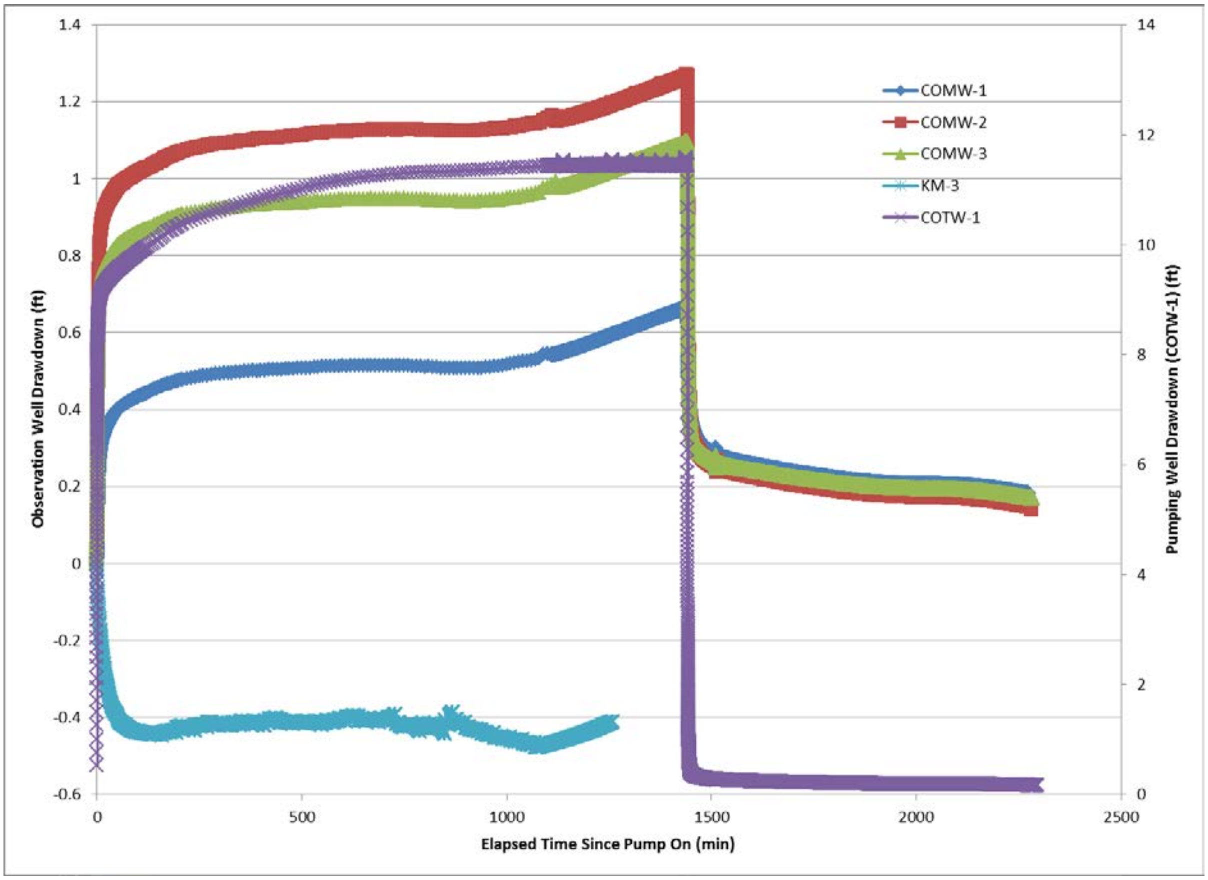
1.1.3 Constant Rate Test

A 24-hour constant rate pumping test was conducted on COTW-1 from July 30, 2015 at 18:00 to July 31, 2015 at 18:02. Water pumped from COTW-1 was transmitted through 3-inch flexible hose and reinjected into TW-1A (approximately 1,100 feet to the northwest of COTW-1). The flow rate was adjusted within the first six minutes of pumping with flow ranging between 25 to 27 gpm until the target rate of 25 gpm was achieved. Discharge from COTW-1 was very stable throughout the pumping test with recorded flows ranging between 25 and 26 gpm and an average pumping rate of 25.2 gpm based on the totalizer flow meter (totalizer readings: start – 166,975 gallons; final – 203,300 gallons). The pump was shut off on July 31, 2015 at 18:02 after 1,442 minutes (24 hours) of pumping.

Water level measurements in wells COTW-1, COMW-1, -2, and -3 were recorded using datalogger pressure transducers set to record at an increasing recording schedule with an initial frequency of one reading per second for the first four minutes and gradually decreasing in frequency to a maximum interval of 1 reading every 10 minutes. Water levels in KM-3 were monitored at a 30-second frequency throughout the pumping and recovery phases. Periodic manual water level measurements were recorded using an electronic water level indicator for confirmation.

Figure 3-6 shows the drawdown trends over time during the pumping and recovery tests for each well monitored during the pumping test. Pumping produced a quick drawdown response in COTW-1 with drawdown at approximately 9.1 feet after 10 mins of pumping. The rate of drawdown quickly decreased after the initial drawdown and became relatively stable by the end of the pumping test, with a maximum drawdown of 11.5 feet. Assuming a well efficiency of 41%, the drawdown in the aquifer at COTW-1 is estimated at 4.7 feet (Table 3-1).

FIGURE 1-5. 24-HR CONSTANT RATE TEST
PUMPING AND RECOVERY DATA



Drawdown in wells COMW-2 (located about 6 feet to the SE of COTW-1) and COMW-3 (located approximately 19 feet northwest of COTW-1) had similar trends. Twenty minutes into the pumping test drawdown were 0.9 and 0.75 feet, respectively. As with the pumping well the rate of drawdown decreased after the initial drawdown with drawdown stabilizing at 1.1 feet (COMW-2) and 0.9 (COMW-3) after 12 hours of pumping. After 16 hours of pumping the drawdown in COMW-2 and -3 increased again with maximum drawdown of 1.3 and 1.1 feet at the end of the pumping test, respectively (Table 3-1). Well COMW-1 located about 23 feet southeast of COTW-1, had similar trends in drawdown; however they were subdued compared to COMW-2 and -3. Initial drawdown in COMW-1 was approximately 0.3 feet after 20 minutes, then stabilized at 0.5 feet after 12 hours of pumping, and increased to a maximum drawdown of 0.66 feet at the end of pumping. The subdued drawdown at well COMW-1 is indicative of heterogeneous aquifers and indicates the hydraulic conductivity at COMW-1 is likely higher than the material at COTW-1. There was no discernable drawdown observed at KM-3 that could be attributed to the COTW-1 pumping test.

Three potential causes of the increase in drawdown during the latter part of the pumping test were evaluated: 1) pumping rate increase/faulty flow meter, 2) boundary conditions encountered, and 3) additional stress applied to aquifer. The pumping rate does not appear to be the cause as the drawdown in the pumping well did not increase and any unmeasured increase in flow would have resulted in an increase in drawdown in the pumping well. It is also unlikely that a boundary condition was encountered as the increase in drawdown occurs at the same time in all observation wells and boundary effects would occur at different times in each observation well based on their proximity to the boundary. Simultaneous increases in drawdown are likely due to additional stresses on the aquifer system. It should also be noted that the background water level data showed similar trends that are indicative of outside stresses being applied to the aquifer. A survey of the area did not identify any potential stresses that could be quantified; therefore the increase in drawdown during the latter part of the test was not used as part of the aquifer test analysis.

TABLE 1-1. MAXIMUM DRAWDOWN FOR PRE-WALL PUMPING TEST

Well	Max Drawdown (feet)
COTW-1	4.7*
COMW-1	0.66
COMW-2	1.3
COMW-3	1.1

*Drawdown adjusted based on well efficiency (41%) from step-drawdown test; actual drawdown measured in well = 11.5 feet.

Water levels recovered rapidly in the pumping well after pumping had ceased, with 96% of the drawdown being recovered within 10 minutes. Observation wells COMW-2 and COMW-3 also had relatively rapid recoveries in water levels with 75% of the drawdown being recovered within 30 minutes. The recovery was delayed in COMW-1 compared to the other wells with only 50% of the drawdown being recovered after 30 minutes. The slower recovery at COMW-1 could be from higher effective storage that is sometimes found in coarser material. The recovery rate decreased in all of the observation wells after the initial recovery with none of the wells being fully recovered 13 hours after pumping had stopped.

Data obtained from the pre-wall aquifer test were analyzed with analytical aquifer test solutions within AQTESOLV (ver. 4.5) aquifer test analysis software. The COTW-1 drawdown data was adjusted based on a well efficiency of 41% as calculated in the step test. The lowest hydraulic conductivity (K) values (76 – 83 ft/day) were estimated at COTW-1. Well COMW-1 had the highest average K from each of the analyses, which is indicative of the likely heterogeneities discussed above. Analysis of data from COMW-2 and COMW-3 resulted in similar estimates for K ranging from 77 to 171 ft/day. Curve matching solutions are included in Appendix E and estimated aquifer characteristics are summarized in Table 3-2. The COTW-1 aquifer test indicates the hydraulic conductivity of the A-Zone aquifer ranges between 75 and 175 feet/day in the vicinity of the pilot test grout wall. Specific yield and storage coefficients were estimated based on the drawdown in the observations wells, resulting in estimates of specific yield ranging from 0.01 to 0.25 and a storage coefficient of 0.009 to 0.010.

TABLE 1-2: AQUIFER COEFICIENTS OBTAINED FROM PRE-WALL AQUIFER TEST ANALYSES

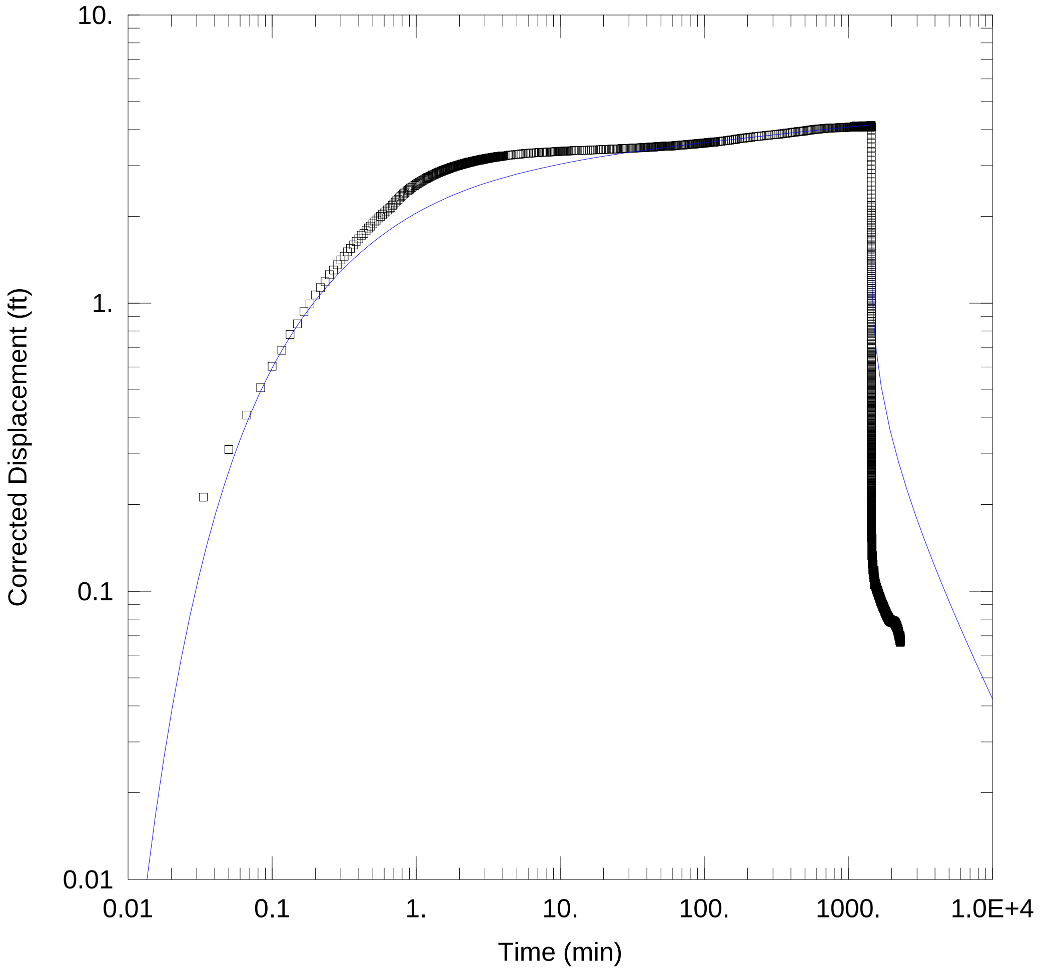
Site	Solution	b (feet)	T (ft^2/day)	K (ft/day)	Sy	S	Notes
COTW-1	Theis	18	1410	78	NA	NA	Drawdown adjusted based on well efficiency (41%) from step test
	Neuman	18	1360	76	NA	NA	
	Moench	18	1490	83	NA	NA	
COMW-1	Theis	18	2610	145	NA	0.16	
	Neuman	18	2428	135	0.25	NA	
	Moench	18	2880	160	0.22	NA	
COMW-2	Theis	18	3070	171	NA	0.009	Recovery Fit
	Neuman	18	1760	98	0.01	NA	
	Moench	18	2240	124	0.11	NA	
COMW-3	Theis	18	2810	156	NA	0.01	Recovery Fit
	Neuman	18	1380	77	0.25	NA	
	Moench	18	1880	104	0.14	NA	

1.1.4 Water Quality Monitoring

Water quality samples were collected from well COTW-1 for cyanide (free at pH 6, total, and WAD) and fluoride at the start and end of the constant rate pumping test. In addition, field parameters (temperature, specific conductance, and pH) were monitored on a near hourly basis throughout the pumping test. The field parameters remained relatively stable throughout the test (Table 3-3). Water temperature fluctuated during some periods, this can be attributed to the water heating up or cooling off before it could be measured due to changes in ambient air temperatures. The water quality results from the test at COTW-1 are summarized in Table 3-3 and analytical reports are included in the Data Report on Additional Field Characterization (Hydrometrics, 2016a).

TABLE 1-3. COTW-1 WATER QUALITY DURING THE CONSTANT RATE TEST

Date	Time	Specific Conductivity (µS/cm)	pH	Temp (^{0}C)	Cyanide, free at pH 6 (mg/L)	Cyanide, total (mg/L)	Cyanide, WAD (mg/L)	Fluoride (mg/L)
7/30/2015	18:18	678	8.4	14.8	< 0.0100	0.0370	0.0130	1.04
	19:05	681	8.4	18.0				
	20:01	718	8.4	17				
	21:08	685	8.1	15				
	22:03	688	8.4	14.6				
	23:00	681	8.1	14.2				
7/31/2015	0:05	681	8.3	13.5				
	1:01	685	8.3	12.8				
	2:02	683	8.3	12.4				
	3:02	682	8.4	12.2				
	4:02	682	8.3	11.9				
	4:59	682	8.4	11.5				
	5:56	690	8.6	11.8				
	6:56	679	8.4	15.7				
	8:04	667	8.5	15.2				
	8:53	676	8.6	15.5				
	9:55	671	8.4	18.6				
	10:58	679	8.4	15.1				
	11:58	672	8.4	17.6				
	12:59	676	8.2	16.5				
	13:59	669	8.4	20.9				
	14:59	678	8.2	14.9				
	15:59	670	8.2	14.7				
	16:59	685	8.1	14.8				
	17:59	676	8.2	13.8	<0.0100	0.0580	0.0190	0.967



WELL TEST ANALYSIS

Data Set: C:\...\COTW-1_EffAdjustment_Theis.aqt
Date: 07/26/16 Time: 09:42:35

PROJECT INFORMATION

Company: Hydrometrics
Client: Mead Custodial Trust
Project: 9088
Location: Kaiser Mead
Test Well: COTW-1
Test Date: 7-30-2015

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
COTW-1	2489654.49	295574.87

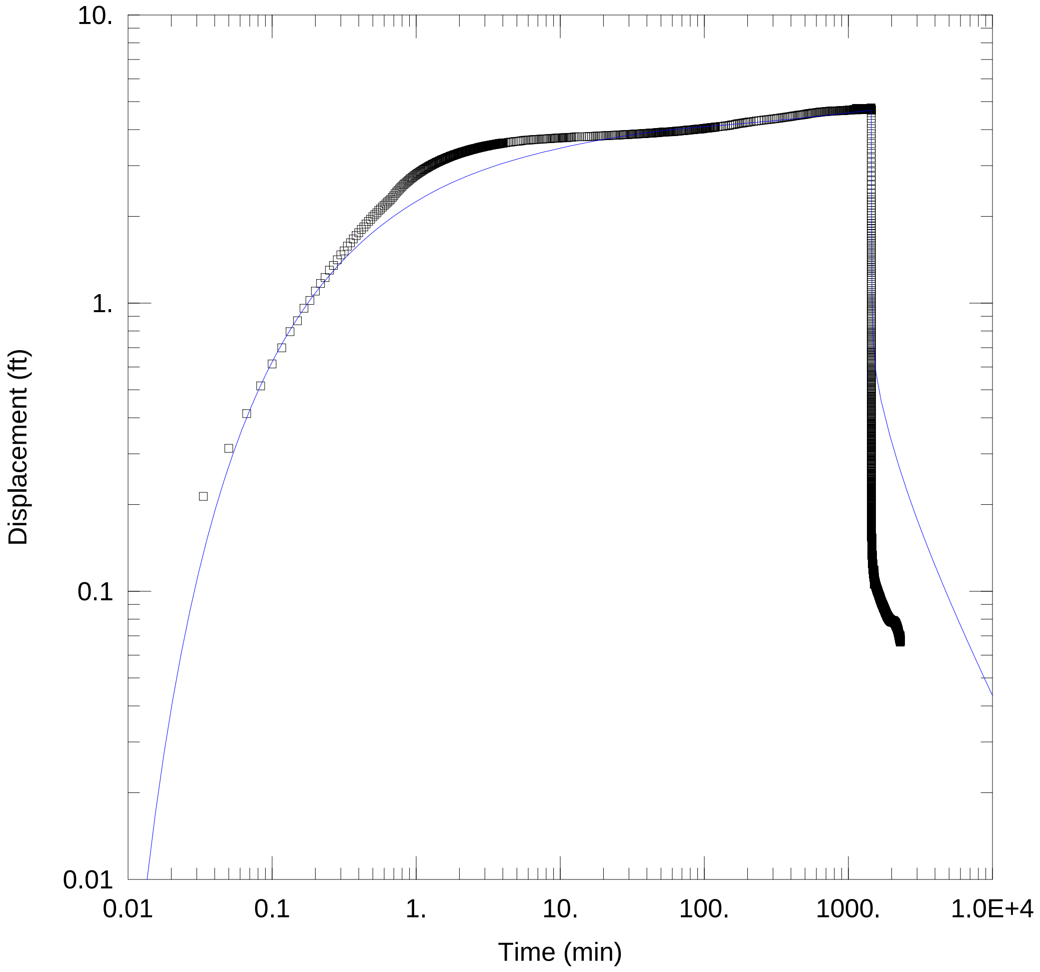
Observation Wells

Well Name	X (ft)	Y (ft)
□ COTW-1	2489654.49	295574.87

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 1406.8 ft^2/day
S = 3.892
Kz/Kr = 7.774
b = 18.34 ft



WELL TEST ANALYSIS

Data Set: C:\Users\gdavis\Desktop\Projects\Kaiser Mead\Cutoff Wall\Construction Report\COTW-1_EffAdjustment.aqt
Date: 07/26/16 Time: 09:49:27

PROJECT INFORMATION

Company: Hydrometrics
Client: Mead Custodial Trust
Project: 9088
Location: Kaiser Mead
Test Well: COTW-1
Test Date: 7-30-2015

AQUIFER DATA

Saturated Thickness: 18.34 ft

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
COTW-1	2489654.49	295574.87

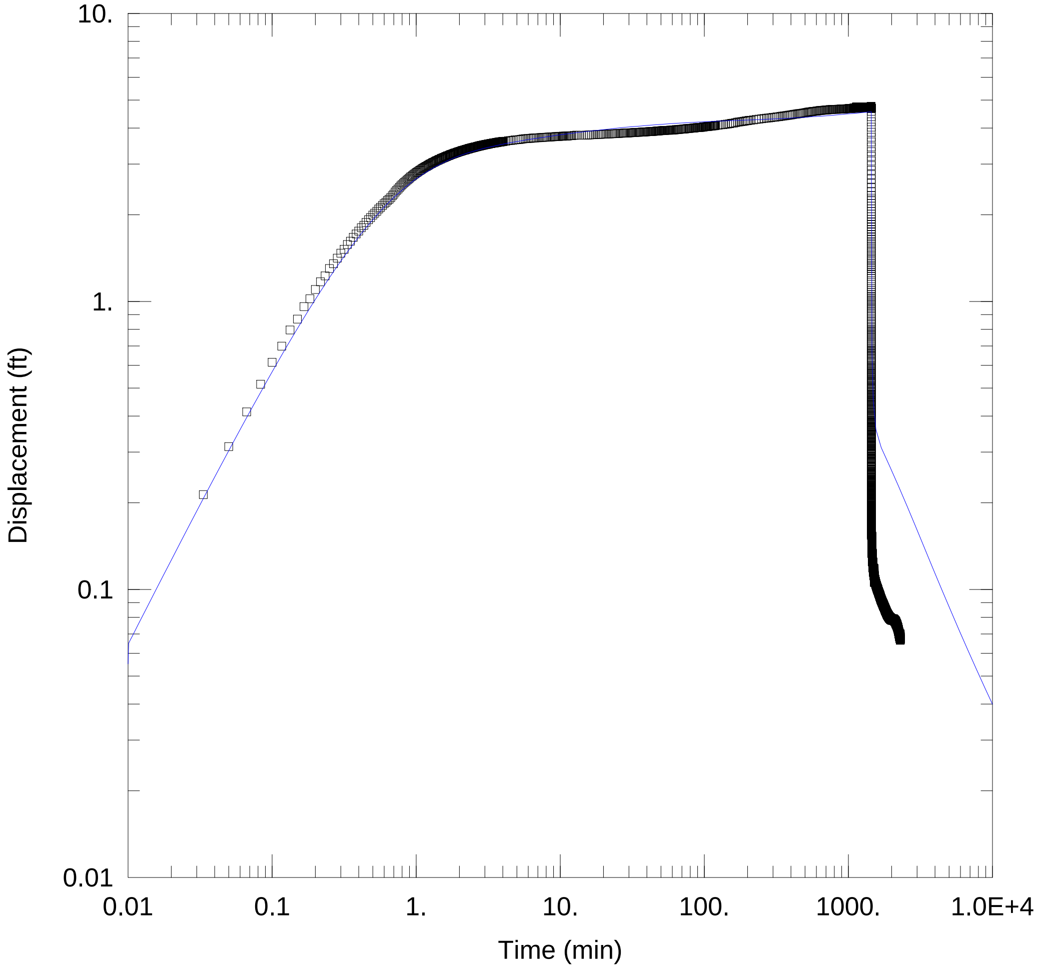
Observation Wells

Well Name	X (ft)	Y (ft)
□ COTW-1	2489654.49	295574.87

SOLUTION

Aquifer Model: Unconfined
Solution Method: Neuman

T = 1362.5 ft^2/day
S = 3.77
Sy = 6.389
ß = 0.001



WELL TEST ANALYSIS

Data Set: C:\...\COTW-1_EffAdj_Moench_1997.aqt
Date: 07/26/16 Time: 09:53:27

PROJECT INFORMATION

Company: Hydrometrics
Client: Mead Custodial Trust
Project: 9088
Location: Kaiser Mead
Test Well: COTW-1
Test Date: 7-30-2015

AQUIFER DATA

Saturated Thickness: 18.34 ft
Anisotropy Ratio (Kz/Kr): 3.167

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
COTW-1	2489654.49	295574.87

Observation Wells

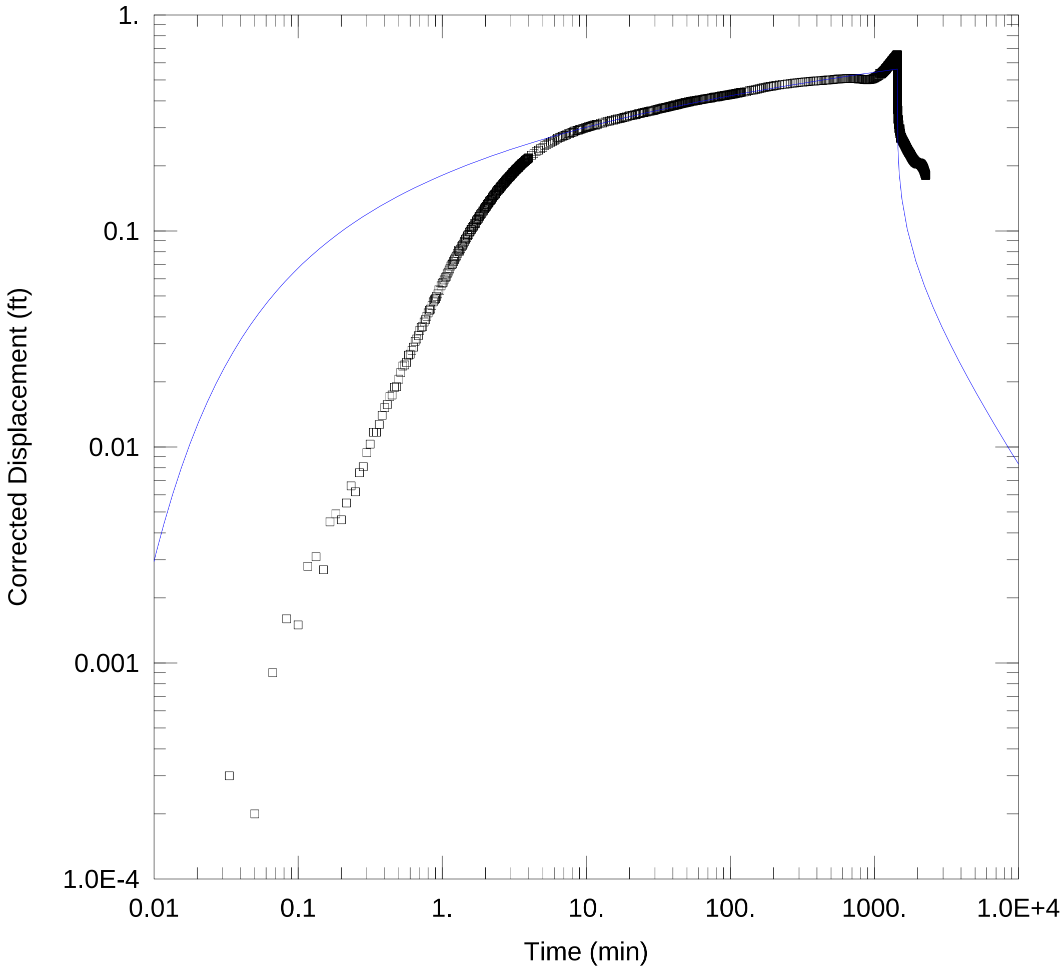
Well Name	X (ft)	Y (ft)
□ COTW-1	2489654.49	295574.87

SOLUTION

Aquifer Model: Unconfined
Solution Method: Moench

T = 1493.9 ft^2/day
Sy = 0.1045
Sw = -1.125
r(c) = 0.4345 ft

S = 0.01266
ß = 0.000309
r(w) = 0.1812 ft
alpha = 0.001585 min^{-1}



WELL TEST ANALYSIS

Data Set: C:\...\COMW-1_Theis.aqt
Date: 07/26/16 Time: 09:24:54

PROJECT INFORMATION

Company: Hydrometrics
Client: Mead Custodial Trust
Project: 9088
Location: Kaiser Mead
Test Well: COTW-1
Test Date: 7-30-2015

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
COTW-1	2489654.49	295574.87

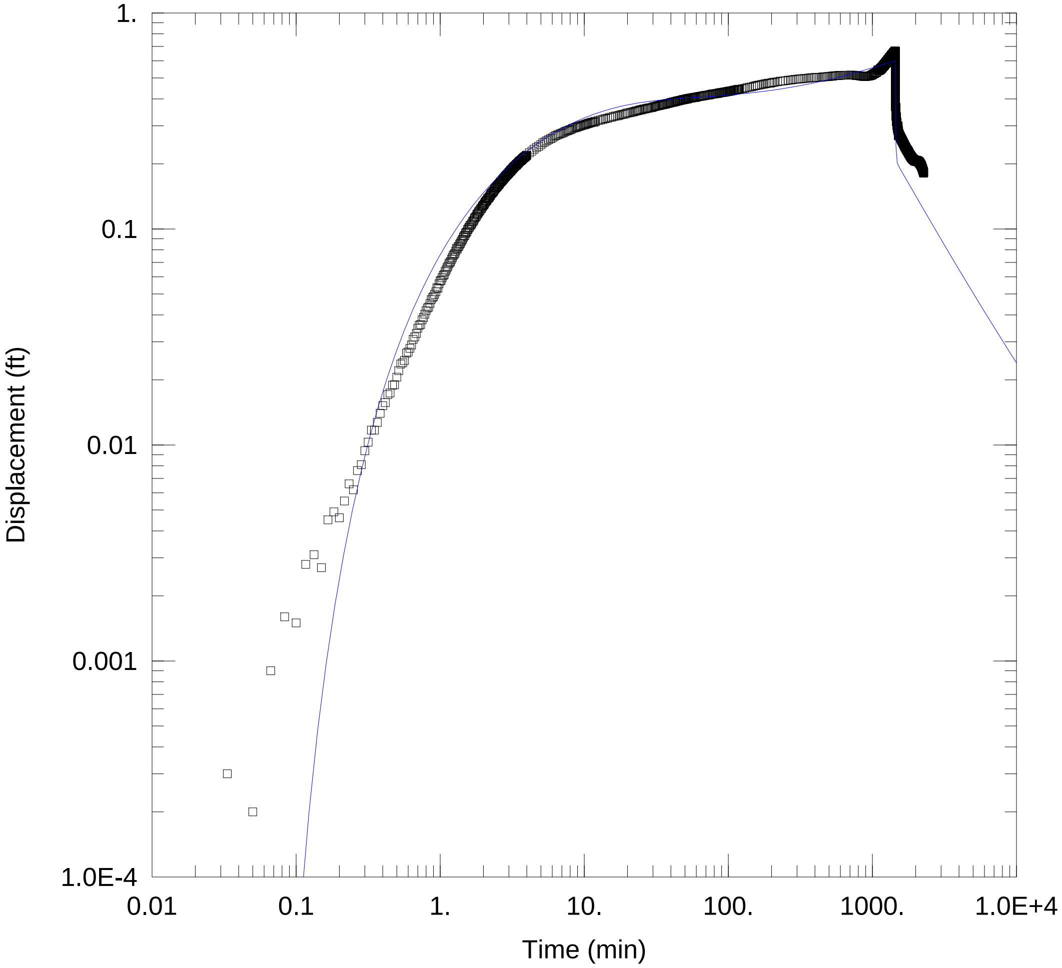
Observation Wells

Well Name	X (ft)	Y (ft)
□ COMW-1	2489676.1	295565.3

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 7155.6 ft^2/day
S = 0.0006809
Kz/Kr = 0.03613
b = 18.34 ft



WELL TEST ANALYSIS

Data Set: C:\...\COMW-1_Neuman.aqt
Date: 07/26/16 Time: 09:23:28

PROJECT INFORMATION

Company: Hydrometrics
Client: Mead Custodial Trust
Project: 9088
Location: Kaiser Mead
Test Well: COTW-1
Test Date: 7-30-2015

AQUIFER DATA

Saturated Thickness: 18.34 ft

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
COTW-1	2489654.49	295574.87

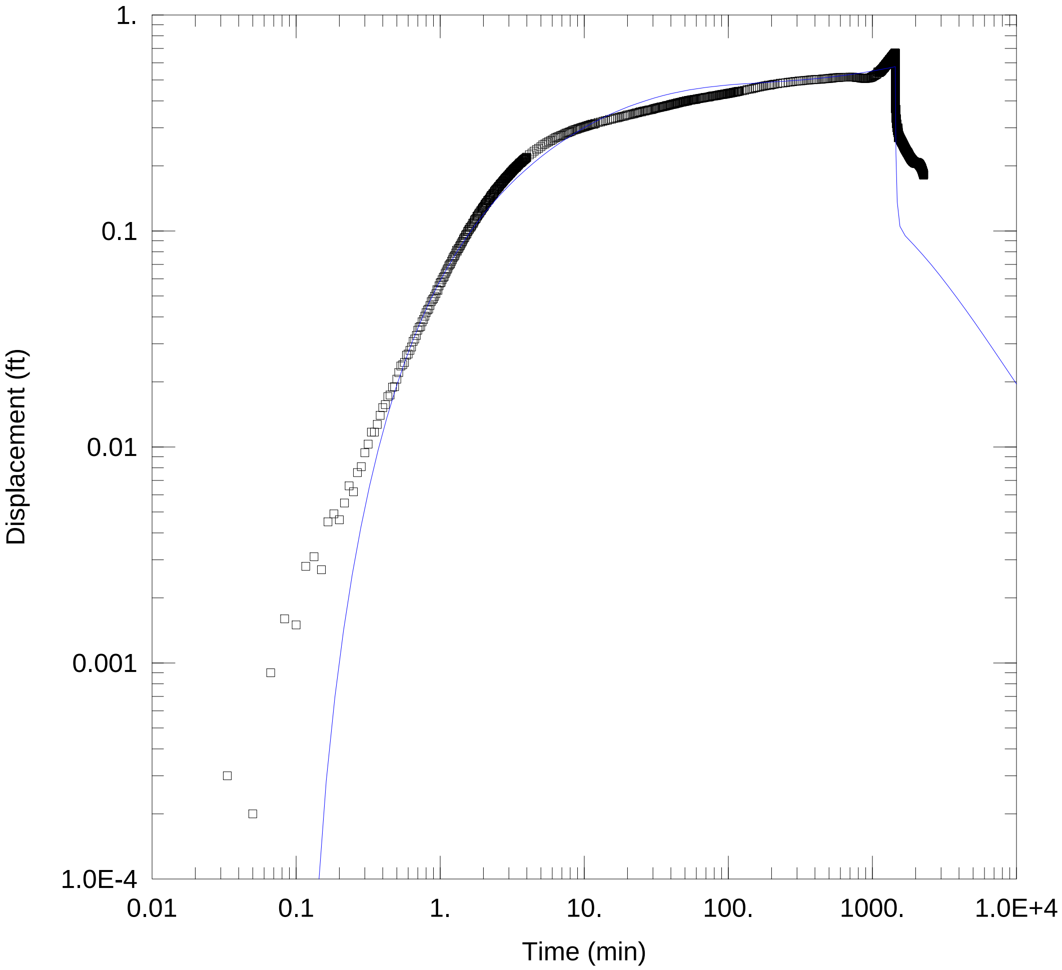
Observation Wells

Well Name	X (ft)	Y (ft)
□ COMW-1	2489676.1	295565.3

SOLUTION

Aquifer Model: Unconfined
Solution Method: Neuman

T = 2428.1 ft^2/day
S = 0.006907
Sy = 0.2524
ß = 0.06



WELL TEST ANALYSIS

Data Set: C:\Users\gdavis\Desktop\Projects\Kaiser Mead\Cutoff Wall\Construction Report\COMW-1_Moench_1997.aqt
Date: 07/26/16 Time: 09:21:16

PROJECT INFORMATION

Company: Hydrometrics
Client: Mead Custodial Trust
Project: 9088
Location: Kaiser Mead
Test Well: COTW-1
Test Date: 7-30-2015

AQUIFER DATA

Saturated Thickness: 18.34 ft
Anisotropy Ratio (Kz/Kr): 0.01196

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
COTW-1	2489654.49	295574.87

Observation Wells

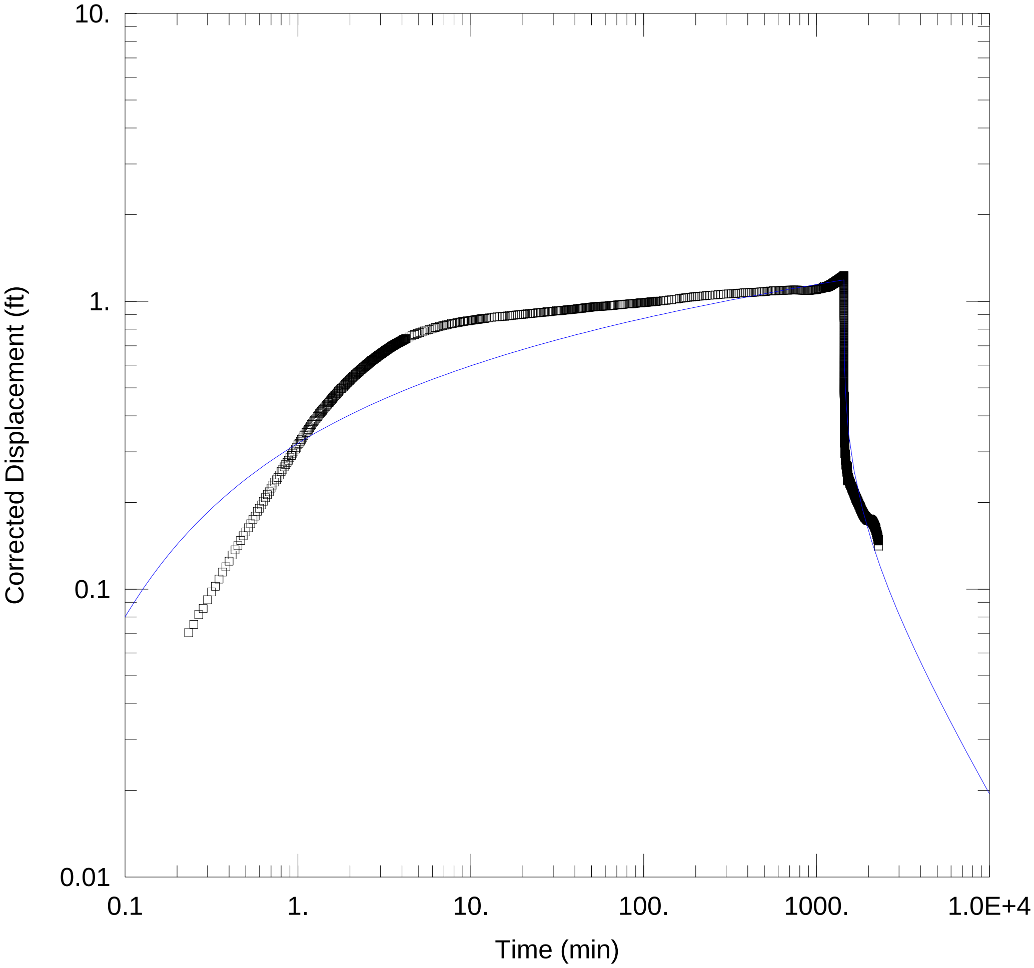
Well Name	X (ft)	Y (ft)
□ COMW-1	2489676.1	295565.3

SOLUTION

Aquifer Model: Unconfined
Solution Method: Moench

T = 2881.3 ft^2/day
Sy = 0.2206
Sw = 1.425
r(c) = 0.177 ft

S = 0.008548
ß = 0.01987
r(w) = 0.3615 ft
alpha = 1.585 min^{-1}



WELL TEST ANALYSIS

Data Set: C:\...\COMW-2_Theis_RecFit.aqt
Date: 07/26/16 Time: 09:26:19

PROJECT INFORMATION

Company: Hydrometrics
Client: Mead Custodial Trust
Project: 9088
Location: Kaiser Mead
Test Well: COTW-1
Test Date: 7-30-2015

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
COTW-1	2489654.49	295574.87

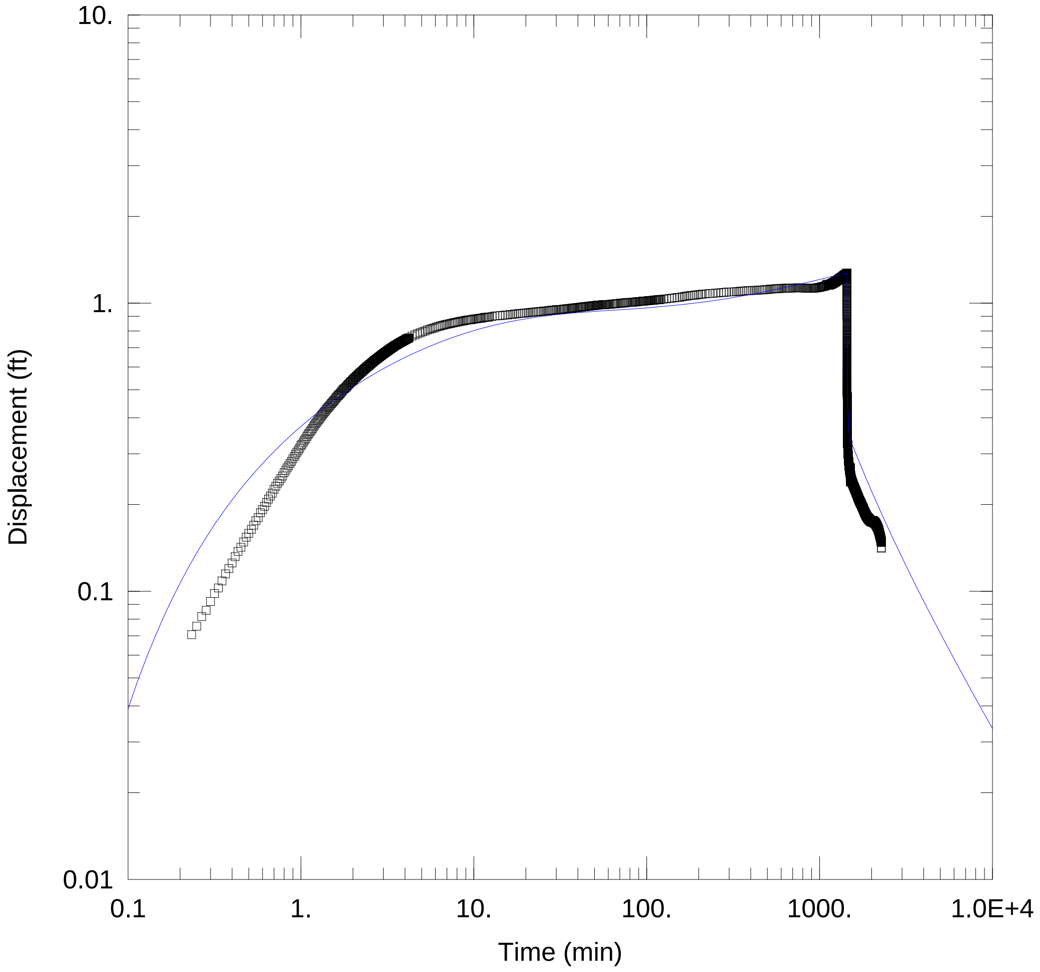
Observation Wells

Well Name	X (ft)	Y (ft)
□ COMW-2	2489657.58	295569.15

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 3065.5 ft^2/day
S = 0.00884
Kz/Kr = 0.07958
b = 18.34 ft



WELL TEST ANALYSIS

Data Set: C:\...\COMW-2_Neuman.aqt
Date: 07/26/16 Time: 09:27:04

PROJECT INFORMATION

Company: Hydrometrics
Client: Mead Custodial Trust
Project: 9088
Location: Kaiser Mead
Test Well: COTW-1
Test Date: 7-30-2015

AQUIFER DATA

Saturated Thickness: 18.34 ft

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
COTW-1	2489654.49	295574.87

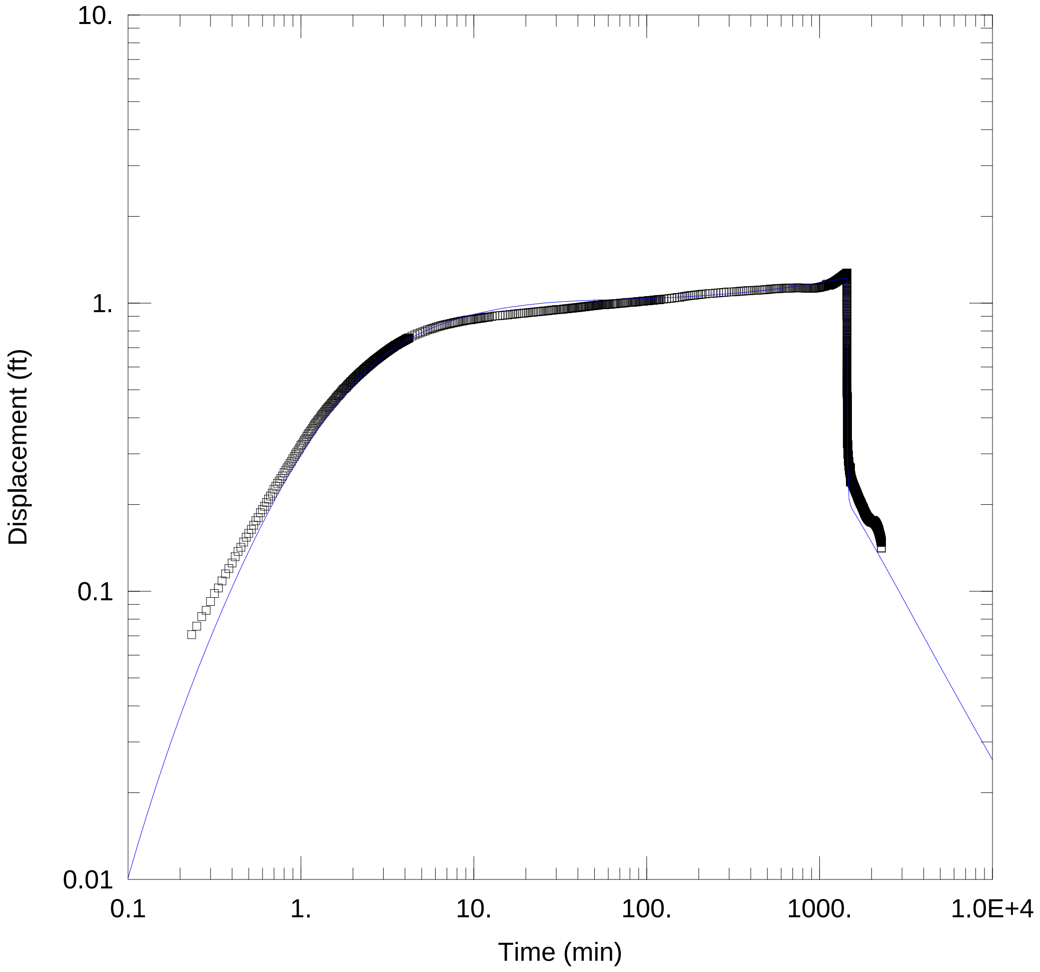
Observation Wells

Well Name	X (ft)	Y (ft)
□ COMW-2	2489657.58	295569.15

SOLUTION

Aquifer Model: Unconfined
Solution Method: Neuman

T = 1761. ft^2/day
S = 0.01302
Sy = 0.2862
ß = 0.01



WELL TEST ANALYSIS

Data Set: C:\Users\gdavis\Desktop\Projects\Kaiser Mead\Cutoff Wall\Construction Report\COMW-2_Moench_1997.aqt
Date: 07/26/16 Time: 09:38:29

PROJECT INFORMATION

Company: Hydrometrics
Client: Mead Custodial Trust
Project: 9088
Location: Kaiser Mead
Test Well: COTW-1
Test Date: 7-30-2015

AQUIFER DATA

Saturated Thickness: 18.34 ft
Anisotropy Ratio (Kz/Kr): 0.01625

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
COTW-1	2489654.49	295574.87

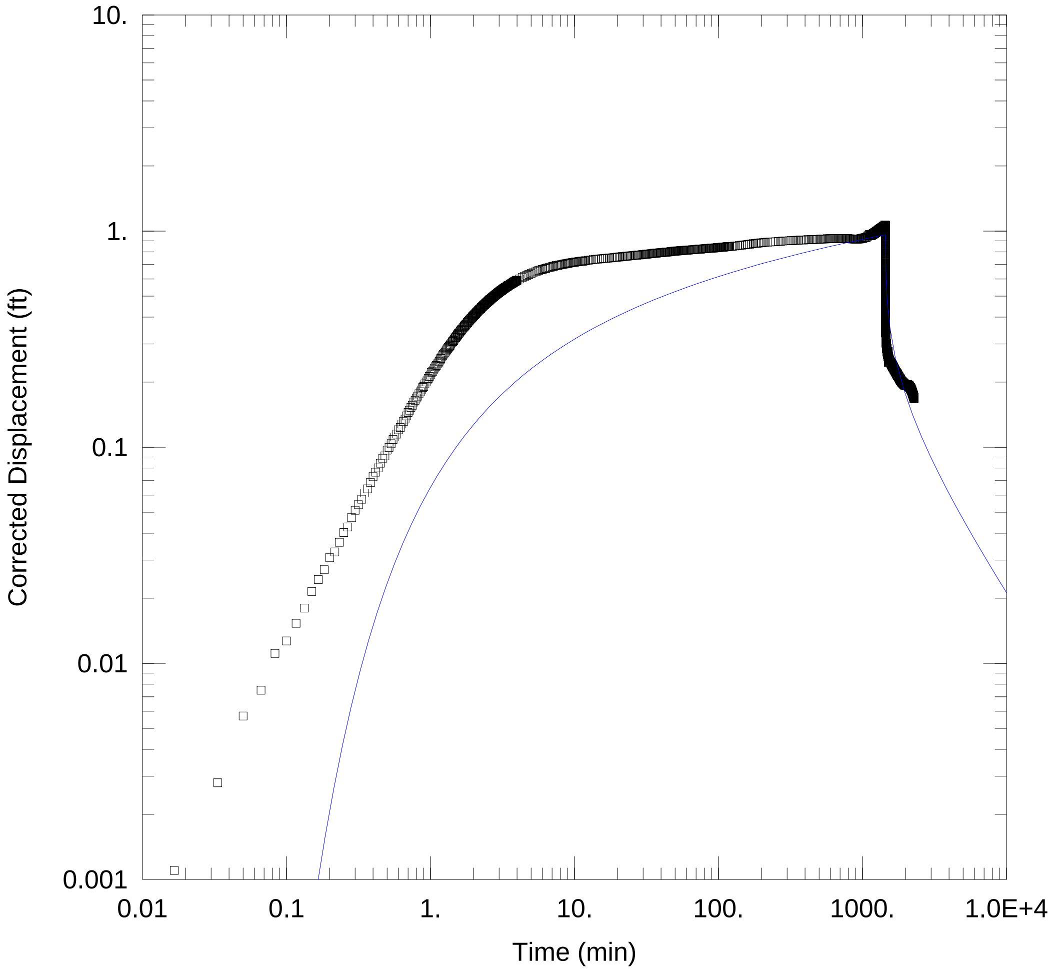
Observation Wells

Well Name	X (ft)	Y (ft)
□ COMW-2	2489657.58	295569.15

SOLUTION

Aquifer Model: Unconfined
Solution Method: Moench

T = 2242.8 ft^2/day
Sy = 0.1092
Sw = 3.975
r(c) = 0.3531 ft
S = 0.00281
ß = 0.002042
r(w) = 0.208 ft
alpha = 0.01 min^{-1}



WELL TEST ANALYSIS

Data Set: C:\Users\gdavis\Desktop\Projects\Kaiser Mead\Cutoff Wall\Construction Report\COMW-3_Theis_RecFit.aqt
Date: 07/26/16 Time: 09:39:31

PROJECT INFORMATION

Company: Hydrometrics
Client: Mead Custodial Trust
Project: 9088
Location: Kaiser Mead
Test Well: COTW-1
Test Date: 7-30-2015

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
COTW-1	2489654.49	295574.87

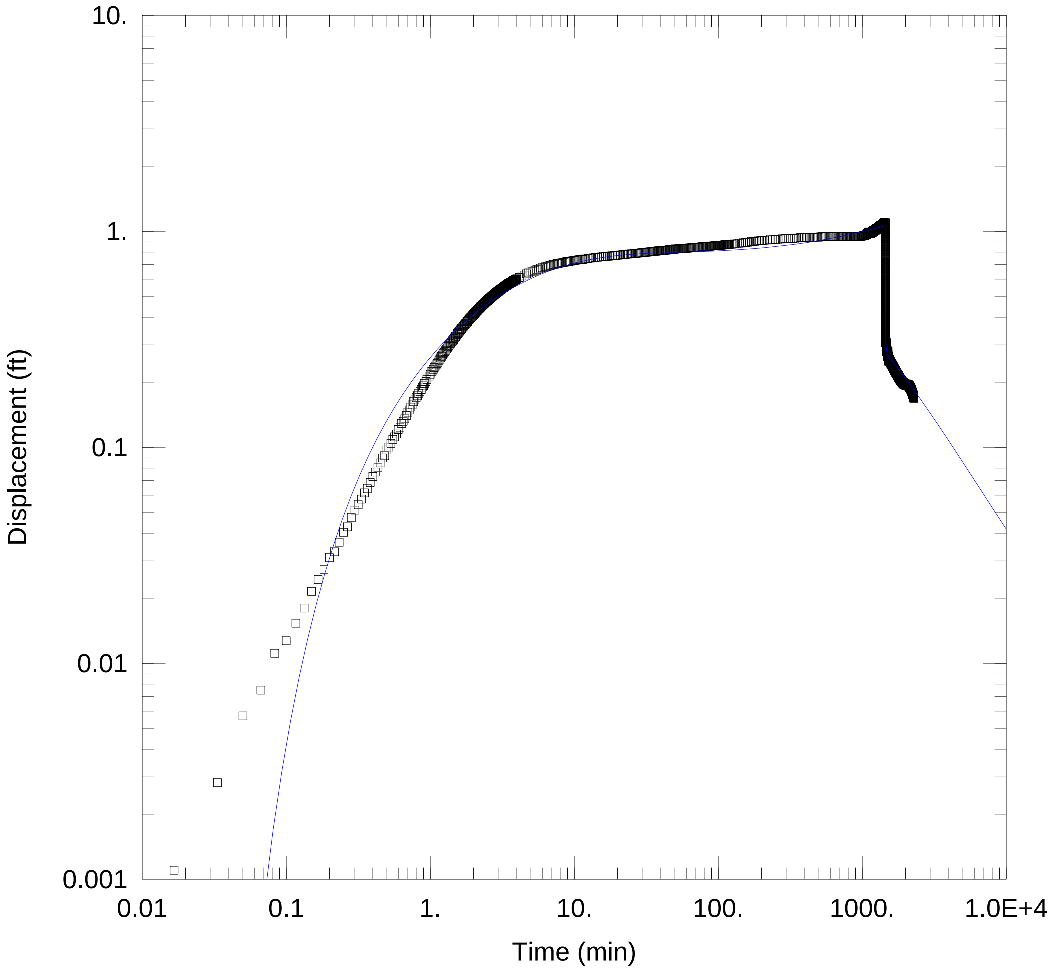
Observation Wells

Well Name	X (ft)	Y (ft)
□ COMW-3	2489635.99	295579.22

SOLUTION

Aquifer Model: Unconfined
Solution Method: Theis

T = 2805.9 ft^2/day
S = 0.01241
Kz/Kr = 0.01242
b = 18.34 ft



WELL TEST ANALYSIS

Data Set: C:\Users\gdavis\Desktop\Projects\Kaiser Mead\Cutoff Wall\Construction Report\COMW-3_Neuman.aqt
Date: 07/26/16 Time: 09:40:21

PROJECT INFORMATION

Company: Hydrometrics
Client: Mead Custodial Trust
Project: 9088
Location: Kaiser Mead
Test Well: COTW-1
Test Date: 7-30-2015

AQUIFER DATA

Saturated Thickness: 18.34 ft

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
COTW-1	2489654.49	295574.87

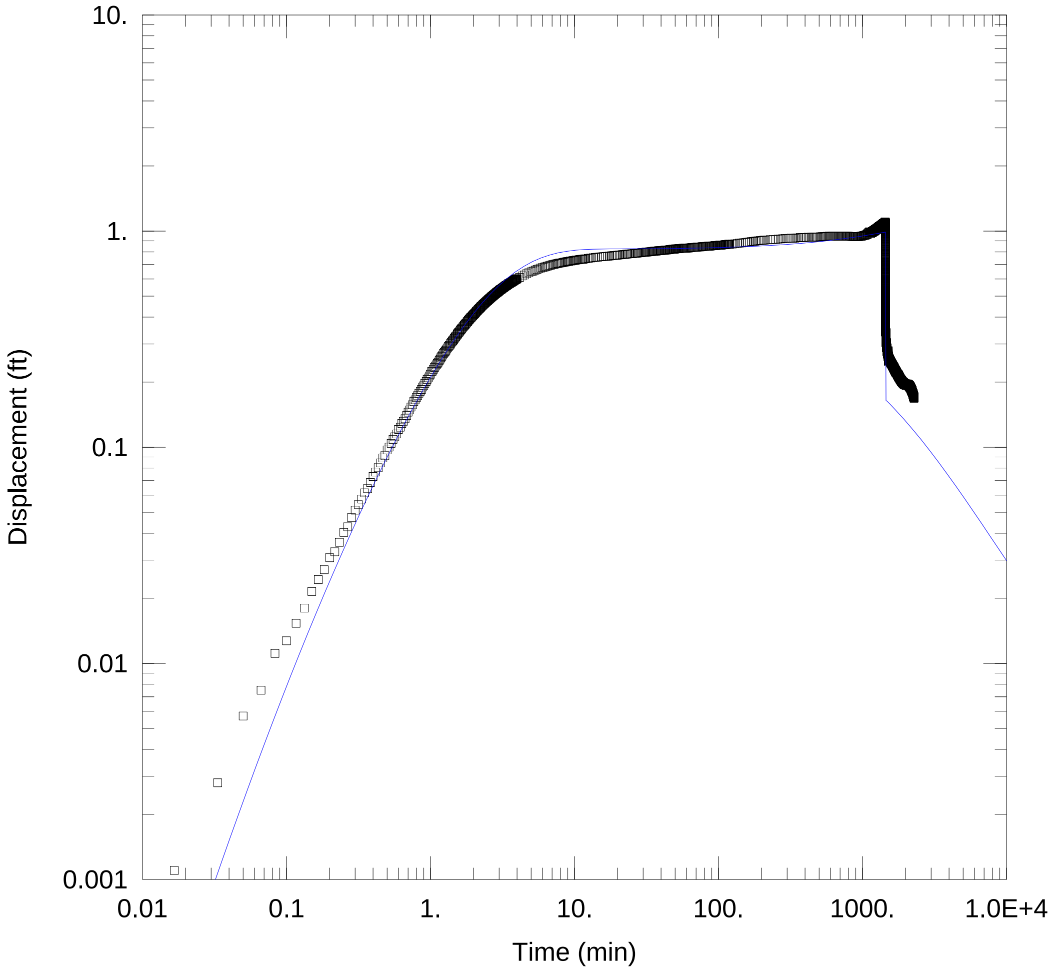
Observation Wells

Well Name	X (ft)	Y (ft)
□ COMW-3	2489635.99	295579.22

SOLUTION

Aquifer Model: Unconfined
Solution Method: Neuman

T = 1375.9 ft^2/day
S = 0.003044
Sy = 0.2538
ß = 0.04317



WELL TEST ANALYSIS

Data Set: C:\Users\gdavis\Desktop\Projects\Kaiser Mead\Cutoff Wall\Construction Report\COMW-3_Moench_1997.aqt
Date: 07/26/16
Time: 09:41:19

PROJECT INFORMATION

Company: Hydrometrics
Client: Mead Custodial Trust
Project: 9088
Location: Kaiser Mead
Test Well: COTW-1
Test Date: 7-30-2015

AQUIFER DATA

Saturated Thickness: 18.34 ft
Anisotropy Ratio (Kz/Kr): 0.01242

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
COTW-1	2489654.49	295574.87

Observation Wells

Well Name	X (ft)	Y (ft)
□ COMW-3	2489635.99	295579.22

SOLUTION

Aquifer Model: Unconfined
Solution Method: Moench

T = 1884.7 ft^2/day
Sy = 0.135
Sw = -4.175
r(c) = 0.25 ft
S = 0.0002692
ß = 0.01334
r(w) = 0.2559 ft
alpha = 1584.9 min^{-1}

APPENDIX B

HBI FINAL CONSTRUCTION REPORT

Attachment A – Daily Site Report Packages

HAYWARD BAKER, INC.
11180 E. Marginal Way S
Tukwila, WA 98168
206-223-1732

DAILY SITE REPORT

SHEET NO.	1	OF	2
SHIFT	DAY	**ONE CALL #**	
START:	7:00 AM	**END:**	7:00 PM
DATE:	Tuesday, September 01, 2015		

JOB NO:	860080	**LOCATION:**	Mead, WA	**TYPE OF WORK:**	Jet Grouting
PROJECT NAME:	Kaiser Mead NPL			**WEATHER:**	
CLIENT:	Hydrometrics			**PROJECT MGR.**	Adam Gerondale

SITE ACTIVITY

7:00 - 12:00 Oriented KB6 nozzles, spoil containment setup
12:00 - 16:40 Jet grouted panels HBI-10A & HBI-10B
16:40 - 19:00 Cleaned up spoil returns

Panels Installed Today	2
Tot. Panels Yesterday	0
# of Panels To Date	2
% Complete	8%

MATERIAL DELIVERED

CEMENT DELIVERED (TONS): TRUCKS
FUEL DELIVERED (GALLONS):

EQUIPMENT USED, MOVED, STANDBY

12k reach forklift, mini-ex, skid steer, Hutte Drill, 825 Hurricane, Agi tank, KB-6, D-station, 3x2 mission pump, 4x3 mission pump, 350 BBL silo
Moyno Pump, 25K genset, 185 compressor, 300k genset, 6500 gallon poly tank, 900cfm compressor, switchbox

CHANGE ORDERS, BACK CHARGES, AND EXTRA WORK

VERBAL DISCUSSIONS,DIRECTIVES OR INSTRUCTIONS

VISITORS ON-SITE

Adam Gerondale, Tony Chavez, Ecology

QA/QC

Activity	Quantity	Panel ID	Comments
Jet Grout	2	HBI-10A, HBI-10B	Deviation @ Bottom of Panel = 1.18%; Air communication with testing wells
Spoils Sampling	5	HBI-10B, SG: 1.81 @ 13:30	
Other			

LABOR FORCE

QTY	TYPE
8	OPERATORS
0	LABORERS
1	MECHANICS
3	OTHER (SUPT,FIELD ENGINEER)

LENGTH OF SHIFT
10 HRS

NOTES:

MANPOWER

Position	NAME	Regular Hours	OT Hours
Superintendent	Frank Kalata	10	
Field Engineer	Taylor Cox	10	
Field Engineer	Dylan Fisher	10	
Mechanic	Kevin Clark	8	4
Driller	Mark Fellows	8	4
Pump Operator	Paul Thomas	8	4
Batch Plant Operator	Auggie Ruesga	8	4
Driller	Jody Welch	8	4
Operator	Shaun Henderson	8	4
Operator	Alan Krouse	8	4
Operator	Linda Currie	8	4
Operator	Ronda Jacobs	8	4

Man Hours

Company Name	Hrs. Today	OT Hrs. Today	Yesterday		Safe Hrs To Date:	
Hayward Baker:	102	36	102		82	
Total Manhours :	678	174				

Owner / Contractor

HAYWARD BAKER INC.

HAYWARD BAKER, INC.

11180 E. Marginal Way S
Tukwila, WA 98168
206-223-1732

DAILY SITE REPORT

SHEET NO.	2	OF	2
SHIFT	DAY	**ONE CALL #**	0
START:	7:00 AM	**END:**	7:00 PM
DATE:	Tuesday, September 01, 2015		

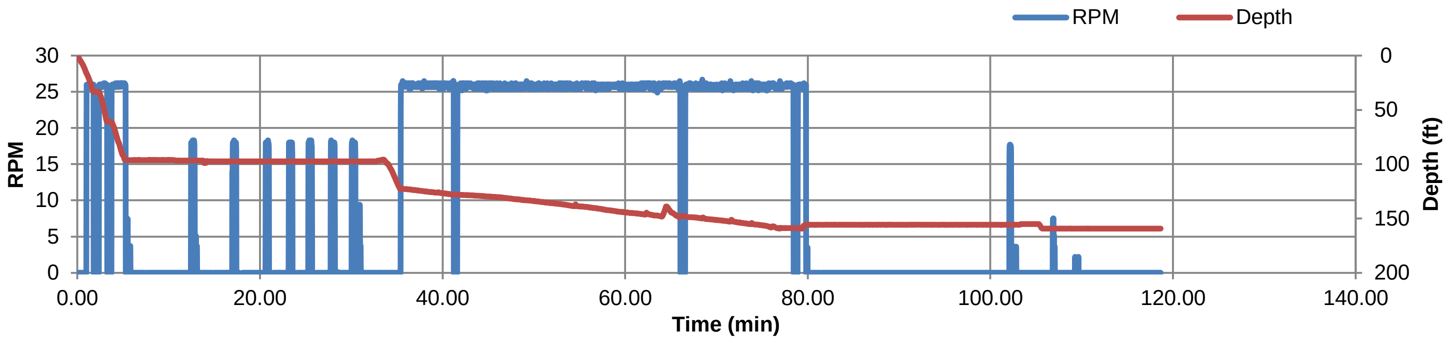
JOB NO:	860080	**LOCATION:**	Mead, WA	**TYPE OF WORK:**	Jet Grouting
PROJECT NAME:	Kaiser Mead NPL			**WEATHER:**	Sunny and hot
CLIENT:	Hydrometrics			**PROJECT MGR.**	Adam Gerondale

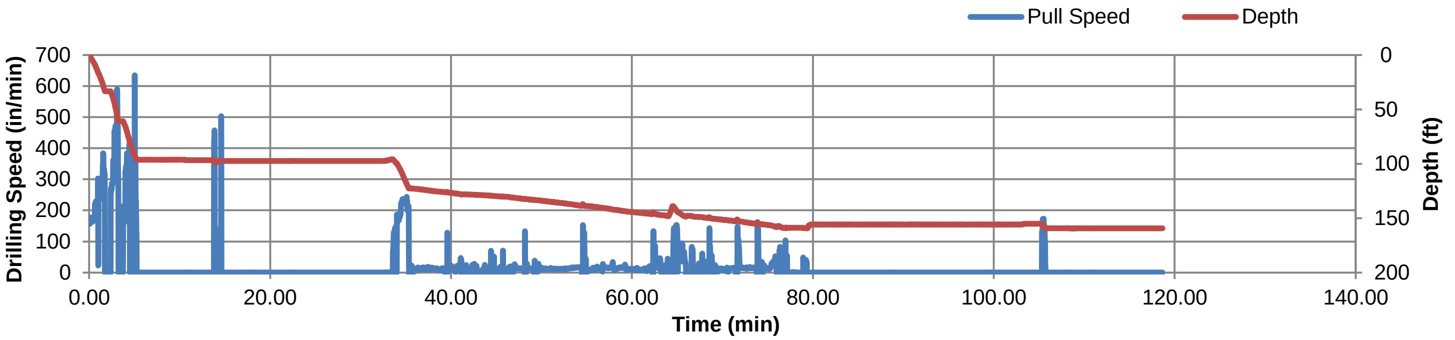
N/A

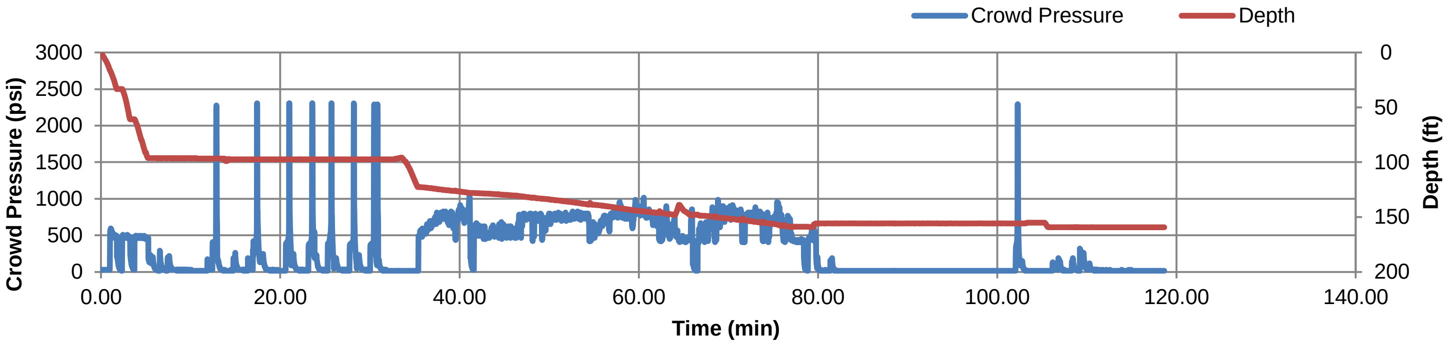
HAYWARD BAKER
Geotechnical Construction
KELLER

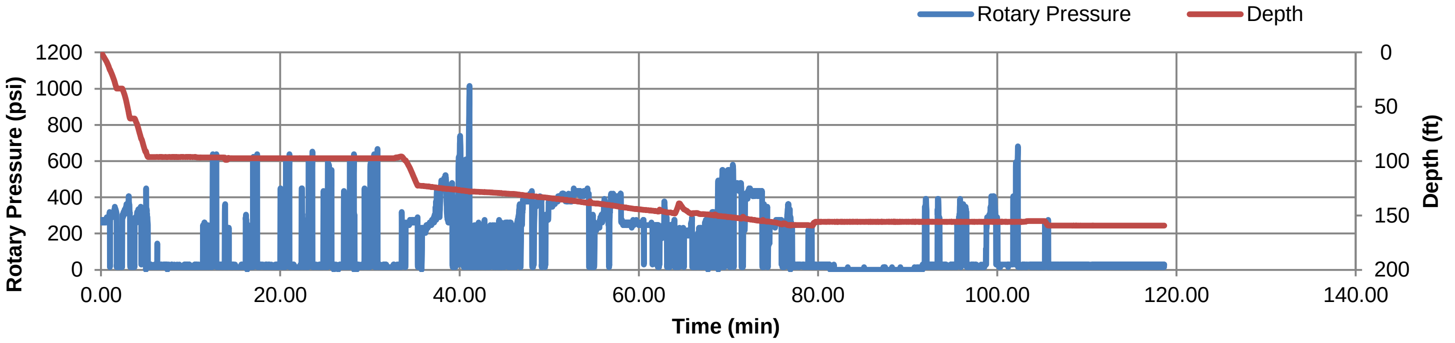
Jet Grout Drilling Report
Kaiser Mead NPL

Column Number:	HBI-10	**Date:**	9/1/2015
Job Number:	860080	**Start Time:**	11:46 AM
Job Location:	Spokane, WA	**End Time:**	2:44 PM
Drilled Depth:	159.35 ft	**Duration:**	02:58:20
Inclination (X, Y):	(16.027 in, -13.539 in)		









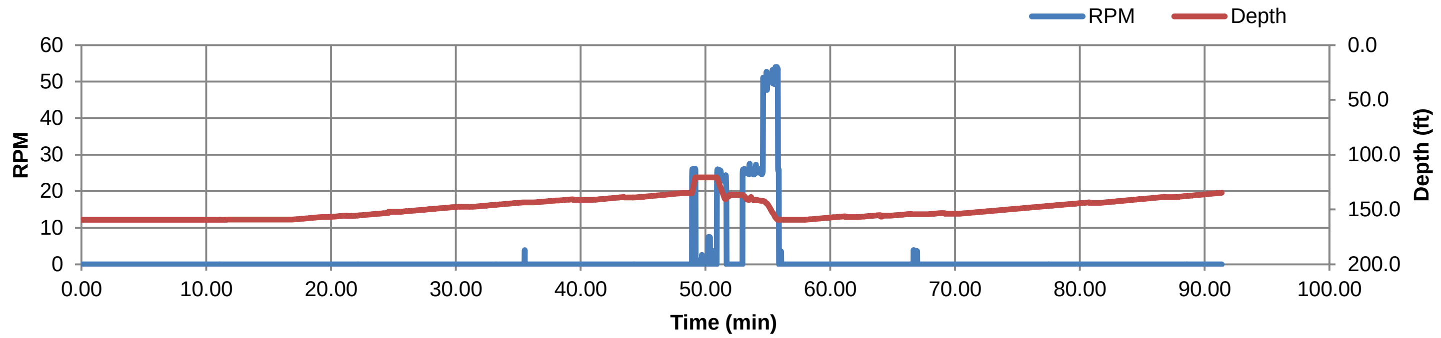
THINK SAFE

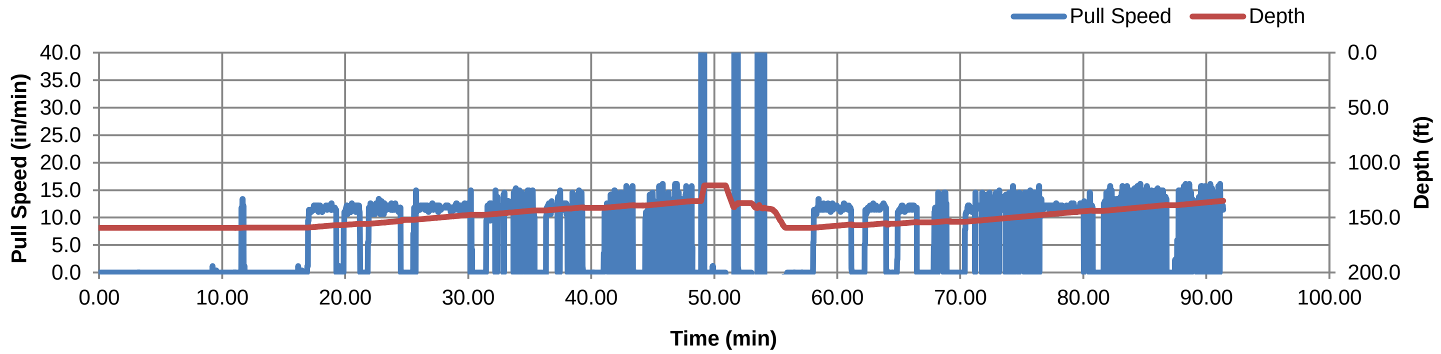
HAYWARD
BAKER
Geotechnical Construction
KELLER

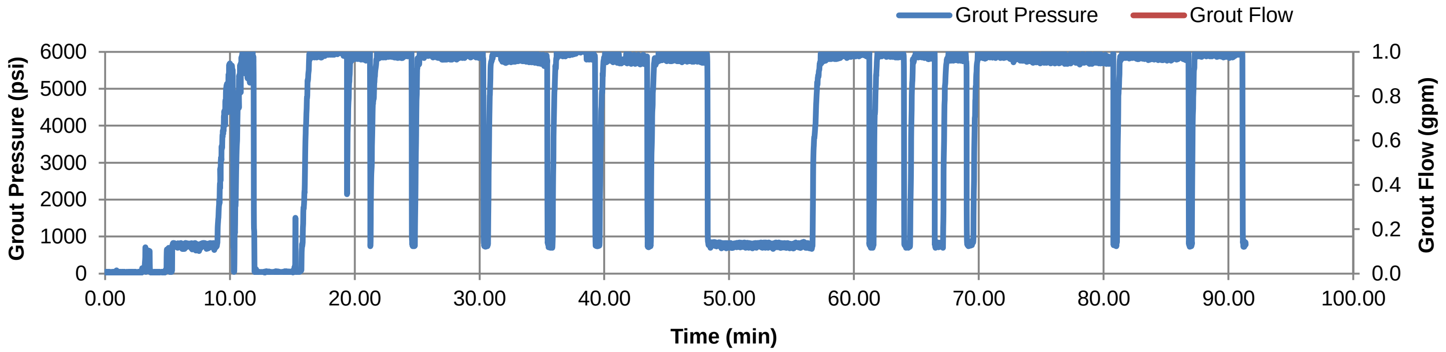
Jet Grouting Report
Kaiser Mead NPL

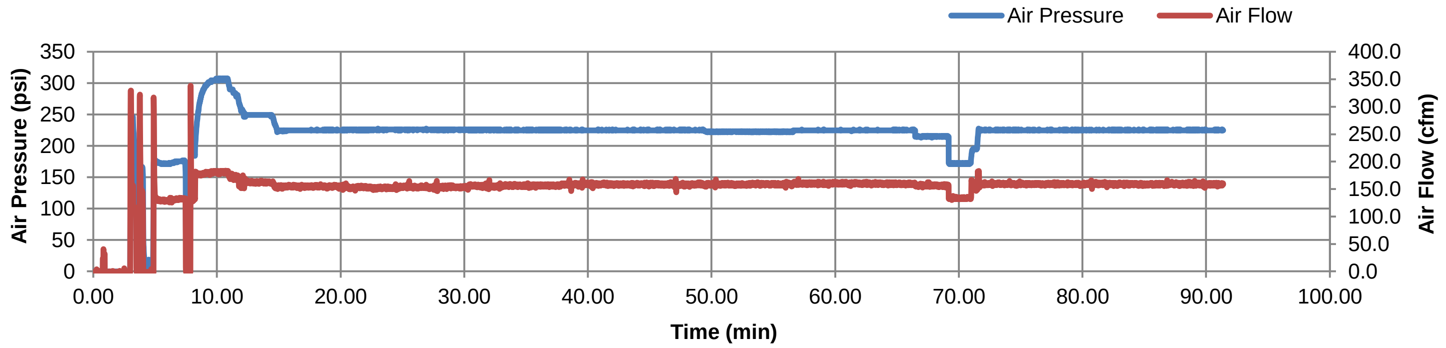
Column Number: HBI-10B,A
Job Number: 860080
Job Location: Spokane, WA
Total Grout Volume: 5235 gal, 4763 gal
Treatment Length: HBI-10B: 24.38 ft, HBI-10A: 24.61 ft

Date: 9/1/2015
Start Time: 2:44 PM
End Time: 4:39 PM
Duration: 01:55:00
Avg. S.G.: 1.52









THINK SAFE

HAYWARD BAKER, INC.
11180 E. Marginal Way S
Tukwila, WA 98168
206-223-1732

DAILY SITE REPORT

SHEET NO.	1	OF	2
SHIFT	DAY	**ONE CALL #**	
START:	7:00 AM	**END:**	7:30 PM
DATE:	Wednesday, September 02, 2015		

JOB NO:	860080	**LOCATION:**	Mead, WA	**TYPE OF WORK:**	Jet Grouting
PROJECT NAME:	Kaiser Mead NPL			**WEATHER:**	
CLIENT:	Hydrometrics			**PROJECT MGR.**	Adam Gerondale

SITE ACTIVITY

7:00 - 19:30 Jet grouted HBI-12B and HBI-12A, drilled casing on HBI-6

Panels Installed Today	2
Tot. Panels Yesterday	2
# of Panels To Date	4
% Complete	17%

MATERIAL DELIVERED

CEMENT DELIVERED (TONS):	34.35	TRUCKS	238066301
FUEL DELIVERED (GALLONS):	364	TRUCKS	No. 41

EQUIPMENT USED, MOVED, STANDBY

12k reach forklift, mini-ex, skid steer, Hutte Drill, 825 Hurricane, Agi tank, KB-6, D-station, 3x2 mission pump, 4x3 mission pump, 350 BBL silo
Moyno Pump, 25K genset, 185 compressor, 300k genset, 6500 gallon poly tank, 900cfm compressor, switchbox

CHANGE ORDERS, BACK CHARGES, AND EXTRA WORK

VERBAL DISCUSSIONS,DIRECTIVES OR INSTRUCTIONS

VISITORS ON-SITE

Morgan

QA/QC

Activity	Quantity	Panel ID	Comments
Jet Grout	2	HBI-12B, HBI-12A	Deviation @ Bottom of Panel = 0.38%
Spoils Sampling	7	HBI-12B, SG: 1.78 @ 14:20	HBI-12B: 7 samples (2 for Hydrometrics)
Other			

LABOR FORCE

QTY	TYPE
8	OPERATORS
0	LABORERS
1	MECHANICS
3	OTHER (SUPT,FIELD ENGINEER)

LENGTH OF SHIFT

10 HRS

NOTES:

MANPOWER

Position	NAME	Regular Hours	OT Hours
Superintendent	Frank Kalata	10	
Field Engineer	Taylor Cox	10	
Field Engineer	Dylan Fisher	10	
Mechanic	Kevin Clark	8	2
Driller	Mark Fellows	8	2
Pump Operator	Paul Thomas	8	2
Batch Plant Operator	Auggie Ruesga	8	6
Driller	Jody Welch	8	6
Operator	Shaun Henderson	8	6
Operator	Alan Krouse	8	2
Operator	Linda Currie	8	2
Operator	Ronda Jacobs	8	2

Man Hours

Company Name	Hrs. Today	OT Hrs. Today	Yesterday		Safe Hrs To Date:	
Hayward Baker:	102	30	102		94.5	
Total Manhours :	780	204				

Owner / Contractor

HAYWARD BAKER INC.

HAYWARD BAKER, INC.

11180 E. Marginal Way S
Tukwila, WA 98168
206-223-1732

DAILY SITE REPORT

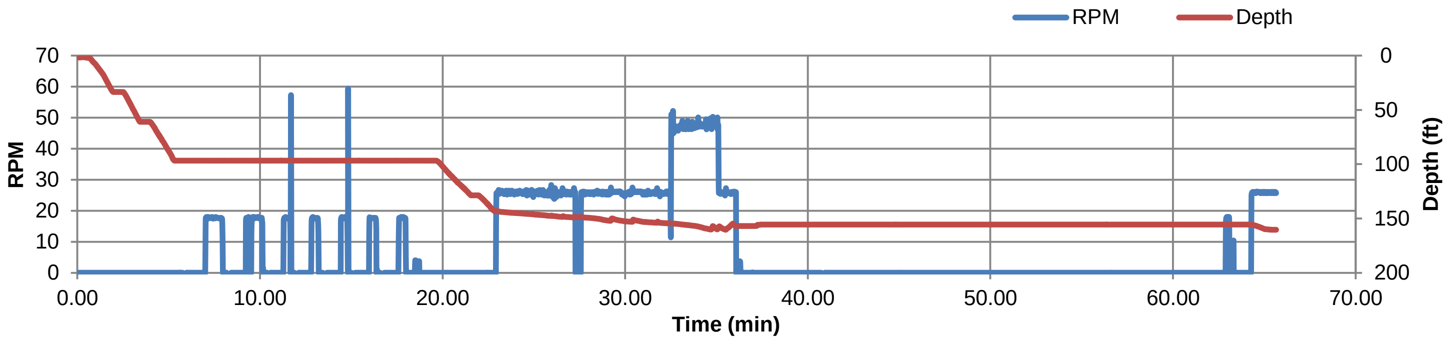
SHEET NO.	2	OF	2
SHIFT	DAY	**ONE CALL #**	0
START:	7:00 AM	**END:**	7:30 PM
DATE:	Wednesday, September 02, 2015		

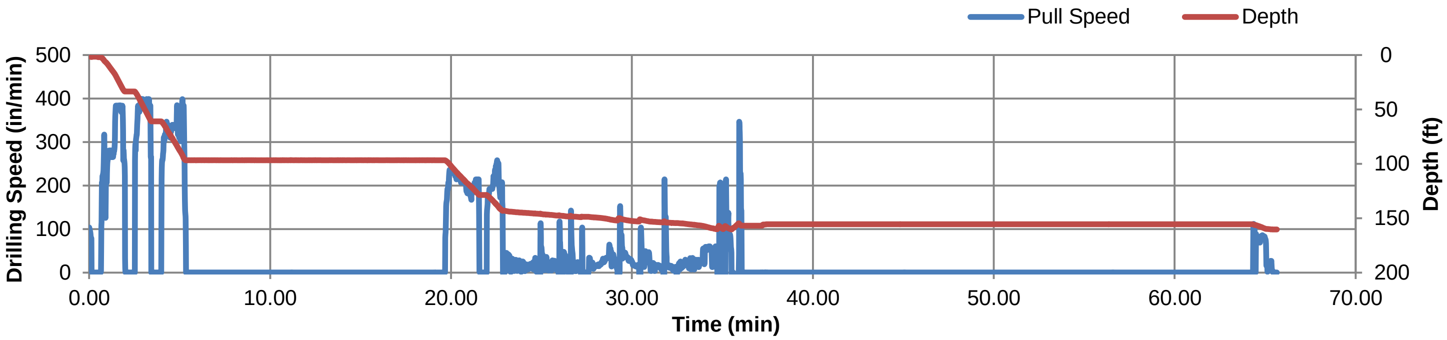
JOB NO:	860080	**LOCATION:**	Mead, WA	**TYPE OF WORK:**	Jet Grouting
PROJECT NAME:	Kaiser Mead NPL			**WEATHER:**	Sunny and hot
CLIENT:	Hydrometrics			**PROJECT MGR.**	Adam Gerondale

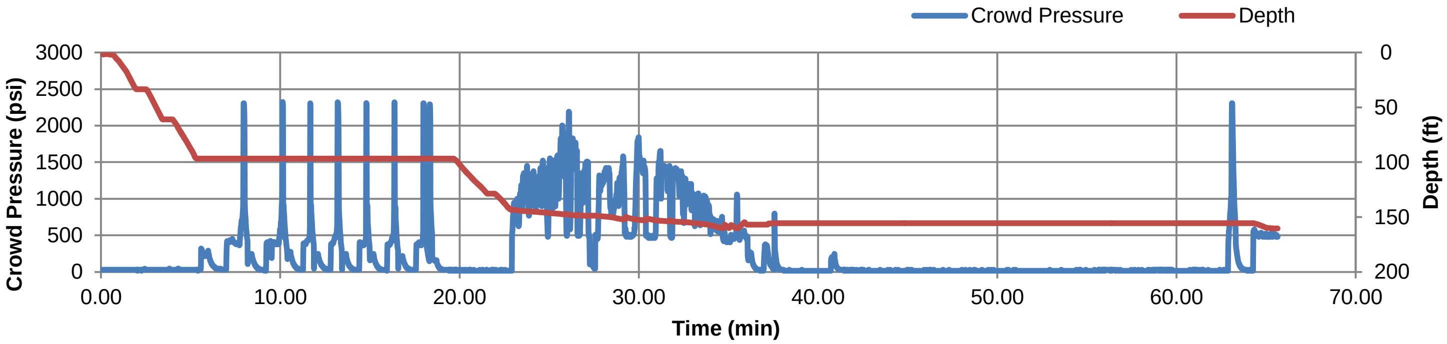
Jet Grout Drilling Report
Kaiser Mead NPL

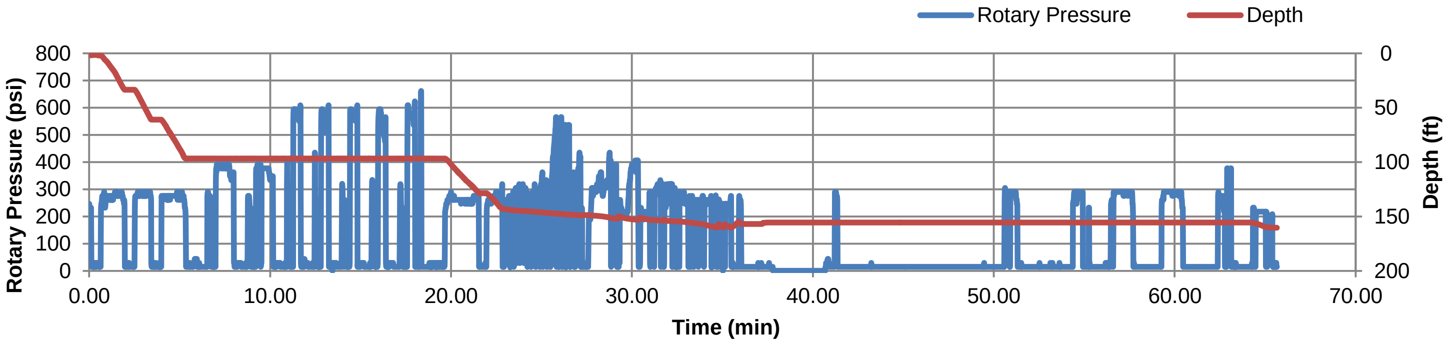
Column Number: HBI-12B
Job Number: 860080
Job Location: Spokane, WA
Drilled Depth: 160.40 ft
Inclination (X, Y): (6.482 in, -1.283 in)

Date: 9/2/2015
Start Time: 11:33 AM
End Time: 1:40 PM
Duration: 02:06:25



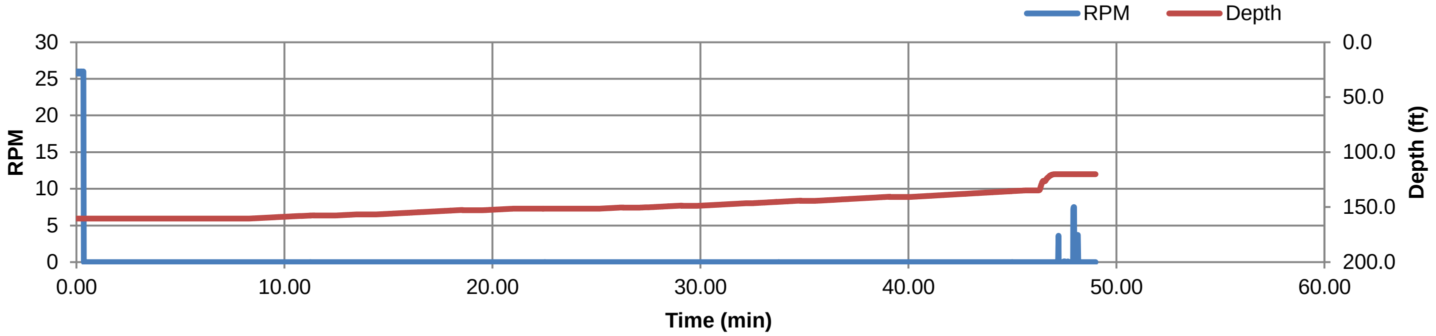


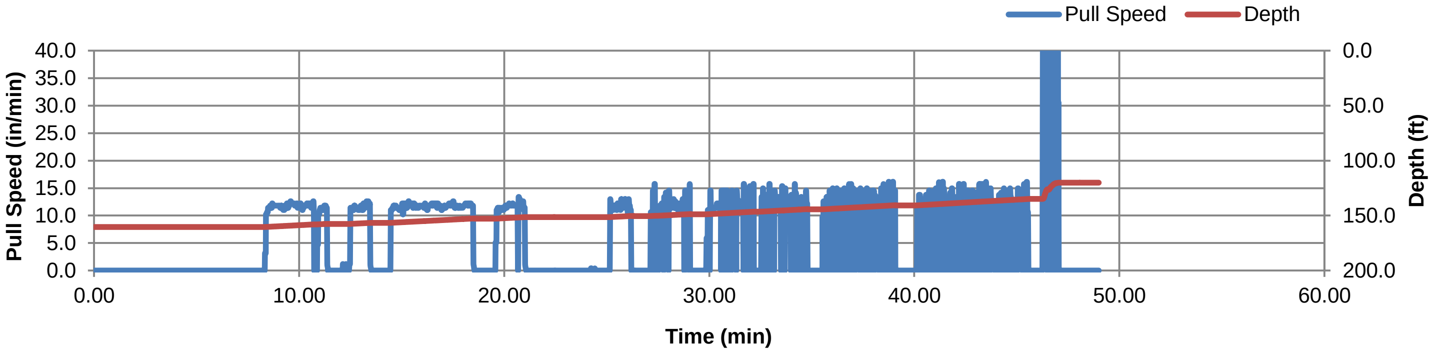


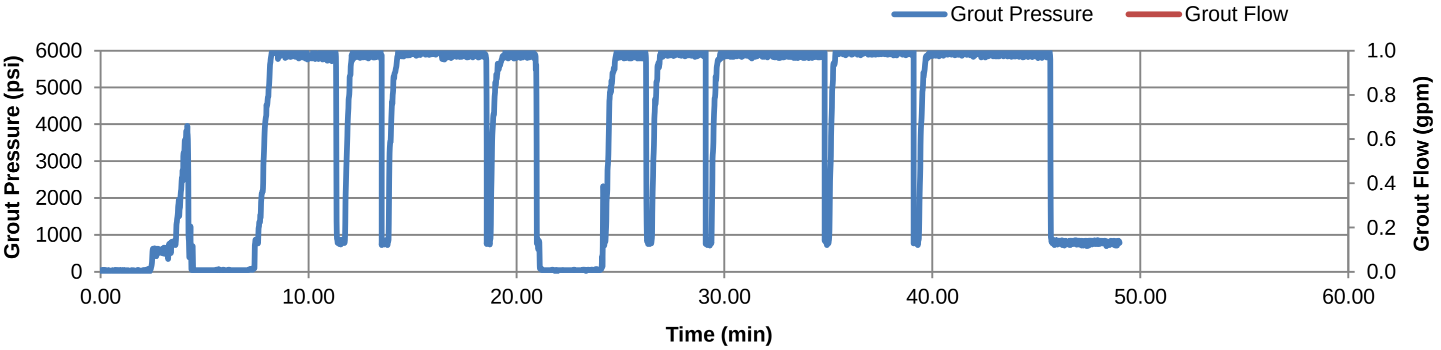


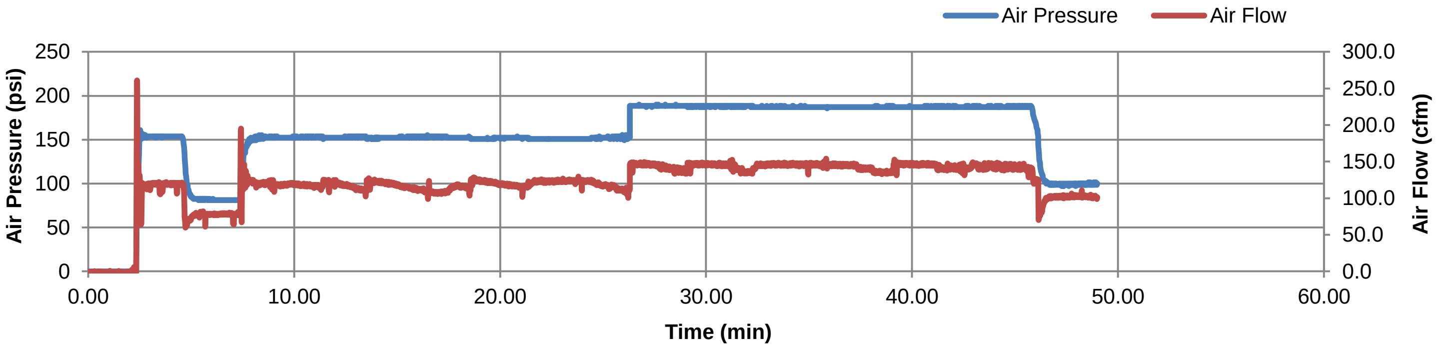
Jet Grouting Report
Kaiser Mead NPL

Column Number:	HBI-12B	**Date:**	9/2/2015
Job Number:	860080	**Start Time:**	1:40 PM
Job Location:	Spokane, WA	**End Time:**	2:49 PM
Total Grout Volume:	3803 gal	**Duration:**	01:09:00
Treatment Length:	25.59 ft	**Avg. S.G.:**	1.52







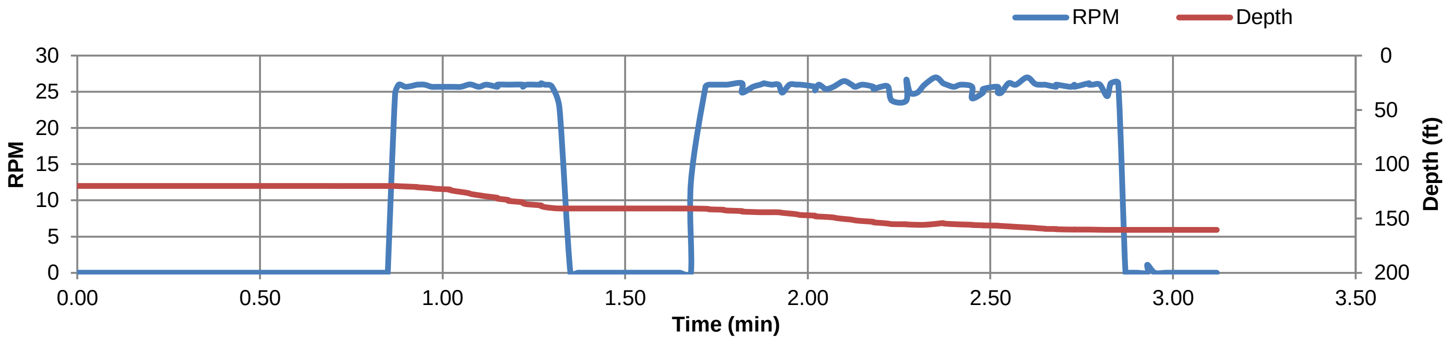


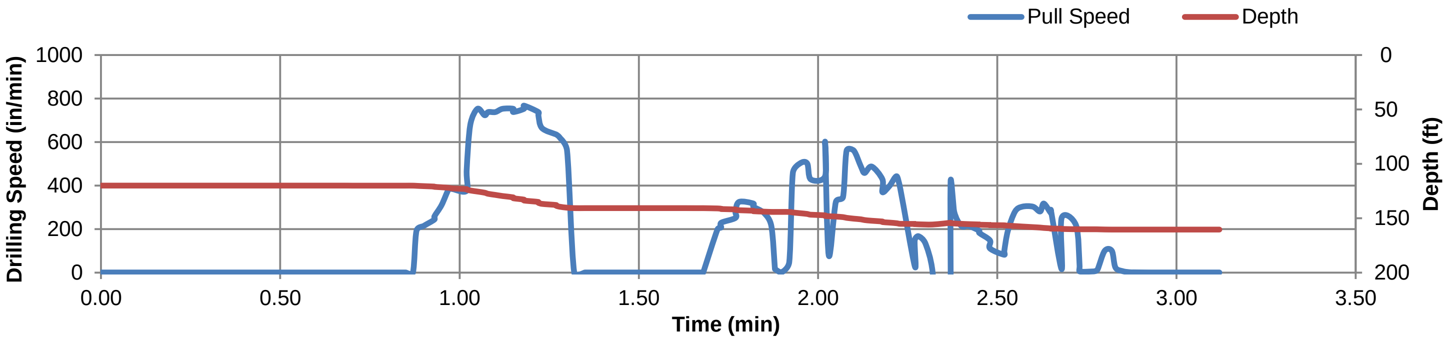
HAYWARD
BAKER
Geotechnical Construction
KELLER

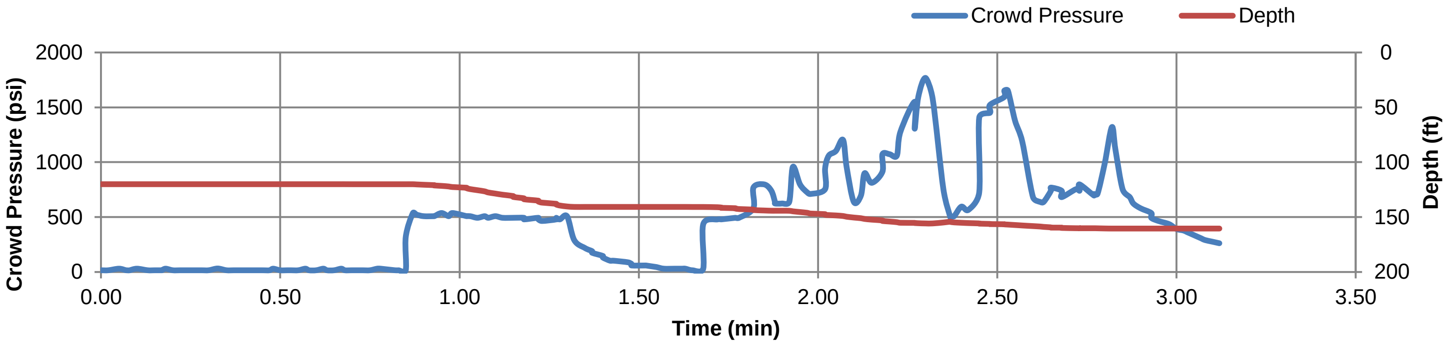
Jet Grout Drilling Report
Kaiser Mead NPL

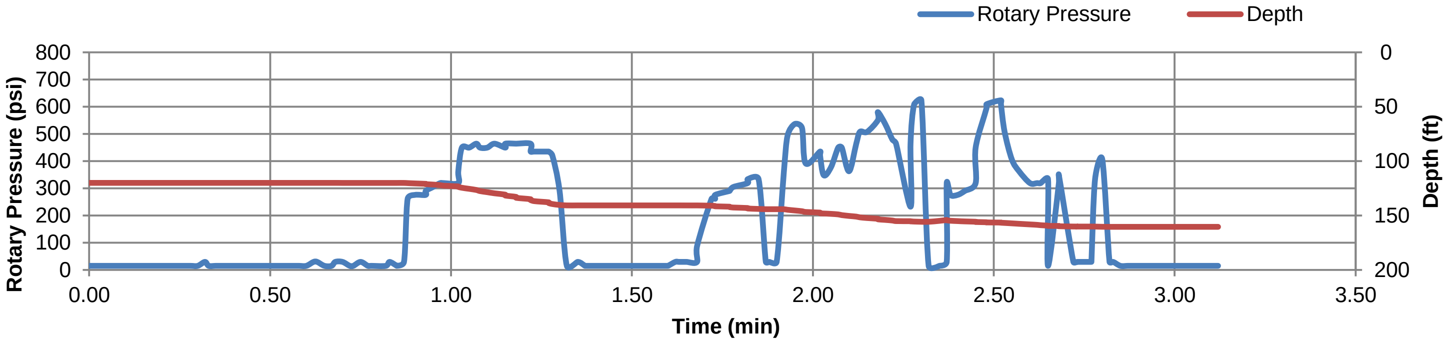
Column Number: HBI-12A
Job Number: 860080
Job Location: Spokane, WA
Drilled Depth: 160.50 ft
Inclination (X, Y): (6.482 in, -1.283 in)

Date: 9/2/2015
Start Time: 2:51 PM
End Time: 2:54 PM
Duration: 00:03:08







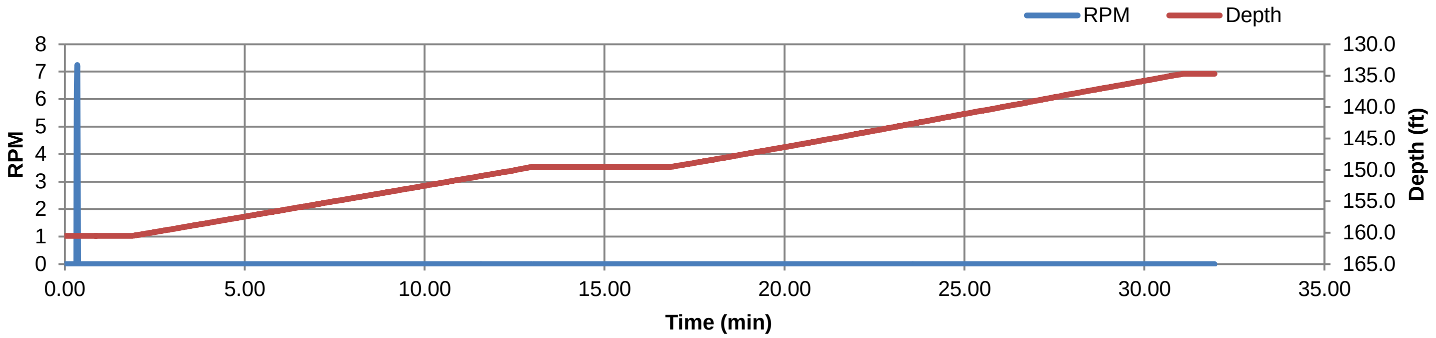


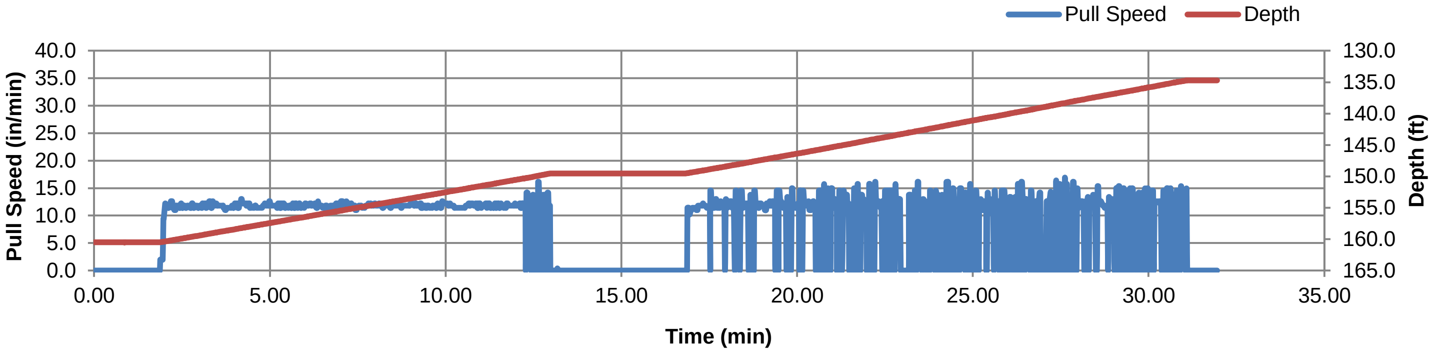
THINK SAFE

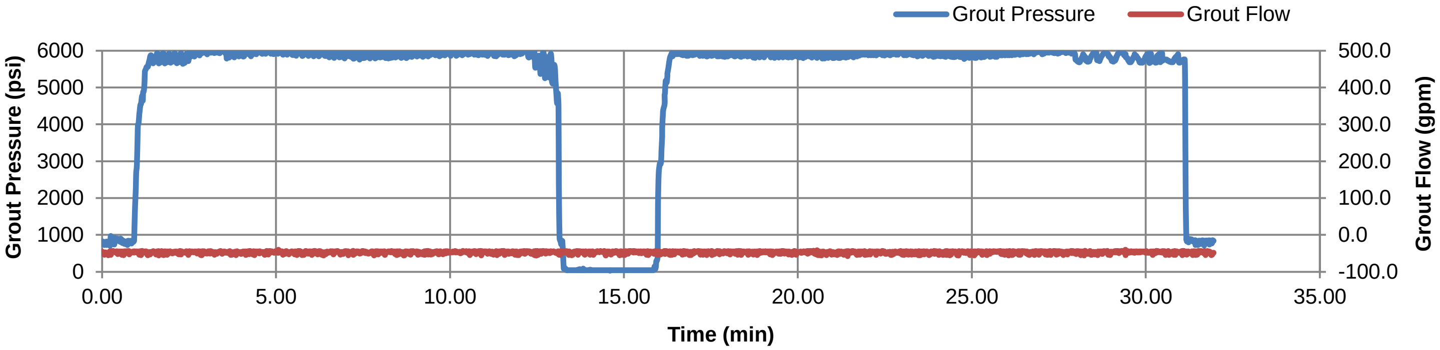
HAYWARD BAKER
Geotechnical Construction
KELLER

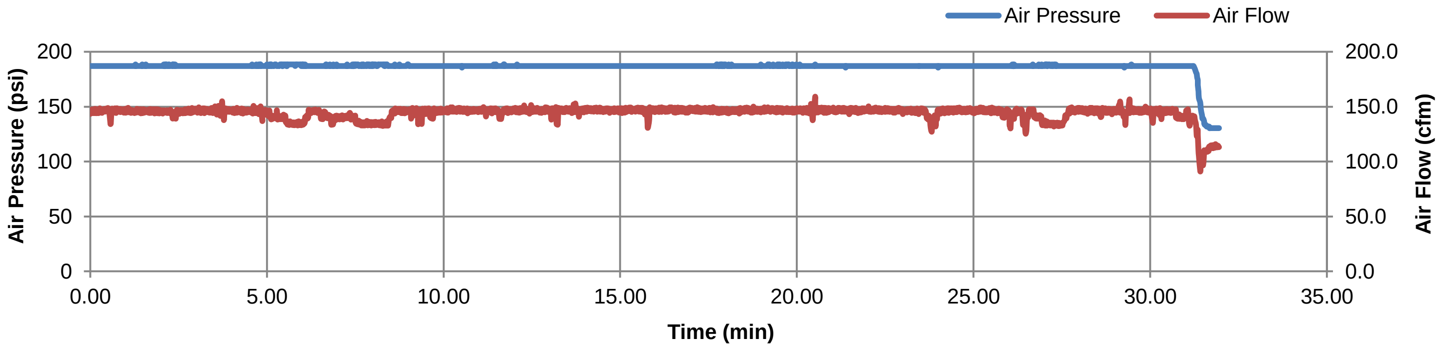
Jet Grouting Report
Kaiser Mead NPL

Column Number:	HBI-12A	**Date:**	9/2/2015
Job Number:	860080	**Start Time:**	2:51 PM
Job Location:	Spokane, WA	**End Time:**	3:26 PM
Total Grout Volume:	3487 gal	**Duration:**	00:35:06
Treatment Length:	25.82 ft	**Avg. S.G.:**	1.52









THINK SAFE

HAYWARD BAKER, INC.

11180 E. Marginal Way S
Tukwila, WA 98168
206-223-1732

DAILY SITE REPORT

SHEET NO.	1	OF	2
SHIFT	DAY	**ONE CALL #**	
START:	7:00 AM	**END:**	6:00 PM
DATE:	Thursday, September 03, 2015		

JOB NO:	860080	**LOCATION:**	Mead, WA	**TYPE OF WORK:**	Jet Grouting
PROJECT NAME:	Kaiser Mead NPL			**WEATHER:**	
CLIENT:	Hydrometrics			**PROJECT MGR.**	Adam Gerondale

SITE ACTIVITY

7:00 - 9:00 Setup
9:00 - 12:00 Drilled and Jet grouted HBI-6B and HBI-6A
12:00 - 18:00 Pre-drill casing on HBI-1

Panels Installed Today	2
Tot. Panels Yesterday	2
# of Panels To Date	6
% Complete	25%

MATERIAL DELIVERED

CEMENT DELIVERED (TONS):	69.62	TRUCKS	238066314, 238066330
FUEL DELIVERED (GALLONS):	331	TRUCKS	No. 41

EQUIPMENT USED, MOVED, STANDBY

12k reach forklift, mini-ex, skid steer, Hutte Drill, 825 Hurricane, Agi tank, KB-6, D-station, 3x2 mission pump, 4x3 mission pump, 350 BBL silo
Moyno Pump, 25K genset, 185 compressor, 300k genset, 6500 gallon poly tank, 900cfm compressor, switchbox

CHANGE ORDERS, BACK CHARGES, AND EXTRA WORK

VERBAL DISCUSSIONS,DIRECTIVES OR INSTRUCTIONS

Instructed by PM to pre-drill casing and then pull casing up to 3 holes ahead on 9/4/2015 instead of jet grouting

VISITORS ON-SITE

Morgan

QA/QC

Activity	Quantity	Panel ID	Comments
Jet Grout	2	HBI-6B, HBI-6A	Deviation @ Bottom of Panel = 0.31%
Spoils Sampling	7	HBI-6A, SG: 1.75 @ 11:43	HBI-6A: 7 samples (2 for Hydrometrics)
Other			

LABOR FORCE

QTY	TYPE
8	OPERATORS
0	LABORERS
1	MECHANICS
2	OTHER (SUPT,FIELD ENGINEER)

LENGTH OF SHIFT 10 HRS

NOTES:

MANPOWER

Position	NAME	Regular Hours	OT Hours
Superintendent	Frank Kalata	10	
Field Engineer	Taylor Cox	10	
Field Engineer	Dylan Fisher		
Mechanic	Kevin Clark	8	2
Driller	Mark Fellows	8	3
Pump Operator	Paul Thomas	8	3
Batch Plant Operator	Auggie Ruesga	8	3
Driller	Jody Welch	8	3
Operator	Shaun Henderson	8	3
Operator	Alan Krouse	8	3
Operator	Linda Currie	8	2
Operator	Ronda Jacobs	8	1

Man Hours

Company Name	Hrs. Today	OT Hrs. Today	Yesterday		Safe Hrs To Date:	
Hayward Baker:	92	23	102		104.5	
Total Manhours :	872	227				

Owner / Contractor

HAYWARD BAKER INC.

HAYWARD BAKER, INC.

11180 E. Marginal Way S
Tukwila, WA 98168
206-223-1732

DAILY SITE REPORT

SHEET NO.	**2**	OF	**2**
SHIFT	DAY	**ONE CALL #**	0
START:	7:00 AM	**END:**	6:00 PM
DATE:	Thursday, September 03, 2015		

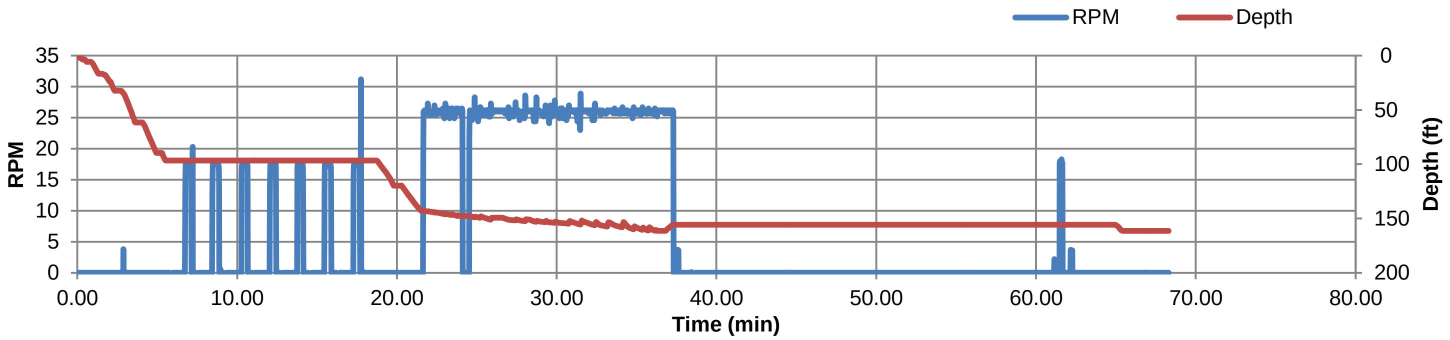
JOB NO:	860080	**LOCATION:**	Mead, WA	**TYPE OF WORK:**	Jet Grouting
PROJECT NAME:	Kaiser Mead NPL			**WEATHER:**	Sunny and hot
CLIENT:	Hydrometrics			**PROJECT MGR.**	Adam Gerondale

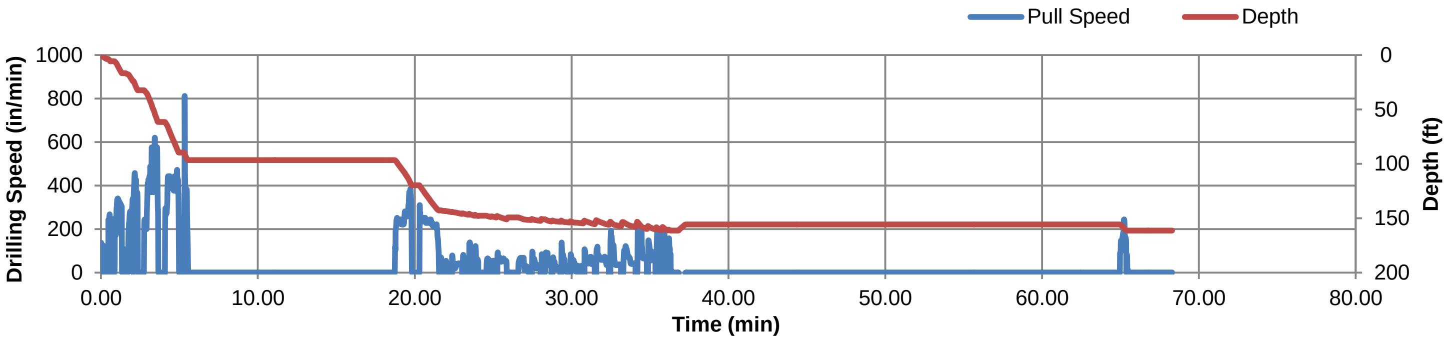
HAYWARD
BAKER
Geotechnical Construction
KELLER

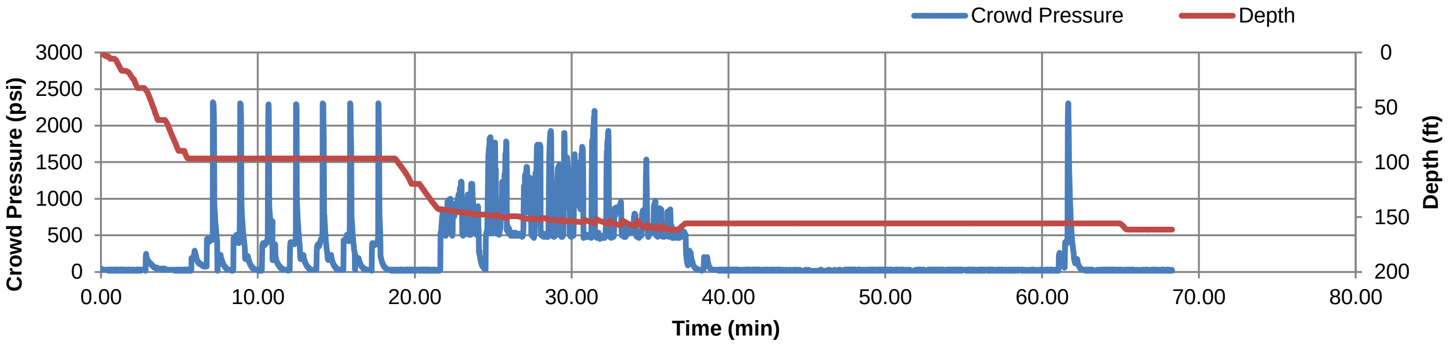
Jet Grout Drilling Report
Kaiser Mead NPL

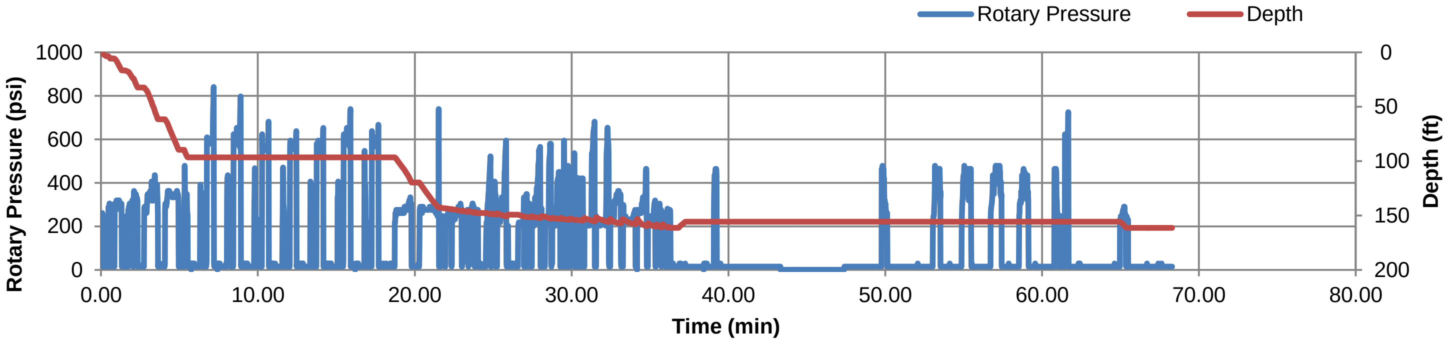
Column Number: HBI-6B
Job Number: 860080
Job Location: Spokane, WA
Drilled Depth: 161.45 ft
Inclination (X, Y): (4.10 in, 4.15 in)

Date: 9/3/2015
Start Time: 8:50 AM
End Time: 10:26 AM
Duration: 01:36:08





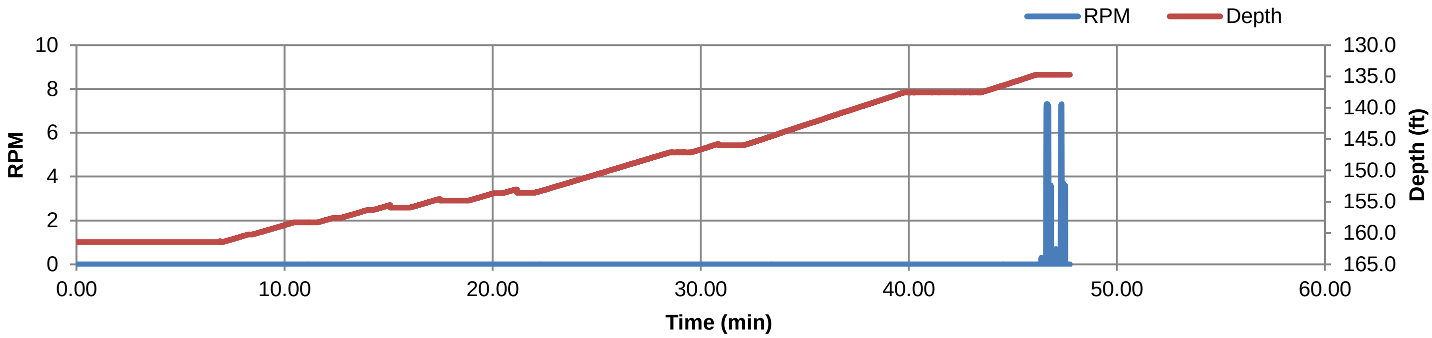


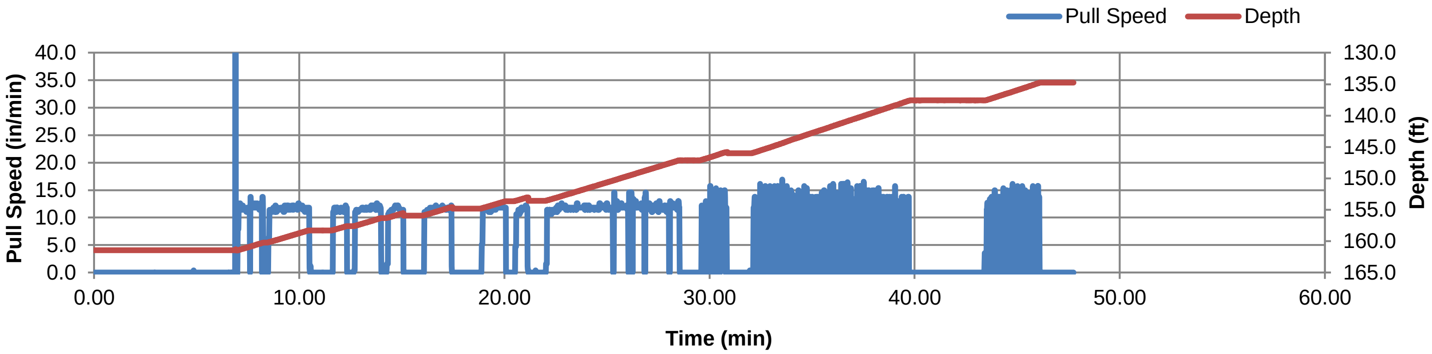


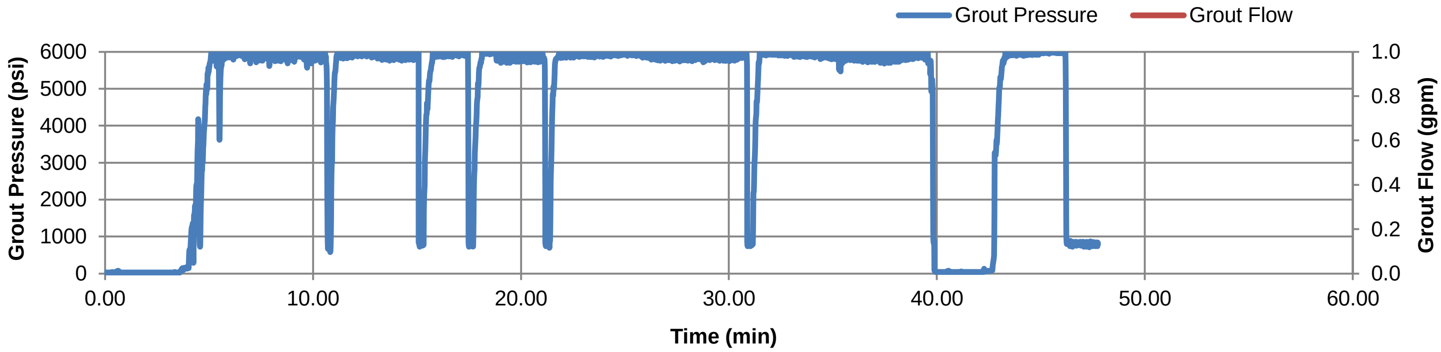
THINK SAFE

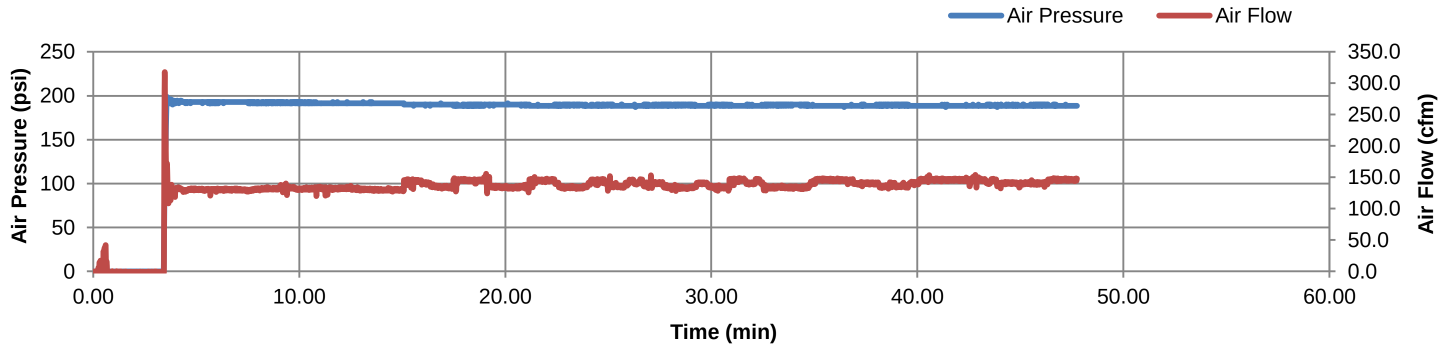
Jet Grouting Report
Kaiser Mead NPL

Column Number:	HBI-6B	**Date:**	9/3/2015
Job Number:	860080	**Start Time:**	10:26 AM
Job Location:	Spokane, WA	**End Time:**	11:25 AM
Total Grout Volume:	5423 gal	**Duration:**	00:59:00
Treatment Length:	26.74 ft	**Avg. S.G.:**	1.52





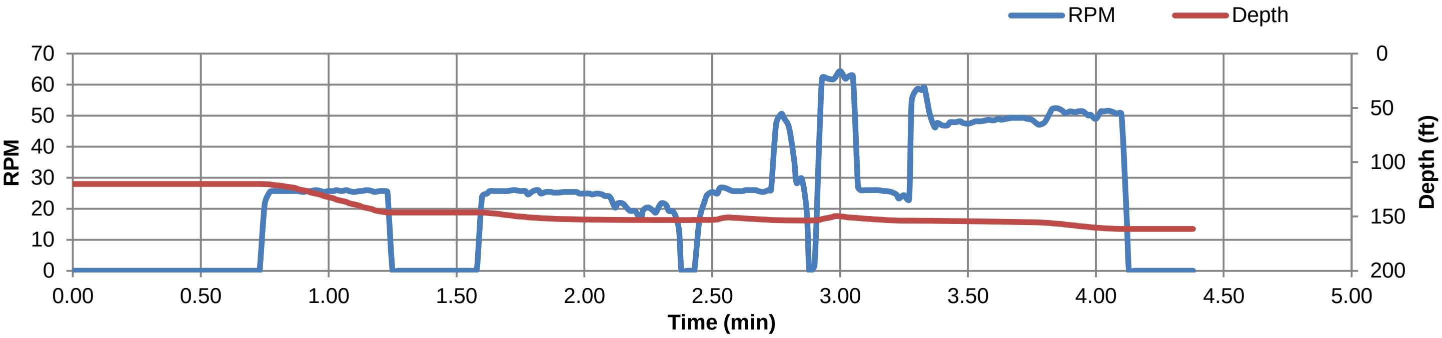


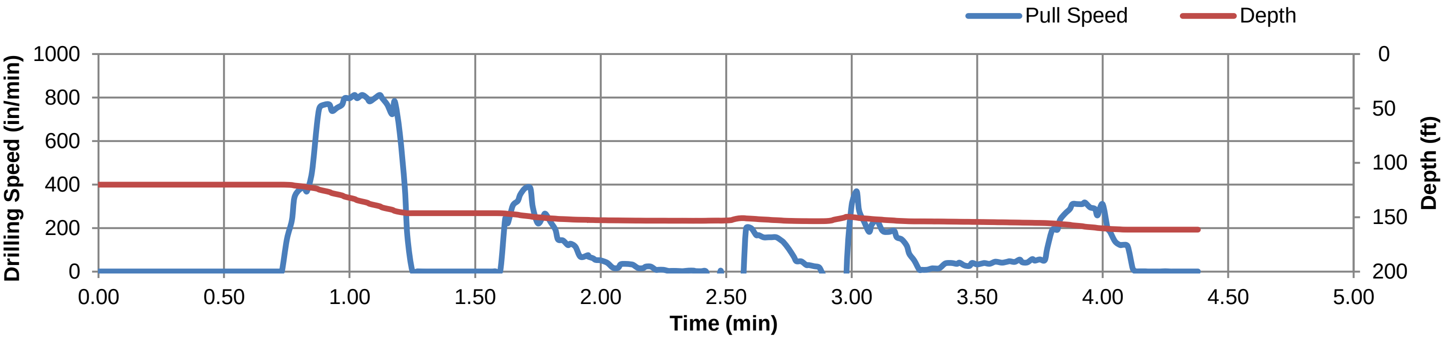


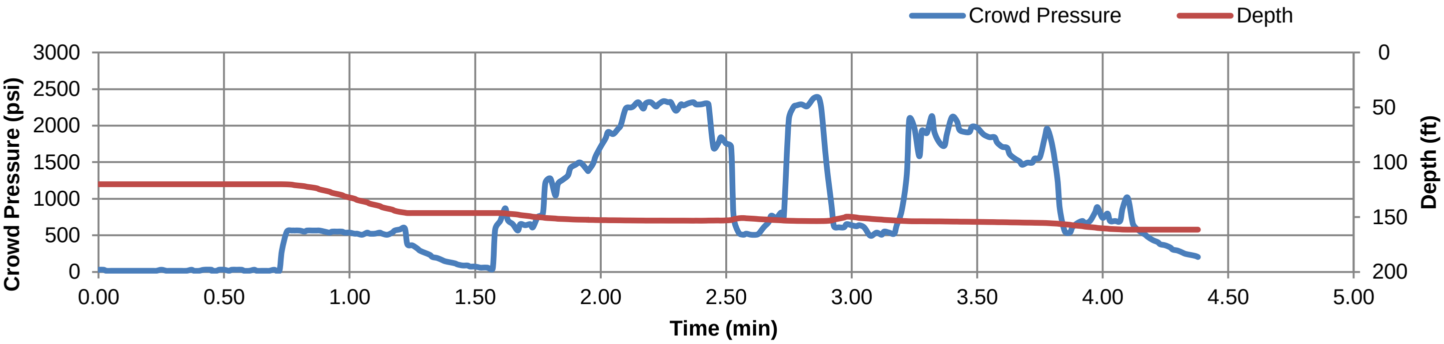
HAYWARD BAKER
Geotechnical Construction
KELLER

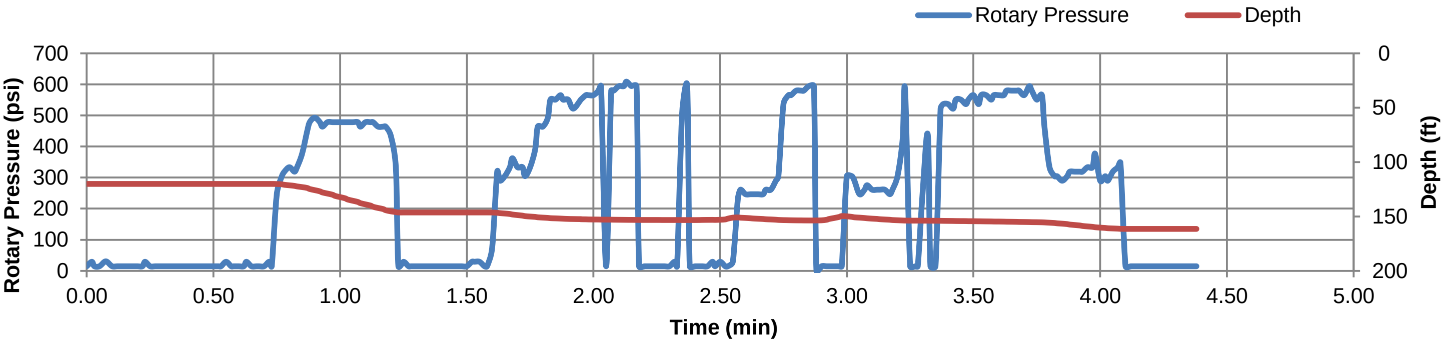
Jet Grout Drilling Report
Kaiser Mead NPL

Column Number:	HBI-6A	**Date:**	9/3/2015
Job Number:	860080	**Start Time:**	11:29 AM
Job Location:	Spokane, WA	**End Time:**	11:33 AM
Drilled Depth:	161.48 ft	**Duration:**	00:04:24
Inclination (X, Y):	(4.10 in, 4.15 in)		









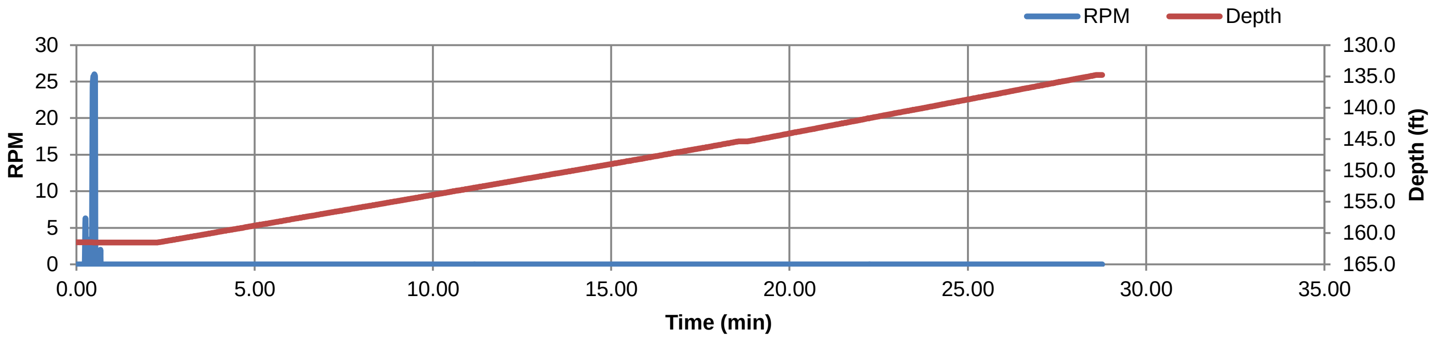
THINK SAFE

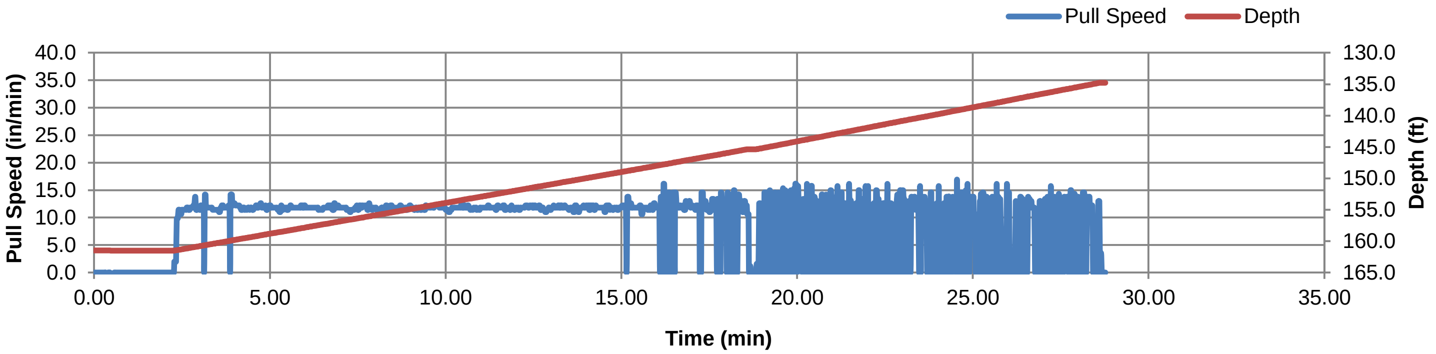
HAYWARD BAKER
Geotechnical Construction
KELLER

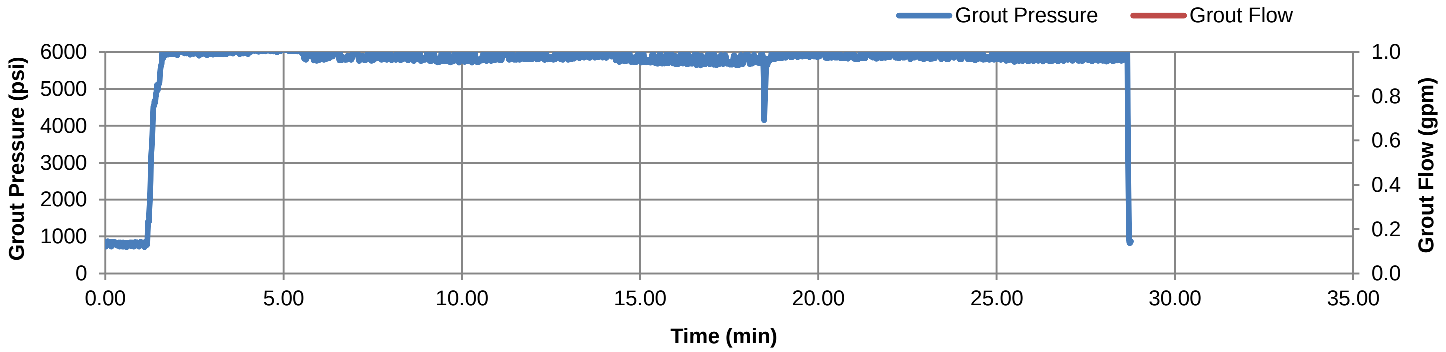
Jet Grouting Report
Kaiser Mead NPL

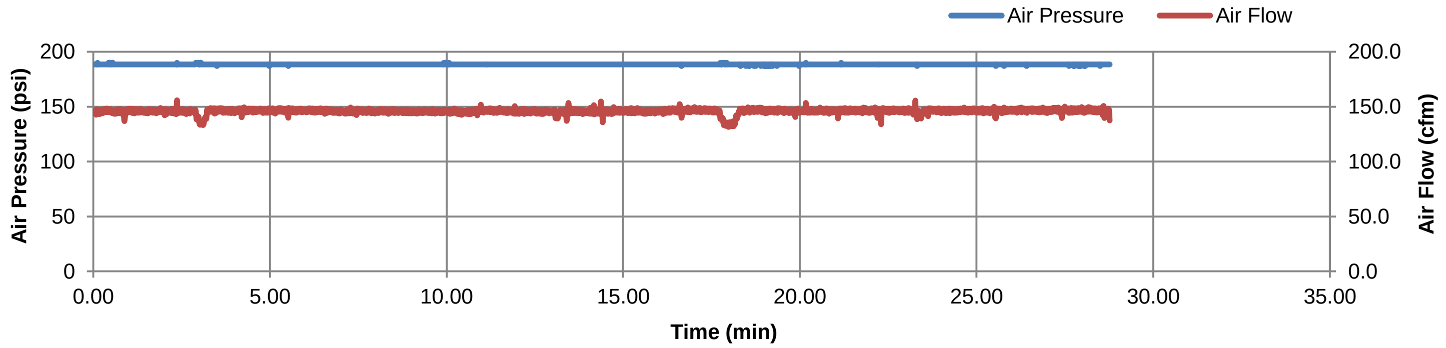
Column Number: HBI-6A
Job Number: 860080
Job Location: Spokane, WA
Total Grout Volume: 3499 gal
Treatment Length: 26.74 ft

Date: 9/3/2015
Start Time: 11:29 AM
End Time: 12:02 PM
Duration: 00:33:11
Avg. S.G.: 1.52









THINK SAFE

HAYWARD BAKER, INC.
11180 E. Marginal Way S
Tukwila, WA 98168
206-223-1732

DAILY SITE REPORT

SHEET NO.	1	OF	2
SHIFT	DAY	**ONE CALL #**	
START:	7:00 AM	**END:**	6:00 PM
DATE:	Friday, September 04, 2015		

JOB NO:	860080	**LOCATION:**	Mead, WA	**TYPE OF WORK:**	Jet Grouting
PROJECT NAME:	Kaiser Mead NPL			**WEATHER:**	
CLIENT:	Hydrometrics			**PROJECT MGR.**	Adam Gerondale

SITE ACTIVITY

7:00 - 18:00 Drilled casing on HBI-3 and HBI-7 in preparation for jet grouting on 9/8/2015

Panels Installed Today	0
Tot. Panels Yesterday	0
# of Panels To Date	6
% Complete	25%

MATERIAL DELIVERED

CEMENT DELIVERED (TONS):		TRUCKS	
FUEL DELIVERED (GALLONS):	295	TRUCKS	No. 41

EQUIPMENT USED, MOVED, STANDBY

12k reach forklift, mini-ex, skid steer, Hutte Drill, 825 Hurricane, Agi tank, 3x2 mission pump
25K genset, 185 compressor, 6500 gallon poly tank, 900cfm compressor, switchbox

CHANGE ORDERS, BACK CHARGES, AND EXTRA WORK

VERBAL DISCUSSIONS,DIRECTIVES OR INSTRUCTIONS

VISITORS ON-SITE

Tony Chavez

QA/QC

Activity	**Quantity**	**Panel ID**	**Comments**
Jet Grout	0		
Spoils Sampling	0		
Other			

LABOR FORCE

QTY	TYPE
4	OPERATORS
0	LABORERS
1	MECHANICS
2	OTHER (SUPT,FIELD ENGINEER)

LENGTH OF SHIFT 10 HRS

NOTES: Reduced number of employees due to not performing jet grout operations

MANPOWER

Position	**NAME**	Regular Hours	OT Hours
Superintendent	Frank Kalata	10	
Field Engineer	Taylor Cox	10	
Field Engineer	Dylan Fisher		
Mechanic	Kevin Clark	8	3
Driller	Mark Fellows	8	3
Pump Operator	Paul Thomas		
Batch Plant Operator	Auggie Ruesga	8	3
Driller	Jody Welch	8	3
Operator	Shaun Henderson	8	3
Operator	Alan Krouse		
Operator	Linda Currie		
Operator	Ronda Jacobs		

Man Hours

Company Name	**Hrs. Today**	**OT Hrs. Today**	**Yesterday**		**Safe Hrs To Date:**	
Hayward Baker:	60	15	92		115.5	
Total Manhours :	932	242				

Owner / Contractor

HAYWARD BAKER INC.

HAYWARD BAKER, INC.

11180 E. Marginal Way S
Tukwila, WA 98168
206-223-1732

DAILY SITE REPORT

SHEET NO.	**2**	OF	**2**
SHIFT	DAY	**ONE CALL #**	0
START:	7:00 AM	**END:**	6:00 PM
DATE:	Friday, September 04, 2015		

JOB NO:	860080	**LOCATION:**	Mead, WA	**TYPE OF WORK:**	Jet Grouting
PROJECT NAME:	Kaiser Mead NPL			**WEATHER:**	Sunny and hot
CLIENT:	Hydrometrics			**PROJECT MGR.**	Adam Gerondale

HAYWARD BAKER, INC.
11180 E. Marginal Way S
Tukwila, WA 98168
206-223-1732

DAILY SITE REPORT

SHEET NO.	**1**	OF	**2**
SHIFT	DAY	**ONE CALL #**	
START:	7:00 AM	**END:**	6:00 PM
DATE:	Tuesday, September 08, 2015		

JOB NO:	860080	**LOCATION:**	Mead, WA	**TYPE OF WORK:**	Jet Grouting
PROJECT NAME:	Kaiser Mead NPL			**WEATHER:**	
CLIENT:	Hydrometrics			**PROJECT MGR.**	Adam Gerondale

SITE ACTIVITY

7:00 - 17:00 Jet grouted HBI-1A,B and HBI-3A,B. Pre-drilled casing on HBI-9 and HBI-11.

Panels Installed Today	0
Tot. Panels Yesterday	0
# of Panels To Date	10
% Complete	42%

MATERIAL DELIVERED

CEMENT DELIVERED (TONS):	34.39	TRUCKS	238066382
FUEL DELIVERED (GALLONS):	203	TRUCKS	No. 41

EQUIPMENT USED, MOVED, STANDBY

12k reach forklift, mini-ex, skid steer, Hutte Drill, 825 Hurricane, Agi tank, KB-6, D-station, 3x2 mission pump, 4x3 mission pump, 350 BBL silo
Moyno Pump, 25K genset, 185 compressor, 300k genset, 6500 gallon poly tank, 900cfm compressor, switchbox

CHANGE ORDERS, BACK CHARGES, AND EXTRA WORK

Due to the 3.06% deviation on HBI-1, remedial panels will be added to insure continuity of panels

VERBAL DISCUSSIONS,DIRECTIVES OR INSTRUCTIONS

VISITORS ON-SITE

Morgan

QA/QC

Activity	Quantity	Panel ID	Comments
Jet Grout	4	HBI-1A,B & HBI-3A,B	Deviation @ Bottom of Panel: HBI-1 = 3.06%; HBI-3 = 1.04%
Spoils Sampling	12	HBI-1A, HBI-3B	HBI-1A: 5 samples, HBI-3B: 7 samples (2 for Hydrometrics)
Other			

LABOR FORCE

QTY	TYPE
7	OPERATORS
0	LABORERS
1	MECHANICS
2	OTHER (SUPT,FIELD ENGINEER)

LENGTH OF SHIFT

10 HRS

NOTES:

MANPOWER

Position	NAME	Regular Hours	OT Hours
Superintendent	Frank Kalata	10	
Field Engineer	Taylor Cox	10	
Field Engineer	Dylan Fisher		
Mechanic	Kevin Clark	8	3
Driller	Mark Fellows	8	3
Pump Operator	Paul Thomas	8	3
Batch Plant Operator	Auggie Ruesga	8	3
Driller	Jody Welch	8	3
Operator	Shaun Henderson	8	3
Operator	Alan Krouse	8	3
Operator	Linda Currie	8	3

Man Hours

Company Name	Hrs. Today	OT Hrs. Today	Yesterday		Safe Hrs To Date:	
Hayward Baker:	84	24	0		126.5	
Total Manhours :	1016	266				

Owner / Contractor

HAYWARD BAKER INC.

HAYWARD BAKER, INC.

11180 E. Marginal Way S
Tukwila, WA 98168
206-223-1732

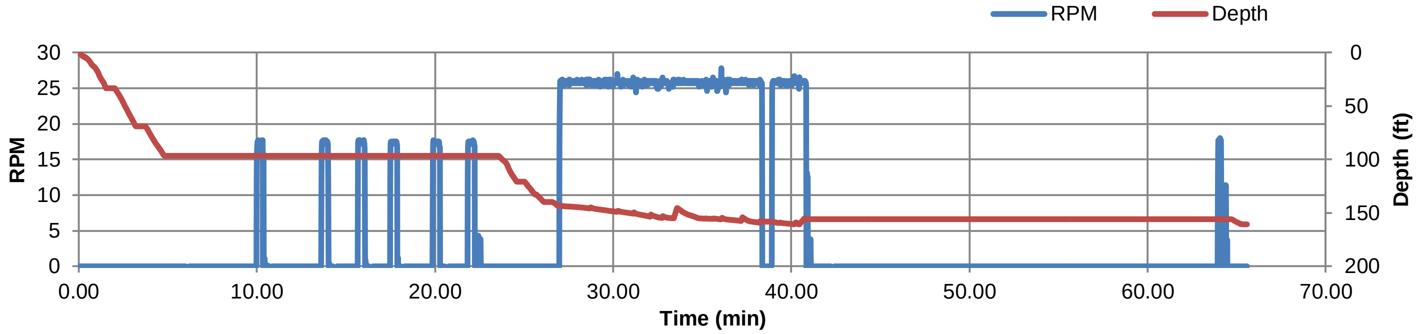
DAILY SITE REPORT

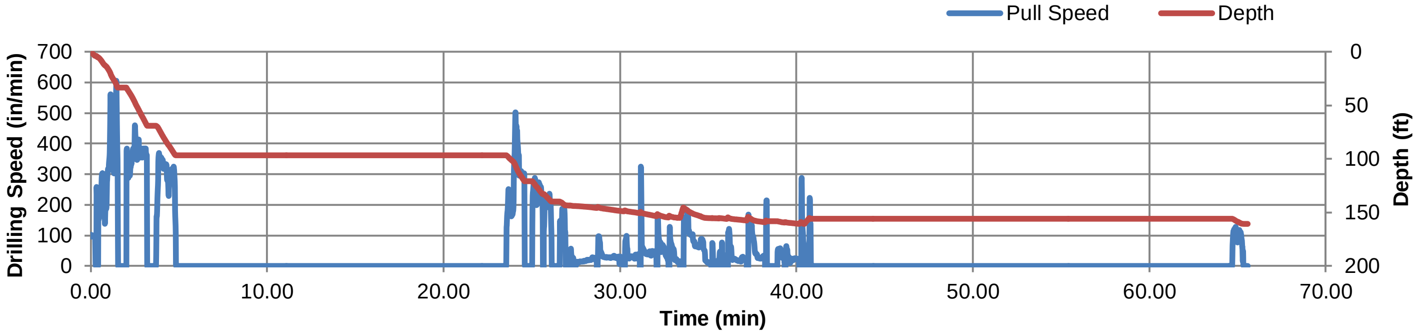
SHEET NO.	2	OF	2
SHIFT	DAY	**ONE CALL #**	0
START:	7:00 AM	**END:**	6:00 PM
DATE:	Tuesday, September 08, 2015		

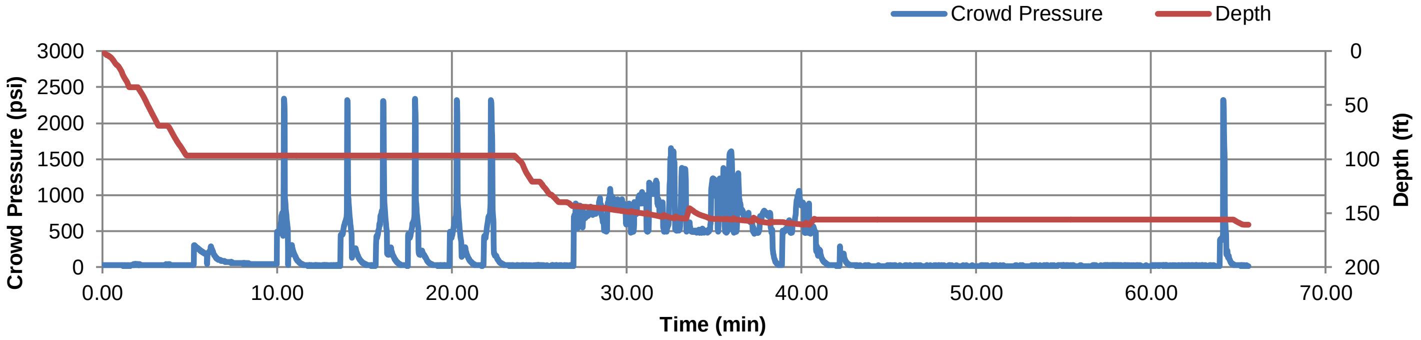
JOB NO:	860080	**LOCATION:**	Mead, WA	**TYPE OF WORK:**	Jet Grouting
PROJECT NAME:	Kaiser Mead NPL			**WEATHER:**	Sunny and hot
CLIENT:	Hydrometrics			**PROJECT MGR.**	Adam Gerondale

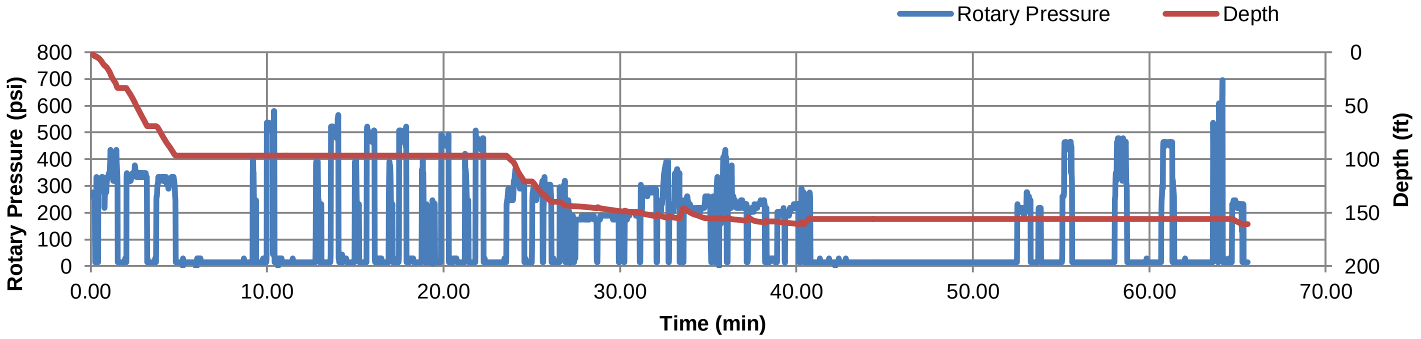
Jet Grout Drilling Report
Kaiser Mead NPL

Column Number:	HBI-1B	**Date:**	9/8/2015
Job Number:	860080	**Start Time:**	8:16 AM
Job Location:	Spokane, WA	**End Time:**	9:40 AM
Drilled Depth:	160.76 ft	**Duration:**	01:23:57
Inclination (X, Y):	(19.386 in, 53.094 in)		







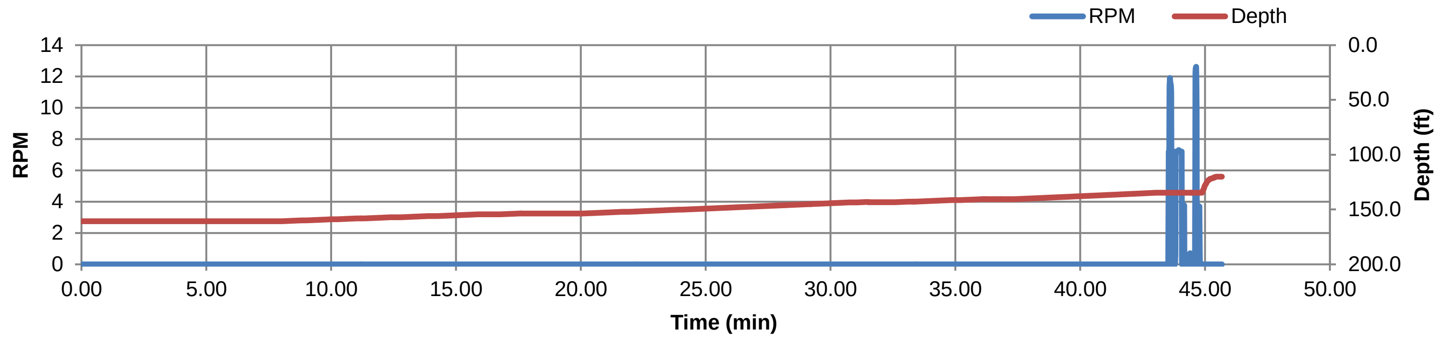


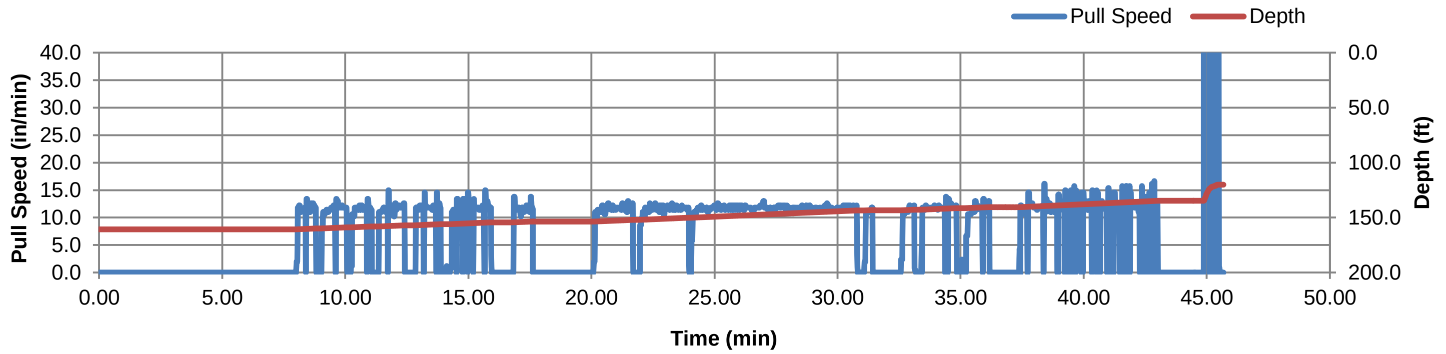
HAYWARD
BAKER
Geotechnical Construction
KELLER

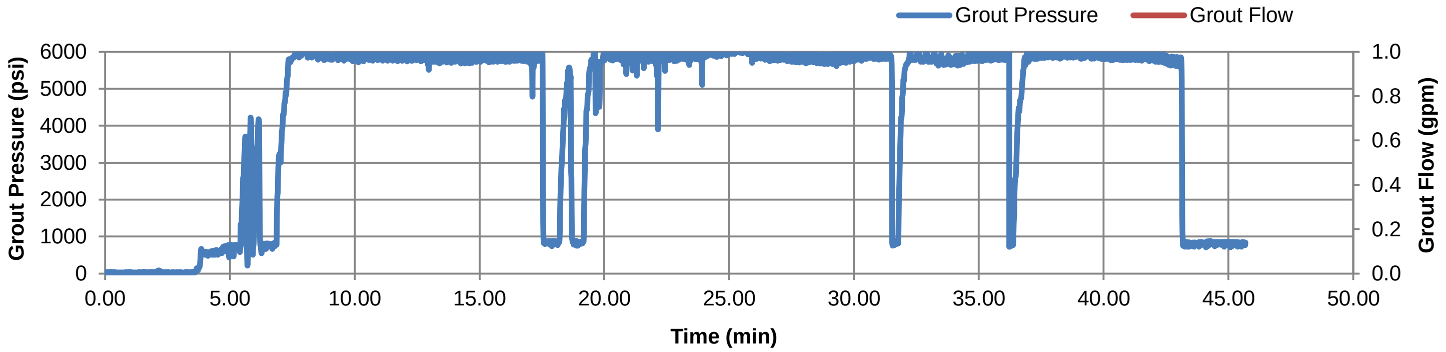
Jet Grouting Report
Kaiser Mead NPL

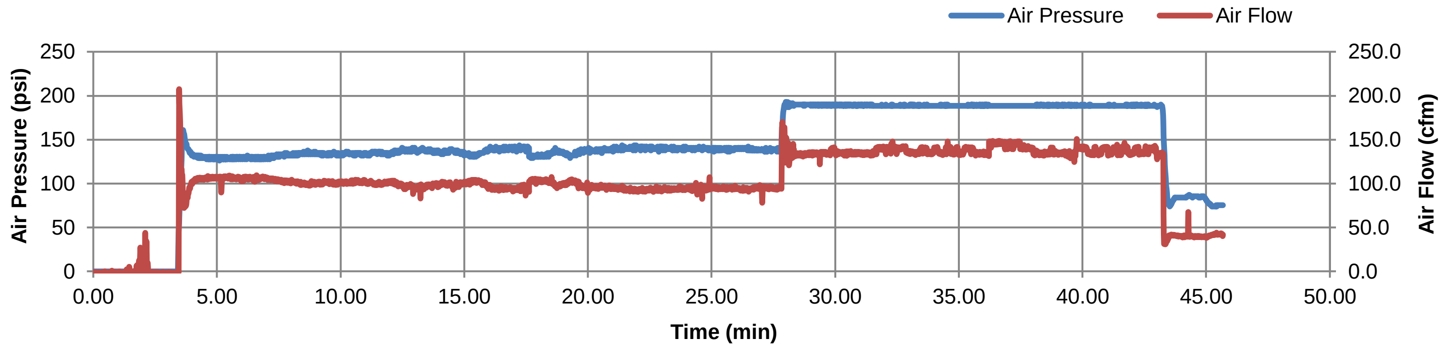
Column Number: HBI-1B
Job Number: 860080
Job Location: Spokane, WA
Total Grout Volume: 4807 gal
Treatment Length: 26.02 ft

Date: 9/8/2015
Start Time: 9:40 AM
End Time: 10:31 AM
Duration: 00:51:00
Avg. S.G.: 1.52









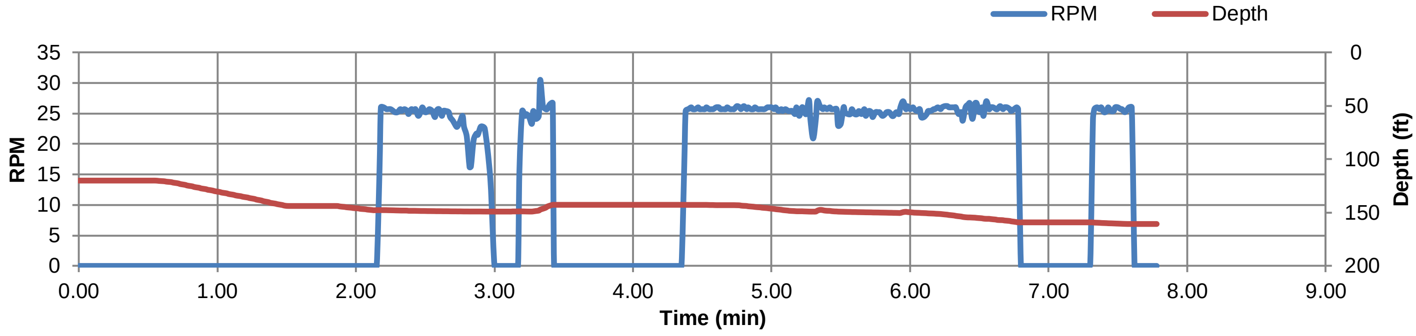
THINK SAFE

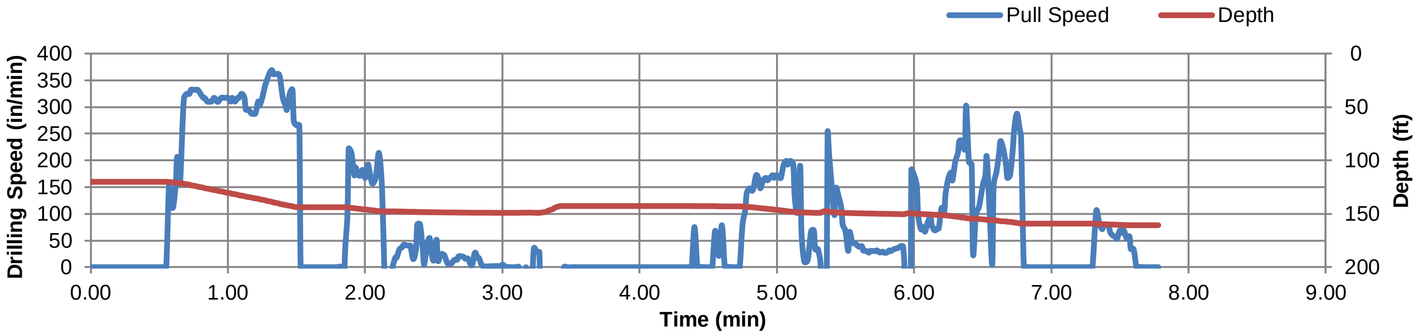
HAYWARD BAKER
Geotechnical Construction
KELLER

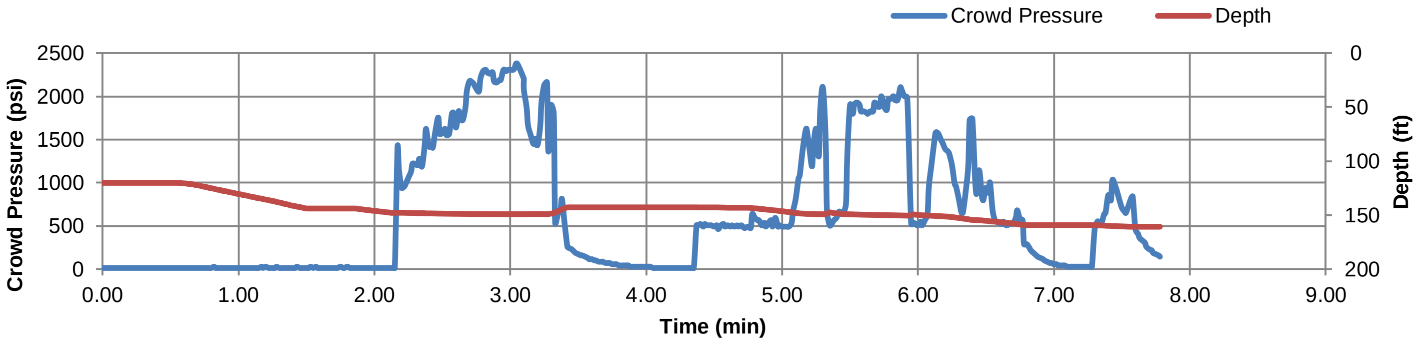
Jet Grout Drilling Report
Kaiser Mead NPL

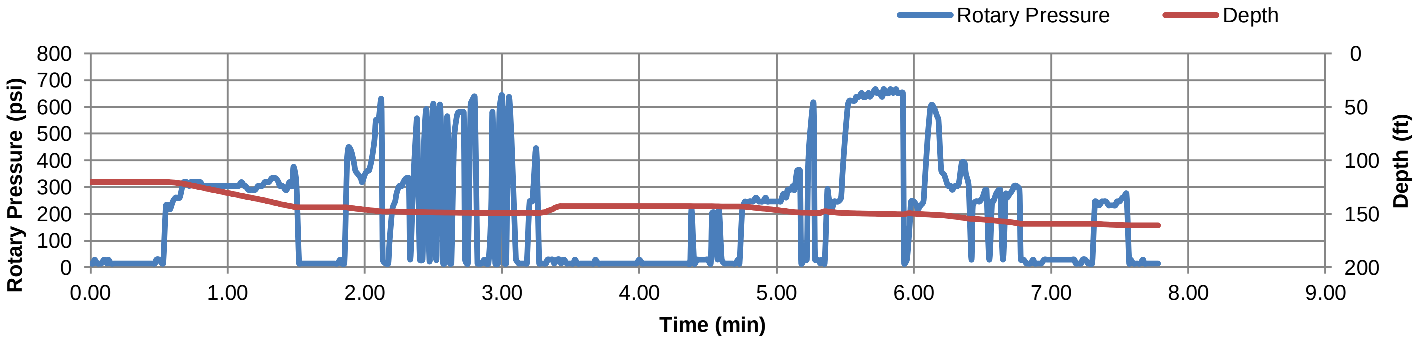
Column Number: HBI-1A
Job Number: 860080
Job Location: Spokane, WA
Drilled Depth: 160.69 ft
Inclination (X, Y): (19.386 in, 53.094 in)

Date: 9/8/2015
Start Time: 10:34 AM
End Time: 10:42 AM
Duration: 00:07:48









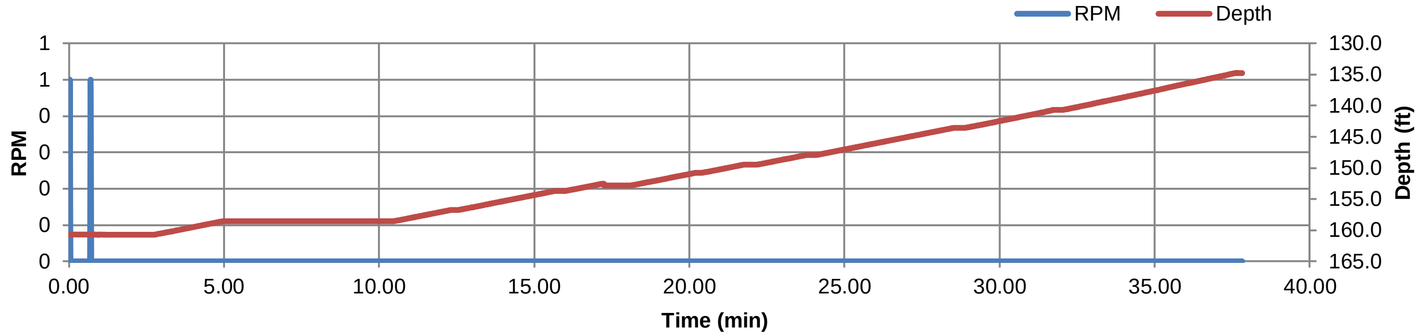
THINK SAFE

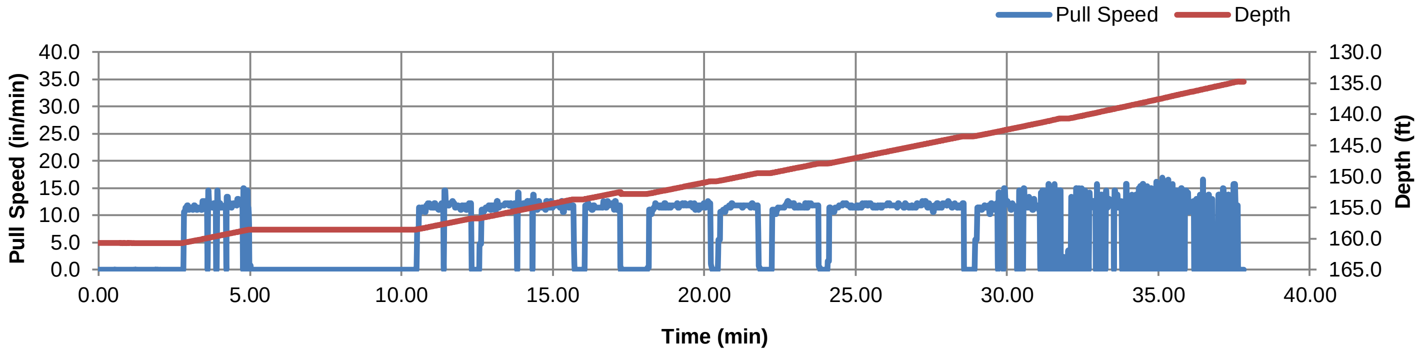
HAYWARD
BAKER
Geotechnical Construction
KELLER

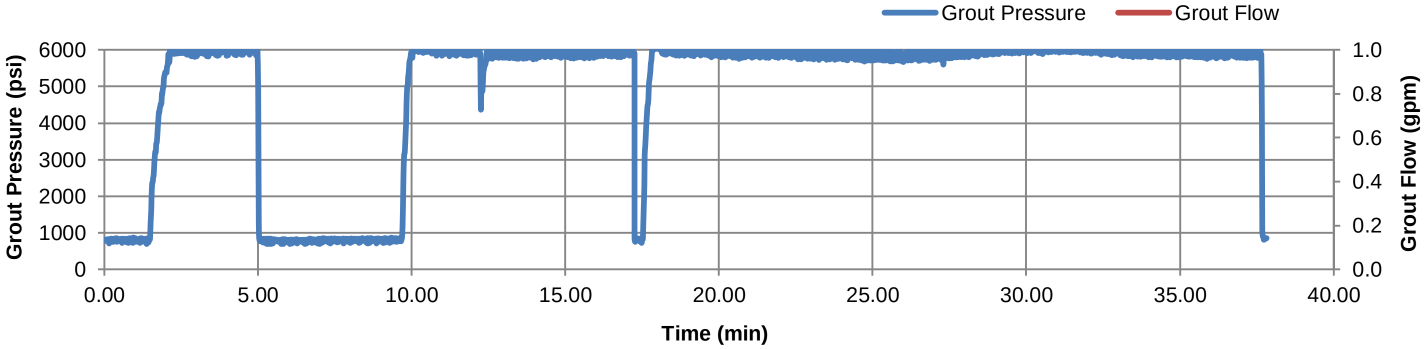
Jet Grouting Report
Kaiser Mead NPL

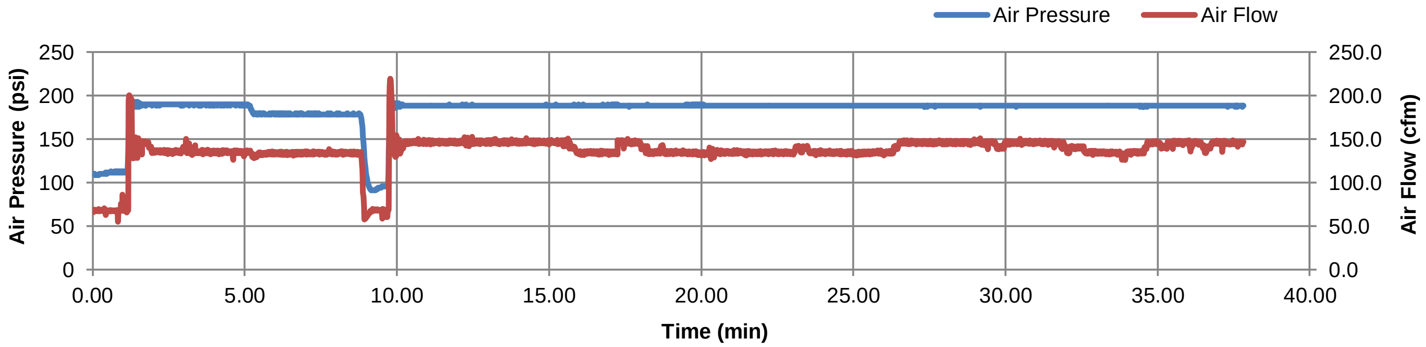
Column Number: HBI-1A
Job Number: 860080
Job Location: Spokane, WA
Total Grout Volume: 4285 gal
Treatment Length: 25.98 ft

Date: 9/8/2015
Start Time: 10:34 AM
End Time: 11:21 AM
Duration: 00:46:41
Avg. S.G.: 1.52







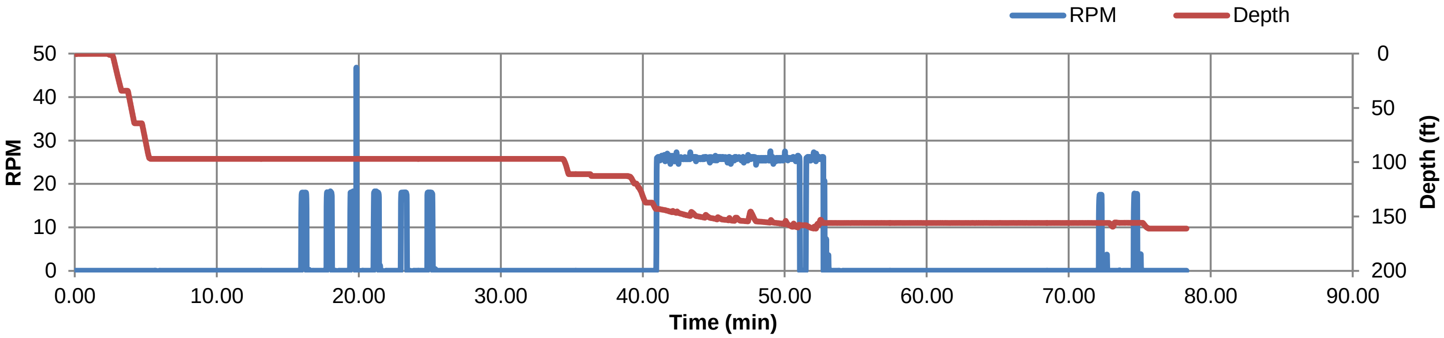


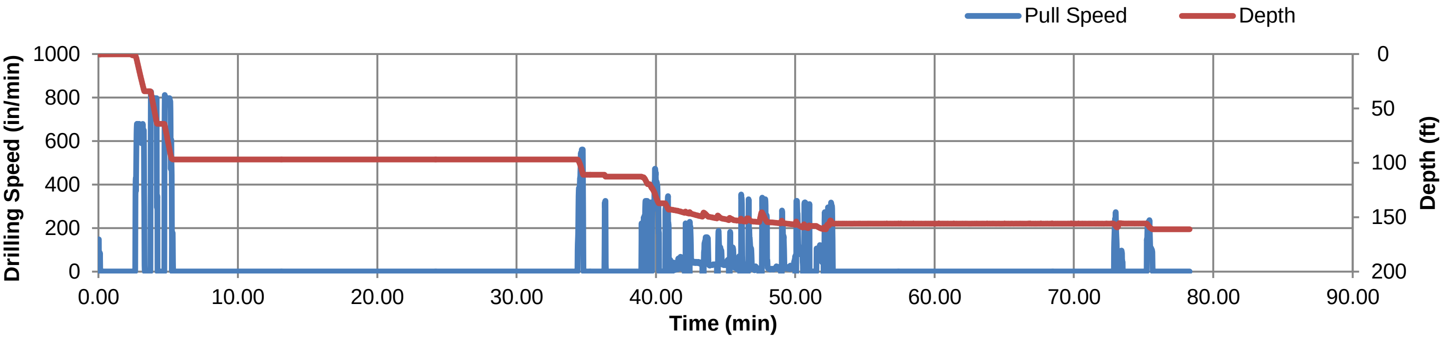
THINK SAFE

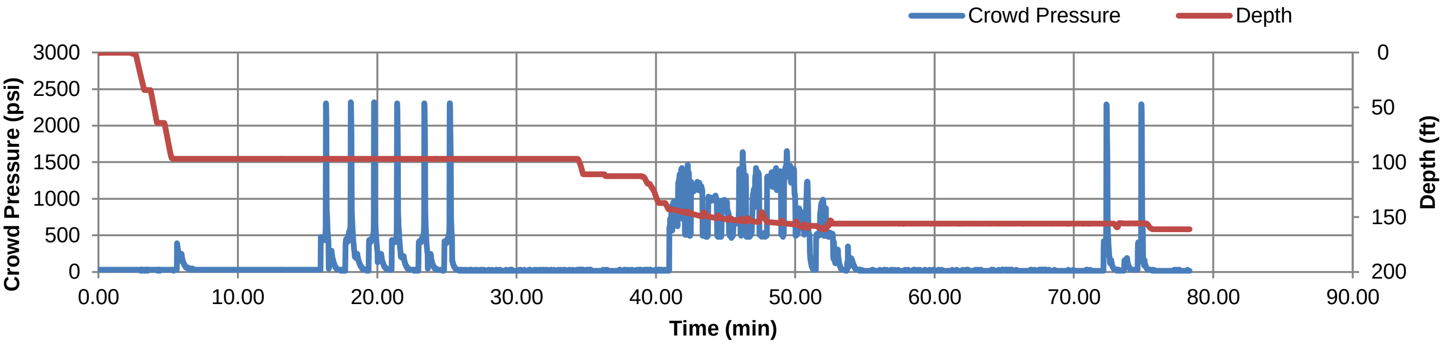
Hayward Baker Geotechnical Construction Keller

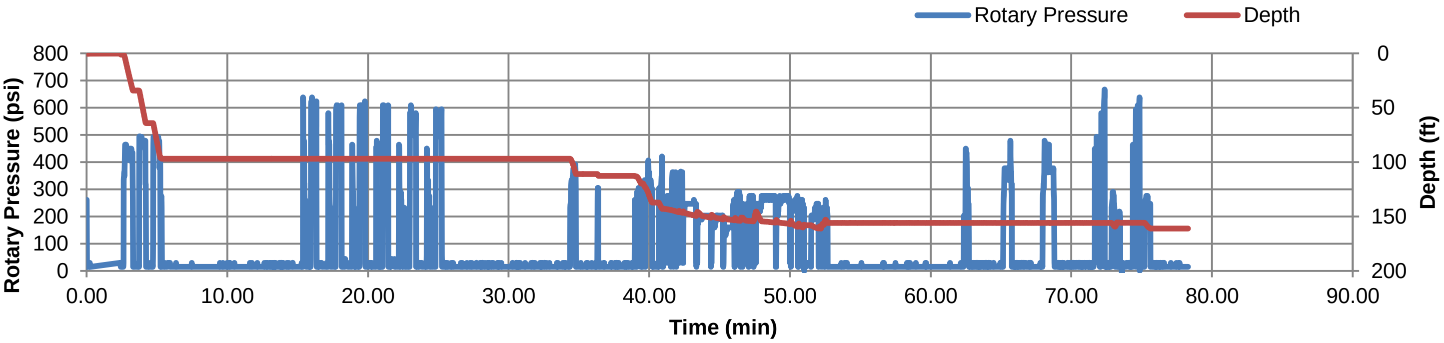
Jet Grout Drilling Report
Kaiser Mead NPL

Column Number:	HBI-3B	**Date:**	9/8/2015
Job Number:	860080	**Start Time:**	12:54 PM
Job Location:	Spokane, WA	**End Time:**	2:20 PM
Drilled Depth:	161.19 ft	**Duration:**	01:25:29
Inclination (X, Y):	(19.145 in, 0.003 in)		







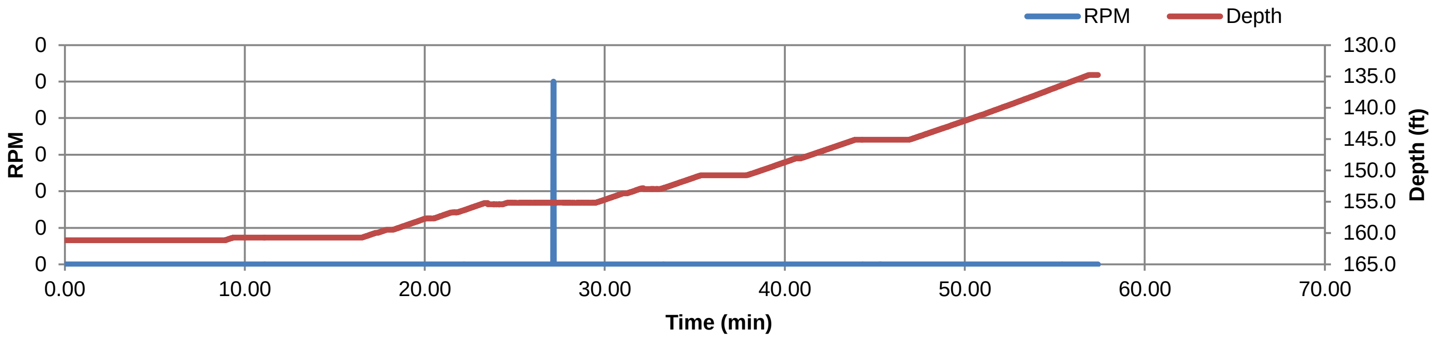


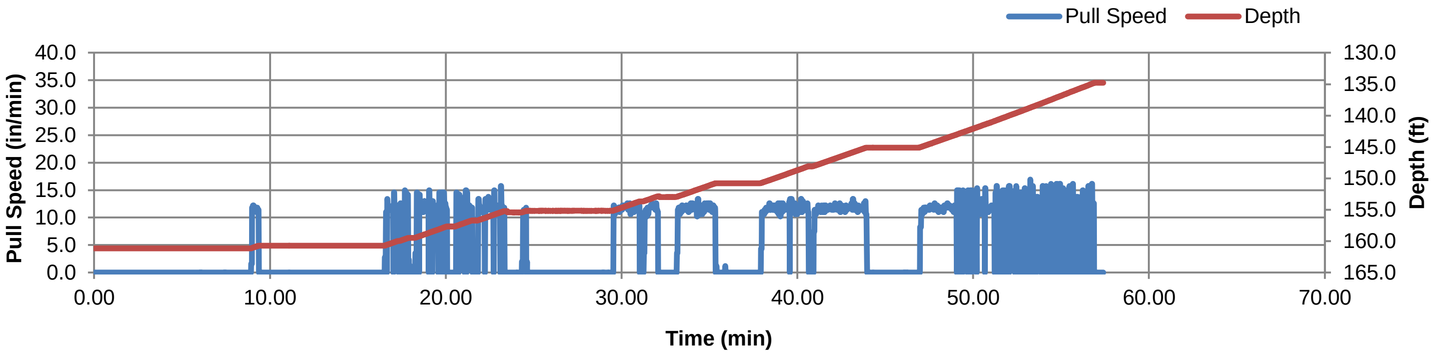
THINK SAFE

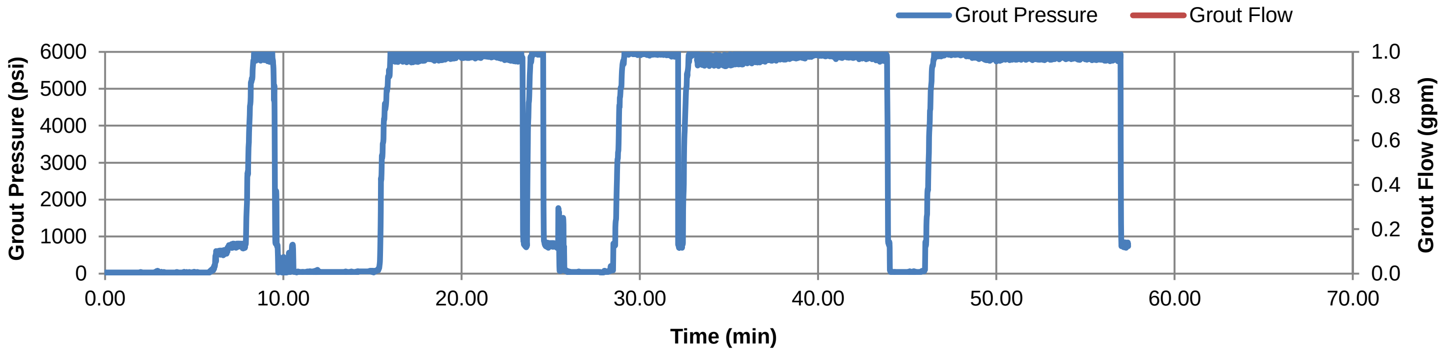
Jet Grouting Report
Kaiser Mead NPL

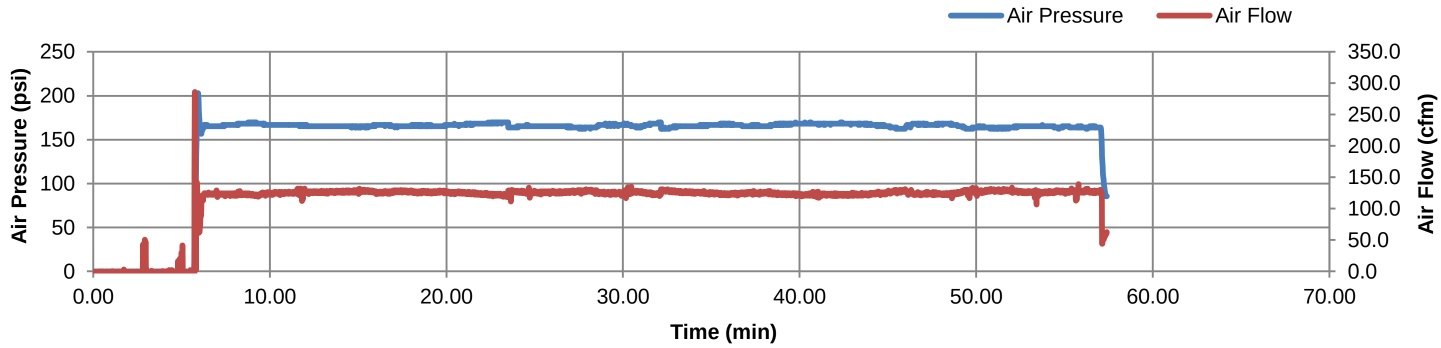
Column Number: HBI-3B
Job Number: 860080
Job Location: Spokane, WA
Total Grout Volume: 5027 gal
Treatment Length: 26.38 ft

Date: 9/8/2015
Start Time: 2:17 PM
End Time: 3:20 PM
Duration: 01:03:00
Avg. S.G.: 1.52





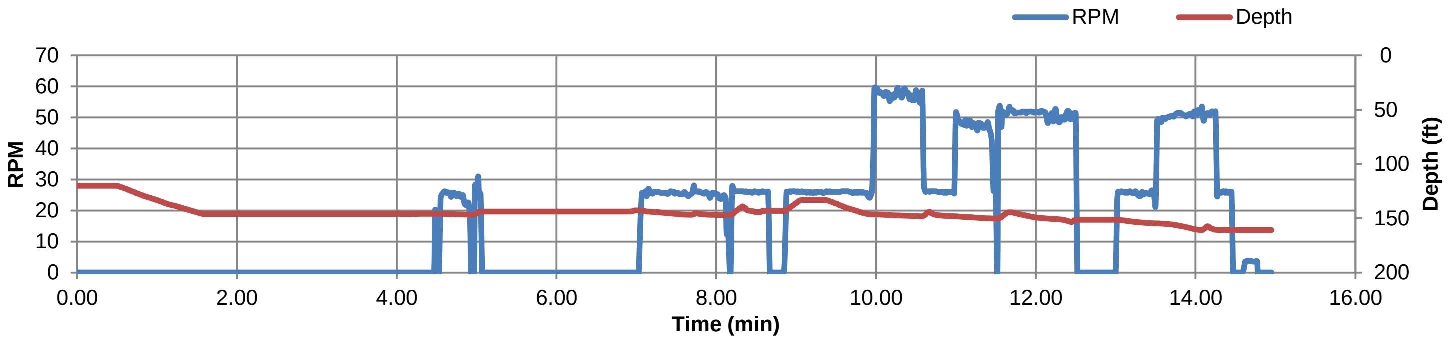


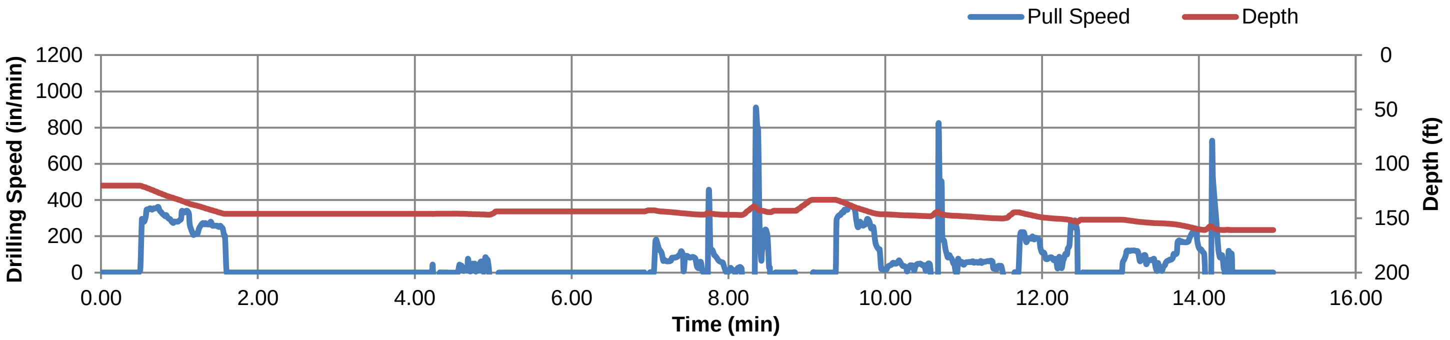


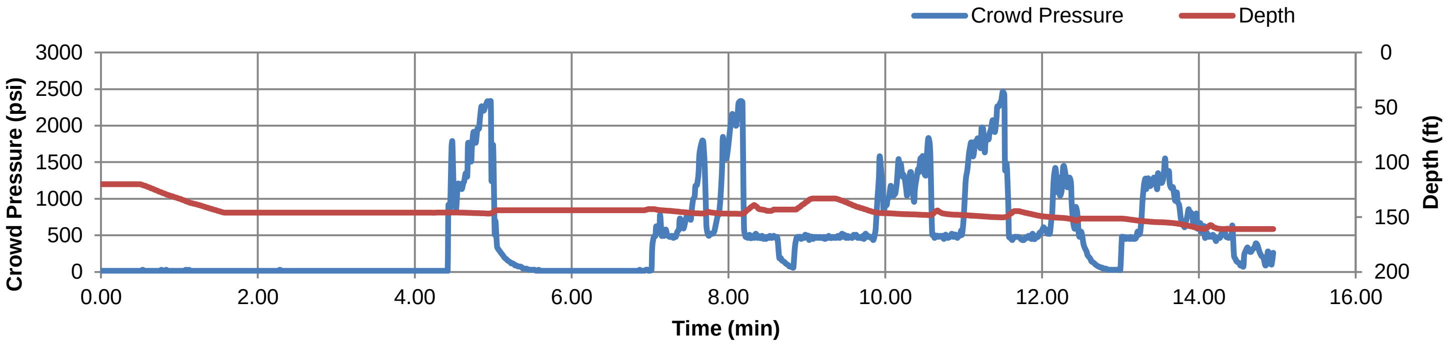
HAYWARD
BAKER
Geotechnical Construction
KELLER

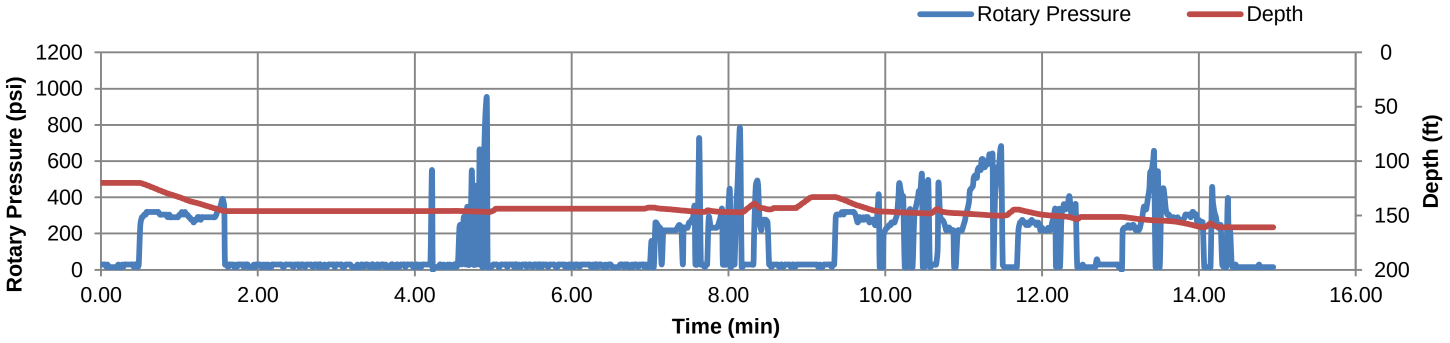
Jet Grout Drilling Report
Kaiser Mead NPL

Column Number:	HBI-3A	**Date:**	9/8/2015
Job Number:	860080	**Start Time:**	3:24 PM
Job Location:	Spokane, WA	**End Time:**	3:39 PM
Drilled Depth:	160.92 ft	**Duration:**	00:14:57
Inclination (X, Y):	(19.145 in, 0.003 in)		









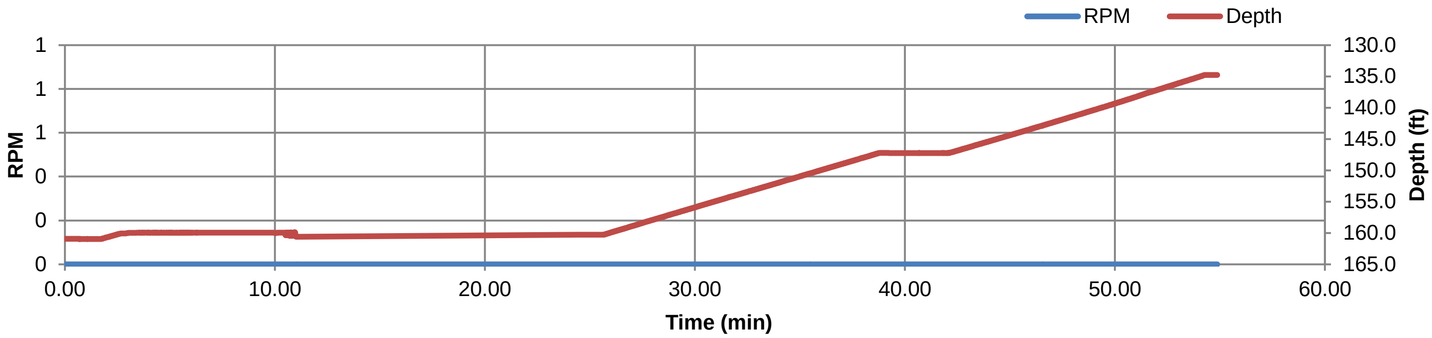
THINK SAFE

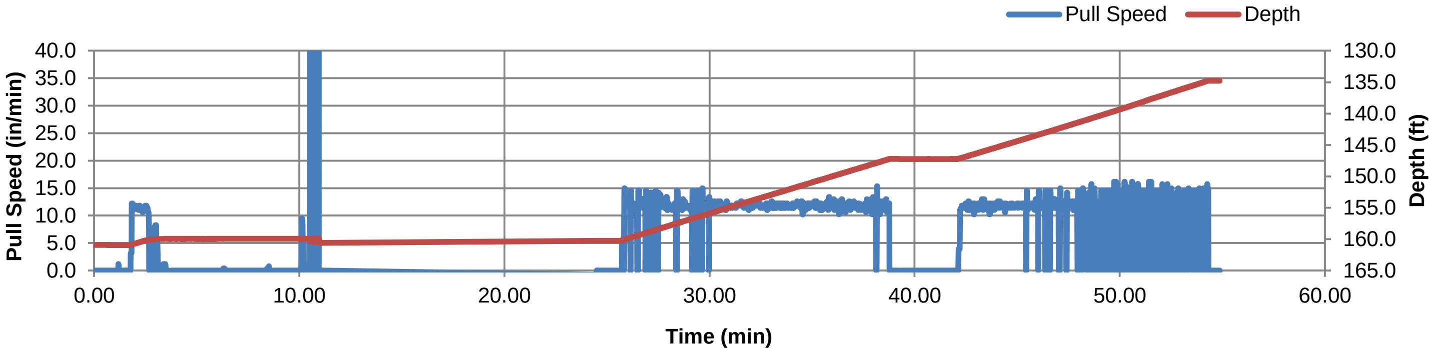
HAYWARD
BAKER
Geotechnical Construction
KELLER

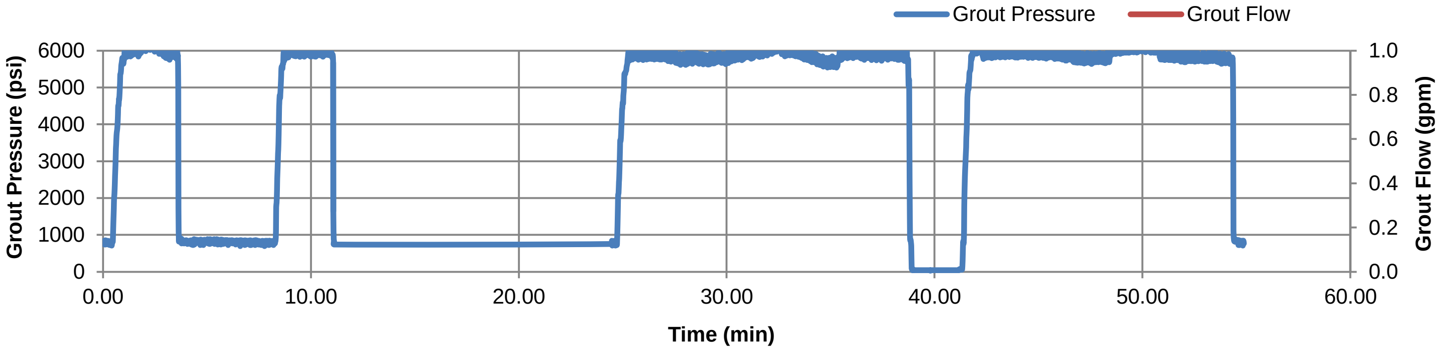
Jet Grouting Report
Kaiser Mead NPL

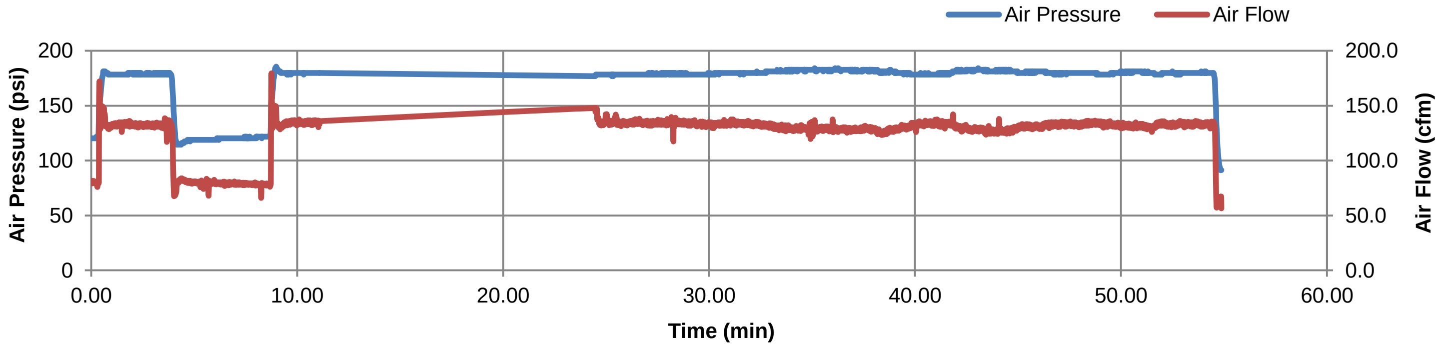
Column Number: HBI-3A
Job Number: 860080
Job Location: Spokane, WA
Total Grout Volume: 4924 gal
Treatment Length: 26.18 ft

Date: 9/8/2015
Start Time: 3:24 PM
End Time: 4:34 PM
Duration: 01:09:52
Avg. S.G.: 1.52









THINK SAFE

HAYWARD BAKER, INC.
11180 E. Marginal Way S
Tukwila, WA 98168
206-223-1732

DAILY SITE REPORT

SHEET NO.	1	OF	2
SHIFT	DAY	**ONE CALL #**	
START:	7:00 AM	**END:**	5:00 PM
DATE:	Wednesday, September 09, 2015		

JOB NO:	860080	**LOCATION:**	Mead, WA	**TYPE OF WORK:**	Jet Grouting
PROJECT NAME:	Kaiser Mead NPL			**WEATHER:**	
CLIENT:	Hydrometrics			**PROJECT MGR.**	Adam Gerondale

SITE ACTIVITY

7:00 - 17:00 Jet grouted HBI-7A,B and setup on HBI-9. Pre-drilled casing on HBI-2. Pre-drilled casing to 40' on HBI-4.

Panels Installed Today	2
Tot. Panels Yesterday	4
# of Panels To Date	12
% Complete	50%

MATERIAL DELIVERED

CEMENT DELIVERED (TONS):	34.36	TRUCKS	238066402
FUEL DELIVERED (GALLONS):	473	TRUCKS	No. 38

EQUIPMENT USED, MOVED, STANDBY

12k reach forklift, mini-ex, skid steer, Hutte Drill, 825 Hurricane, Agi tank, KB-6, D-station, 3x2 mission pump, 4x3 mission pump, 350 BBL silo
Moyno Pump, 25K genset, 185 compressor, 300k genset, 6500 gallon poly tank, 900cfm compressor, switchbox

CHANGE ORDERS, BACK CHARGES, AND EXTRA WORK

VERBAL DISCUSSIONS,DIRECTIVES OR INSTRUCTIONS

VISITORS ON-SITE

Morgan

QA/QC

Activity	Quantity	Panel ID	Comments
Jet Grout	2	HBI-7A,B	HBI-7: Deviation @ Bottom of Panel = 0.64%
Spoils Sampling	7	HBI-7A	HBI-7A: 7 samples (2 for Hydrometrics)
Other			

LABOR FORCE

QTY	TYPE
7	OPERATORS
0	LABORERS
1	MECHANICS
2	OTHER (SUPT,FIELD ENGINEER)

LENGTH OF SHIFT 10 HRS

NOTES:

MANPOWER

Position	NAME	Regular Hours	OT Hours
Superintendent	Frank Kalata	10	
Field Engineer	Taylor Cox	10	
Field Engineer	Dylan Fisher		
Mechanic	Kevin Clark	8	2
Driller	Mark Fellows	8	2
Pump Operator	Paul Thomas	8	2
Batch Plant Operator	Auggie Ruesga	8	2
Driller	Jody Welch	8	2
Operator	Shaun Henderson	8	2
Operator	Alan Krouse	8	2
Operator	Linda Currie	8	2

Man Hours

Company Name	Hrs. Today	OT Hrs. Today	Yesterday		Safe Hrs To Date:	
Hayward Baker:	84	16	84		136.5	
Total Manhours :	1100	282				

Owner / Contractor

HAYWARD BAKER INC.

HAYWARD BAKER, INC.

11180 E. Marginal Way S
Tukwila, WA 98168
206-223-1732

DAILY SITE REPORT

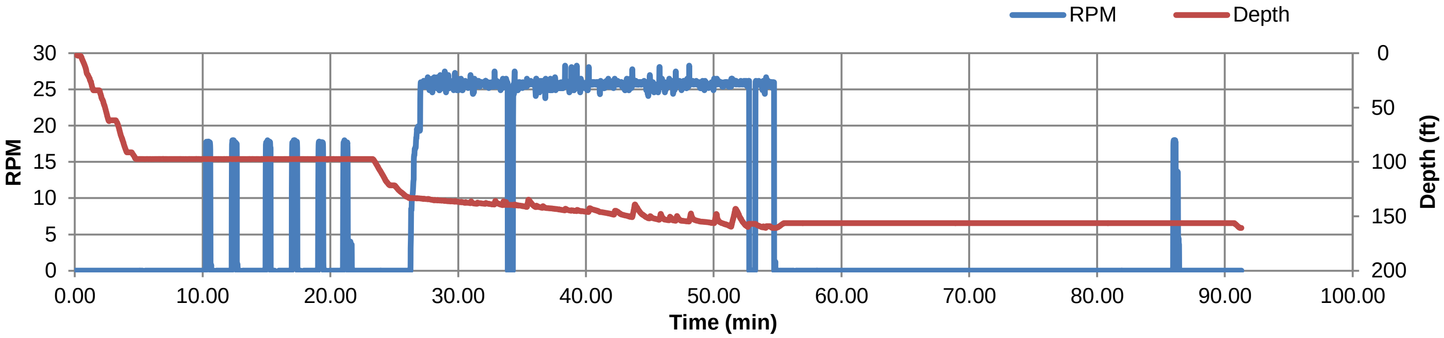
SHEET NO.	**2**	OF	**2**
SHIFT	DAY	**ONE CALL #**	0
START:	7:00 AM	**END:**	5:00 PM
DATE:	Wednesday, September 09, 2015		

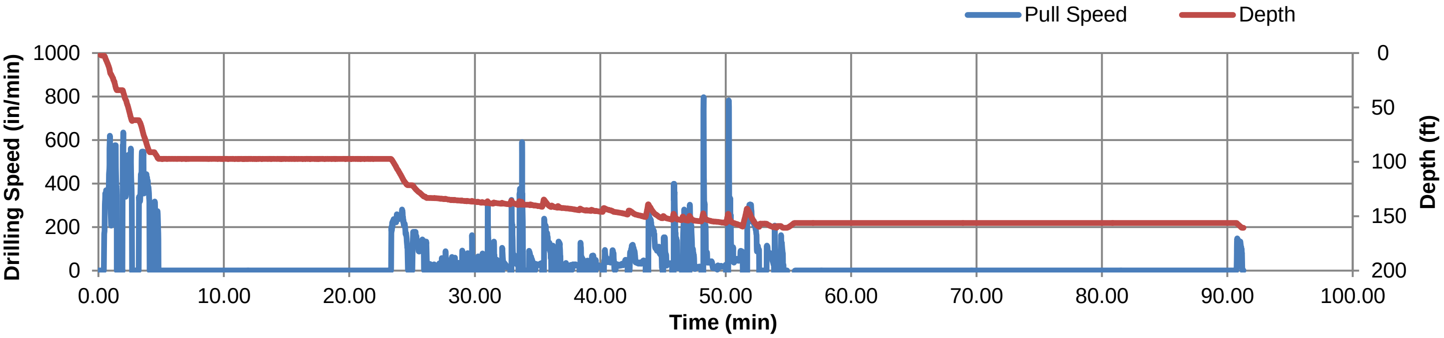
JOB NO:	860080	**LOCATION:**	Mead, WA	**TYPE OF WORK:**	Jet Grouting
PROJECT NAME:	Kaiser Mead NPL			**WEATHER:**	Sunny and hot
CLIENT:	Hydrometrics			**PROJECT MGR.**	Adam Gerondale

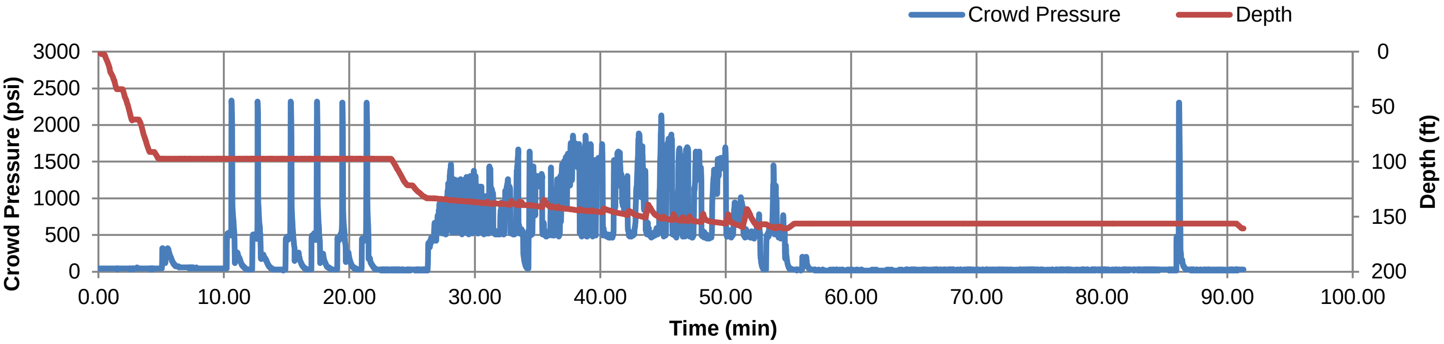
HAYWARD BAKER
Geotechnical Construction
KELLER

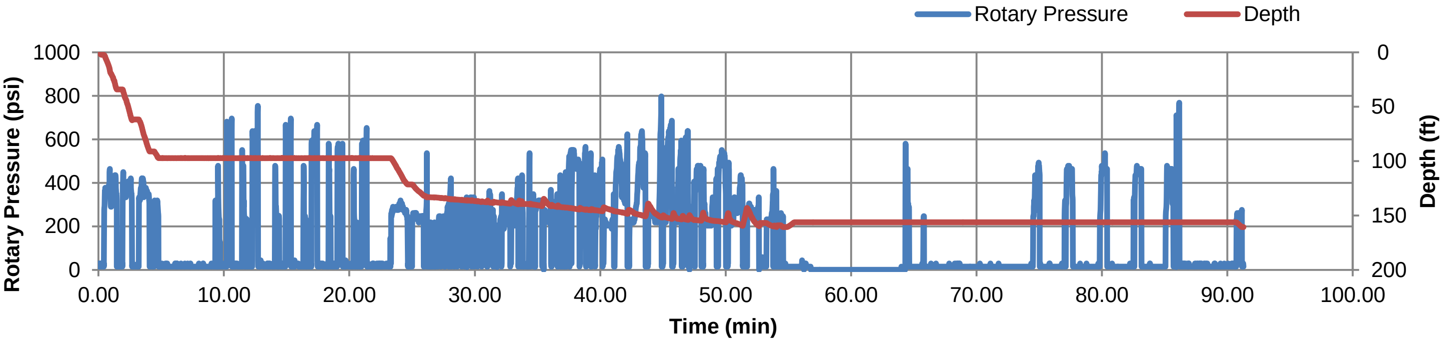
Jet Grout Drilling Report
Kaiser Mead NPL

Column Number:	HBI-7B	**Date:**	9/9/2015
Job Number:	860080	**Start Time:**	7:50 AM
Job Location:	Spokane, WA	**End Time:**	9:36 AM
Drilled Depth:	160.73 ft	**Duration:**	01:46:18
Inclination (X, Y):	(16.447 in, 5.167 in)		









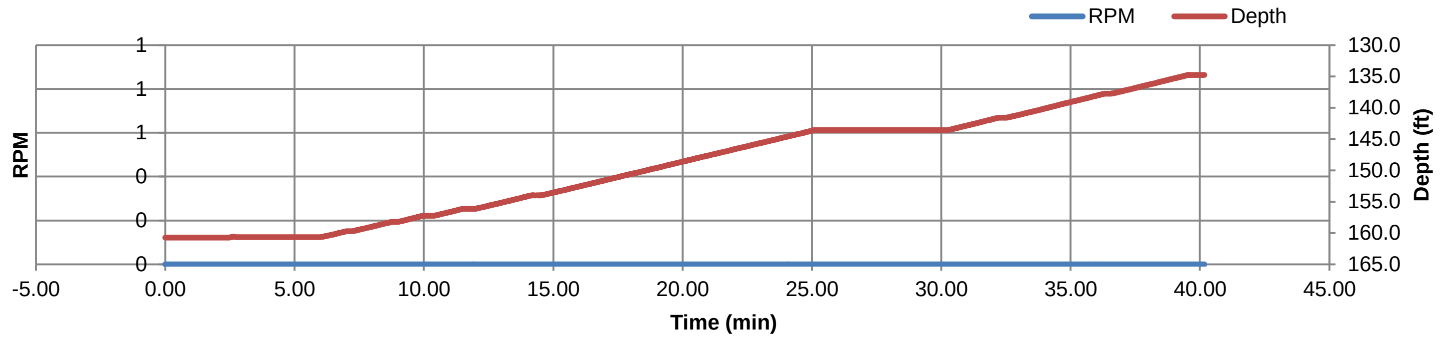
THINK SAFE

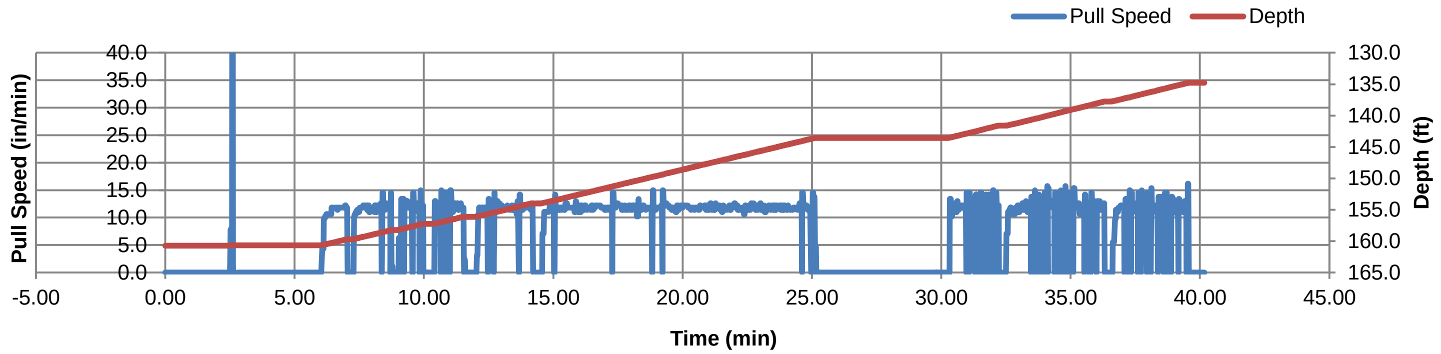
HAYWARD BAKER
Geotechnical Construction
KELLER

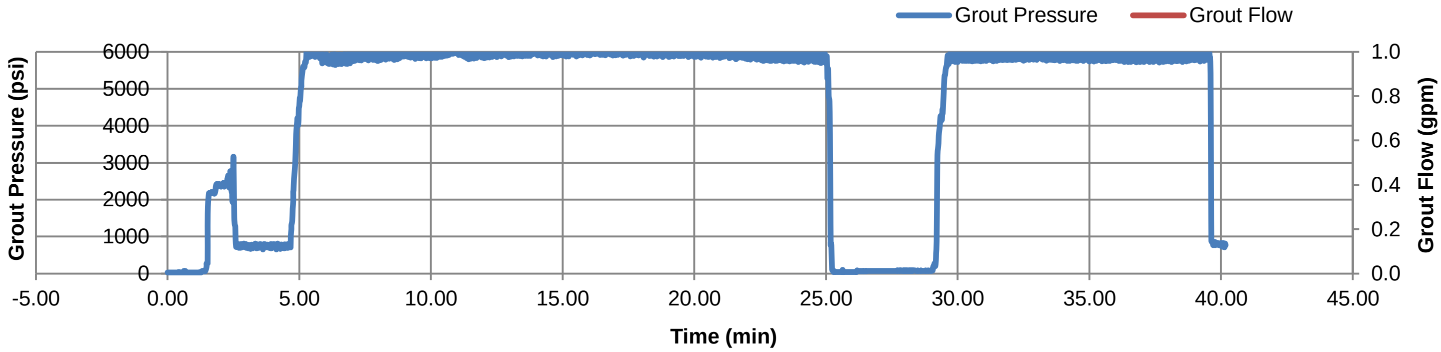
Jet Grouting Report
Kaiser Mead NPL

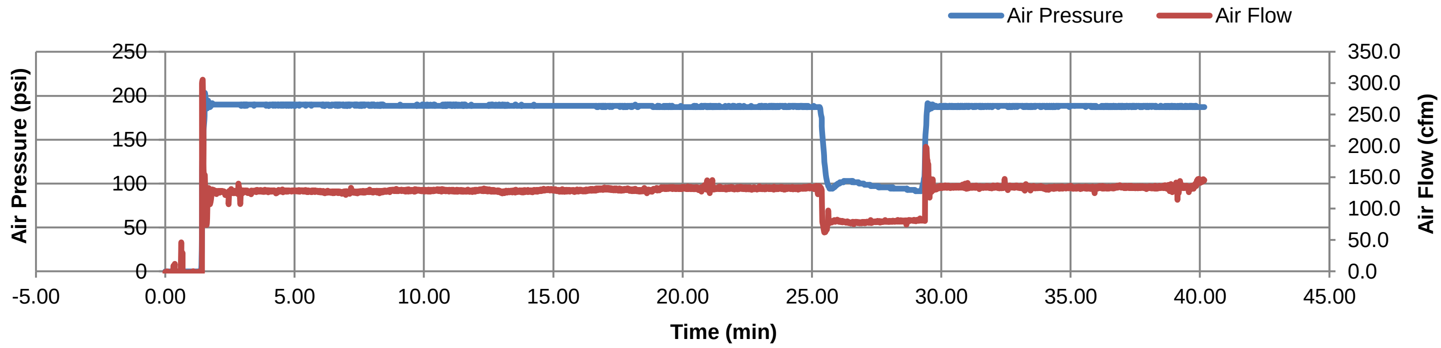
Column Number: HBI-7B
Job Number: 860080
Job Location: Spokane, WA
Total Grout Volume: 4013 gal
Treatment Length: 25.98 ft

Date: 9/9/2015
Start Time: 9:36 AM
End Time: 10:17 AM
Duration: 0:41:00
Avg. S.G.: 1.52





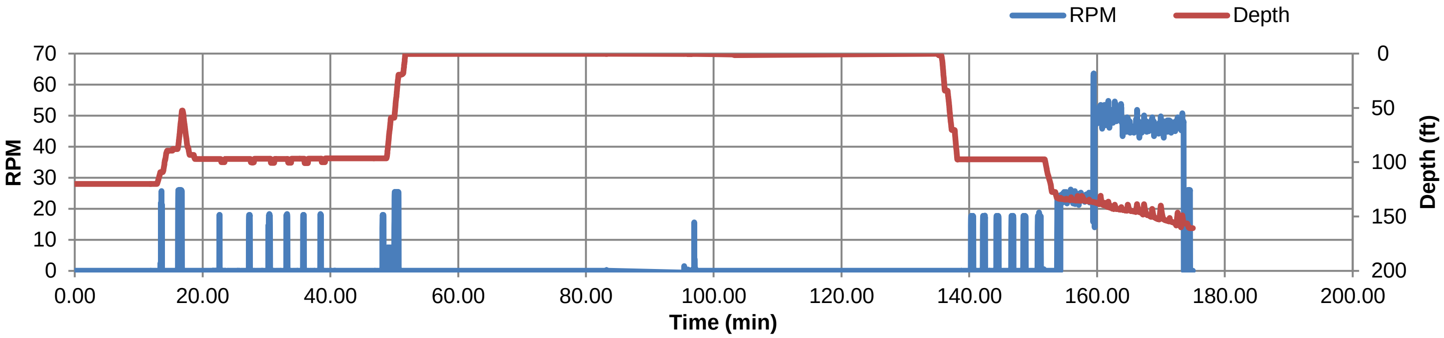


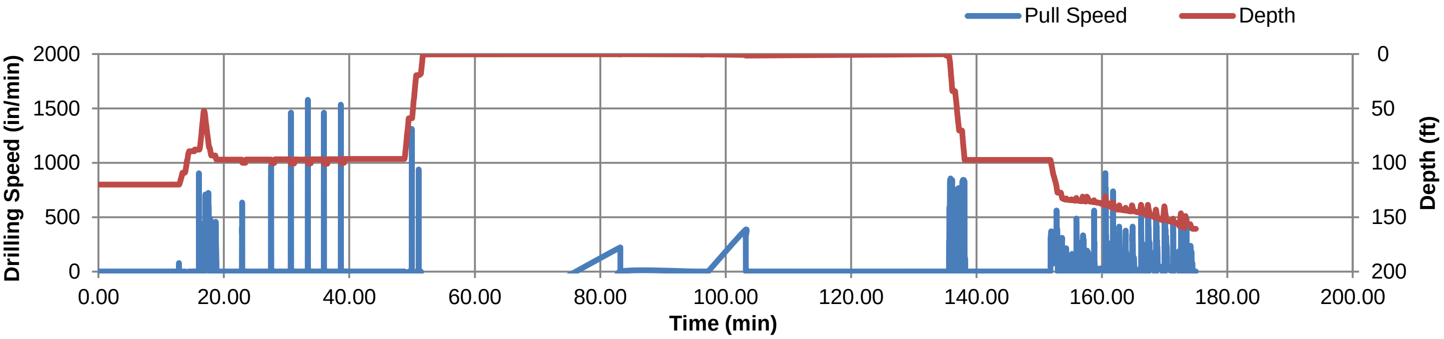


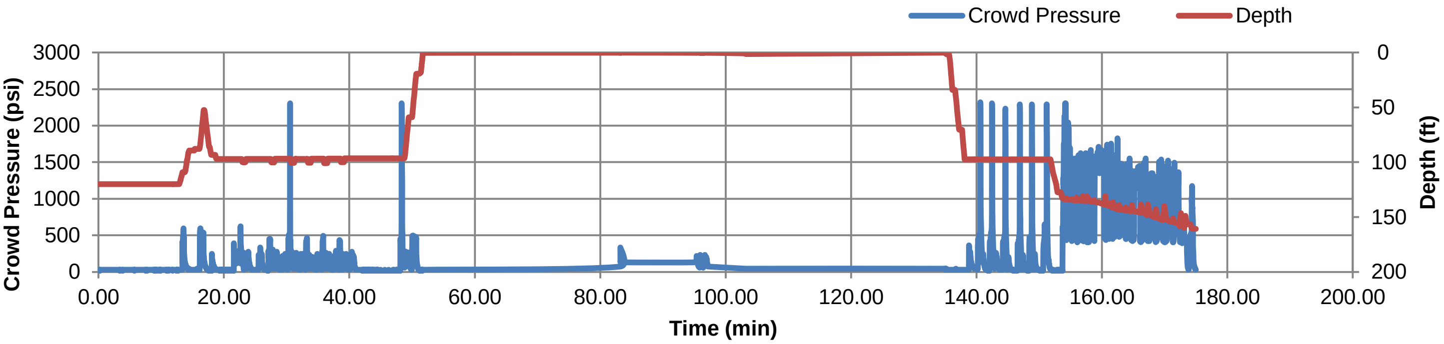
THINK SAFE

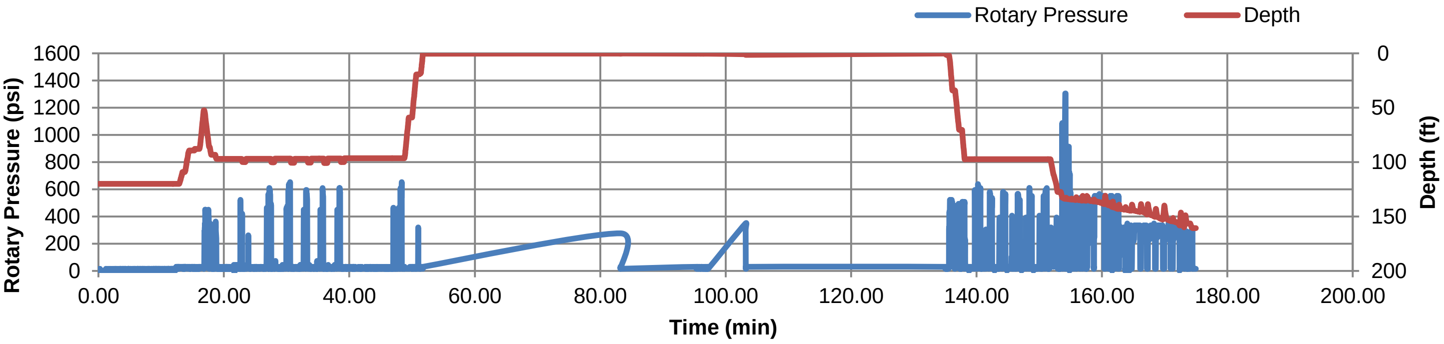
Jet Grout Drilling Report
Kaiser Mead NPL

Column Number:	HBI-7A	**Date:**	9/9/2015
Job Number:	860080	**Start Time:**	10:21 AM
Job Location:	Spokane, WA	**End Time:**	1:15 PM
Drilled Depth:	160.76 ft	**Duration:**	2:44:00
Inclination (X, Y):	(16.447 in, 5.167 in)		







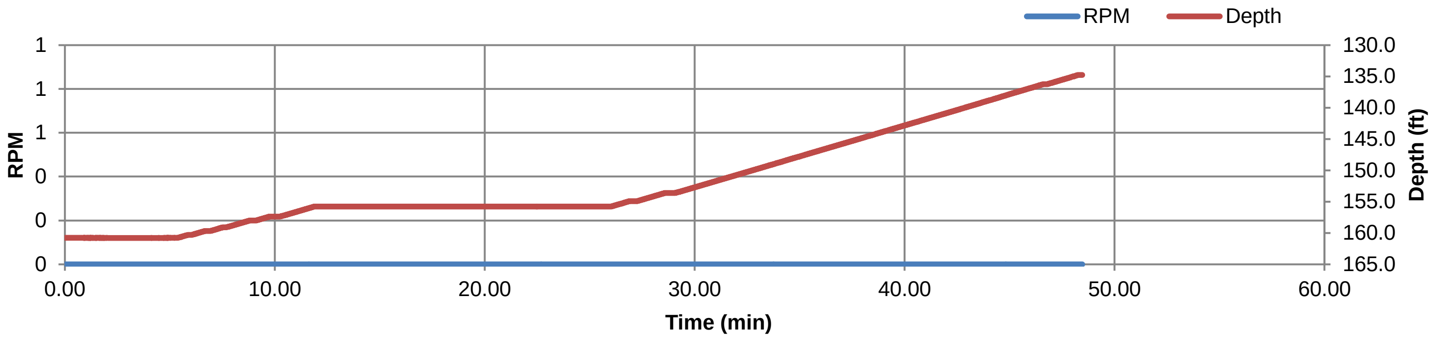


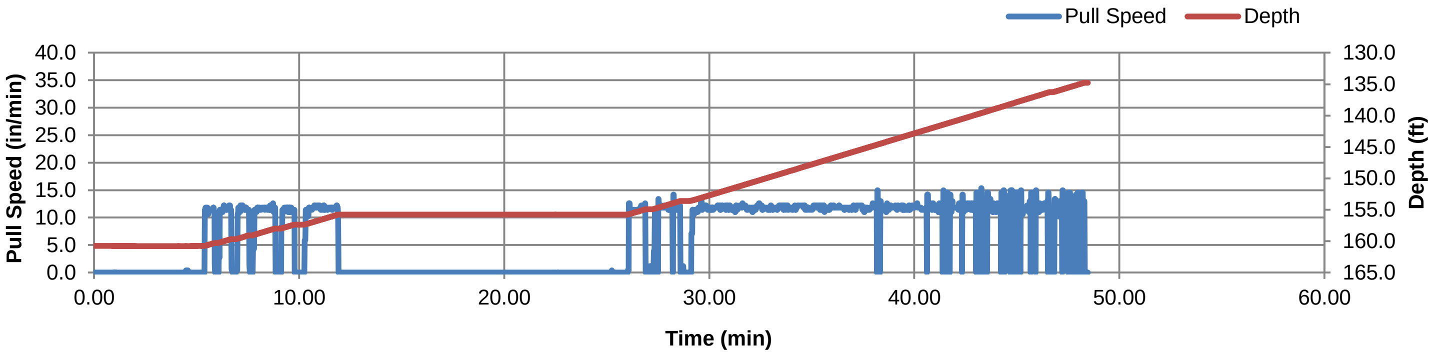
HAYWARD BAKER
Geotechnical Construction
KELLER

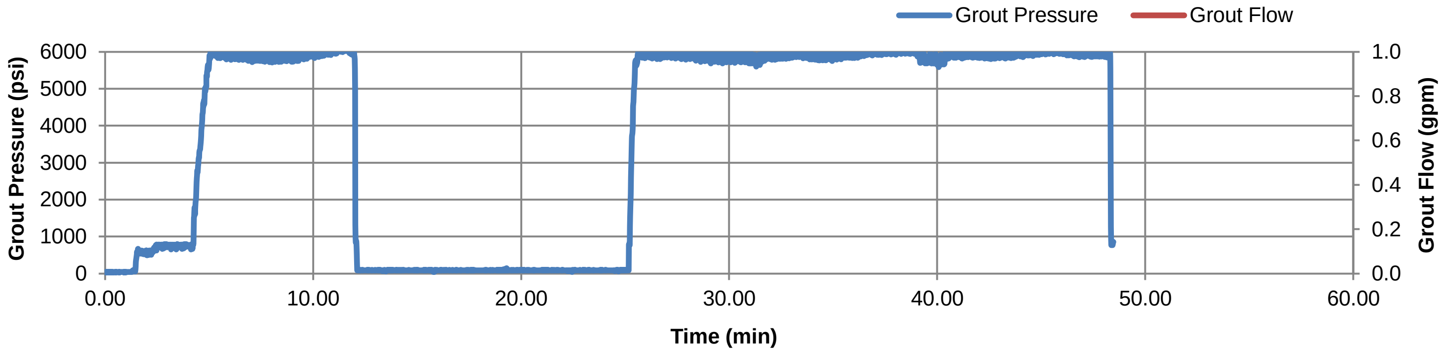
Jet Grouting Report
Kaiser Mead NPL

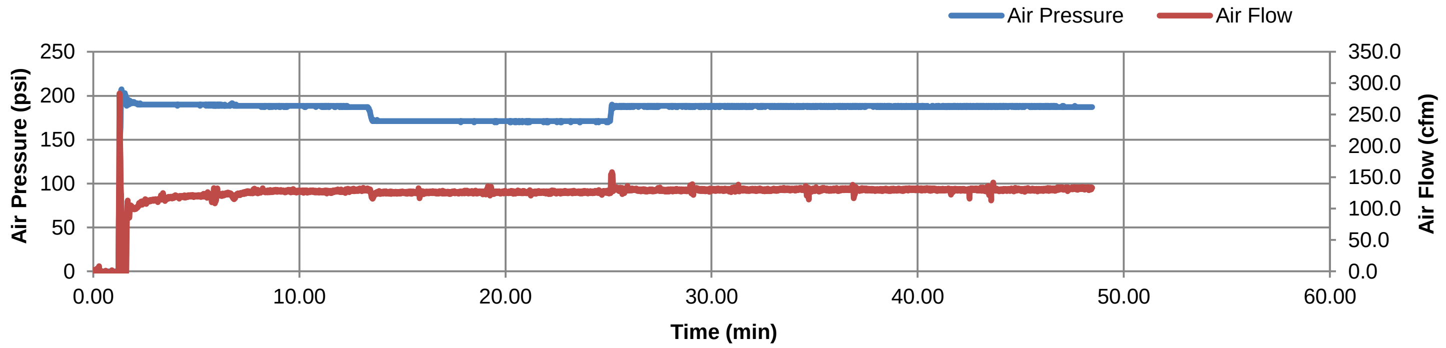
Column Number: HBI-7A
Job Number: 860080
Job Location: Spokane, WA
Total Grout Volume: 3961 gal
Treatment Length: 26.02 ft

Date: 9/9/2015
Start Time: 1:15 PM
End Time: 2:04 PM
Duration: 00:49:00
Avg. S.G.: 1.52









THINK SAFE

HAYWARD BAKER, INC.
11180 E. Marginal Way S
Tukwila, WA 98168
206-223-1732

DAILY SITE REPORT

SHEET NO.	**1**	OF	**2**
SHIFT	DAY	**ONE CALL #**	
START:	7:00 AM	**END:**	5:00 PM
DATE:	Thursday, September 10, 2015		

JOB NO:	860080	**LOCATION:**	Mead, WA	**TYPE OF WORK:**	Jet Grouting
PROJECT NAME:	Kaiser Mead NPL			**WEATHER:**	
CLIENT:	Hydrometrics			**PROJECT MGR.**	Adam Gerondale

SITE ACTIVITY

7:00 - 17:00 Jet grouted HBI-9A,B. Finished pre-drill casing on HBI-4 and part way down on HBI-5.

Panels Installed Today	2
Tot. Panels Yesterday	2
# of Panels To Date	14
% Complete	58%

MATERIAL DELIVERED

CEMENT DELIVERED (TONS):	26	TRUCKS	238066430
FUEL DELIVERED (GALLONS):	328	TRUCKS	No. 41

EQUIPMENT USED, MOVED, STANDBY

12k reach forklift, mini-ex, skid steer, Hutte Drill, 825 Hurricane, Agi tank, KB-6, D-station, 3x2 mission pump, 4x3 mission pump, 350 BBL silo
Moyno Pump, 25K genset, 185 compressor, 300k genset, 6500 gallon poly tank, 900cfm compressor, switchbox

CHANGE ORDERS, BACK CHARGES, AND EXTRA WORK

VERBAL DISCUSSIONS,DIRECTIVES OR INSTRUCTIONS

VISITORS ON-SITE

Morgan

QA/QC

Activity	Quantity	Panel ID	Comments
Jet Grout	2	HBI-9A,B	HBI-9: Deviation @ Bottom of Panel = 0.93%
Spoils Sampling	5	HBI-9A	
Other			

LABOR FORCE

QTY	TYPE
7	OPERATORS
0	LABORERS
1	MECHANICS
2	OTHER (SUPT,FIELD ENGINEER)

LENGTH OF SHIFT 10 HRS

NOTES:

MANPOWER

Position	NAME	Regular Hours	OT Hours
Superintendent	Frank Kalata	10	
Field Engineer	Taylor Cox	10	
Field Engineer	Dylan Fisher		
Mechanic	Kevin Clark	8	2
Driller	Mark Fellows	8	2
Pump Operator	Paul Thomas	8	2
Batch Plant Operator	Auggie Ruesga	8	2
Driller	Jody Welch	8	2
Operator	Shaun Henderson	8	2
Operator	Alan Krouse	8	2
Operator	Linda Currie	8	2

Man Hours

Company Name	Hrs. Today	OT Hrs. Today	Yesterday		Safe Hrs To Date:	
Hayward Baker:	84	16	84		146.5	
Total Manhours :	1184	298				

Owner / Contractor

HAYWARD BAKER INC.

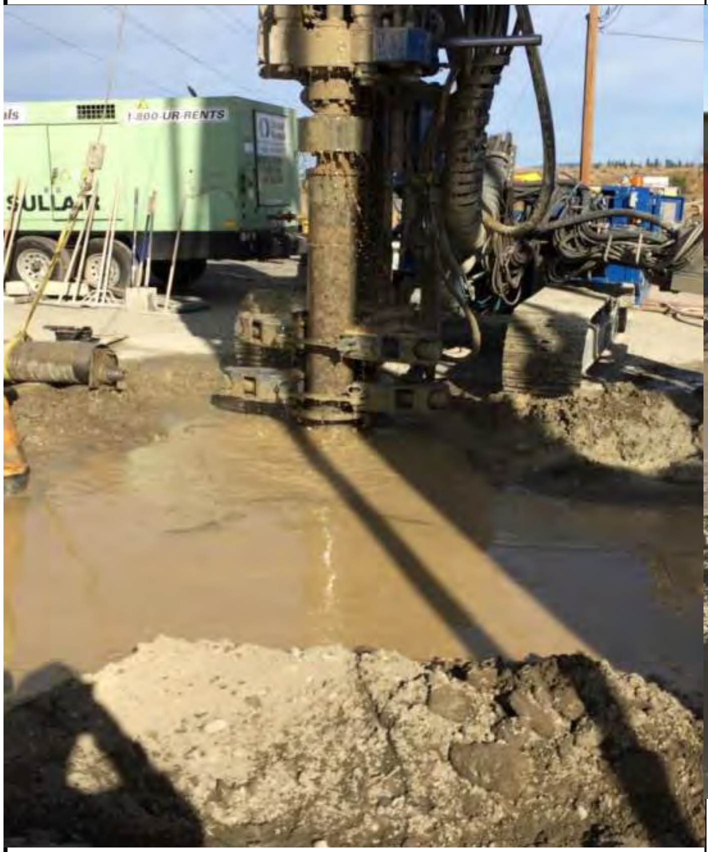
HAYWARD BAKER, INC.

11180 E. Marginal Way S
Tukwila, WA 98168
206-223-1732

DAILY SITE REPORT

SHEET NO.	**2**	OF	**2**
SHIFT	DAY	**ONE CALL #**	0
START:	7:00 AM	**END:**	5:00 PM
DATE:	Thursday, September 10, 2015		

JOB NO:	860080	**LOCATION:**	Mead, WA	**TYPE OF WORK:**	Jet Grouting
PROJECT NAME:	Kaiser Mead NPL			**WEATHER:**	Sunny and hot
CLIENT:	Hydrometrics			**PROJECT MGR.**	Adam Gerondale



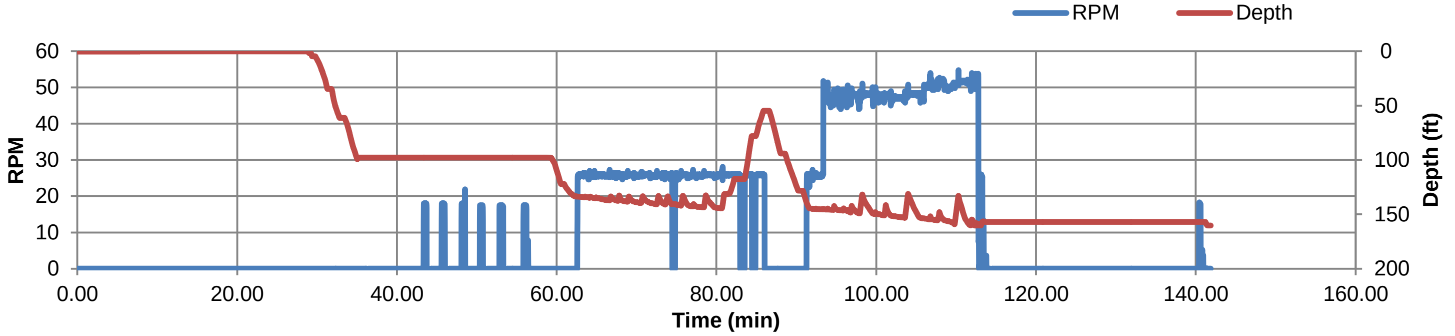
N/A

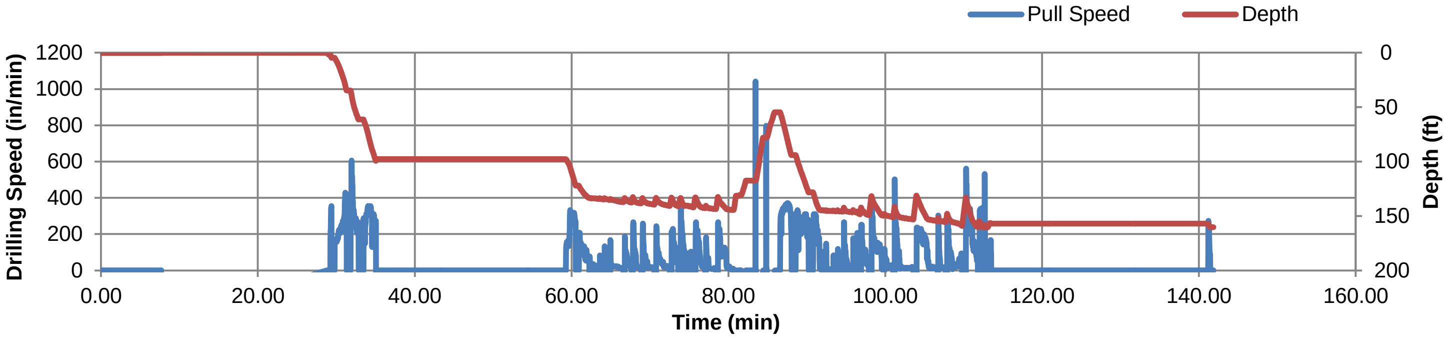
HAYWARD BAKER
Geotechnical Construction
KELLER

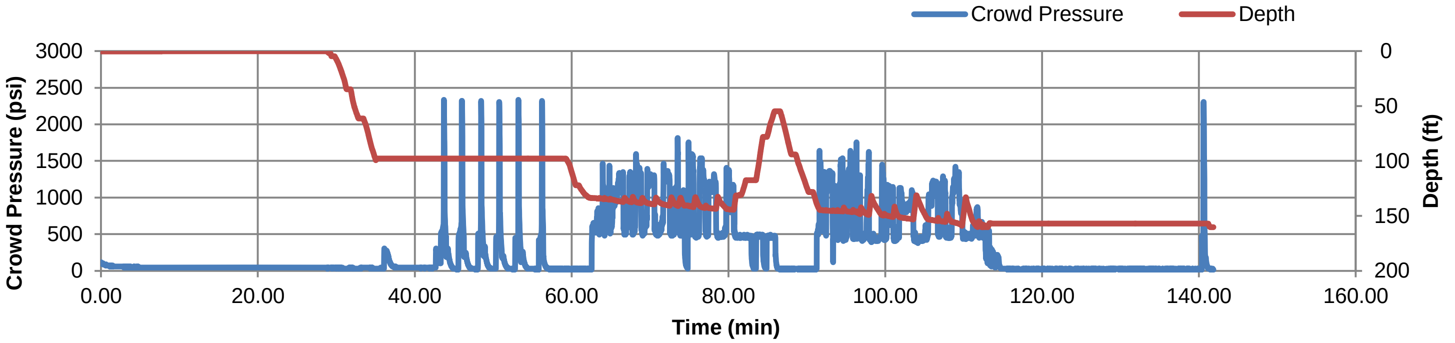
Jet Grout Drilling Report
Kaiser Mead NPL

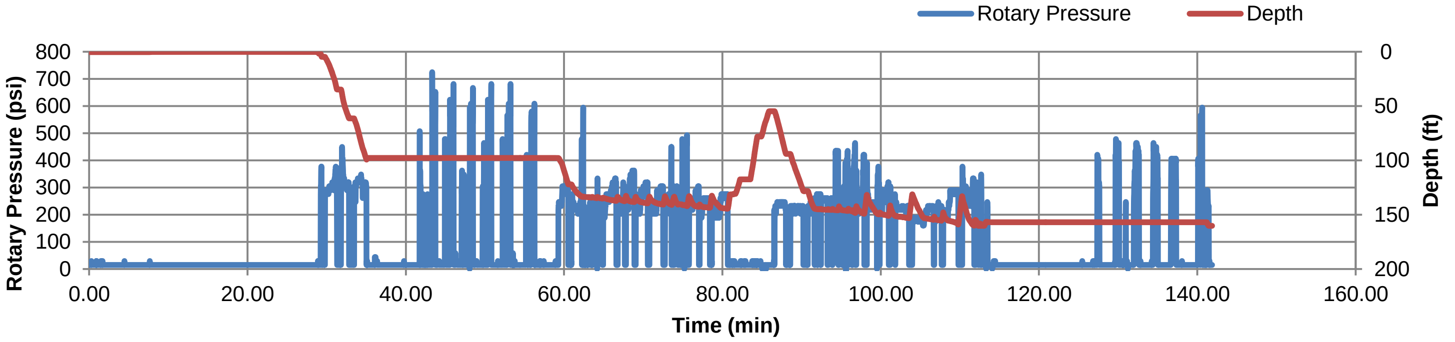
Column Number: HBI-9B
Job Number: 860080
Job Location: Spokane, WA
Drilled Depth: 160.40 ft
Inclination (X, Y): (16.447 in, 5.167 in)

Date: 9/10/2015
Start Time: 7:20 AM
End Time: 9:42 AM
Duration: 02:21:53









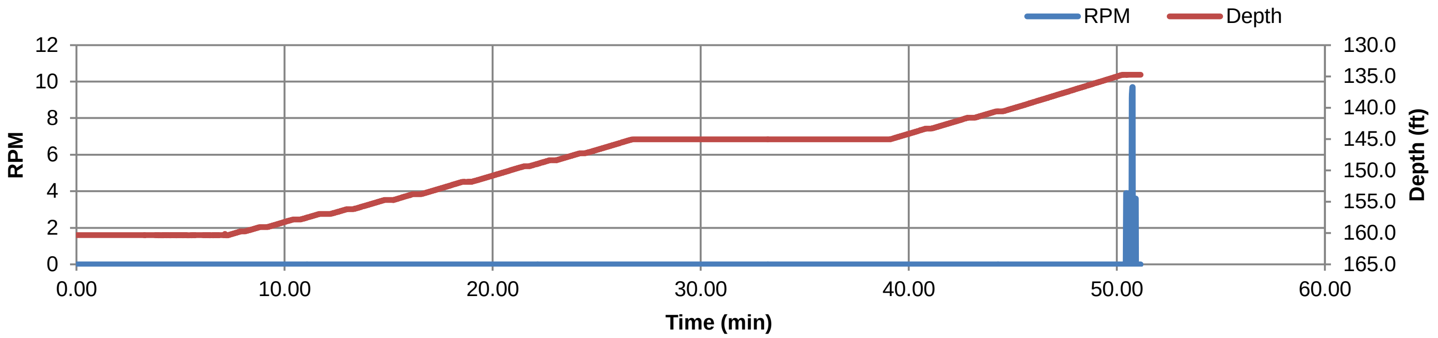
THINK SAFE

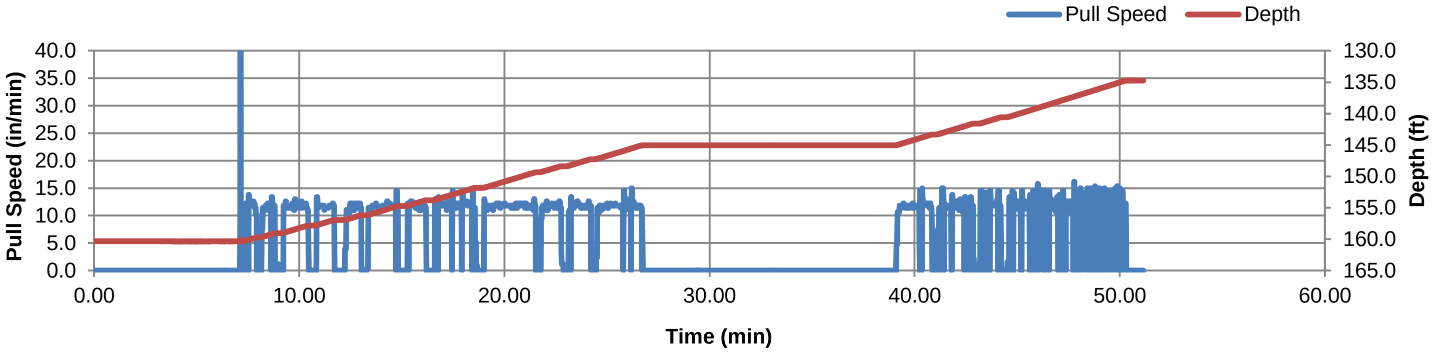
HAYWARD BAKER
Geotechnical Construction
KELLER

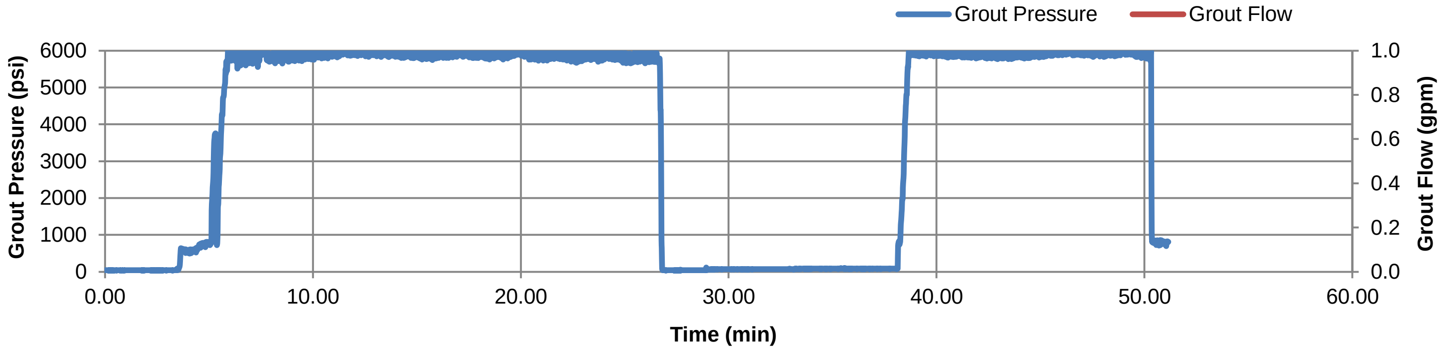
Jet Grouting Report
Kaiser Mead NPL

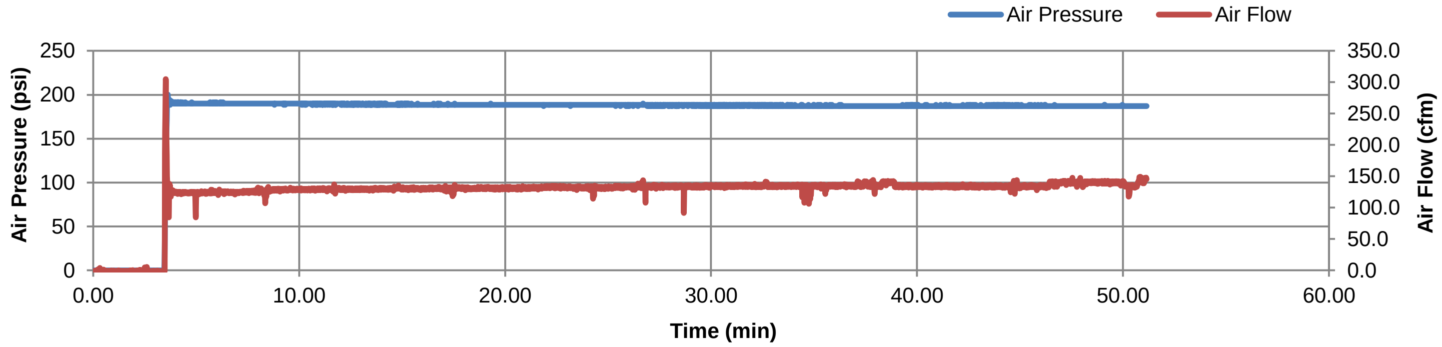
Column Number: HBI-9B
Job Number: 860080
Job Location: Spokane, WA
Total Grout Volume: 4309 gal
Treatment Length: 25.62 ft

Date: 9/10/2015
Start Time: 9:42 AM
End Time: 10:34 AM
Duration: 00:52:00
Avg. S.G.: 1.52









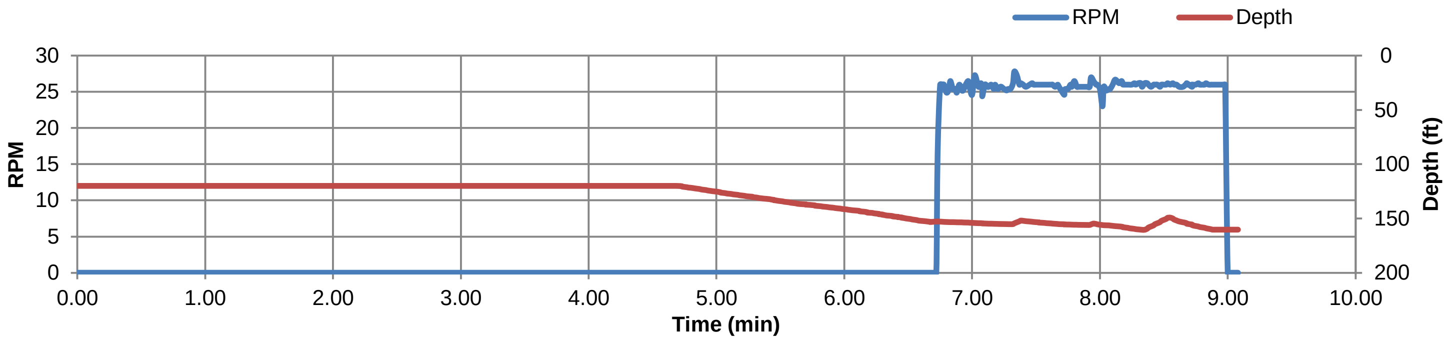
THINK SAFE

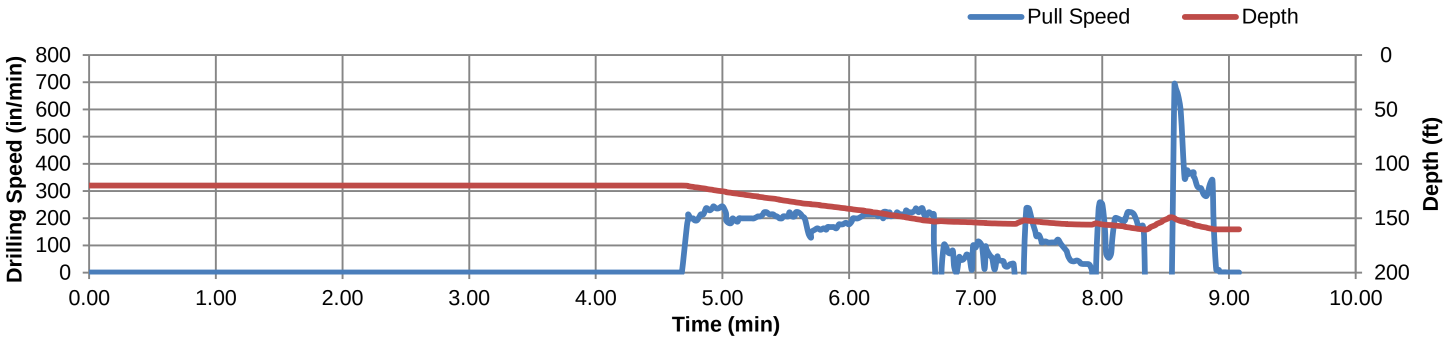
HAYWARD
BAKER
Geotechnical Construction
KELLER

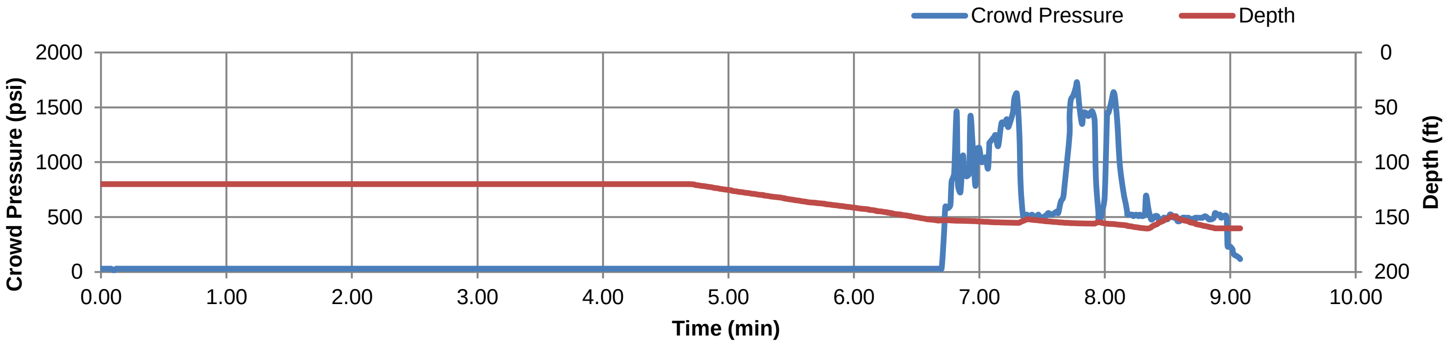
Jet Grout Drilling Report
Kaiser Mead NPL

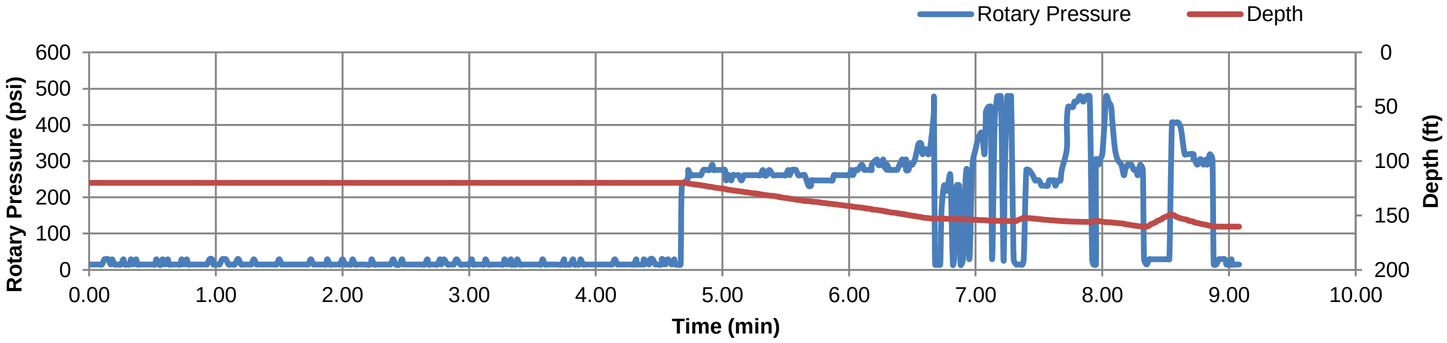
Column Number: HBI-9A
Job Number: 860080
Job Location: Spokane, WA
Drilled Depth: 160.43 ft
Inclination (X, Y): (16.447 in, 5.167 in)

Date: 9/10/2015
Start Time: 10:36 AM
End Time: 10:45 AM
Duration: 00:09:06







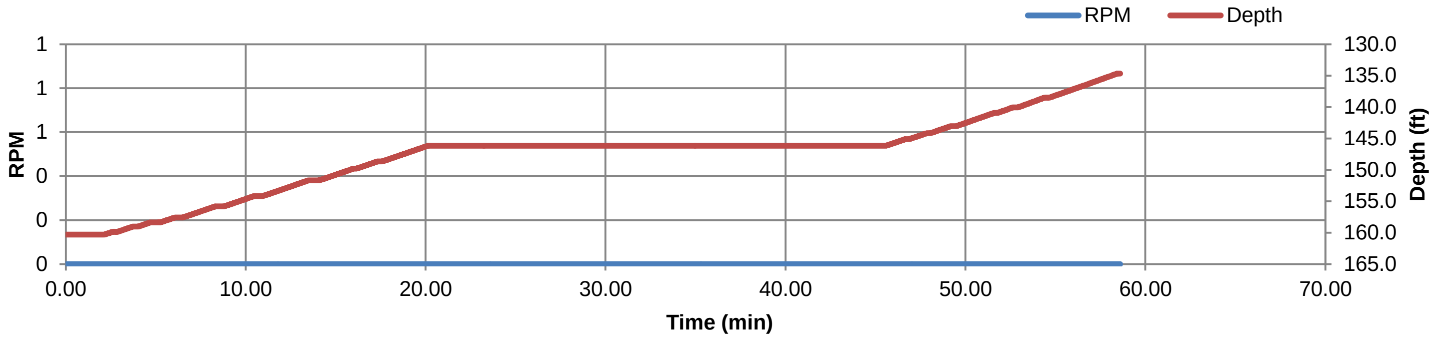


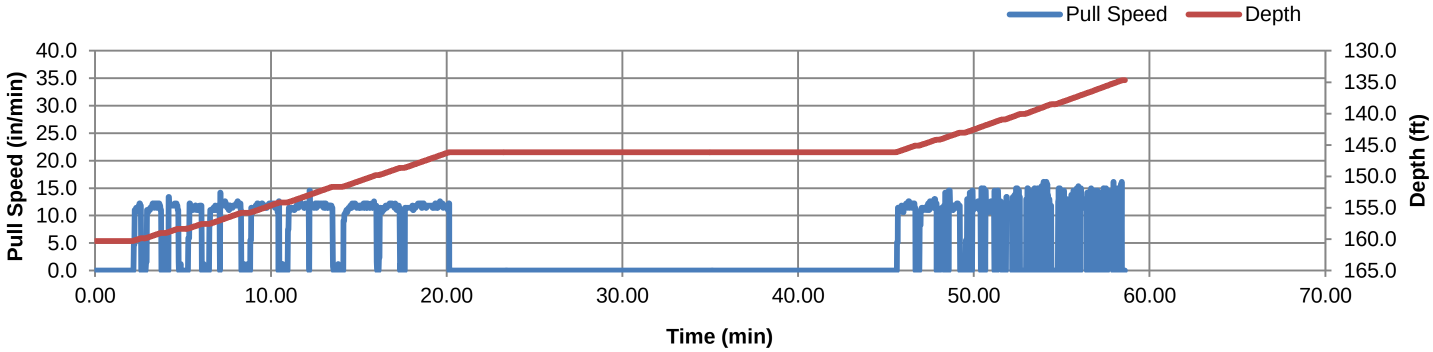
THINK SAFE

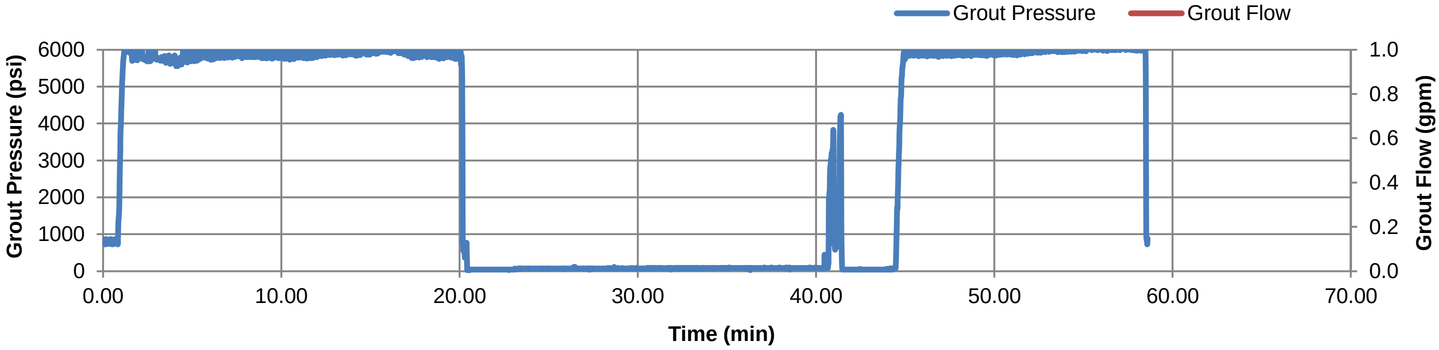
HAYWARD BAKER
Geotechnical Construction
KELLER

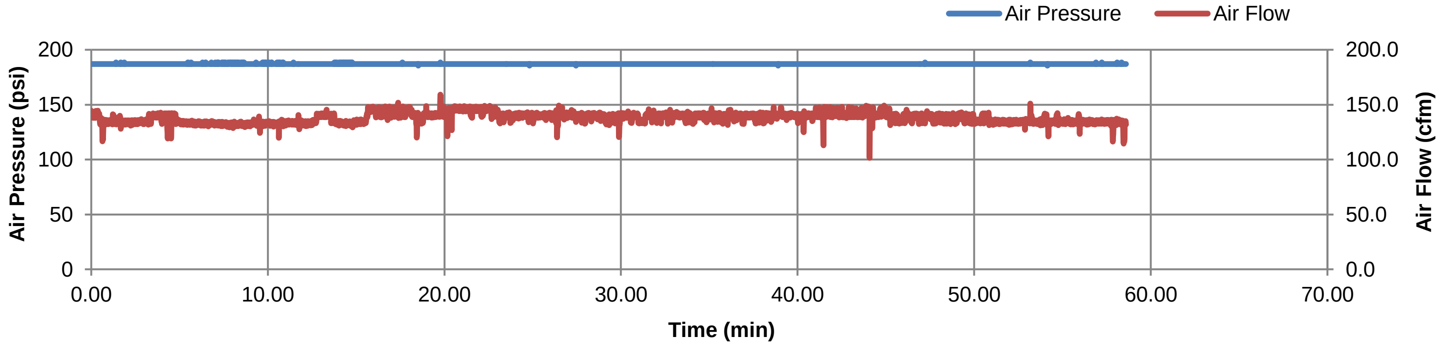
Jet Grouting Report
Kaiser Mead NPL

Column Number:	HBI-9A	**Date:**	9/10/2015
Job Number:	860080	**Start Time:**	10:45 AM
Job Location:	Spokane, WA	**End Time:**	11:44 AM
Total Grout Volume:	4367 gal	**Duration:**	00:59:44
Treatment Length:	25.62 ft	**Avg. S.G.:**	1.52









THINK SAFE

HAYWARD BAKER, INC.
11180 E. Marginal Way S
Tukwila, WA 98168
206-223-1732

DAILY SITE REPORT

SHEET NO.	1	OF	2
SHIFT	DAY	**ONE CALL #**	
START:	7:00 AM	**END:**	6:00 PM
DATE:	Friday, September 11, 2015		

JOB NO:	860080	**LOCATION:**	Mead, WA	**TYPE OF WORK:**	Jet Grouting
PROJECT NAME:	Kaiser Mead NPL			**WEATHER:**	
CLIENT:	Hydrometrics			**PROJECT MGR.**	Adam Gerondale

SITE ACTIVITY

7:00 - 17:00 Jet grouted HBI-11A,B and HBI-2A,B. Pre-drilled casing on HBI-5 and HBI-8.

Panels Installed Today	4
Tot. Panels Yesterday	2
# of Panels To Date	18
% Complete	75%

MATERIAL DELIVERED

CEMENT DELIVERED (TONS):	34	TRUCKS	
FUEL DELIVERED (GALLONS):	107	TRUCKS	No. 35

EQUIPMENT USED, MOVED, STANDBY

12k reach forklift, mini-ex, skid steer, Hutte Drill, 825 Hurricane, Agi tank, KB-6, D-station, 3x2 mission pump, 4x3 mission pump, 350 BBL silo
Moyno Pump, 25K genset, 185 compressor, 300k genset, 6500 gallon poly tank, 900cfm compressor, switchbox

CHANGE ORDERS, BACK CHARGES, AND EXTRA WORK

VERBAL DISCUSSIONS,DIRECTIVES OR INSTRUCTIONS

VISITORS ON-SITE

Morgan, Tony

QA/QC

Activity	Quantity	Panel ID	Comments
Jet Grout	4	HBI-11A,B & HBI-2A,B	Deviation @ Bottom of Panel: HBI-11 = 0.62%; HBI-2 = 1.49%
Spoils Sampling	10	HBI-11B, HBI-2B	HBI-11B: 5 samples, HBI-2B: 5 samples
Other			

LABOR FORCE

QTY	TYPE
7	OPERATORS
0	LABORERS
1	MECHANICS
2	OTHER (SUPT,FIELD ENGINEER)

LENGTH OF SHIFT 10 HRS

NOTES:

MANPOWER

Position	NAME	Regular Hours	OT Hours
Superintendent	Frank Kalata	10	
Field Engineer	Taylor Cox	10	
Field Engineer	Dylan Fisher		
Mechanic	Kevin Clark	8	3
Driller	Mark Fellows	8	3
Pump Operator	Paul Thomas	8	3
Batch Plant Operator	Auggie Ruesga	8	3
Driller	Jody Welch	8	3
Operator	Shaun Henderson	8	3
Operator	Alan Krouse	8	3
Operator	Linda Currie	8	3

Man Hours

Company Name	Hrs. Today	OT Hrs. Today	Yesterday		Safe Hrs To Date:	
Hayward Baker:	84	24	84		156.5	
Total Manhours :	1268	322				

Owner / Contractor

HAYWARD BAKER INC.

HAYWARD BAKER, INC.

11180 E. Marginal Way S
Tukwila, WA 98168
206-223-1732

DAILY SITE REPORT

SHEET NO.	2	OF	2
SHIFT	DAY	**ONE CALL #**	0
START:	7:00 AM	**END:**	6:00 PM
DATE:	Friday, September 11, 2015		

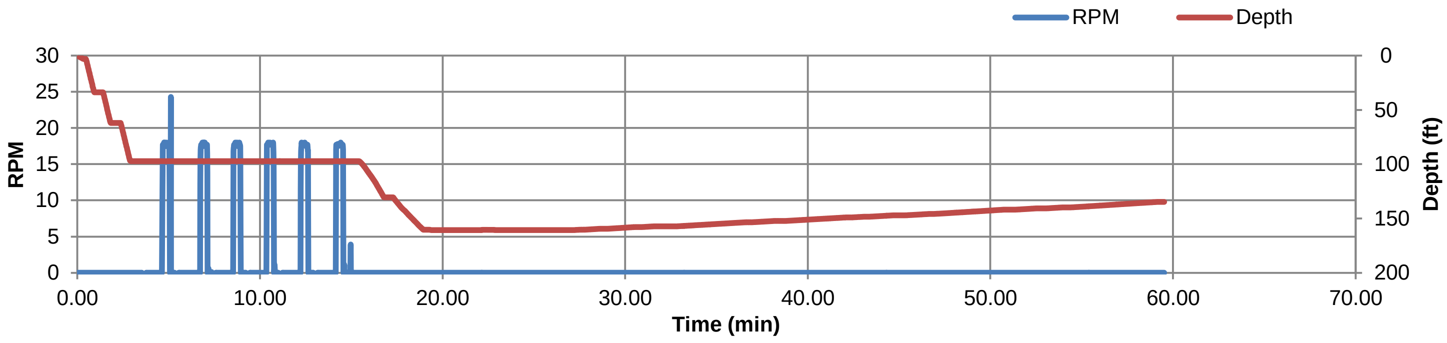
JOB NO:	860080	**LOCATION:**	Mead, WA	**TYPE OF WORK:**	Jet Grouting
PROJECT NAME:	Kaiser Mead NPL			**WEATHER:**	Sunny and hot
CLIENT:	Hydrometrics			**PROJECT MGR.**	Adam Gerondale

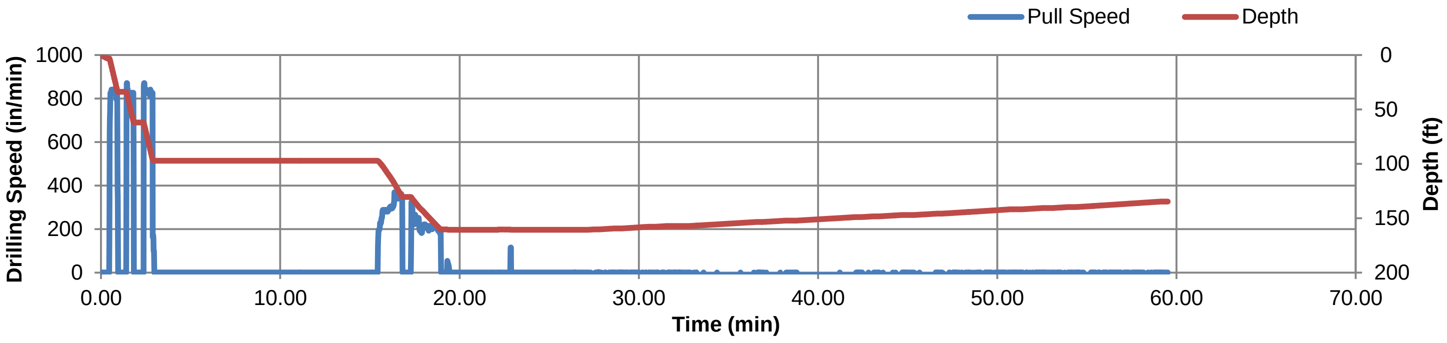
N/A

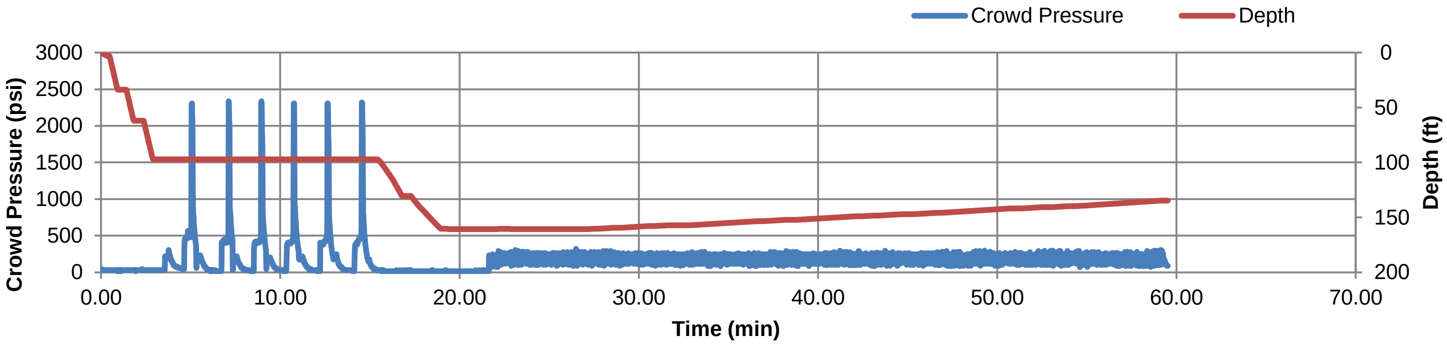
Jet Grout Drilling Report
Kaiser Mead NPL

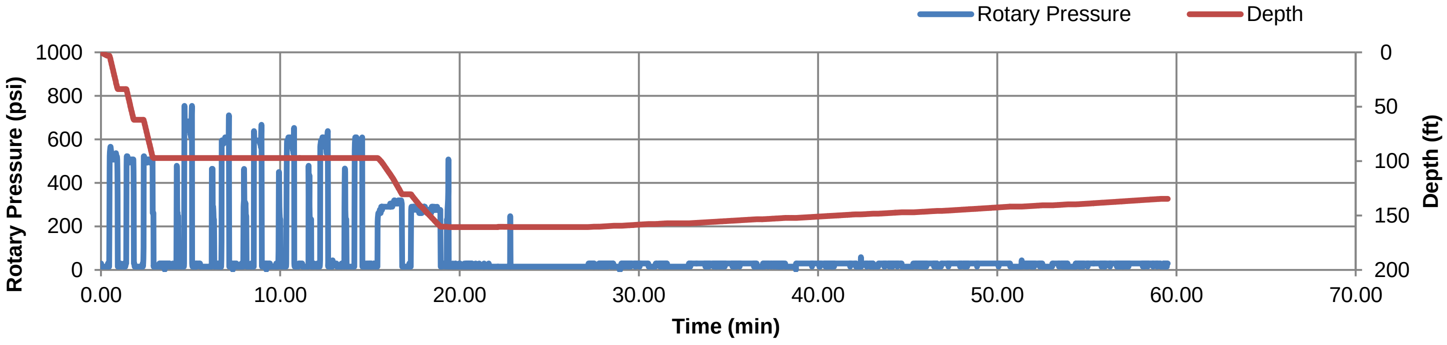
Column Number: HBI-11B
Job Number: 860080
Job Location: Spokane, WA
Drilled Depth: 160.73 ft
Inclination (X, Y): (11.295 in, 0.280 in)

Date: 9/11/2015
Start Time: 8:08 AM
End Time: 8:54 AM
Duration: 00:46:00



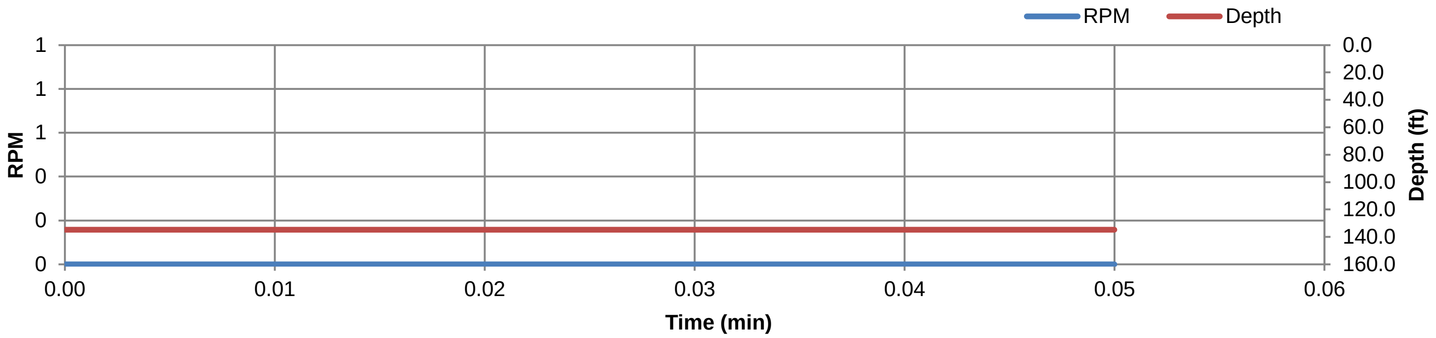


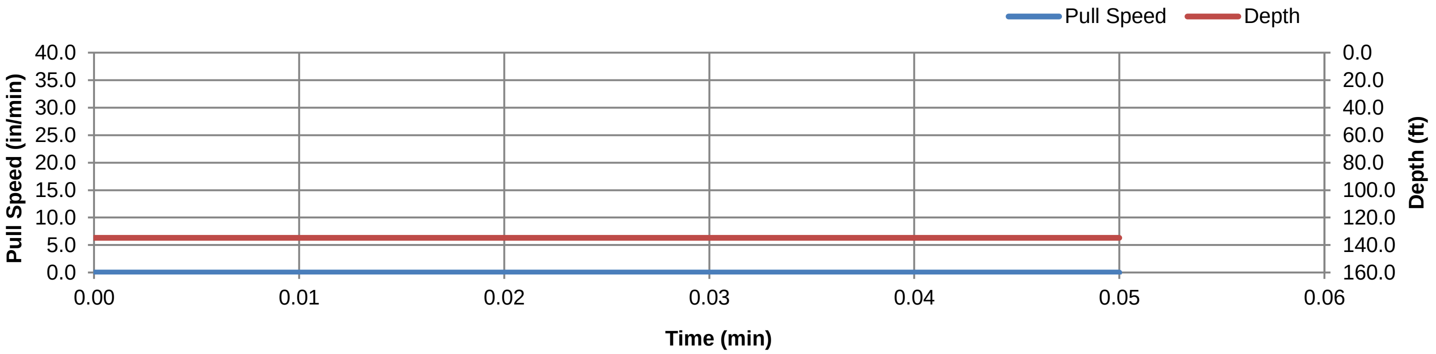


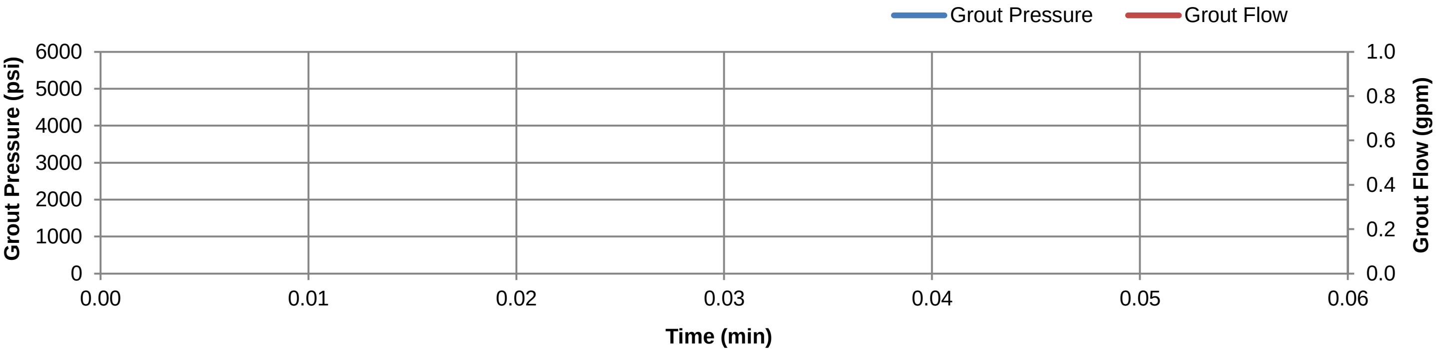


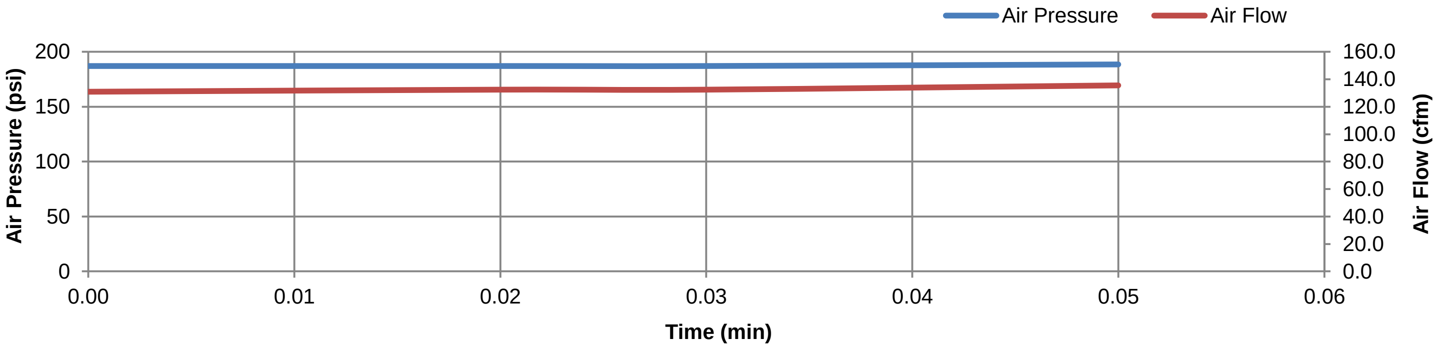
Jet Grouting Report
Kaiser Mead NPL

Column Number:	HBI-11B	**Date:**	9/11/2015
Job Number:	860080	**Start Time:**	8:54 AM
Job Location:	Spokane, WA	**End Time:**	9:34 AM
Total Grout Volume:	4522 gal	**Duration:**	00:40:00
Treatment Length:	25.91 ft	**Avg. S.G.:**	1.52







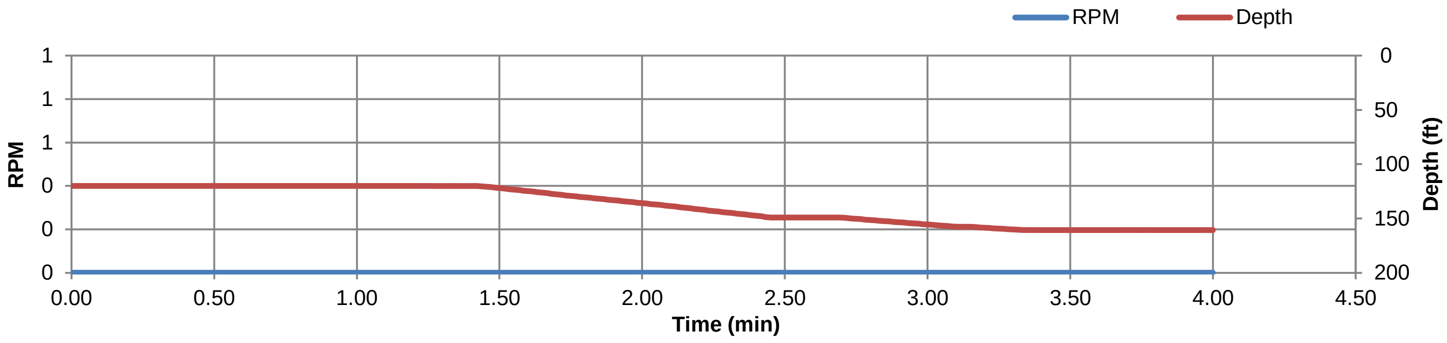


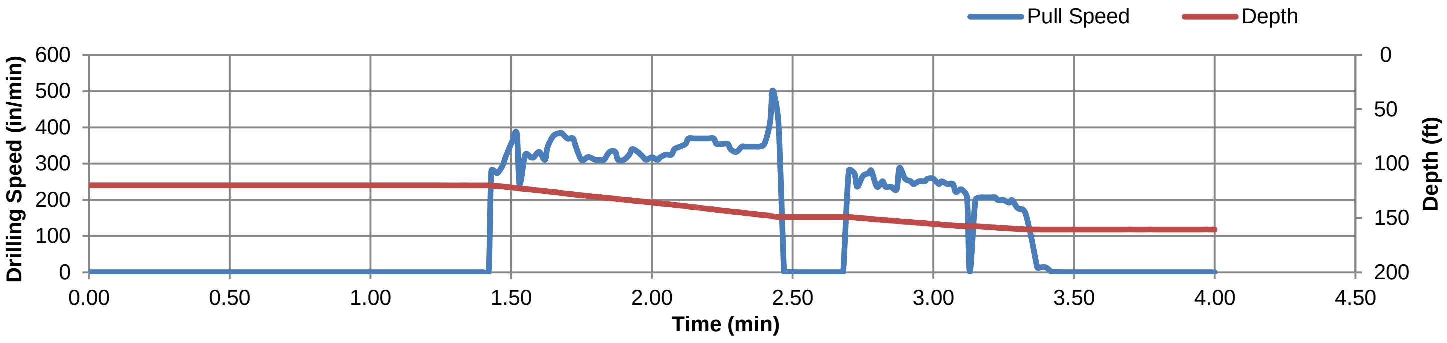
HAYWARD BAKER
Geotechnical Construction
KELLER

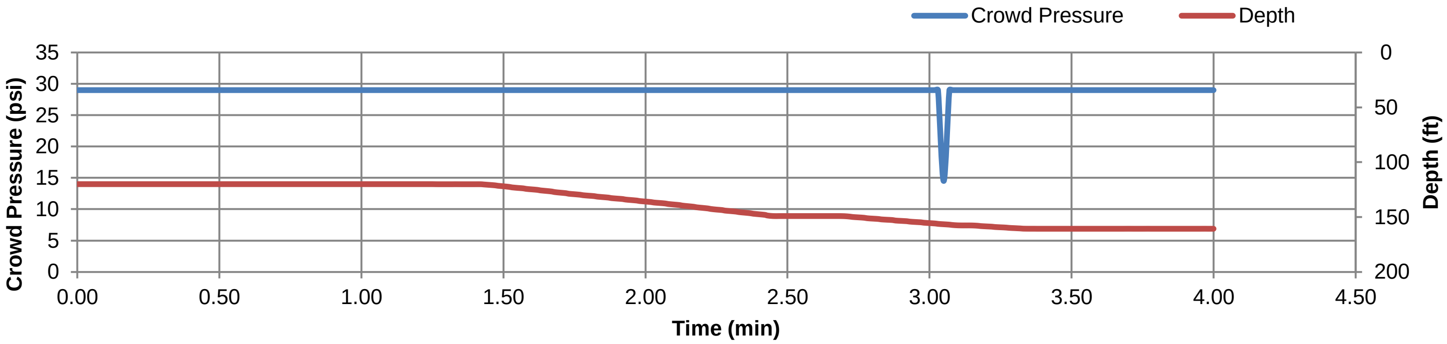
Jet Grout Drilling Report
Kaiser Mead NPL

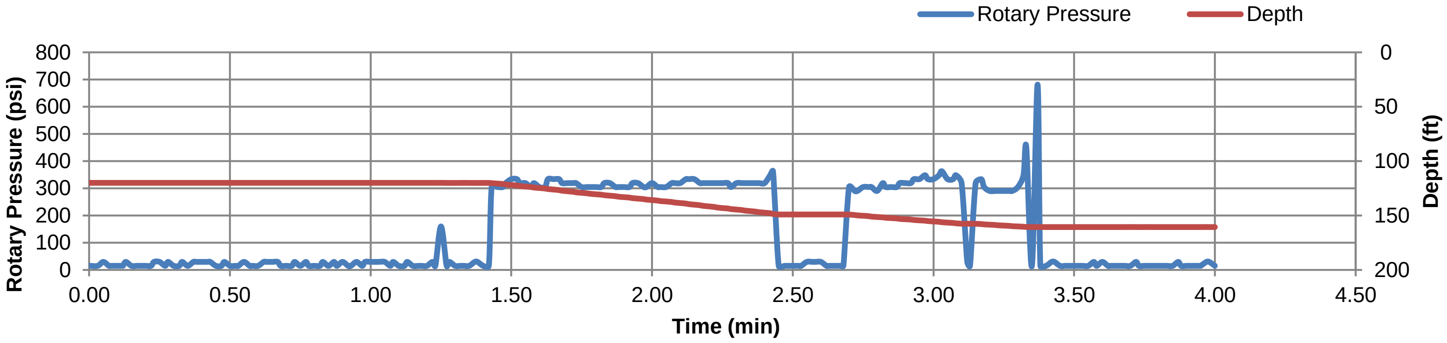
Column Number: HBI-11A
Job Number: 860080
Job Location: Spokane, WA
Drilled Depth: 160.69 ft
Inclination (X, Y): (11.295 in, 0.280 in)

Date: 9/11/2015
Start Time: 9:37 AM
End Time: 9:41 AM
Duration: 00:04:00









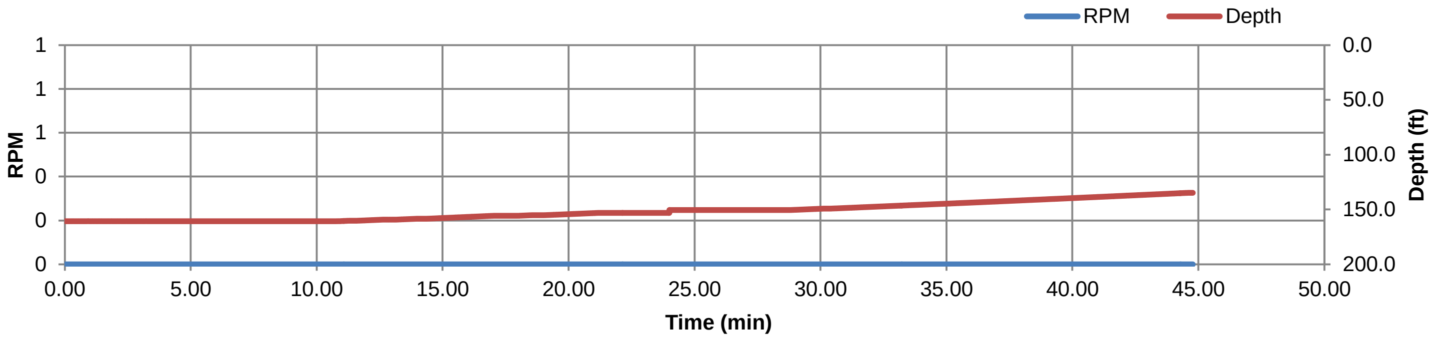
THINK SAFE

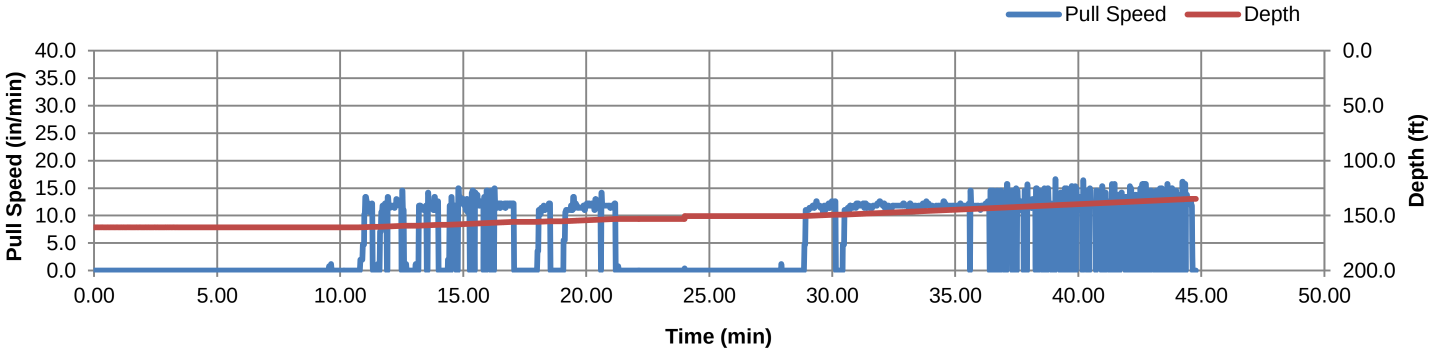
HAYWARD
BAKER
Geotechnical Construction
KELLER

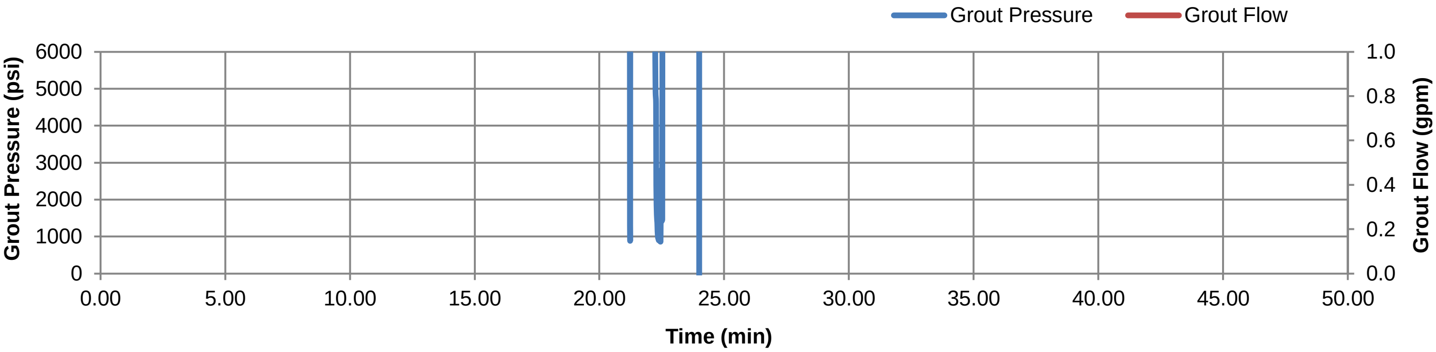
Jet Grouting Report
Kaiser Mead NPL

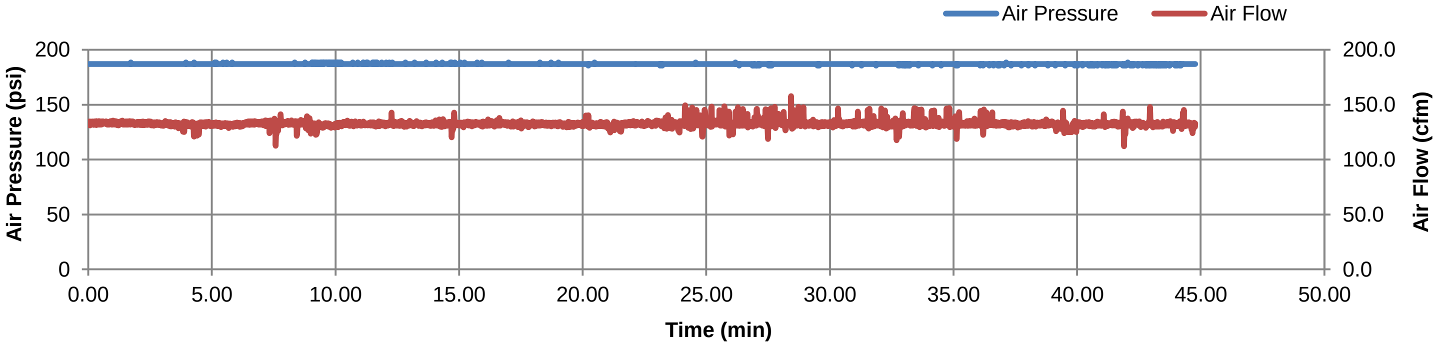
Column Number: HBI-11A
Job Number: 860080
Job Location: Spokane, WA
Total Grout Volume: 4188
Treatment Length: 25.92 ft

Date: 9/11/2015
Start Time: 9:41 AM
End Time: 10:53 AM
Duration: 01:12:00
Avg. S.G.: 1.52









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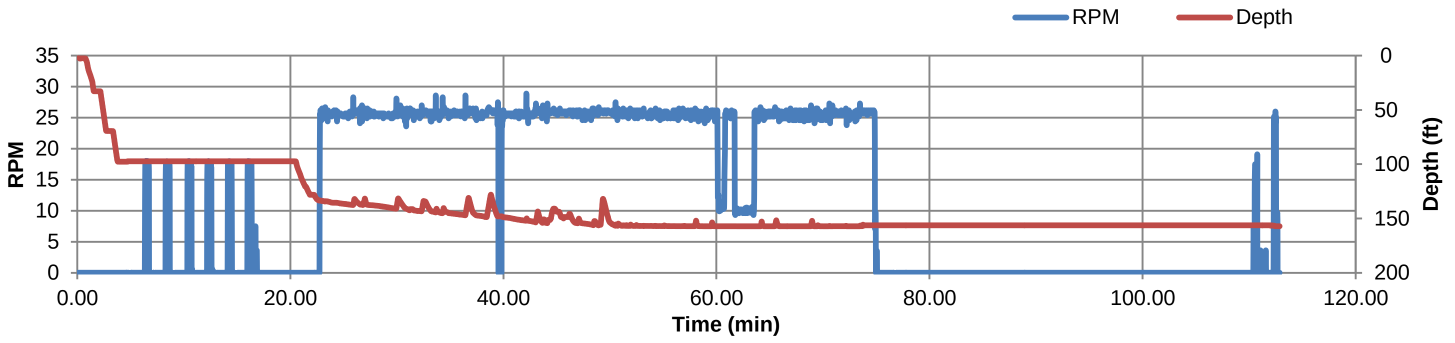
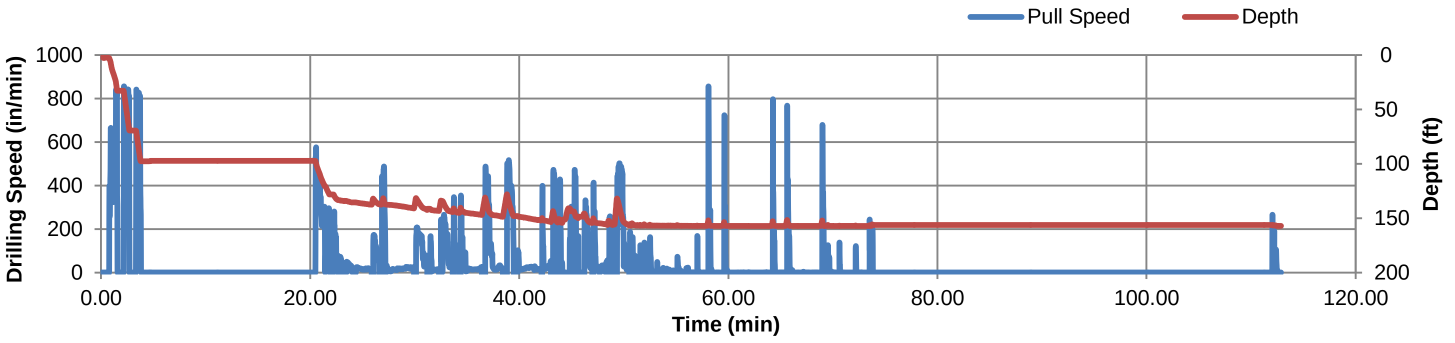
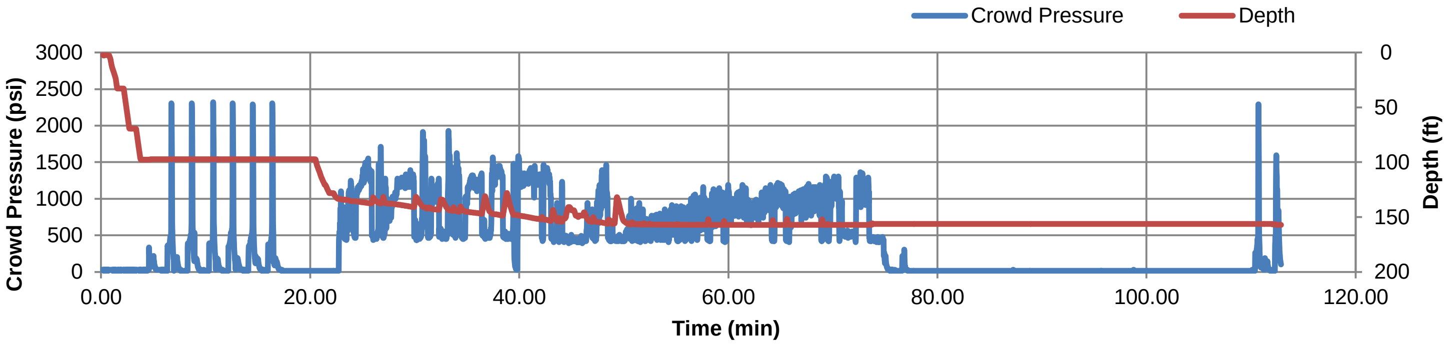
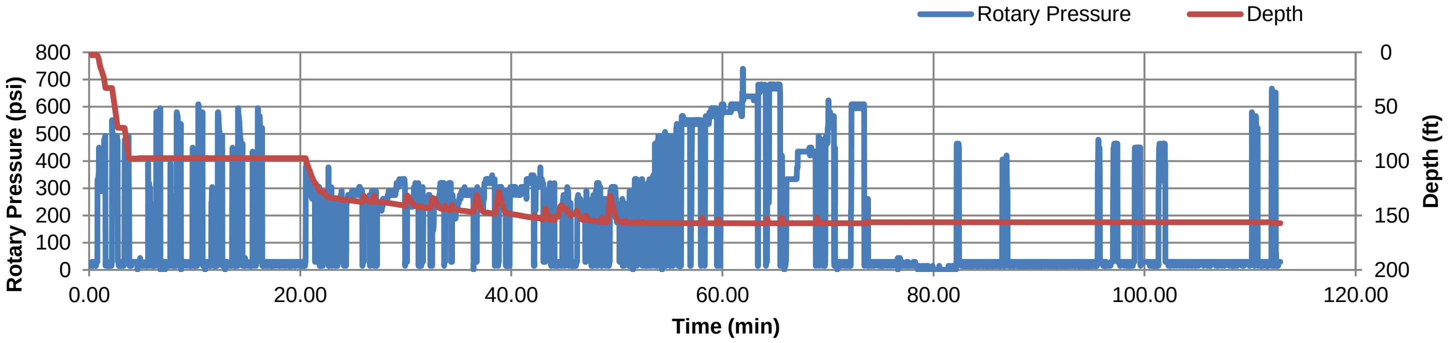
Jet Grout Drilling Report
Kaiser Mead NPL

Column Number:	HBI-2B	**Date:**	9/11/2015
Job Number:	860080	**Start Time:**	12:07 PM
Job Location:	Spokane, WA	**End Time:**	2:22 PM
Drilled Depth:	157.18 ft	**Duration:**	02:14:45
Inclination (X, Y):	(23.860 in, 13.973 in)		





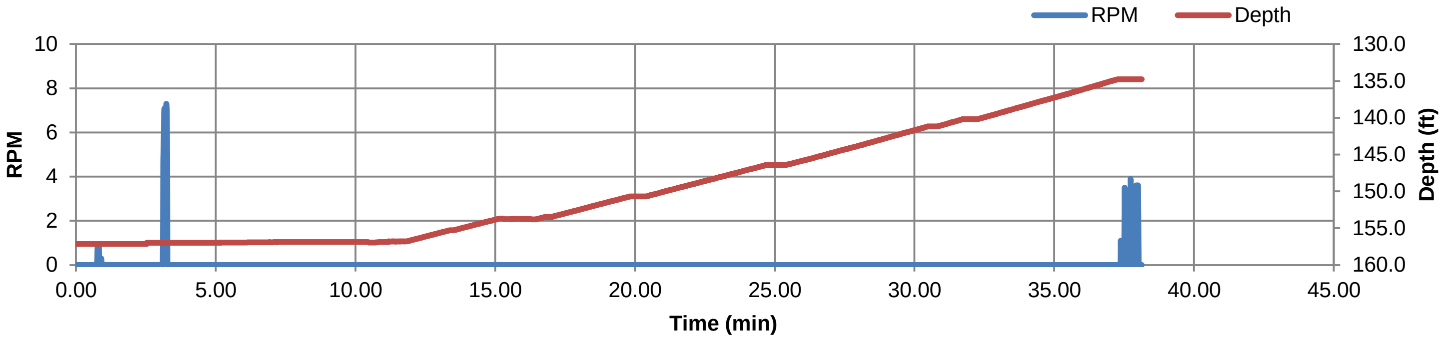


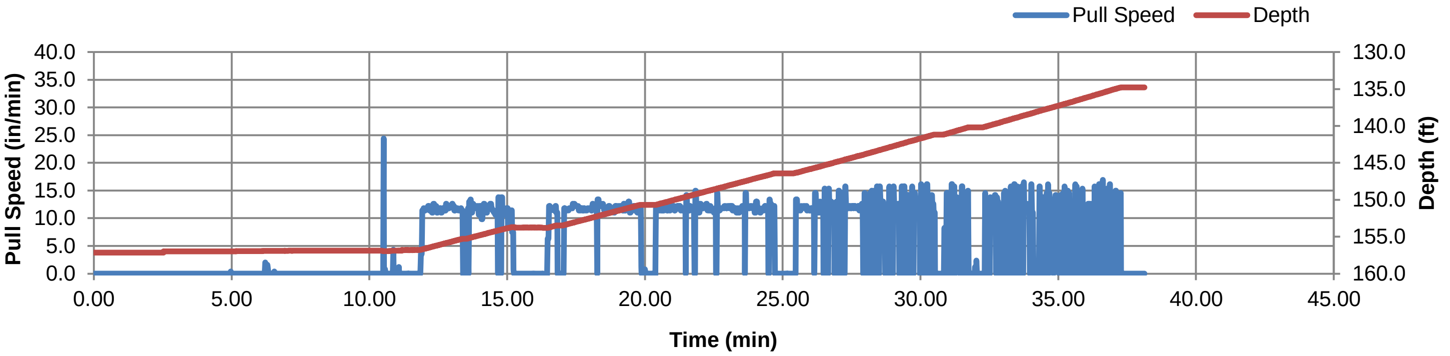


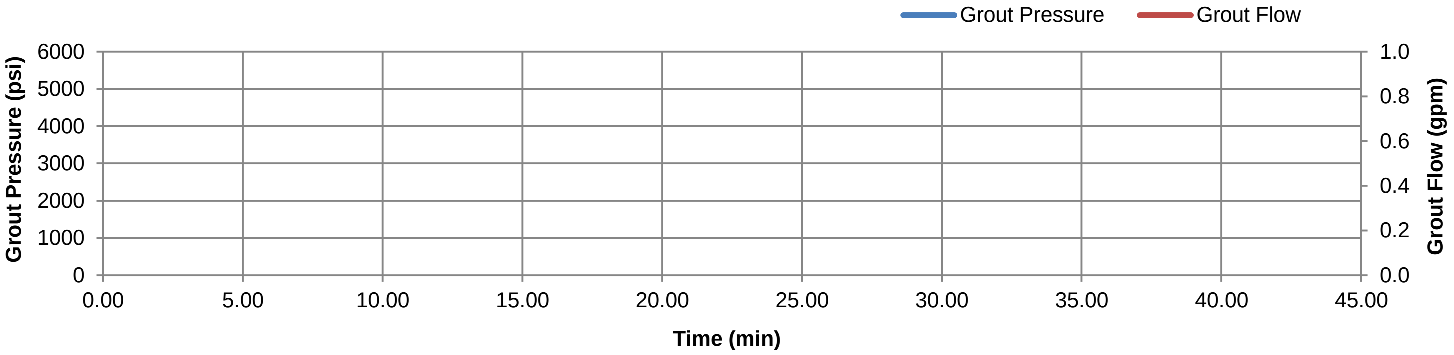
HAYWARD BAKER
Geotechnical Construction
KELLER

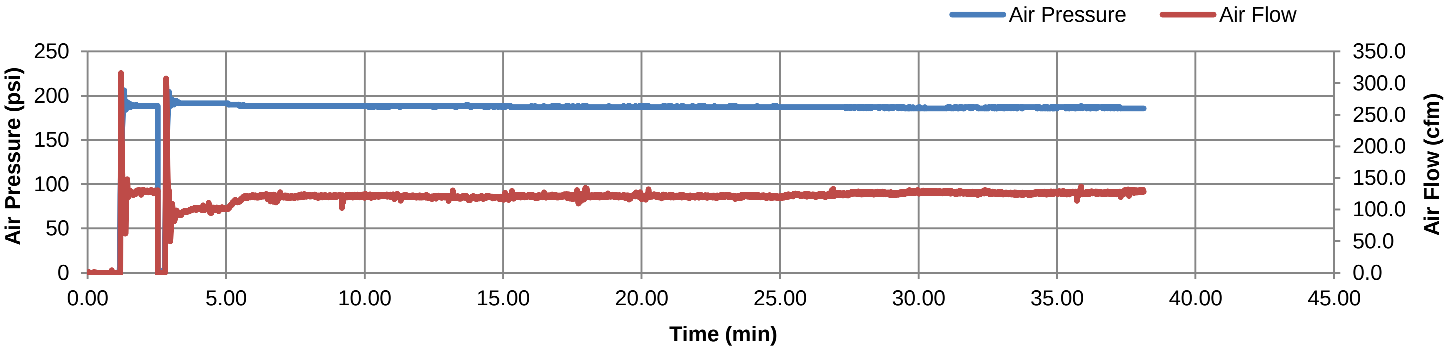
Jet Grouting Report
Kaiser Mead NPL

Column Number:	HBI-2B	**Date:**	9/11/2015
Job Number:	860080	**Start Time:**	2:21 PM
Job Location:	Spokane, WA	**End Time:**	4:31 PM
Total Grout Volume:	4213 gal	**Duration:**	02:10:00
Treatment Length:	22.37 ft	**Avg. S.G.:**	1.52









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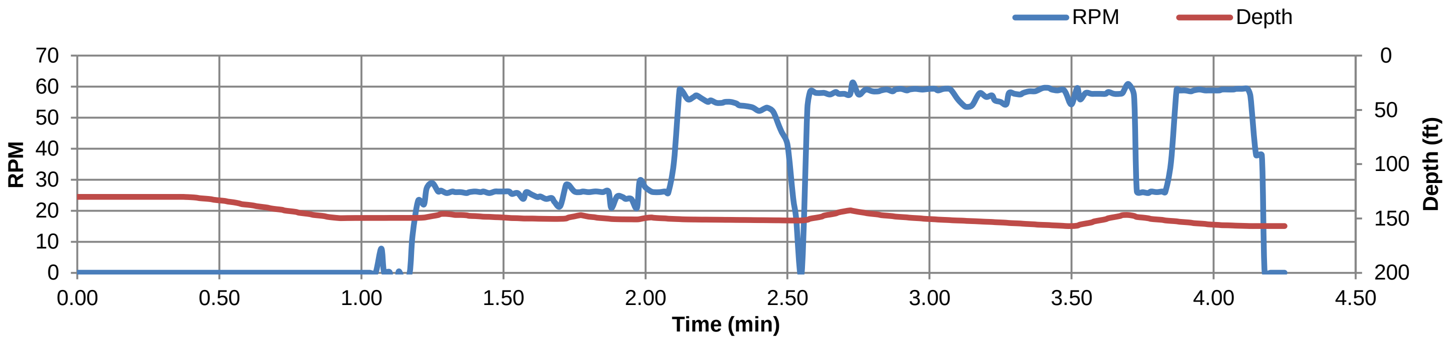
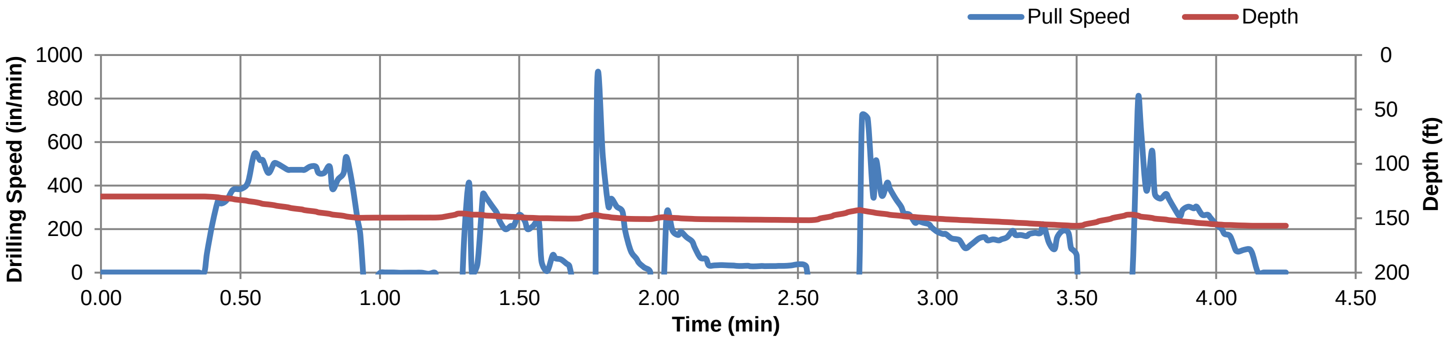
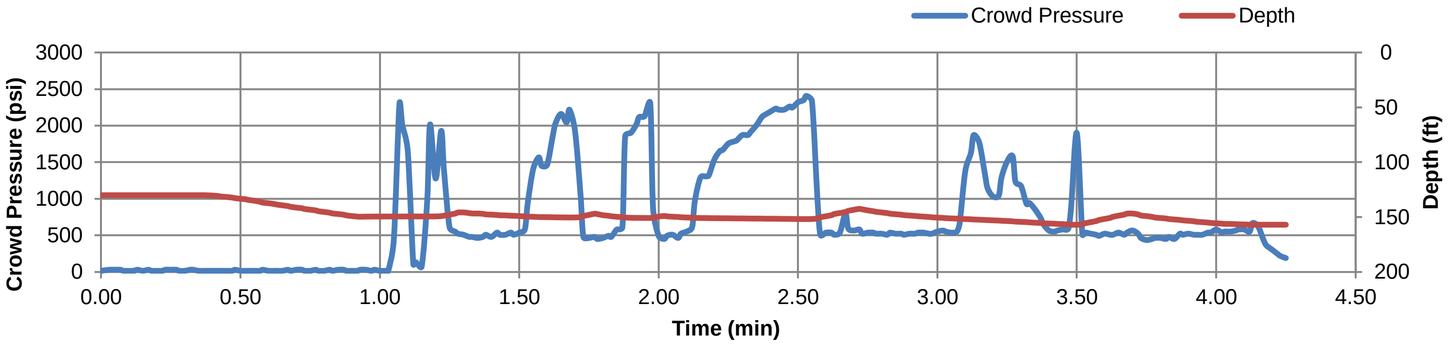
Jet Grout Drilling Report
Kaiser Mead NPL

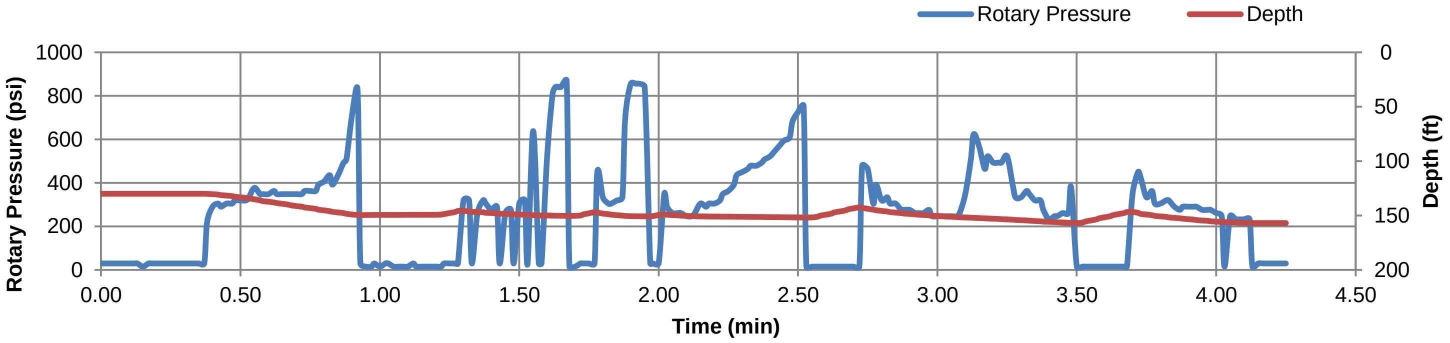
Column Number: HBI-2A
Job Number: 860080
Job Location: Spokane, WA
Drilled Depth: 157.02 ft
Inclination (X, Y): (23.860 in, 13.973 in)

Date: 9/11/2015
Start Time: 4:33 PM
End Time: 4:37 PM
Duration: 00:04:15





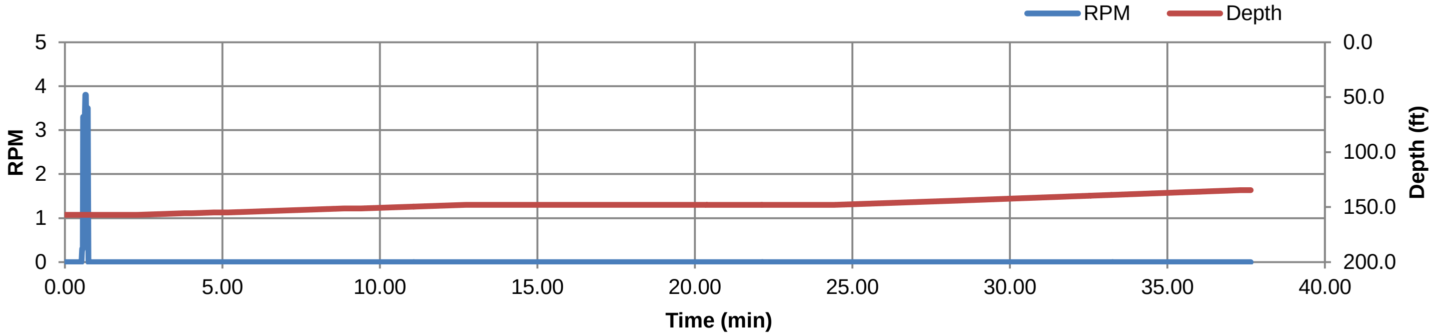


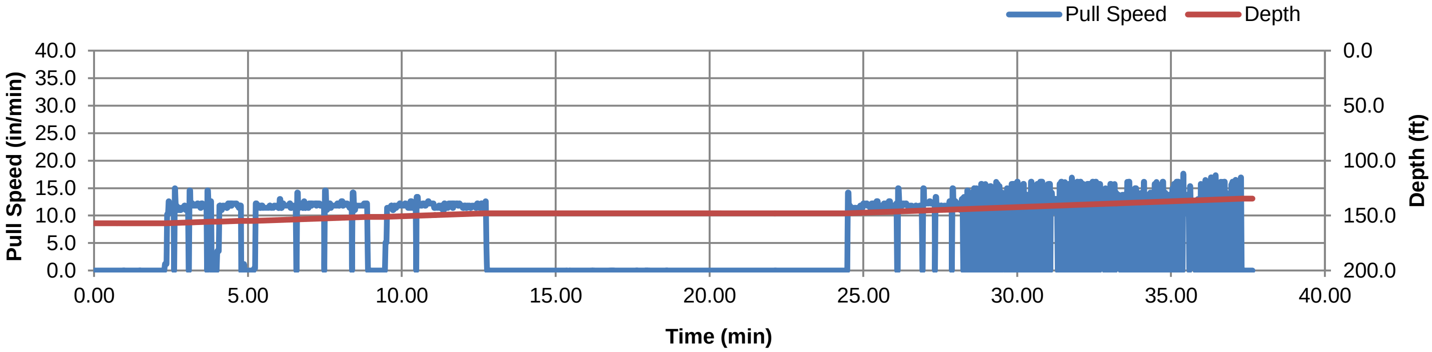


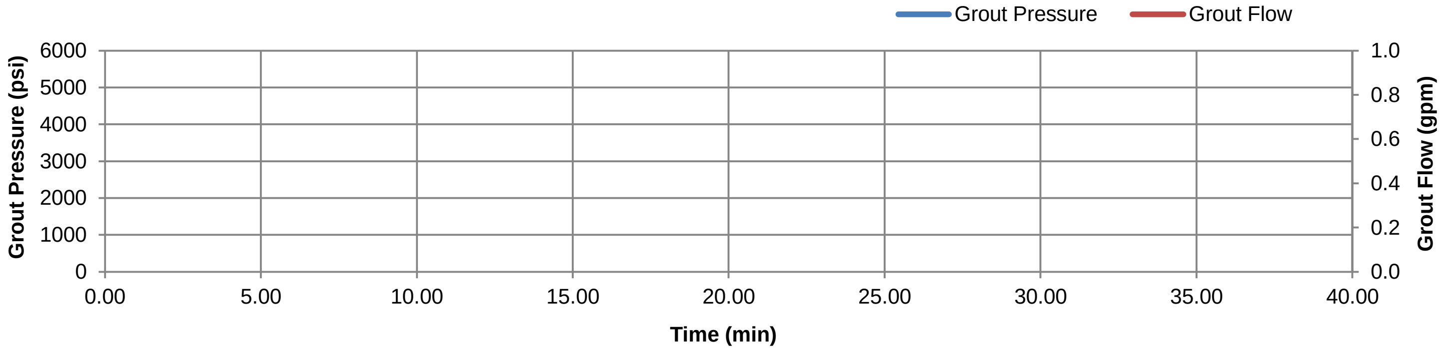
Jet Grouting Report
Kaiser Mead NPL

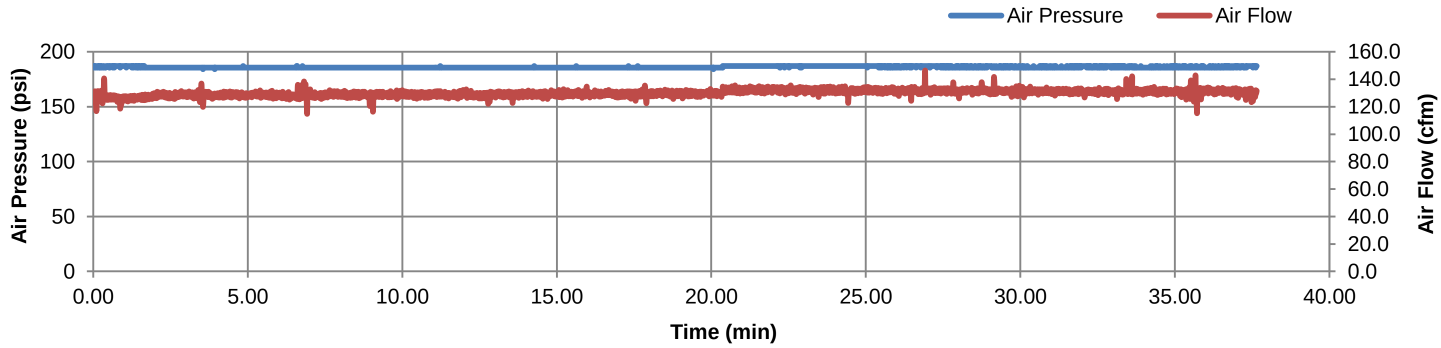
Column Number: HBI-2A
Job Number: 860080
Job Location: Spokane, WA
Total Grout Volume: 3698
Treatment Length: 22.44 ft

Date: 9/11/2015
Start Time: 4:33 PM
End Time: 5:22 PM
Duration: 00:48:49
Avg. S.G.: 1.52









HAYWARD BAKER, INC.

11180 E. Marginal Way S
Tukwila, WA 98168
206-223-1732

DAILY SITE REPORT

SHEET NO.	1	OF	2
SHIFT	DAY	**ONE CALL #**	
START:	7:00 AM	**END:**	5:00 PM
DATE:	Monday, September 14, 2015		

JOB NO:	860080	**LOCATION:**	Mead, WA	**TYPE OF WORK:**	Jet Grouting
PROJECT NAME:	Kaiser Mead NPL			**WEATHER:**	
CLIENT:	Hydrometrics			**PROJECT MGR.**	Adam Gerondale

SITE ACTIVITY

7:00 - 17:00 Jet grouted HBI-4A,B and HBI-5A,B. Finished pre-drilling casing on HBI-8. Pre-drilled casing on HBI-Remedial.

Panels Installed Today	4
Tot. Panels Yesterday	0
# of Panels To Date	22
% Complete	92%

MATERIAL DELIVERED

CEMENT DELIVERED (TONS):	60.09	TRUCKS	238066490, 238066496
FUEL DELIVERED (GALLONS):	526	TRUCKS	No. 35

EQUIPMENT USED, MOVED, STANDBY

12k reach forklift, mini-ex, skid steer, Hutte Drill, 825 Hurricane, Agi tank, KB-6, D-station, 3x2 mission pump, 4x3 mission pump, 350 BBL silo
Moyno Pump, 25K genset, 185 compressor, 300k genset, 6500 gallon poly tank, 900cfm compressor, switchbox

CHANGE ORDERS, BACK CHARGES, AND EXTRA WORK

VERBAL DISCUSSIONS,DIRECTIVES OR INSTRUCTIONS

VISITORS ON-SITE

Morgan

QA/QC

Activity	Quantity	Panel ID	Comments
Jet Grout	4	HBI-4A,B & HBI-5A,B	Deviation @ Bottom of Panel: HBI-4 = 0.79%; HBI-5 = 1.05%
Spoils Sampling	10	HBI-4B & HBI-5A	HBI-4B: 5 samples, HBI-5A: 5 samples
Other			

LABOR FORCE

QTY	TYPE
7	OPERATORS
0	LABORERS
1	MECHANICS
2	OTHER (SUPT,FIELD ENGINEER)

LENGTH OF SHIFT 10 HRS

NOTES:

MANPOWER

Position	NAME	Regular Hours	OT Hours
Superintendent	Frank Kalata	10	
Field Engineer	Taylor Cox	10	
Field Engineer	Dylan Fisher		
Mechanic	Kevin Clark	8	2
Driller	Mark Fellows	8	2
Pump Operator	Paul Thomas	8	2
Batch Plant Operator	Auggie Ruesga	8	2
Driller	Jody Welch	8	2
Operator	Shaun Henderson	8	2
Operator	Alan Krouse	8	2
Operator	Linda Currie	8	2

Man Hours

Company Name	Hrs. Today	OT Hrs. Today	Yesterday		Safe Hrs To Date:	
Hayward Baker:	84	16	0		166.5	
Total Manhours :	1352	338				

Owner / Contractor

HAYWARD BAKER INC.

HAYWARD BAKER, INC.

11180 E. Marginal Way S
Tukwila, WA 98168
206-223-1732

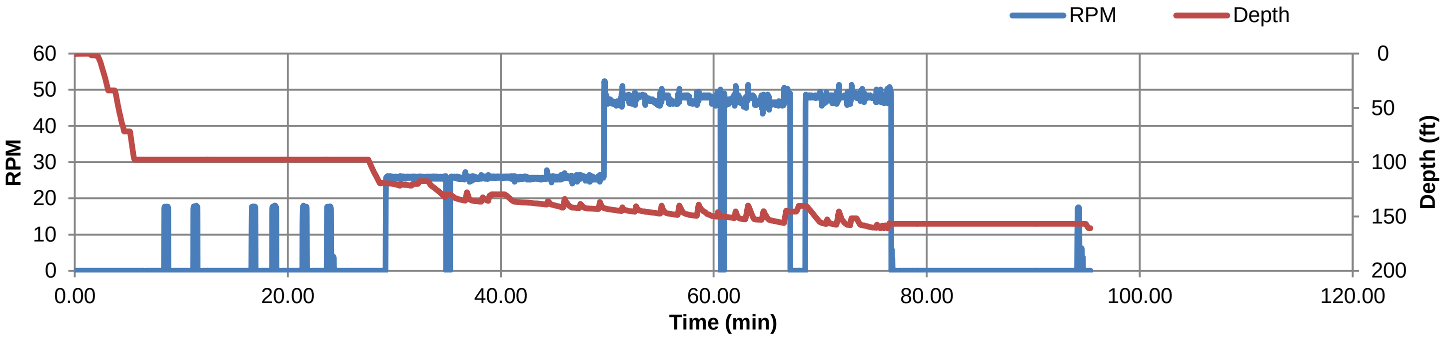
DAILY SITE REPORT

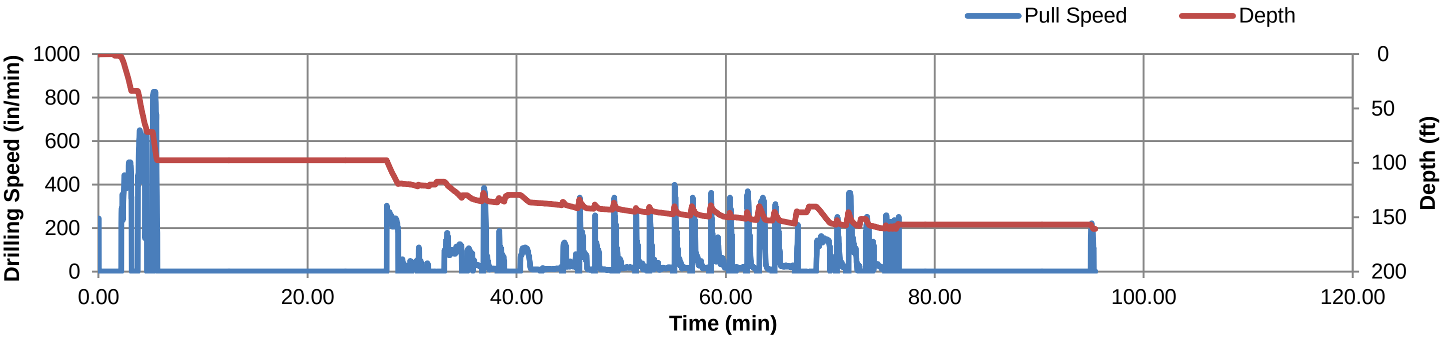
SHEET NO.	**2**	OF	**2**
SHIFT	DAY	**ONE CALL #**	0
START:	7:00 AM	**END:**	5:00 PM
DATE:	Monday, September 14, 2015		

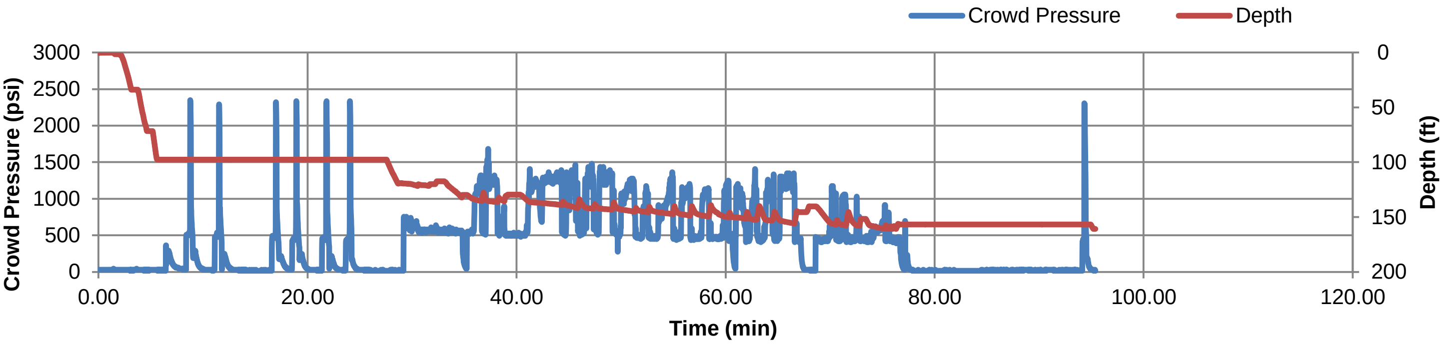
JOB NO:	860080	**LOCATION:**	Mead, WA	**TYPE OF WORK:**	Jet Grouting
PROJECT NAME:	Kaiser Mead NPL			**WEATHER:**	Sunny and hot
CLIENT:	Hydrometrics			**PROJECT MGR.**	Adam Gerondale

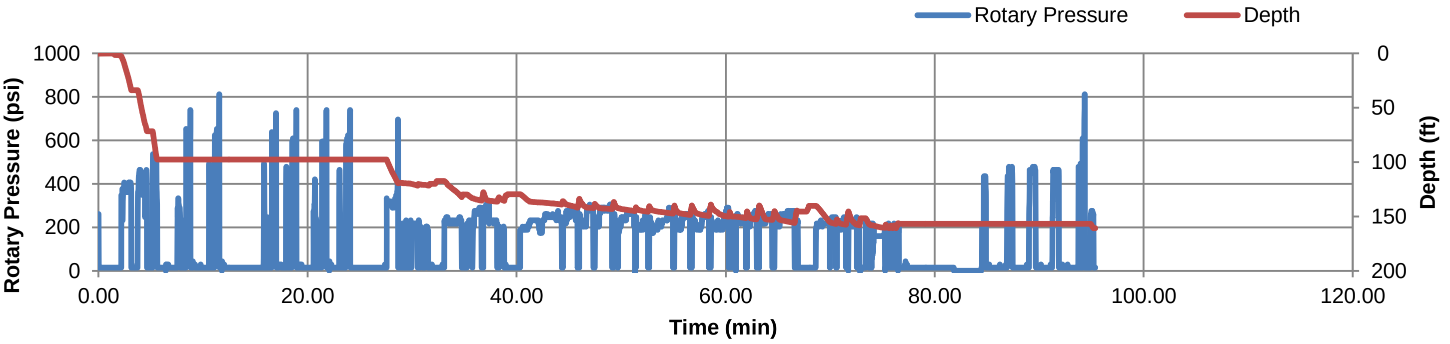
Jet Grout Drilling Report
Kaiser Mead NPL

Column Number:	HBI-4B	**Date:**	9/14/2015
Job Number:	860080	**Start Time:**	7:53 AM
Job Location:	Spokane, WA	**End Time:**	9:47 AM
Drilled Depth:	160.82 ft	**Duration:**	01:53:32
Inclination (X, Y):	(-1.179 in, 14.567 in)		





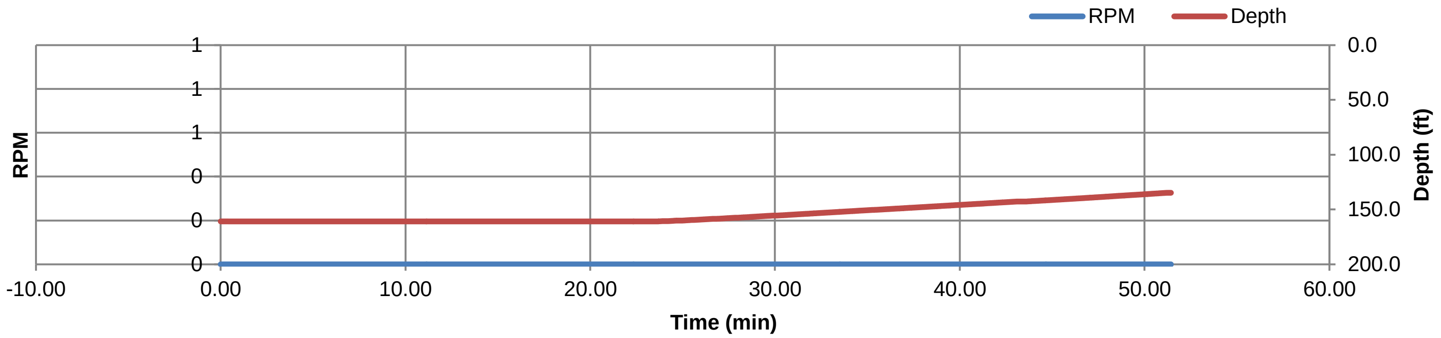


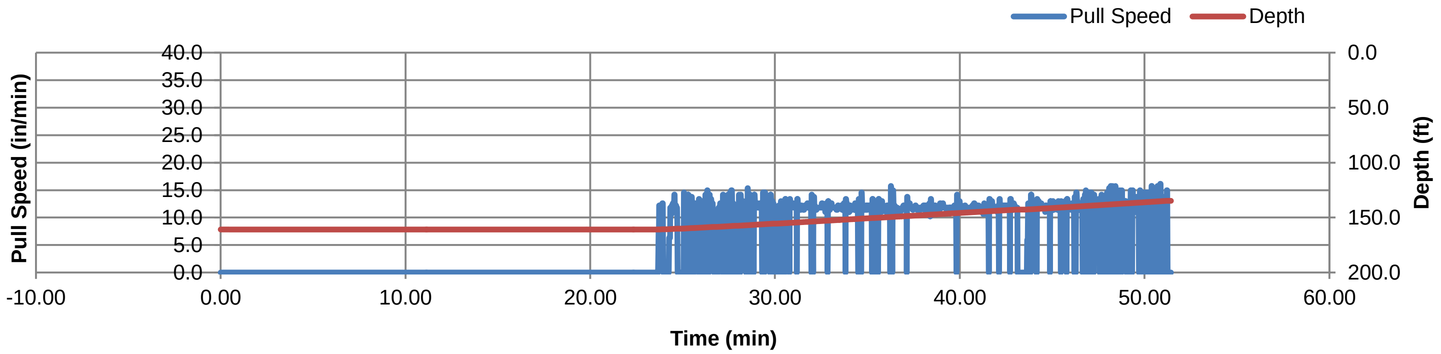


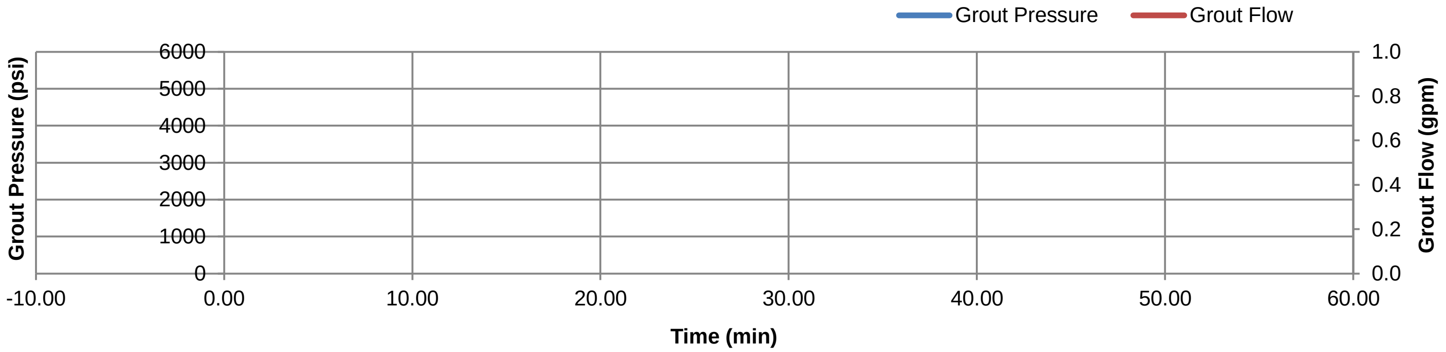
HAYWARD BAKER
Geotechnical Construction
KELLER

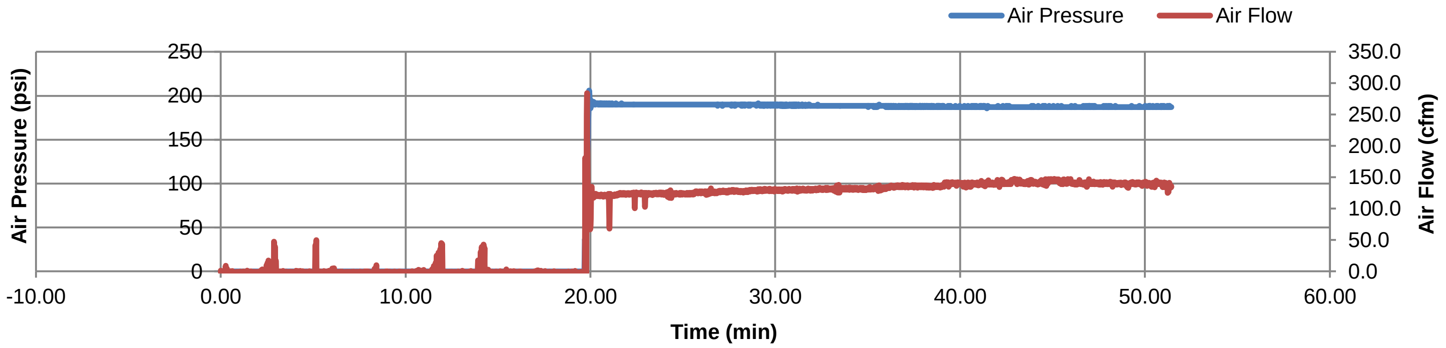
Jet Grouting Report
Kaiser Mead NPL

Column Number:	HBI-4B	**Date:**	9/14/2015
Job Number:	860080	**Start Time:**	9:47 AM
Job Location:	Spokane, WA	**End Time:**	10:38 AM
Total Grout Volume:	3751 gal	**Duration:**	00:51:00
Treatment Length:	26.09 ft	**Avg. S.G.:**	1.52









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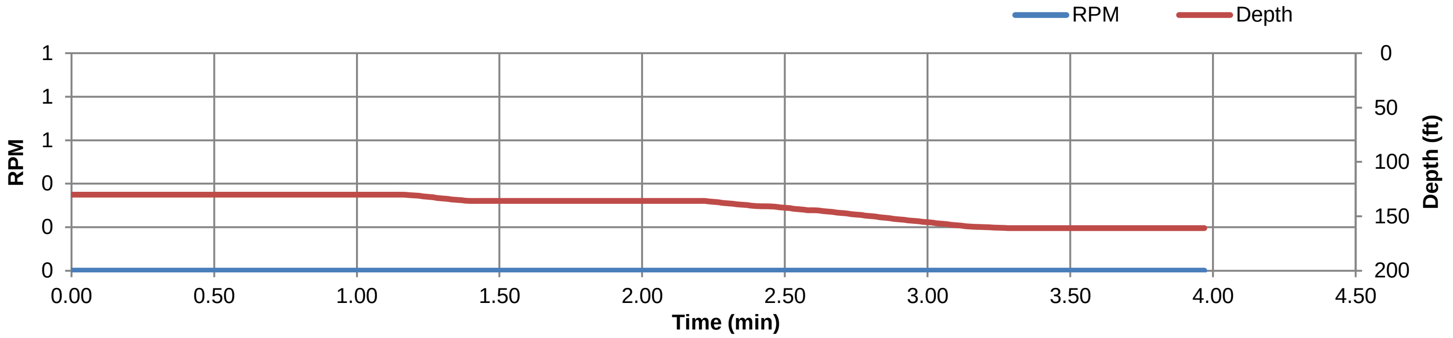
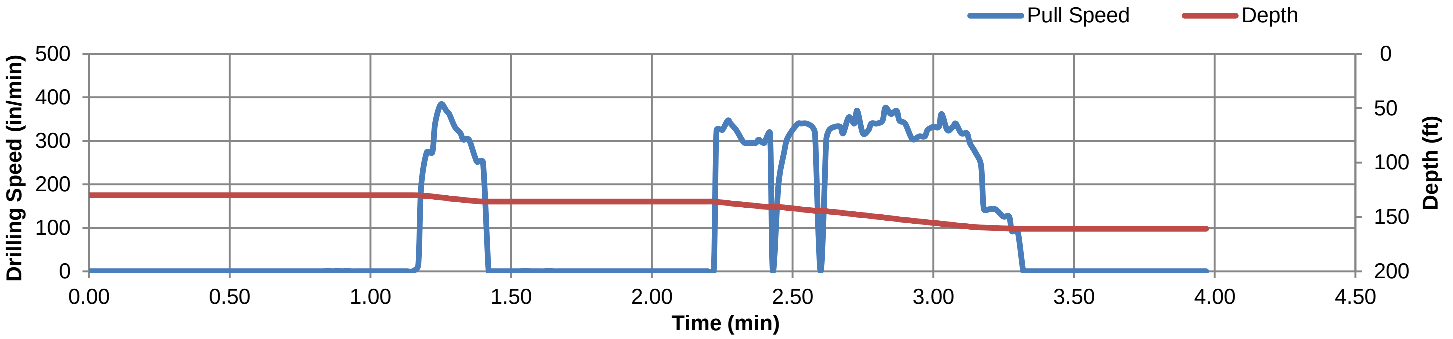
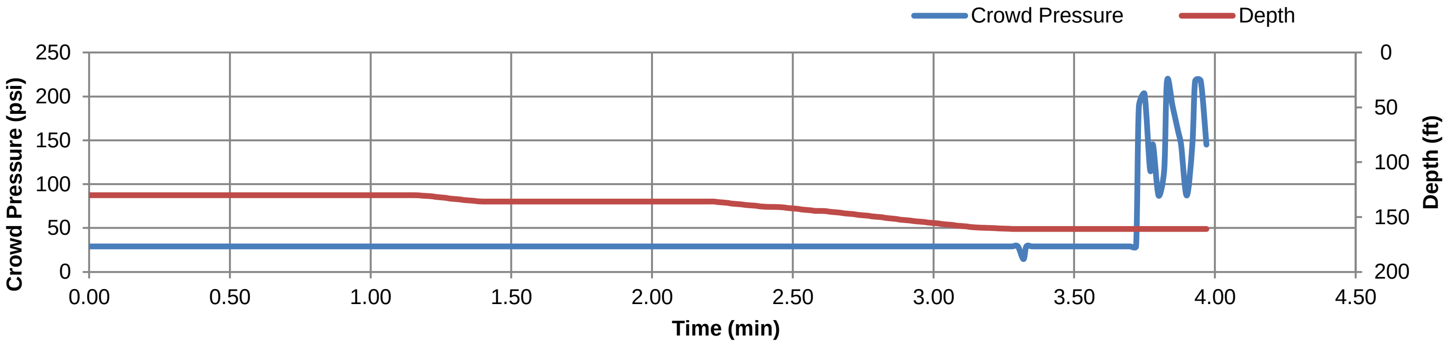
HAYWARD
BAKER
Geotechnical Construction
KELLER

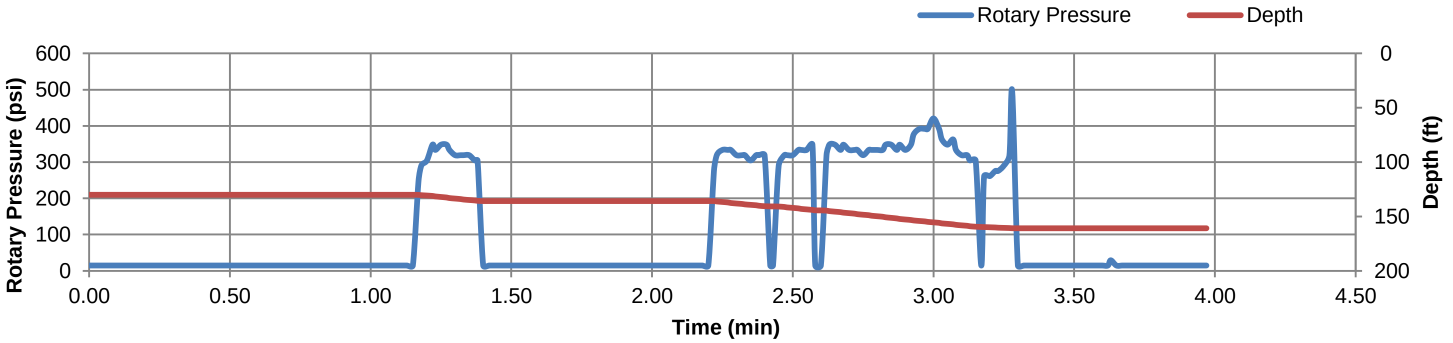
Jet Grout Drilling Report
Kaiser Mead NPL

Column Number:	HBI-4A	**Date:**	9/14/2015
Job Number:	860080	**Start Time:**	10:40 AM
Job Location:	Spokane, WA	**End Time:**	10:44 AM
Drilled Depth:	160.89 ft	**Duration:**	00:03:58
Inclination (X, Y):	(-1.179 in, 14.567 in)		









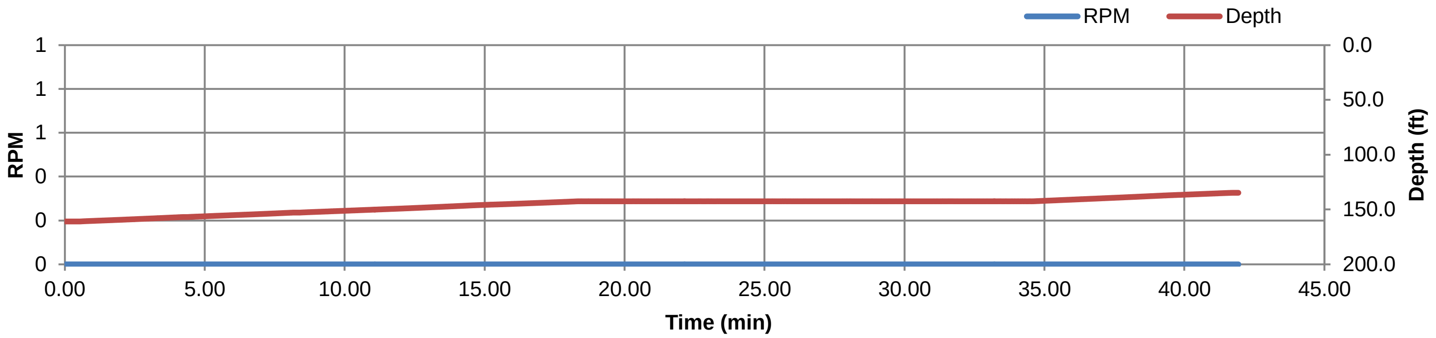
THINK SAFE

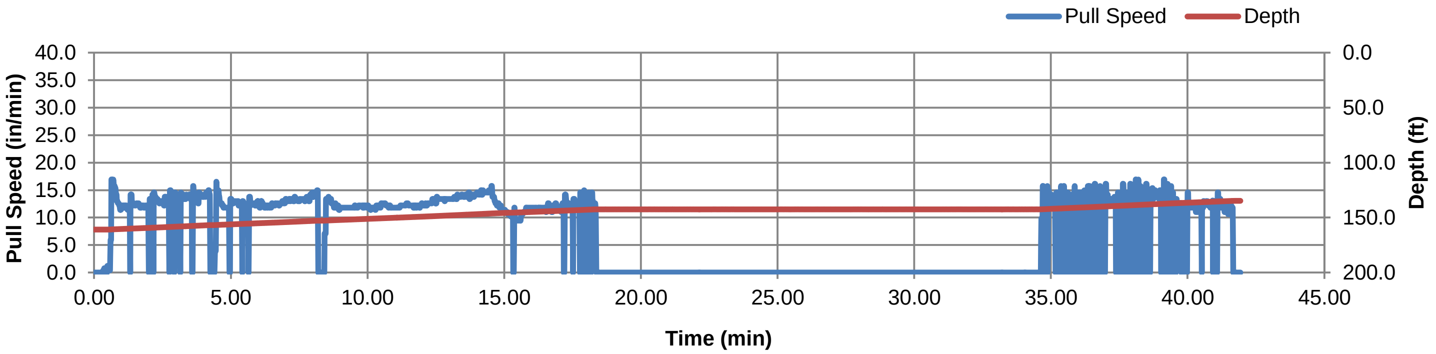
HAYWARD BAKER
Geotechnical Construction
KELLER

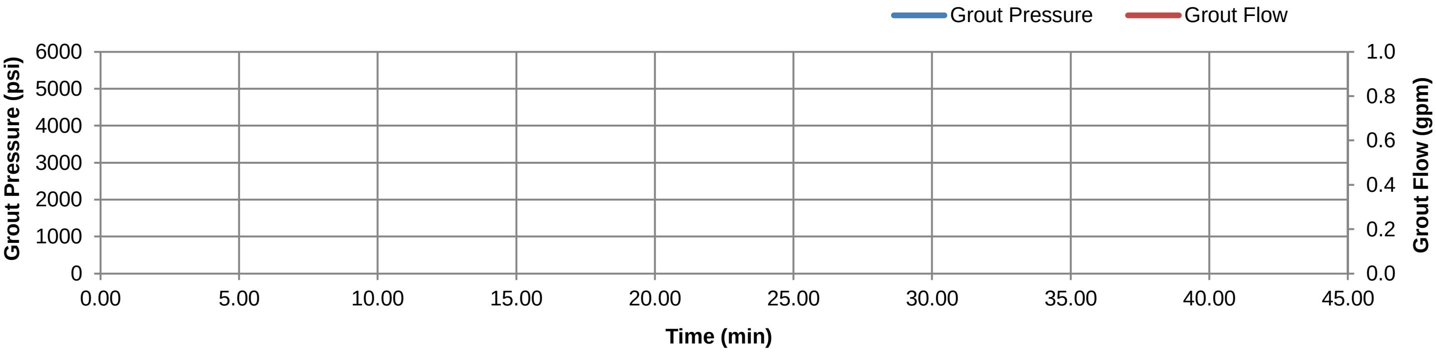
Jet Grouting Report
Kaiser Mead NPL

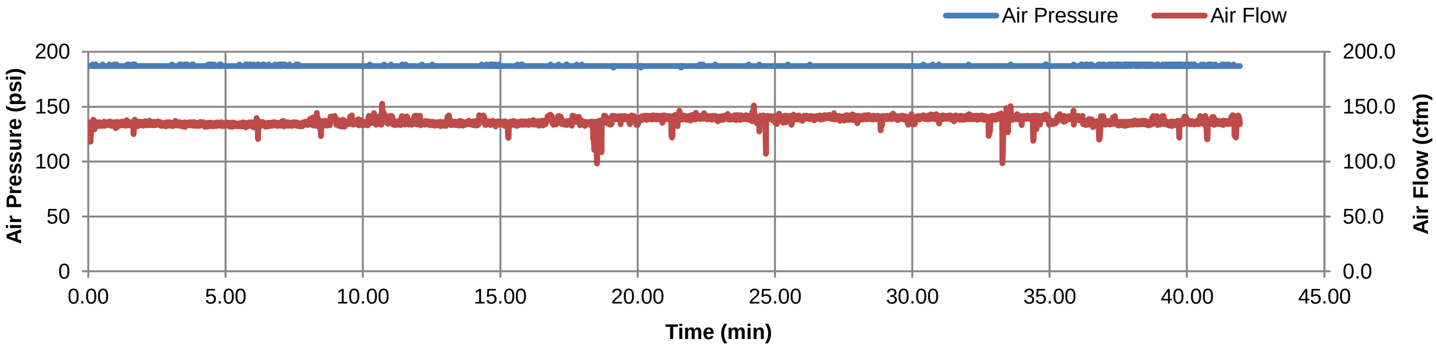
Column Number: HBI-4A
Job Number: 860080
Job Location: Spokane, WA
Total Grout Volume: 4023 gal
Treatment Length: 26.15 ft

Date: 9/14/2015
Start Time: 10:49 AM
End Time: 11:31 AM
Duration: 00:42:07
Avg. S.G.: 1.52









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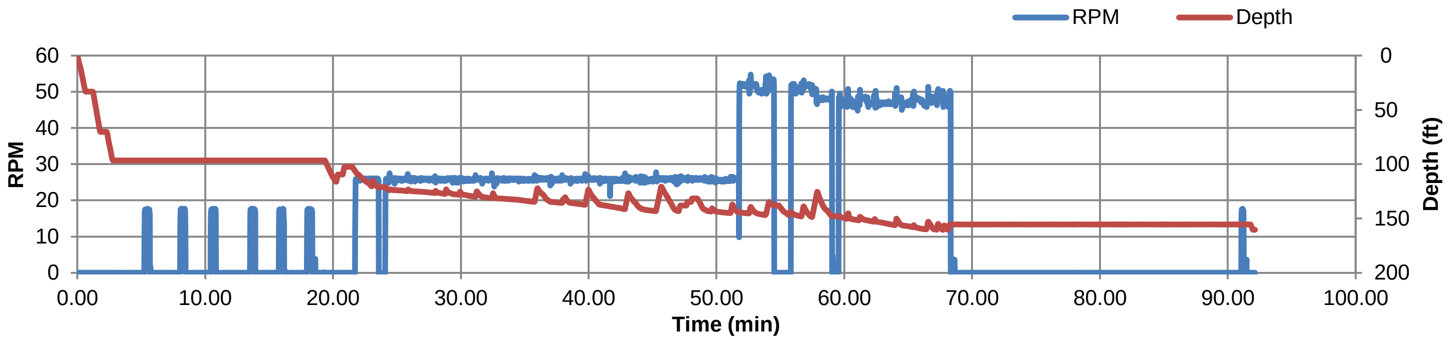
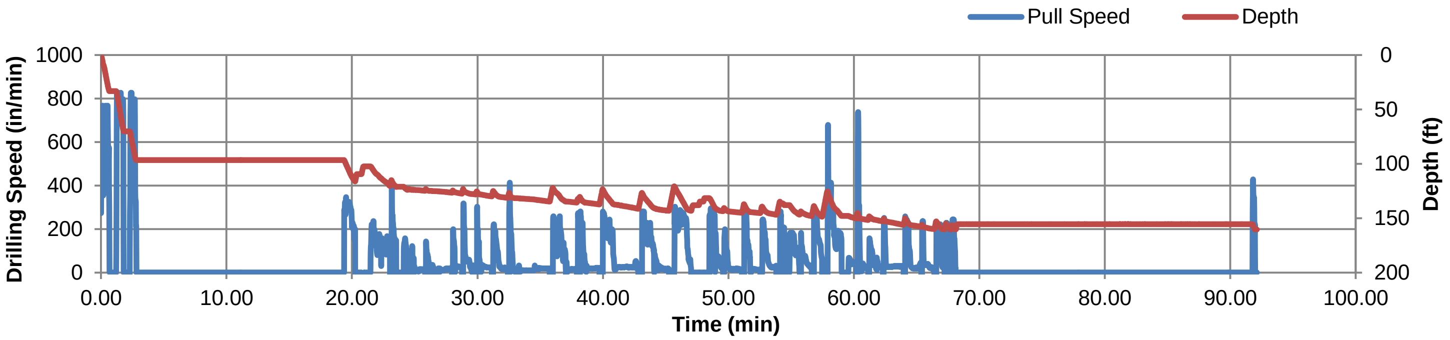
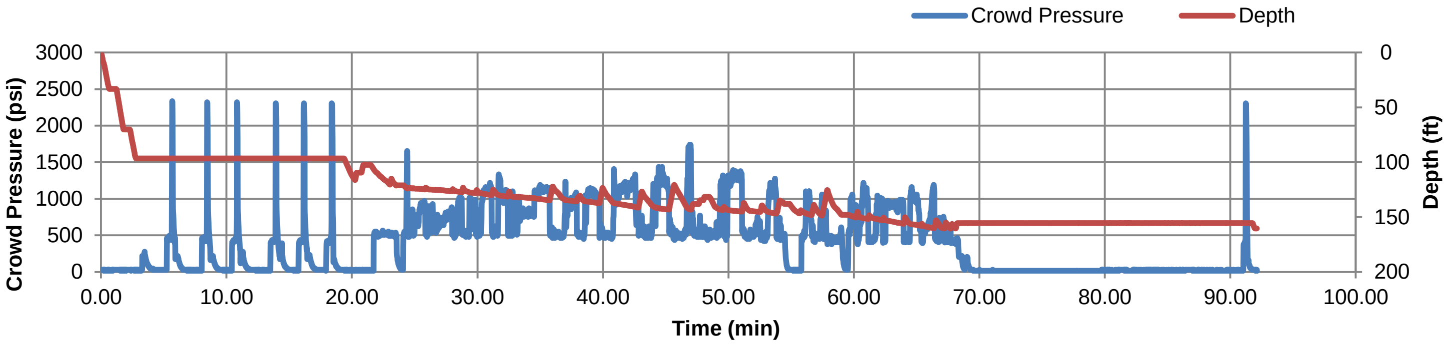
HAYWARD
BAKER
Geotechnical Construction
KELLER

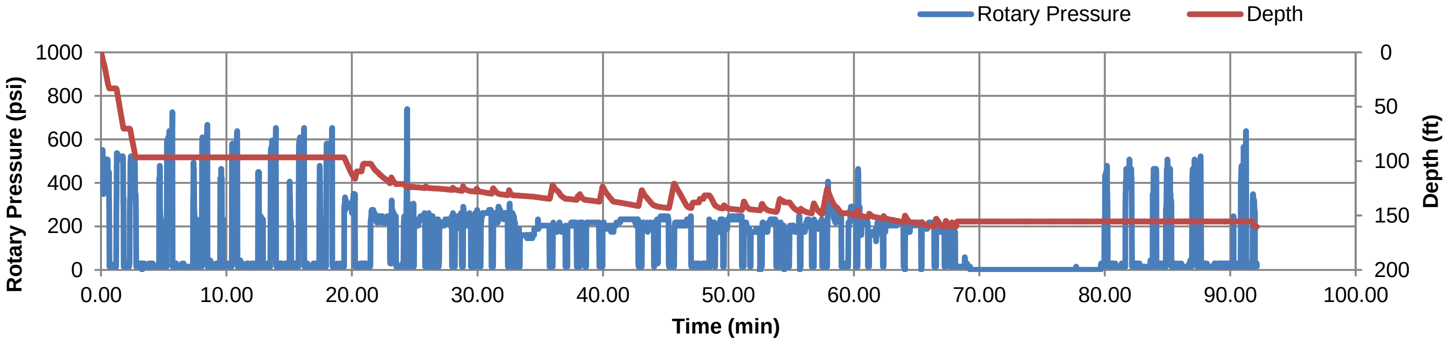
Jet Grout Drilling Report
Kaiser Mead NPL

Column Number:	HBI-5B	**Date:**	9/14/2015
Job Number:	860080	**Start Time:**	12:23 PM
Job Location:	Spokane, WA	**End Time:**	2:44 PM
Drilled Depth:	160.46 ft	**Duration:**	02:20:35
Inclination (X, Y):	(17.057 in, 9.475 in)		









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HAYWARD
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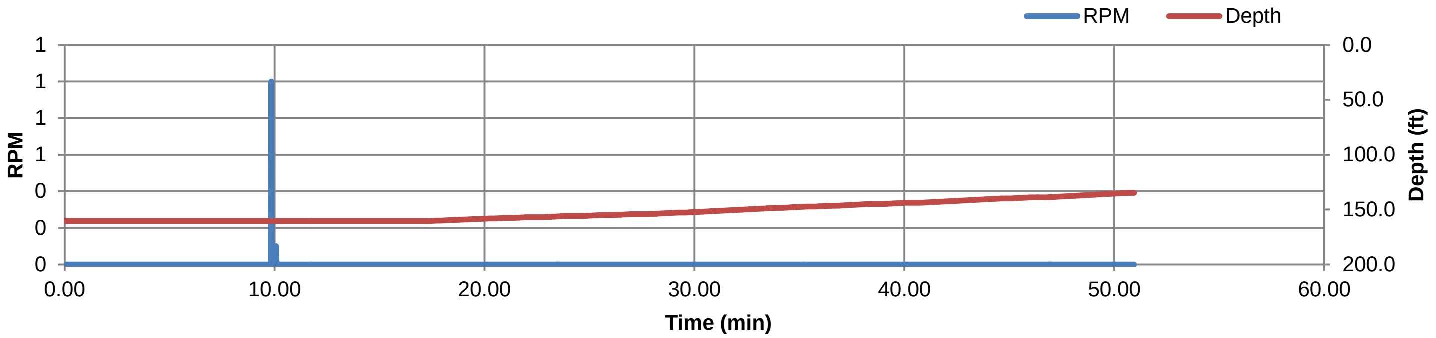
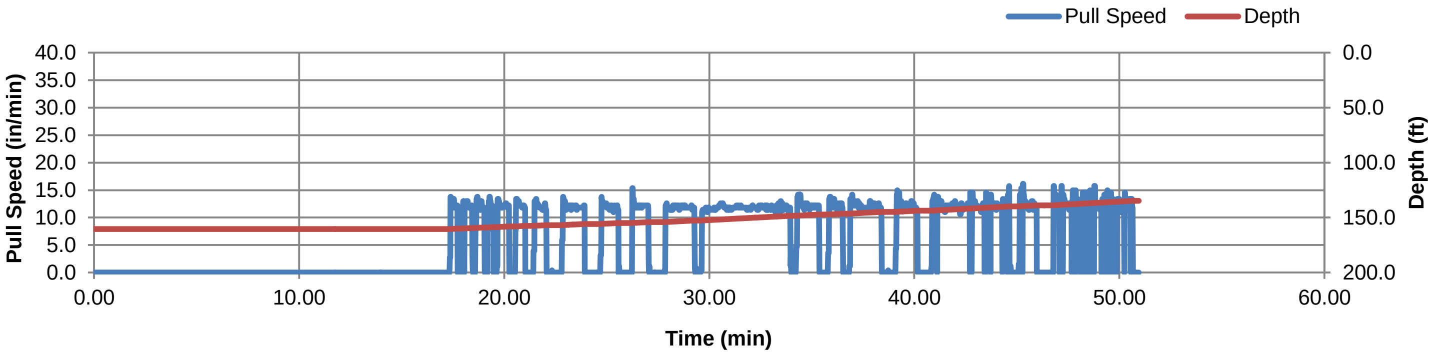
KELLER

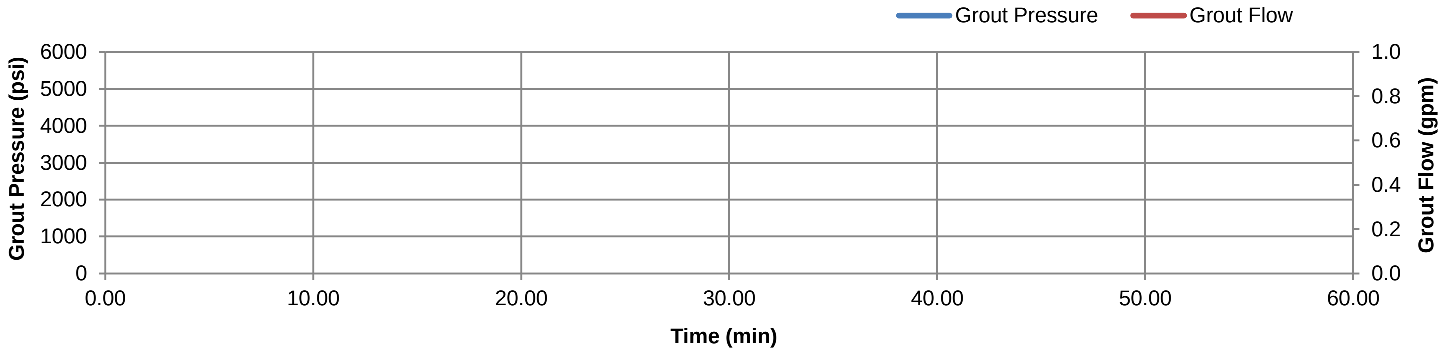
Jet Grouting Report
Kaiser Mead NPL

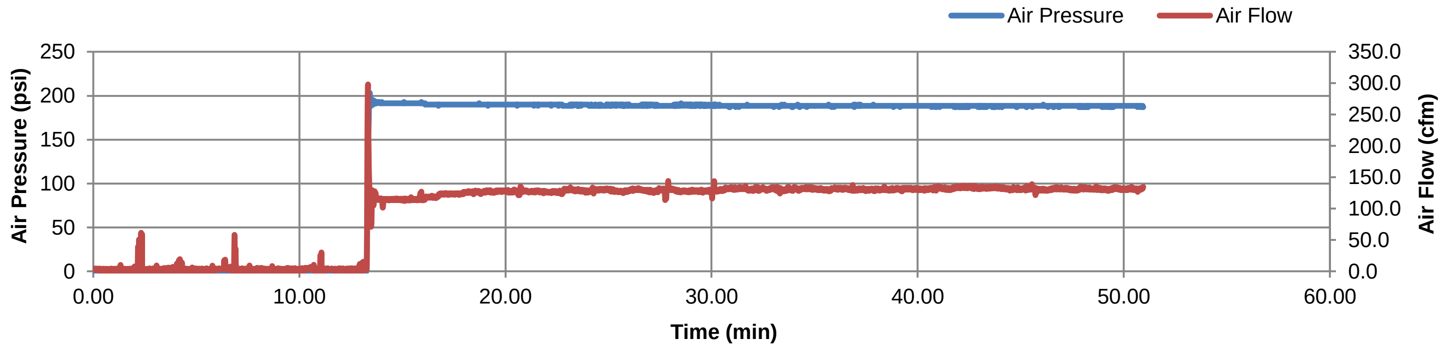
Column Number: HBI-5B
Job Number: 860080
Job Location: Spokane, WA
Total Grout Volume: 4383 gal
Treatment Length: 25.69 ft

Date: 9/14/2015
Start Time: 2:44 PM
End Time: 3:36 PM
Duration: 00:52:00
Avg. S.G.: 1.52







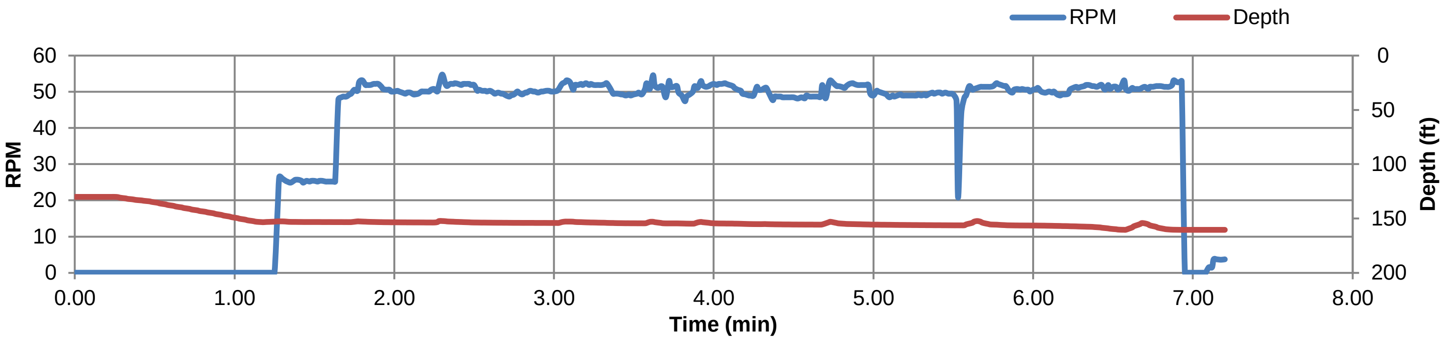


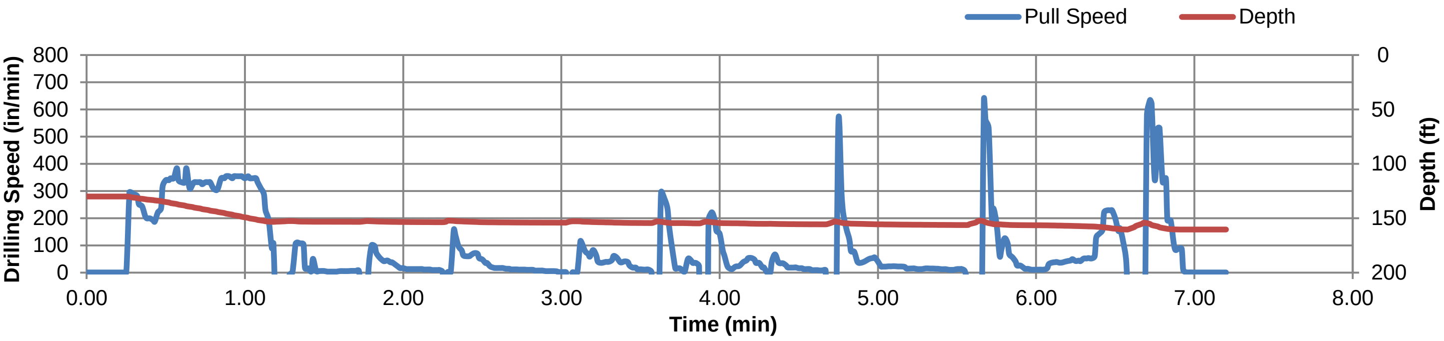
THINK SAFE

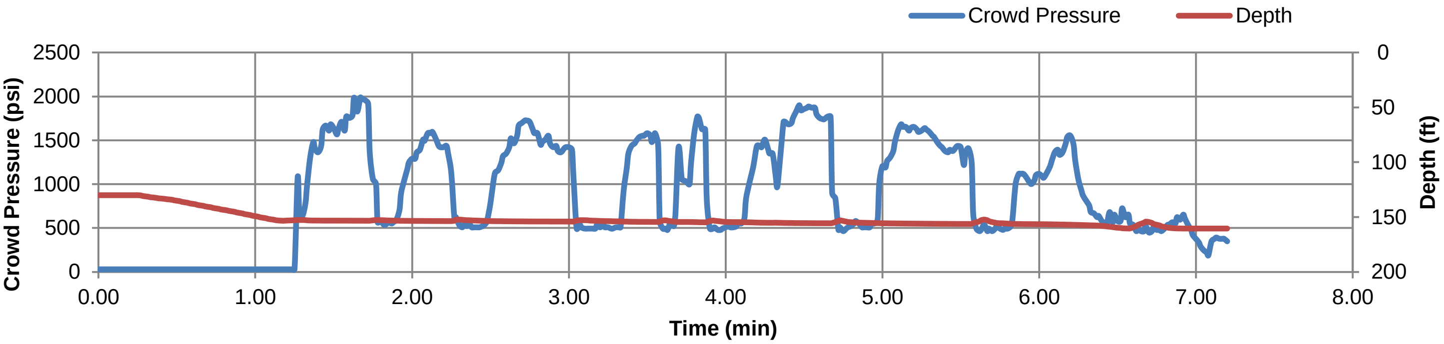
HAYWARD BAKER
Geotechnical Construction
KELLER

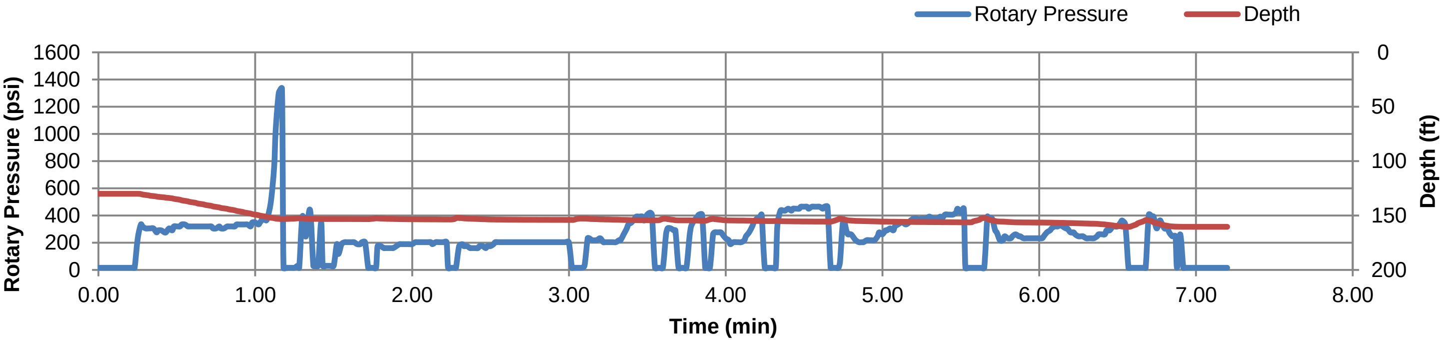
Jet Grout Drilling Report
Kaiser Mead NPL

Column Number:	HBI-5A	**Date:**	9/14/2015
Job Number:	860080	**Start Time:**	3:40 PM
Job Location:	Spokane, WA	**End Time:**	3:47 PM
Drilled Depth:	160.46 ft	**Duration:**	00:07:13
Inclination (X, Y):	(17.057 in, 9.475 in)		





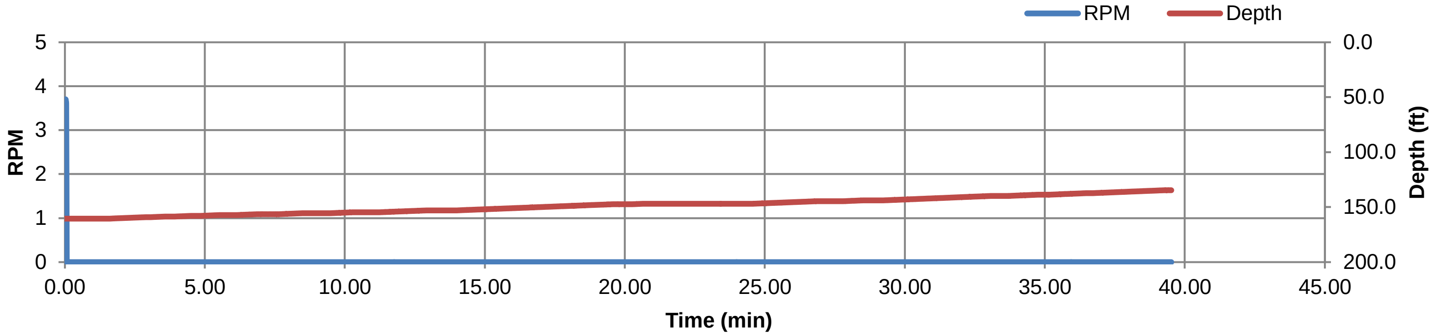


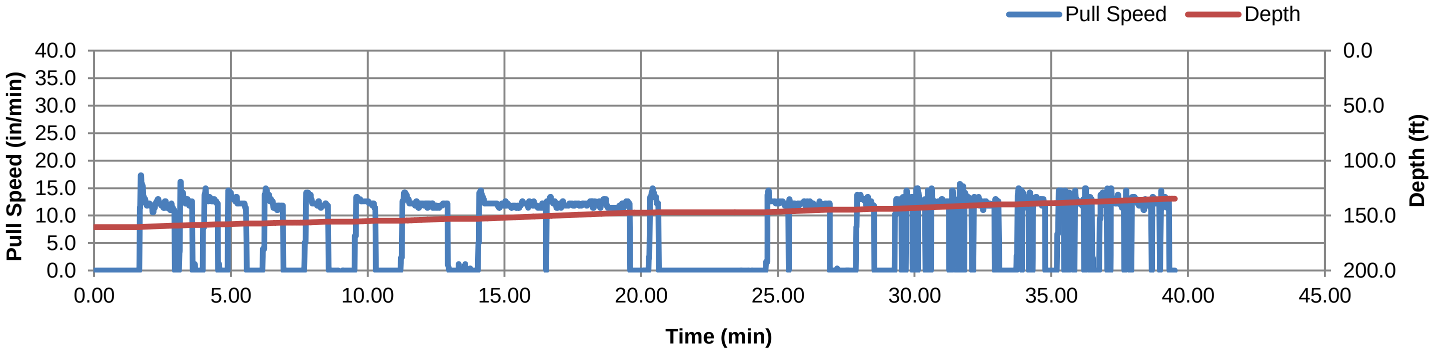


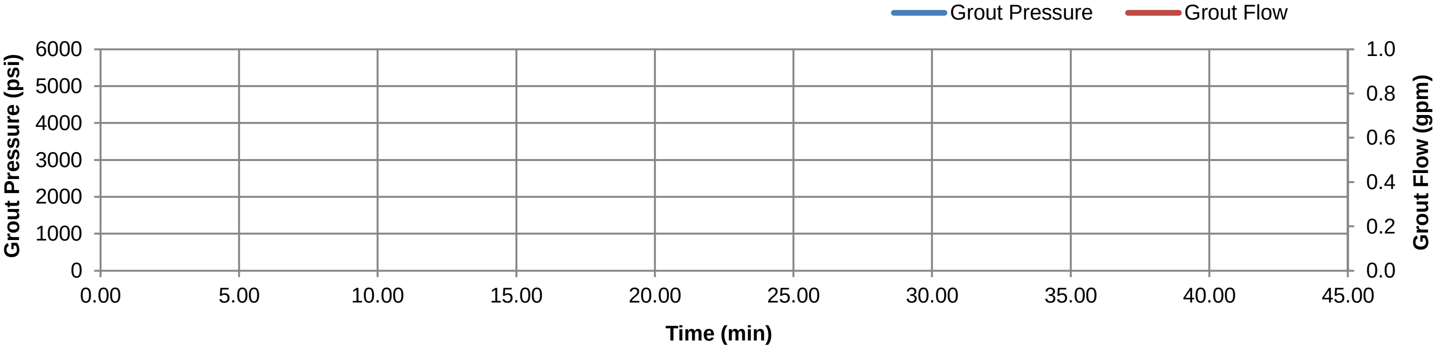
THINK SAFE

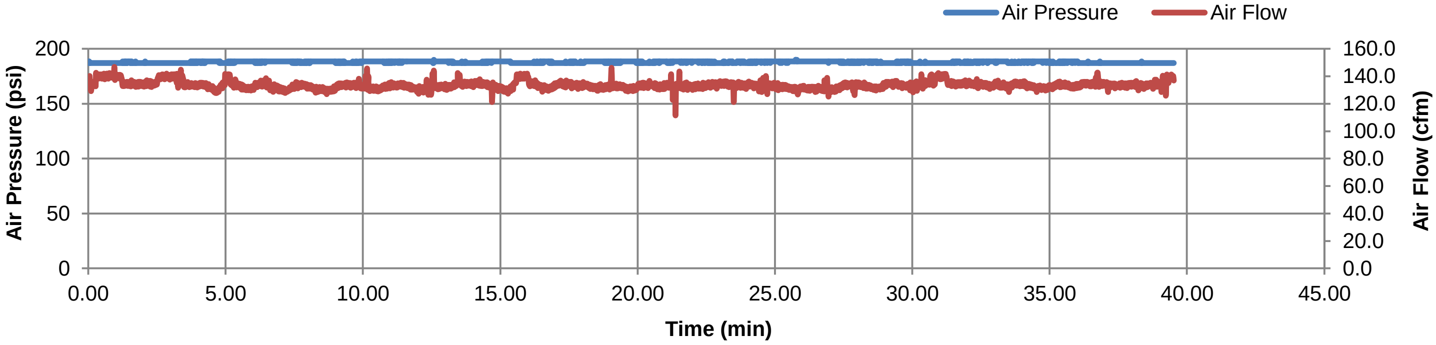
Jet Grouting Report
Kaiser Mead NPL

Column Number:	HBI-5A	**Date:**	9/14/2015
Job Number:	860080	**Start Time:**	3:40 PM
Job Location:	Spokane, WA	**End Time:**	4:27 PM
Total Grout Volume:	4545 gal	**Duration:**	00:46:45
Treatment Length:	25.82 ft	**Avg. S.G.:**	1.52









HAYWARD BAKER, INC.

11180 E. Marginal Way S
Tukwila, WA 98168
206-223-1732

DAILY SITE REPORT

SHEET NO.	1	OF	2
SHIFT	DAY	**ONE CALL #**	
START:	7:00 AM	**END:**	6:00 PM
DATE:	Tuesday, September 15, 2015		

JOB NO:	860080	**LOCATION:**	Mead, WA	**TYPE OF WORK:**	Jet Grouting
PROJECT NAME:	Kaiser Mead NPL			**WEATHER:**	
CLIENT:	Hydrometrics			**PROJECT MGR.**	Adam Gerondale

SITE ACTIVITY

7:00 - 16:00 Finished pre-drilling casing on HBI-R, jet grouted HBI-8 & HBI-R.
16:00 - 18:00 Began washing equipment and demobilizing .

Panels Installed Today	4
Tot. Panels Yesterday	4
# of Panels To Date	26
% Complete	108%

MATERIAL DELIVERED

CEMENT DELIVERED (TONS):	25	TRUCKS	238066520
FUEL DELIVERED (GALLONS):	377	TRUCKS	No. 41

EQUIPMENT USED, MOVED, STANDBY

12k reach forklift, mini-ex, skid steer, Hutte Drill, 825 Hurricane, Agi tank, KB-6, D-station, 3x2 mission pump, 4x3 mission pump, 350 BBL silo
Moyno Pump, 25K genset, 185 compressor, 300k genset, 6500 gallon poly tank, 900cfm compressor, switchbox

CHANGE ORDERS, BACK CHARGES, AND EXTRA WORK

VERBAL DISCUSSIONS,DIRECTIVES OR INSTRUCTIONS

VISITORS ON-SITE

Morgan, Tony

QA/QC

Activity	Quantity	Panel ID	Comments
Jet Grout	4	HBI-8A,B & HBI-R,R1	Deviation @ Bottom of Panel: HBI-8 = 1.60%; HBI-R = 1.34%
Spoils Sampling	10	HBI-8B & HBI-R	HBI-8B: 5 samples, HBI-R: 5 samples
Other			

LABOR FORCE

QTY	TYPE
7	OPERATORS
0	LABORERS
1	MECHANICS
2	OTHER (SUPT,FIELD ENGINEER)

LENGTH OF SHIFT 10 HRS

NOTES:

MANPOWER

Position	NAME	Regular Hours	OT Hours
Superintendent	Frank Kalata	10	
Field Engineer	Taylor Cox	10	
Field Engineer	Dylan Fisher		
Mechanic	Kevin Clark	8	3
Driller	Mark Fellows	8	3
Pump Operator	Paul Thomas	8	3
Batch Plant Operator	Auggie Ruesga	8	3
Driller	Jody Welch	8	3
Operator	Shaun Henderson	8	3
Operator	Alan Krouse	8	3
Operator	Linda Currie	8	3

Man Hours

Company Name	Hrs. Today	OT Hrs. Today	Yesterday		Safe Hrs To Date:	
Hayward Baker:	84	24	0		176.5	
Total Manhours :	1436	362				

Owner / Contractor

HAYWARD BAKER INC.

HAYWARD BAKER, INC.

11180 E. Marginal Way S
Tukwila, WA 98168
206-223-1732

DAILY SITE REPORT

SHEET NO.	**2**	OF	**2**
SHIFT	DAY	**ONE CALL #**	0
START:	7:00 AM	**END:**	6:00 PM
DATE:	Tuesday, September 15, 2015		

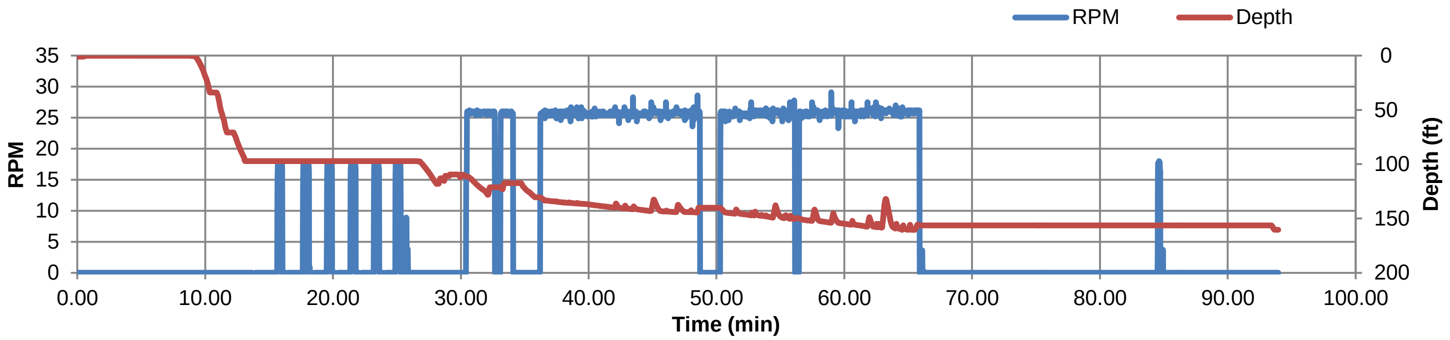
JOB NO:	860080	**LOCATION:**	Mead, WA	**TYPE OF WORK:**	Jet Grouting
PROJECT NAME:	Kaiser Mead NPL			**WEATHER:**	Sunny and hot
CLIENT:	Hydrometrics			**PROJECT MGR.**	Adam Gerondale

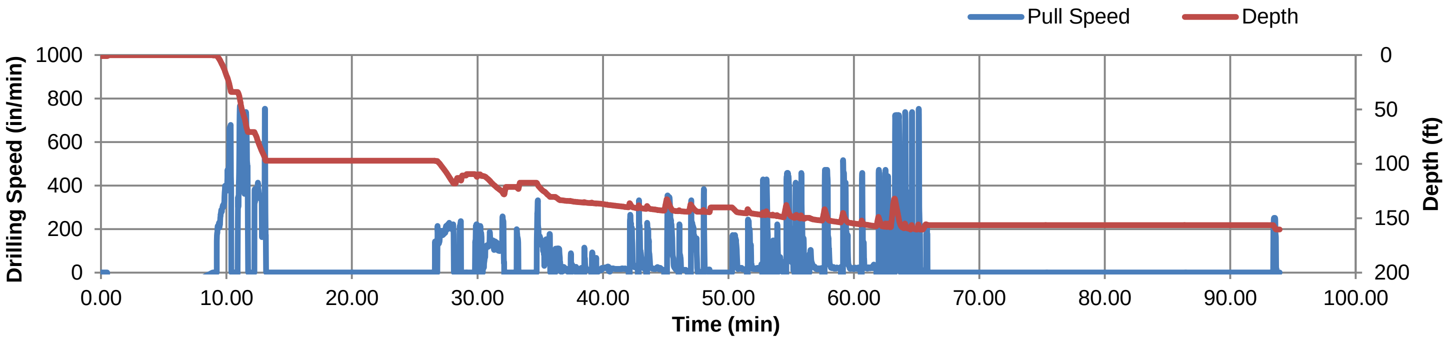
N/A

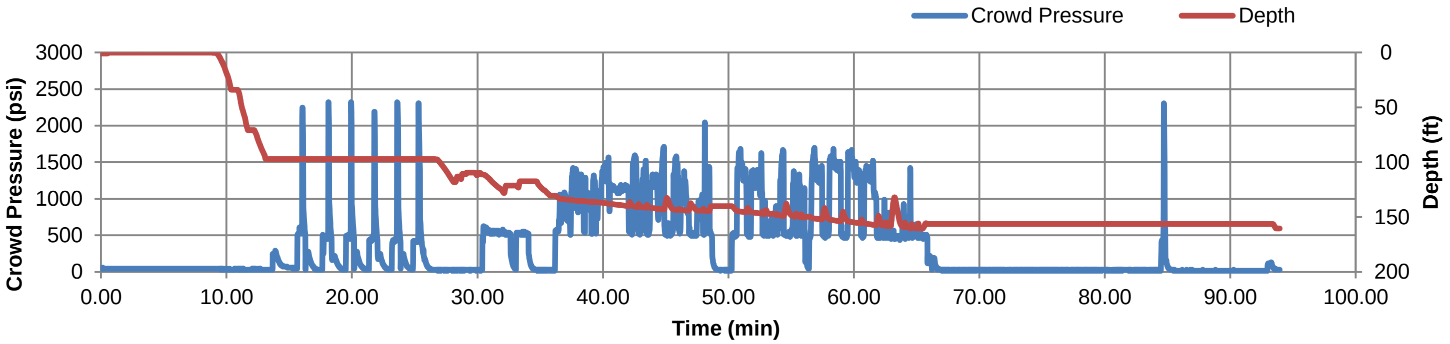
HAYWARD
BAKER
Geotechnical Construction
KELLER

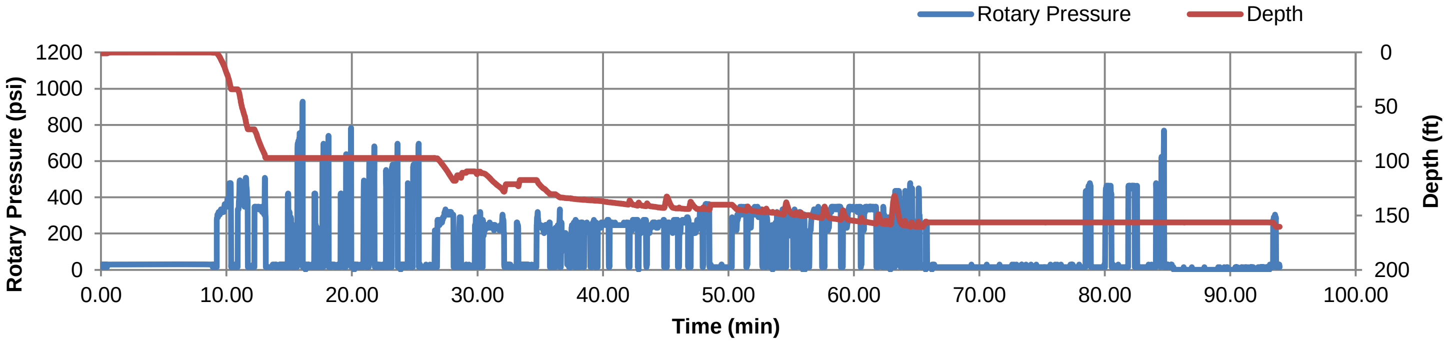
Jet Grout Drilling Report
Kaiser Mead NPL

Column Number:	HBI-8B	**Date:**	9/15/2015
Job Number:	860080	**Start Time:**	7:56 AM
Job Location:	Spokane, WA	**End Time:**	9:30 AM
Drilled Depth:	160.50 ft	**Duration:**	01:33:57
Inclination (X, Y):	(29.033 in, -0.077 in)		





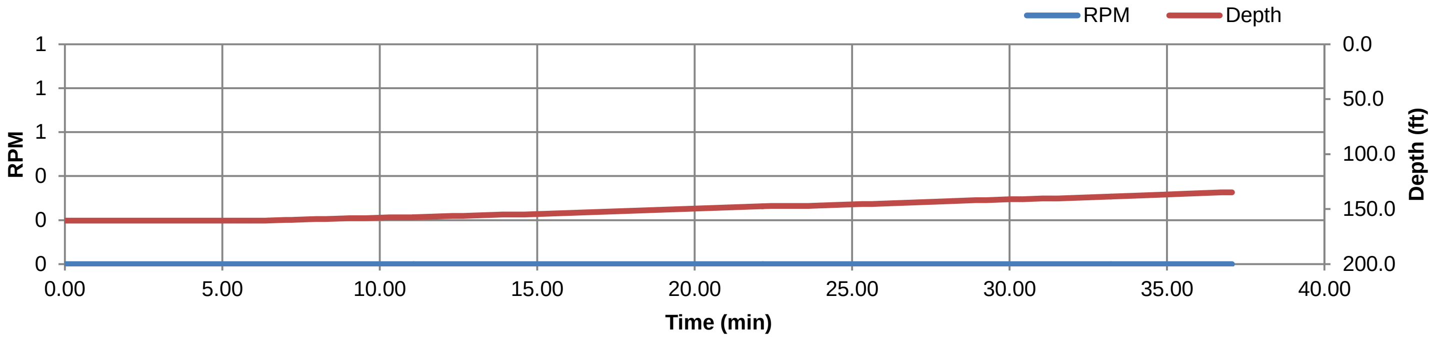


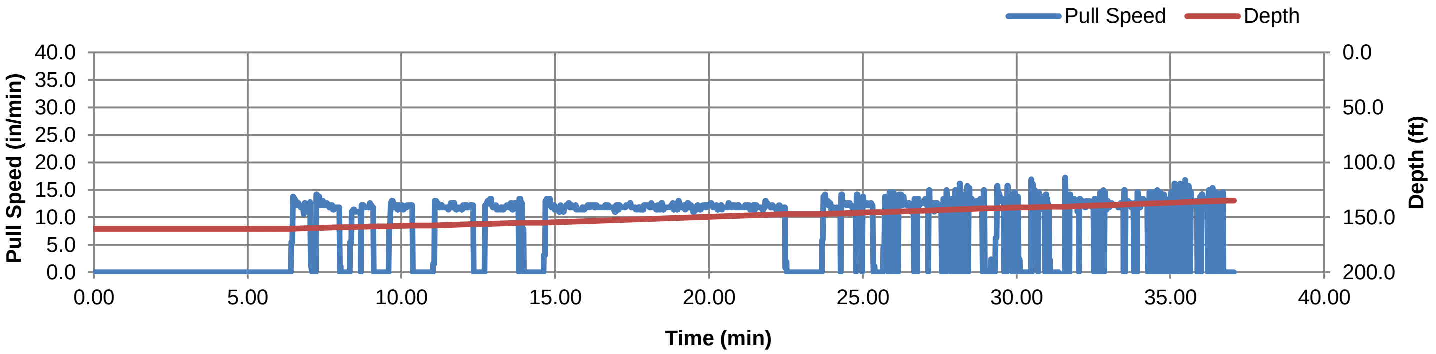


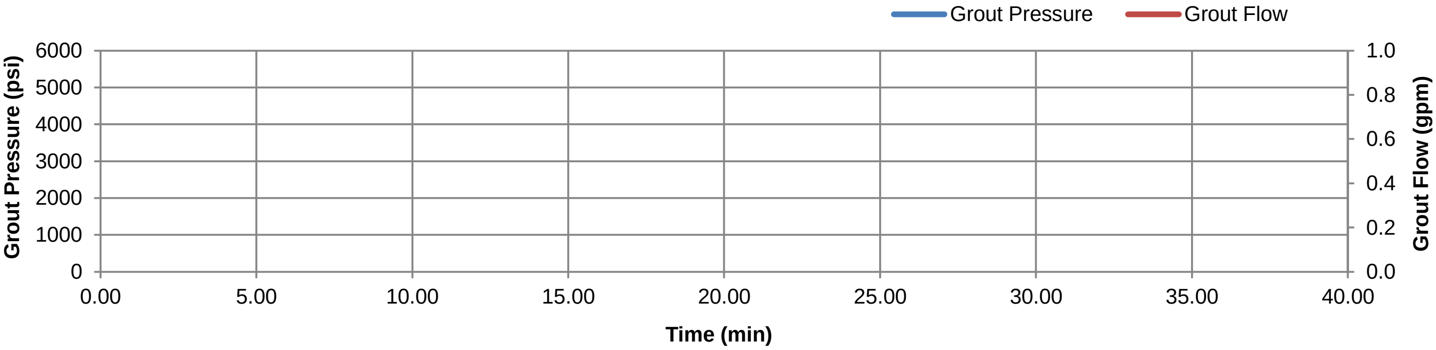
THINK SAFE

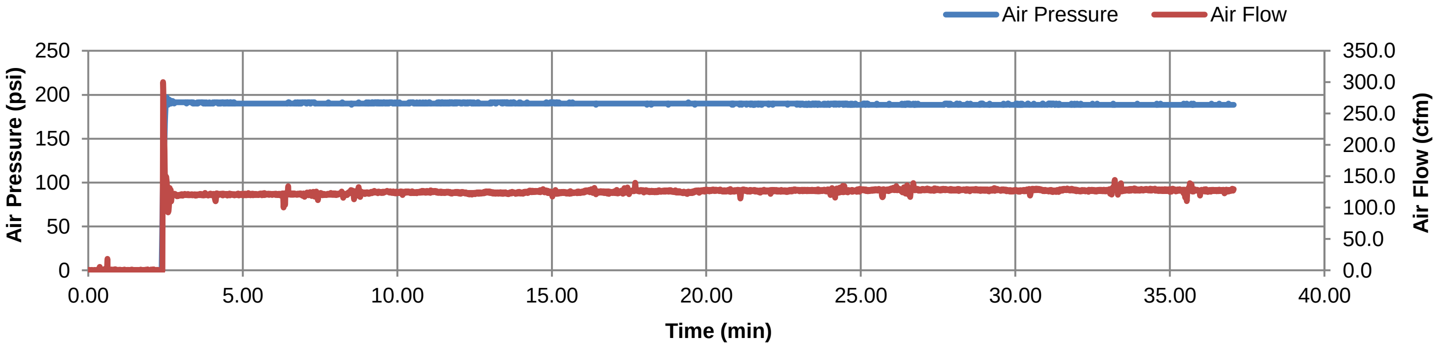
Jet Grouting Report
Kaiser Mead NPL

Column Number:	HBI-8B	**Date:**	9/15/2015
Job Number:	860080	**Start Time:**	9:30 AM
Job Location:	Spokane, WA	**End Time:**	10:07 AM
Total Grout Volume:	4096 gal	**Duration:**	00:37:00
Treatment Length:	25.69 ft	**Avg. S.G.:**	1.52



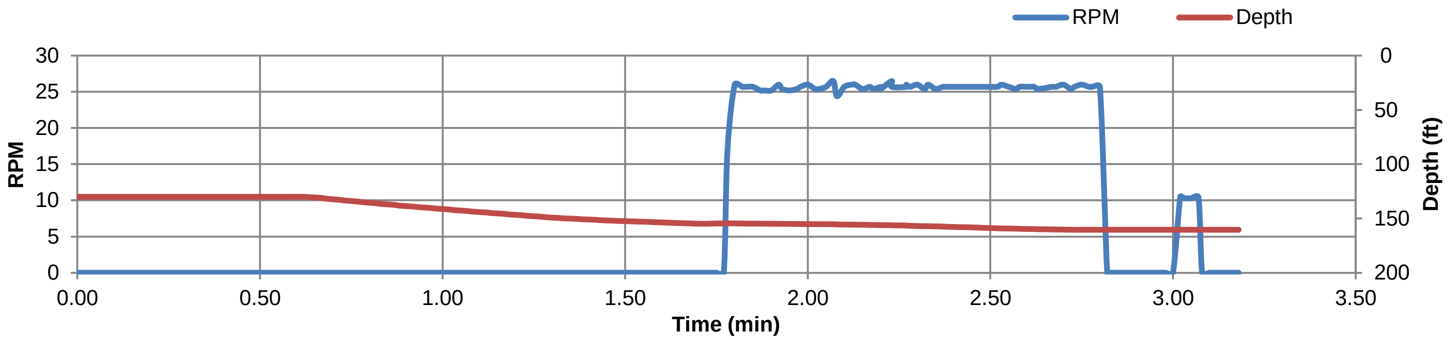


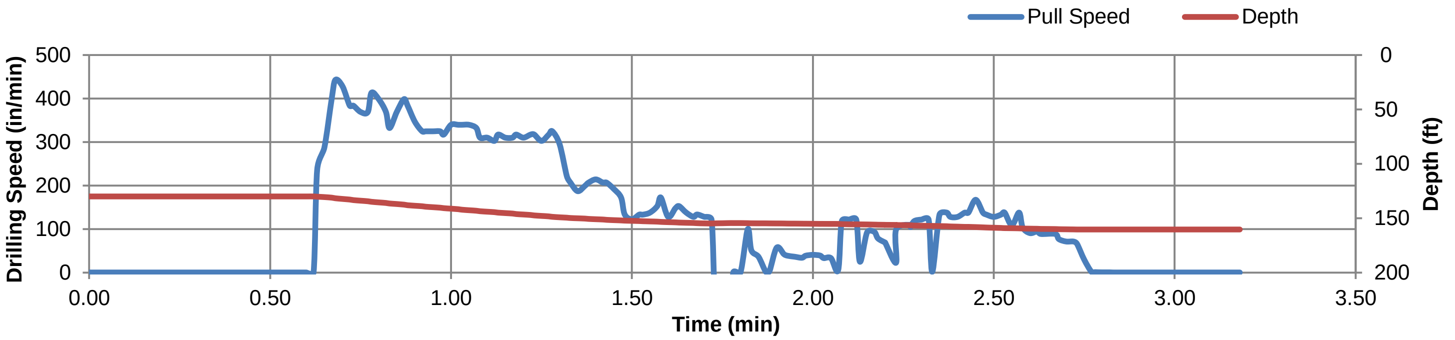


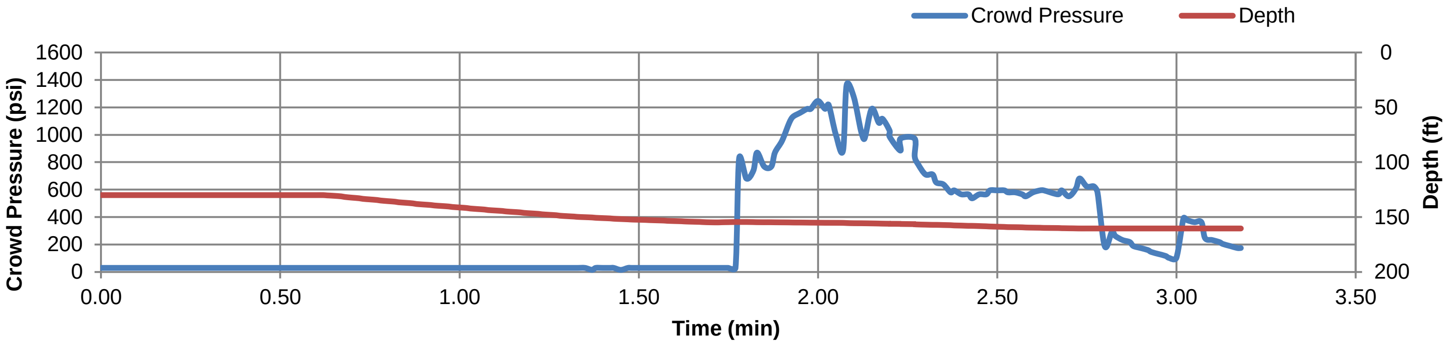


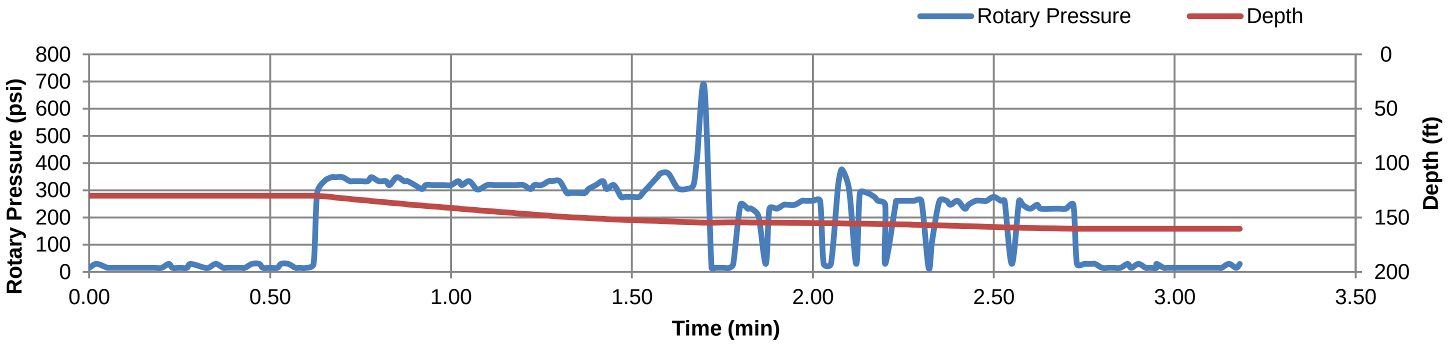
Jet Grout Drilling Report
Kaiser Mead NPL

Column Number:	HBI-8A	**Date:**	9/15/2015
Job Number:	860080	**Start Time:**	10:10 AM
Job Location:	Spokane, WA	**End Time:**	10:13 AM
Drilled Depth:	160.43 ft	**Duration:**	00:03:12
Inclination (X, Y):	(29.033 in, -0.077 in)		





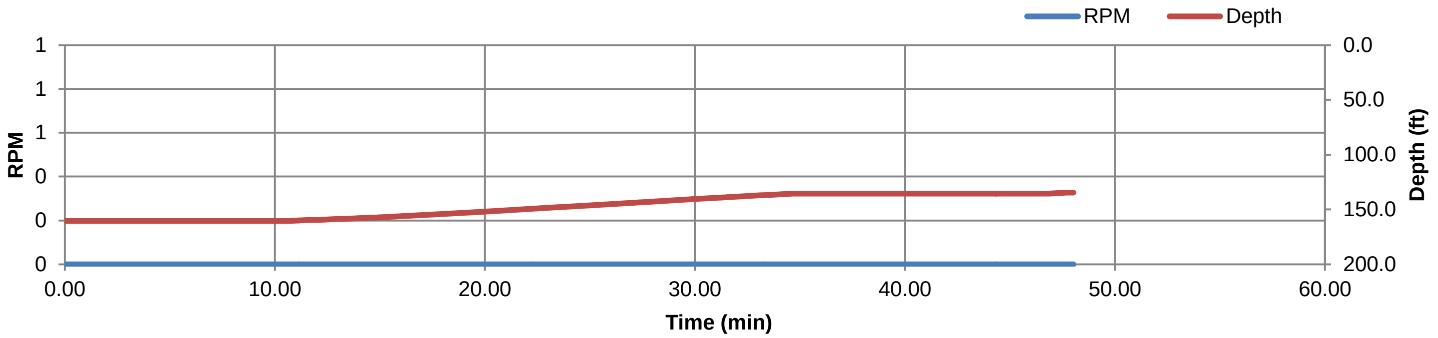


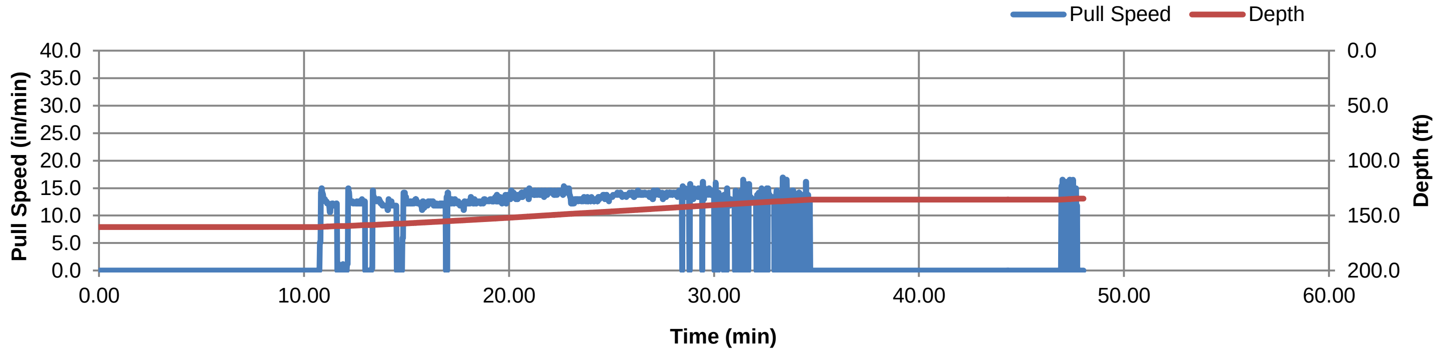


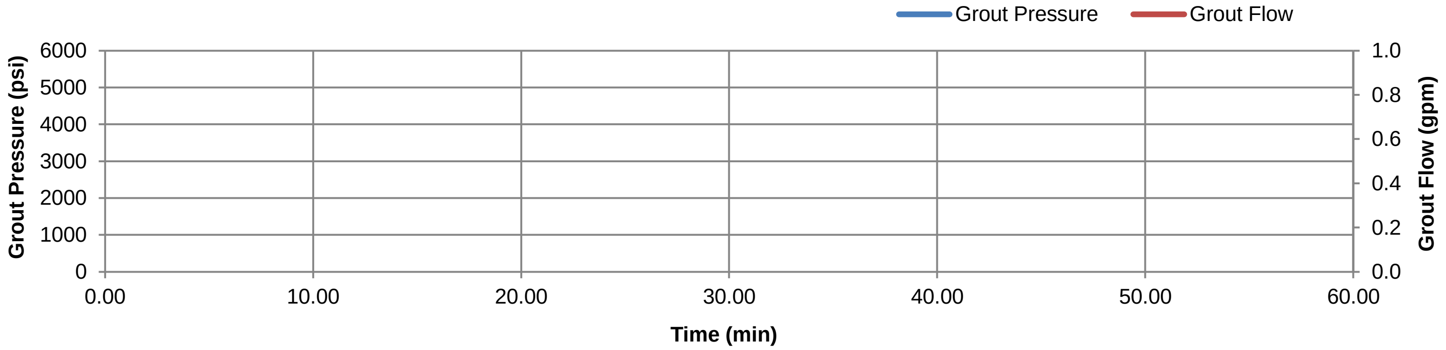
Jet Grouting Report
Kaiser Mead NPL

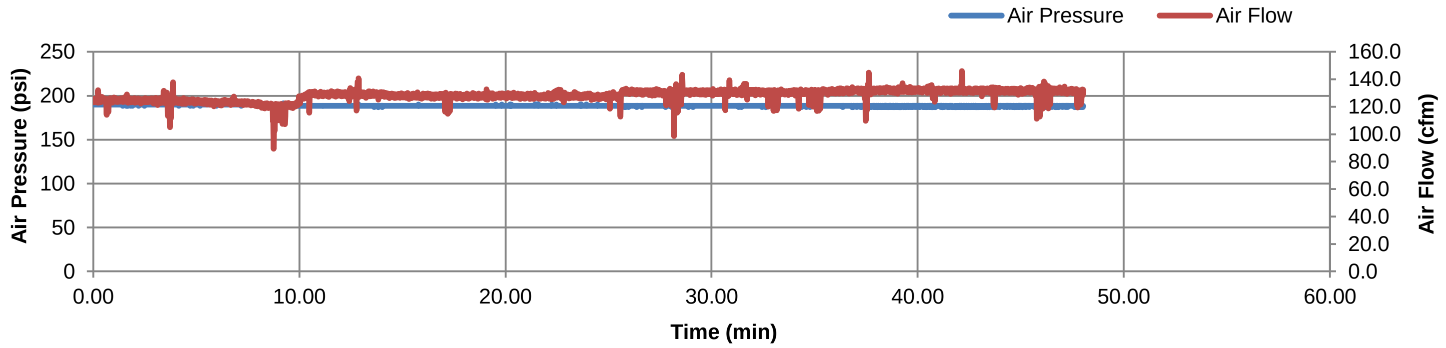
Column Number: HBI-8A
Job Number: 860080
Job Location: Spokane, WA
Total Grout Volume: 3847 gal
Treatment Length: 25.88 ft

Date: 9/15/2015
Start Time: 10:13 AM
End Time: 11:01 AM
Duration: 00:48:00
Avg. S.G.: 1.52



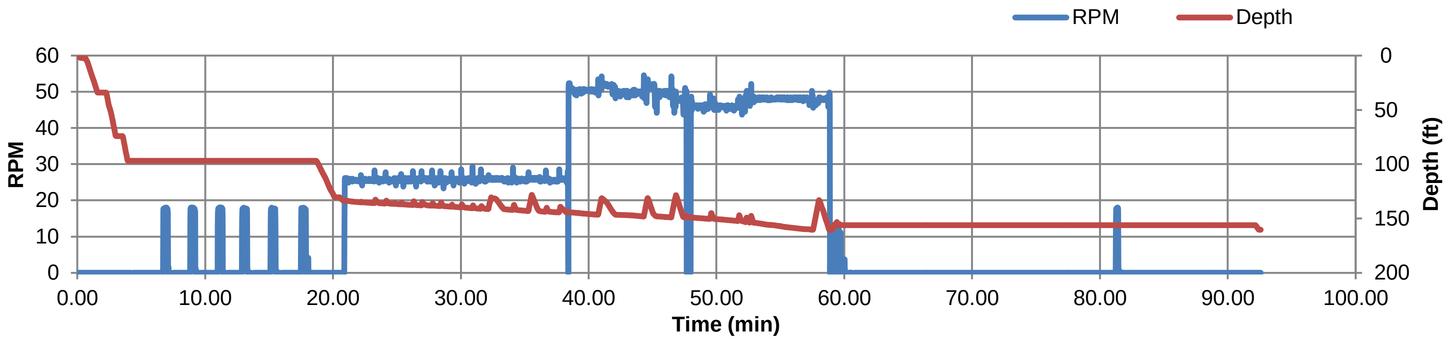


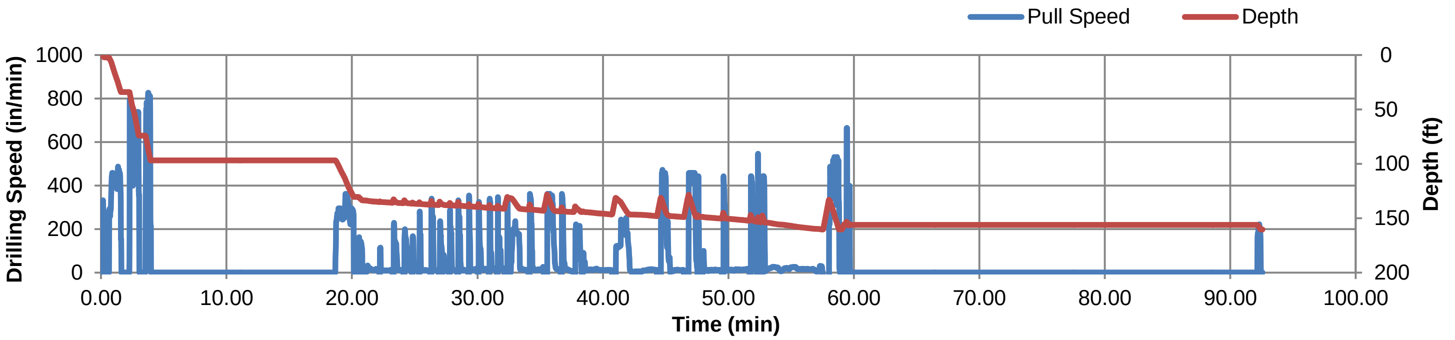


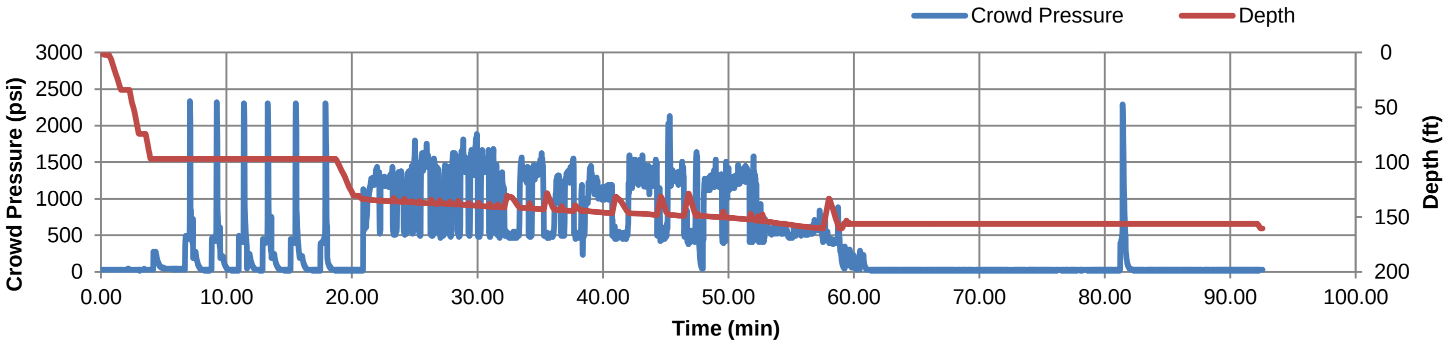


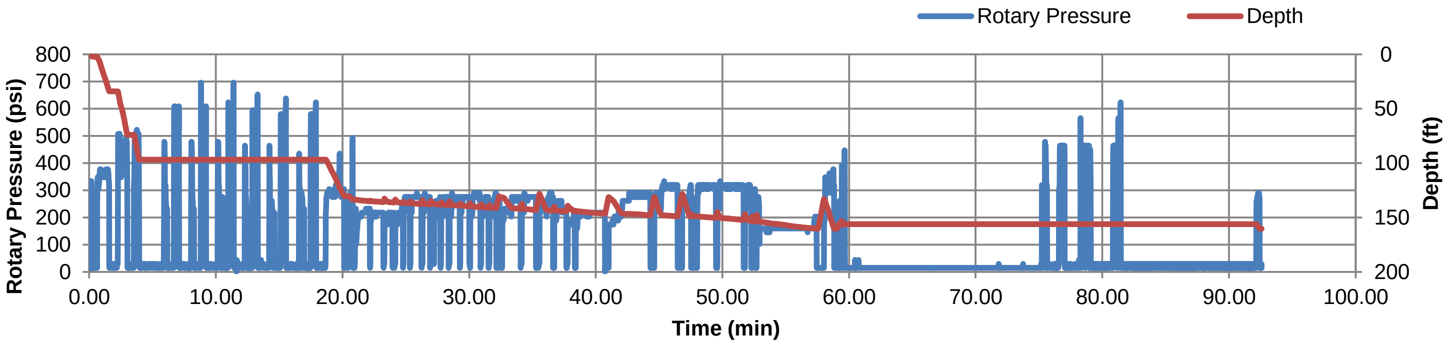
Jet Grout Drilling Report
Kaiser Mead NPL

Column Number:	HBI-R	**Date:**	9/15/2015
Job Number:	860080	**Start Time:**	12:48 PM
Job Location:	Spokane, WA	**End Time:**	2:25 PM
Drilled Depth:	160.46 ft	**Duration:**	01:37:48
Inclination (X, Y):	(-1.822 in, 24.324 in)		





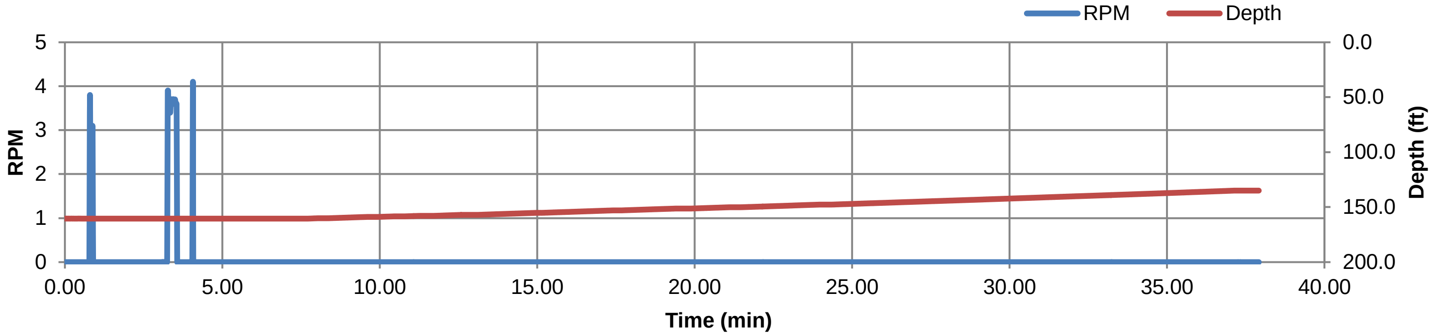


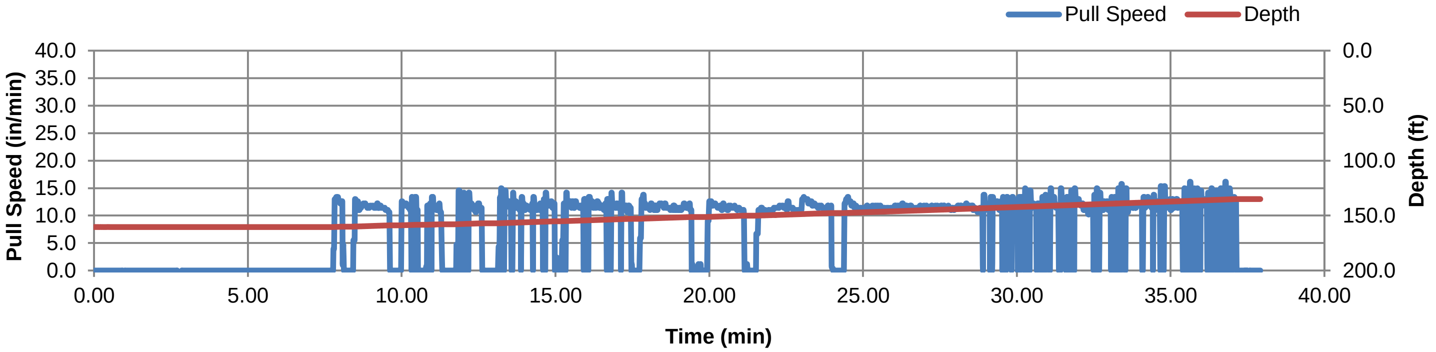


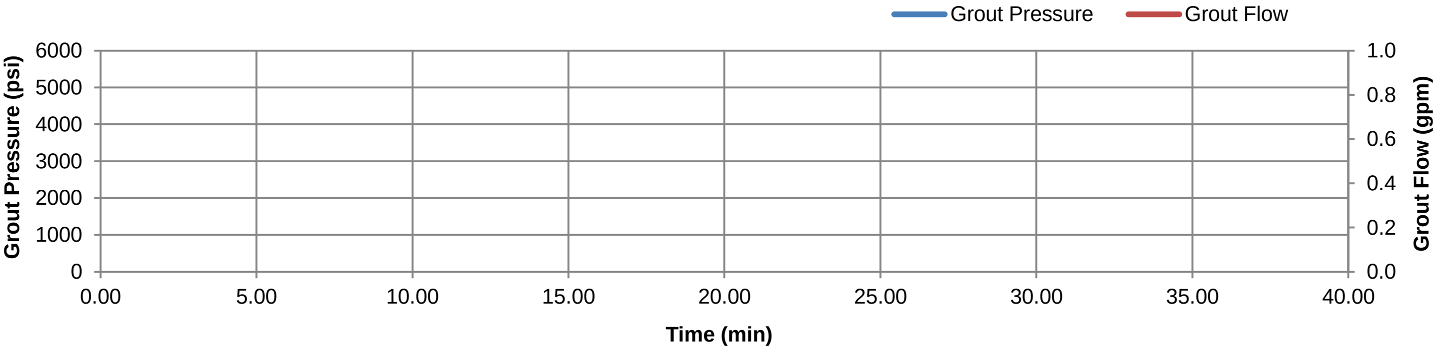
HAYWARD BAKER
Geotechnical Construction
KELLER

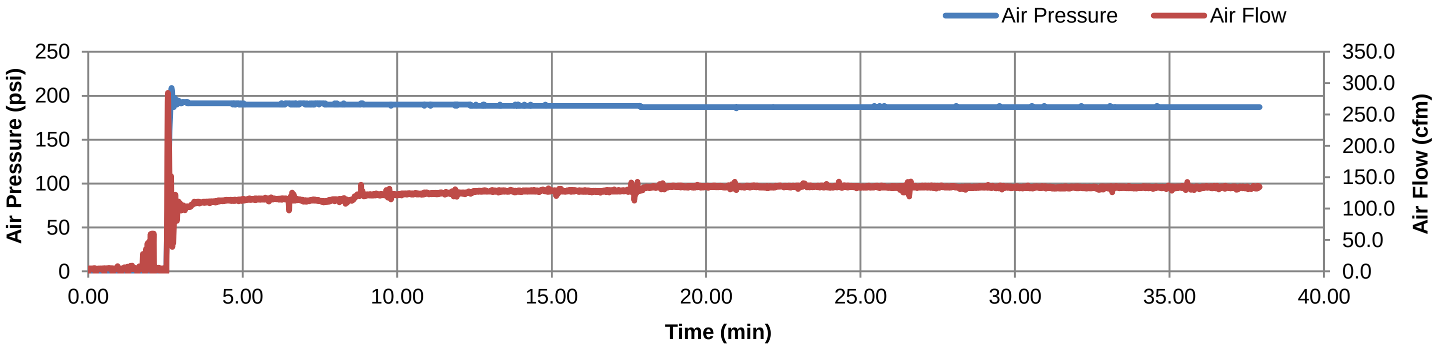
Jet Grouting Report
Kaiser Mead NPL

Column Number:	HBI-R	**Date:**	9/15/2015
Job Number:	860080	**Start Time:**	2:25 PM
Job Location:	Spokane, WA	**End Time:**	3:03 PM
Total Grout Volume:	4074 gal	**Duration:**	00:38:00
Treatment Length:	25.46 ft	**Avg. S.G.:**	1.52









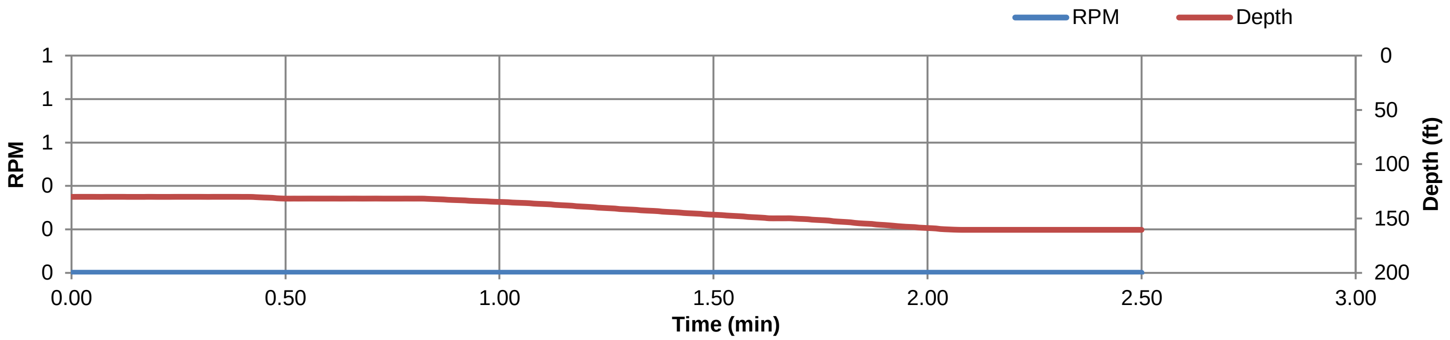
THINK SAFE

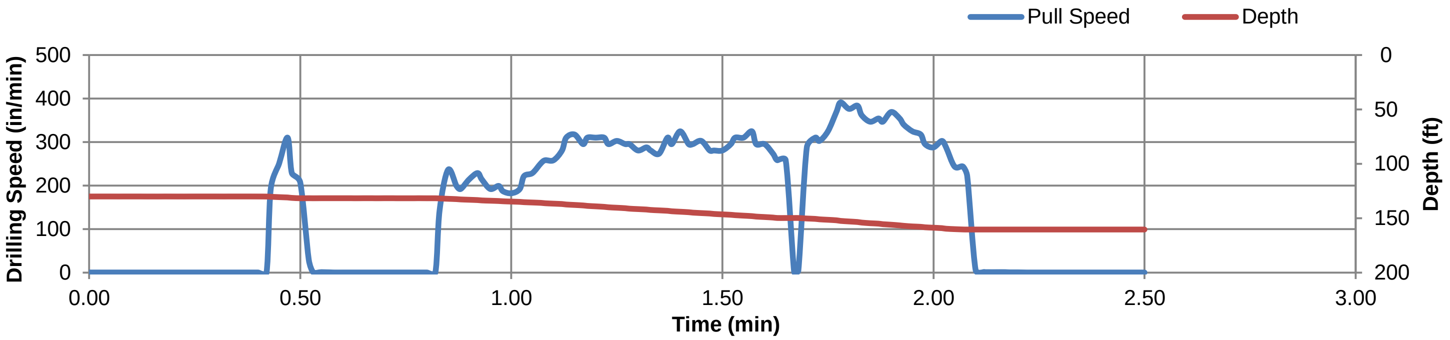
HAYWARD
BAKER
Geotechnical Construction
KELLER

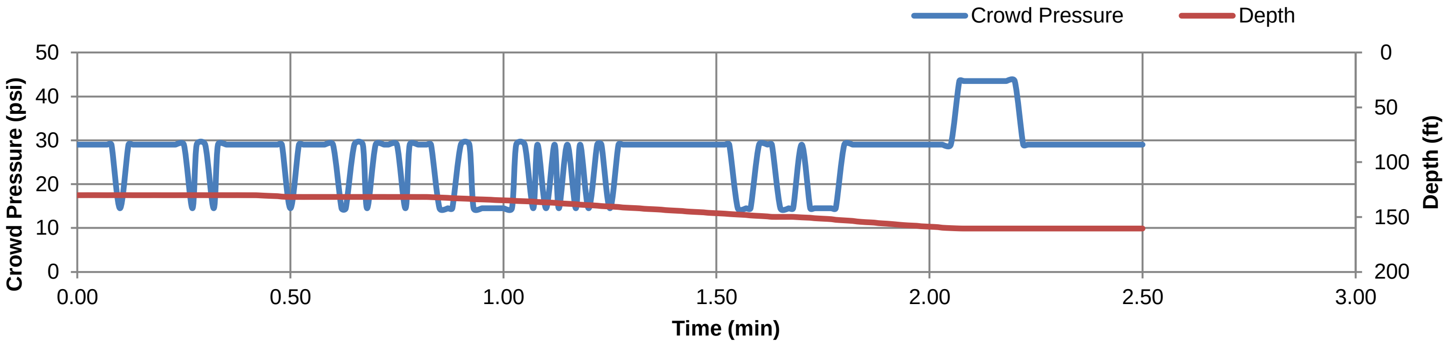
Jet Grout Drilling Report
Kaiser Mead NPL

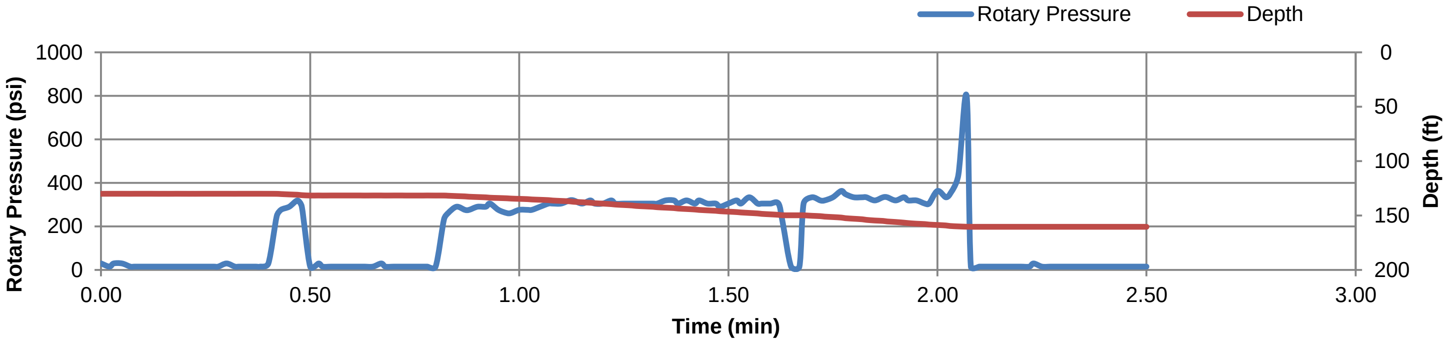
Column Number: HBI-R1
Job Number: 860080
Job Location: Spokane, WA
Drilled Depth: 160.46 ft
Inclination (X, Y): (-1.822 in, 24.324 in)

Date: 9/15/2015
Start Time: 3:06 PM
End Time: 3:08 PM
Duration: 00:02:31







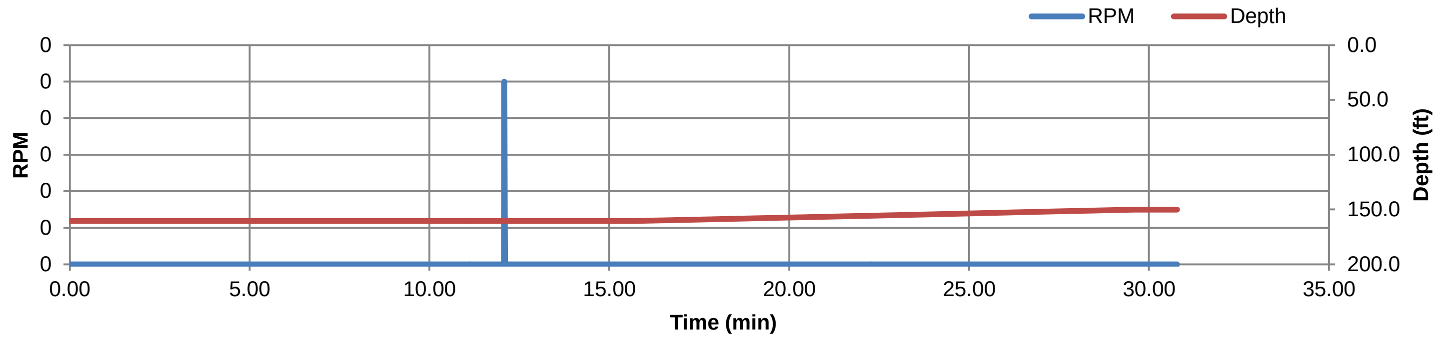


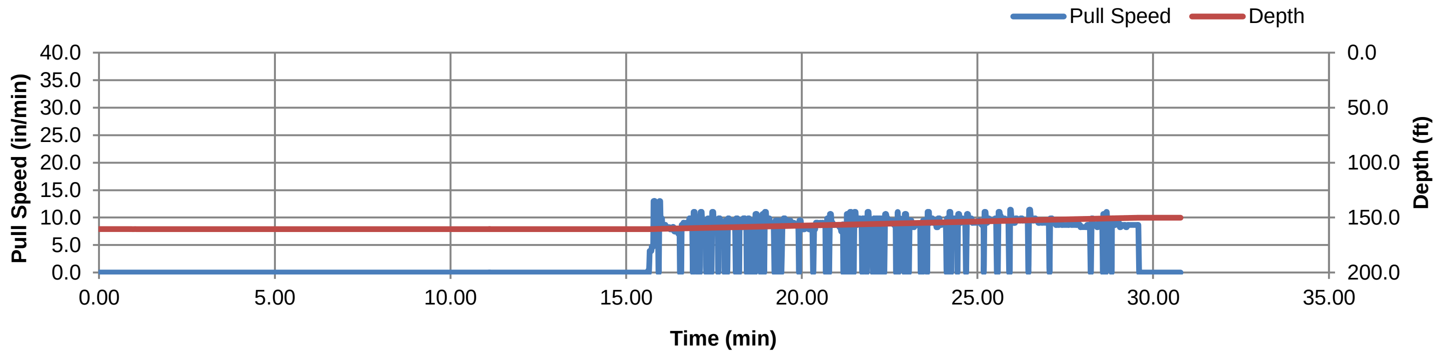
THINK SAFE

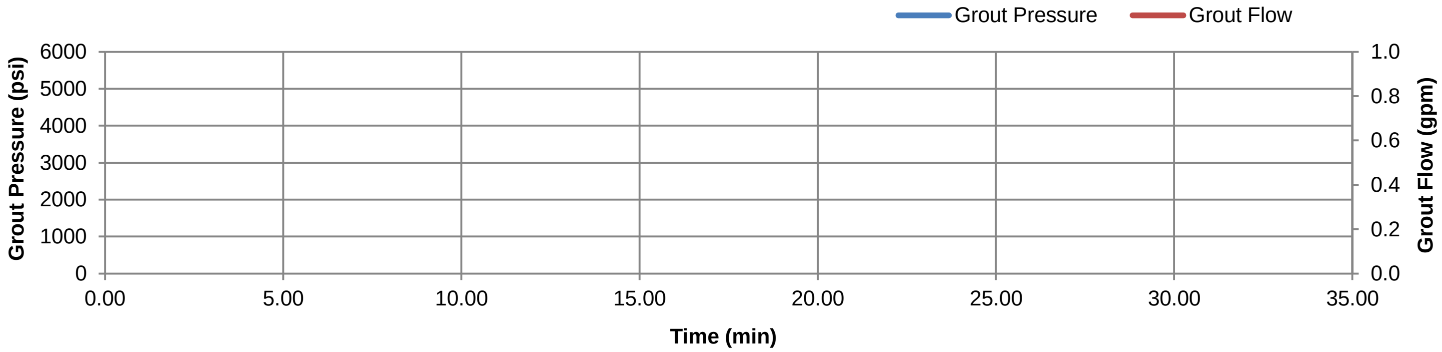
Jet Grouting Report
Kaiser Mead NPL

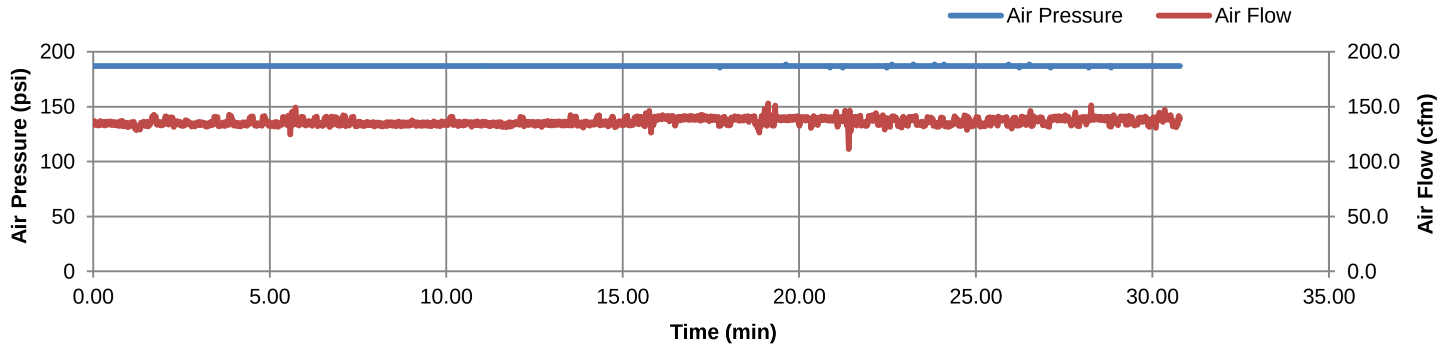
Column Number: HBI-R1
Job Number: 860080
Job Location: Spokane, WA
Total Grout Volume: 1929 gal
Treatment Length: 10.34 ft

Date: 9/15/2015
Start Time: 3:06 PM
End Time: 3:39 PM
Duration: 00:33:19
Avg. S.G.: 1.52









Attachment B – Hayward Baker Field Logs

HAYWARD BAKER
Geotechnical Construction

Jet Grout Panel Report
Project: Kaiser Mead NPL

Client:	Hydrometrics	Panels Completed to Date:	**2**
Date:	9/1/2015	Design Grout Mix	**1.52**
Job Number:	860080		
Superintendent:	Frank Kalata		
Location:	Mead, WA		

HBI-10A and HBI-10B

Sample Time	**Neat Grout SG**
11:30	1.52
12:30	1.53
13:30	1.52
14:30	1.52

Drill Time		**Drill Depth (ft)**	
Start	End	Start	End
11:46	14:44	0	159.3

Panel	**Jet Time**		**Jet Depth (ft)**	
	Start	End	Start	End
B	14:44	15:42	159.3	135
A	15:42	16:39	159.3	135

Panel	Jet Grout Volume
B	5235 gal
A	4703 gal

Spoils Samples Taken

Panel	**Time**	**Quantity**	**Depth (ft)**	**SG**
A	13:30	5	145	1.81

Comments:

HBI-10A: Reemed @ 155.7', 152.1', 147.4', and 141.1'
HBI-10B: Reemed @ 156.8', 155.8', 154.3', 153.8', 143.9', and 138.7'

HAYWARD
BAKER
Geotechnical Construction

Jet Grout Panel Report
Project: Kaiser Mead NPL

Client:	Hydrometrics	Panels Completed to Date:	**4**
Date:	9/2/2015	Design Grout Mix	**1.52**
Job Number:	860080		
Superintendent:	Frank Kalata		
Location:	Mead, WA		

HBI-12A and HBI-12B

Sample Time	Neat Grout SG
13:00	1.53
14:00	1.52
15:00	1.52
15:20	1.52

Drill Time		Drill Depth (ft)	
Start	End	Start	End
11:34	13:40	0	160.4

Panel	Jet Time		Jet Depth (ft)	
	Start	End	Start	End
B	13:40	14:49	160.4	135
A	14:54	15:26	160.5	134.7

Panel	Jet Grout Volume
B	3803 gal
A	3487 gal

Spoils Samples Taken

Panel	Time	Quantity	Depth (ft)	SG
B	14:20	7 (2 for Hydrometrics)	150.5	1.78

Comments:

HBI-10A: Reamed @ 157.8', 156.6', 152.8', 151.3' (screen clean), 150.4', 148.8', 144.2', and 140.7'
HBI-10B: Reamed @ 149.5' (basket clean)
Note: Grout volume is actually higher, but D-station did not output volume readings at the start

HAYWARD BAKER
Geotechnical Construction

Jet Grout Panel Report
Project: Kaiser Mead NPL

Client:	Hydrometrics	Panels Completed to Date:	**6**
Date:	9/3/2015	Design Grout Mix	**1.52**
Job Number:	860080		
Superintendent:	Frank Kalata		
Location:	Mead, WA		

HBI-6A & HBI-6B

Sample Time	**Neat Grout SG**
10:30	1.52
11:30	1.52
12:00	1.52

Drill Time		**Drill Depth (ft)**	
Start	End	Start	End
8:50	10:26	0	161.42

Panel	**Jet Time**		**Jet Depth (ft)**	
	Start	End	Start	End
B	10:26	11:29	161.42	134.68
A	11:33	12:03	161.42	134.7

Panel	Jet Grout Volume
B	5423 gal
A	3499 gal

Spoils Samples Taken

Panel	**Time**	**Quantity**	**Depth (ft)**	**SG**
A	11:43	7 (2 for Hydrometrics)	154.4	1.75

Comments:

HBI-10B: Reamed @ 155.9', 154.8', 153.5', and 146'
Pre-drill casing on HBI-1: Encountered rock, SAA test on Tuesday will show if the borehole is within deviation tolerance of 1%. If not, we will add another panel.

HAYWARD BAKER
Geotechnical Construction

Jet Grout Panel Report
Project: Kaiser Mead NPL

Client:	Hydrometrics	Panels Completed to Date:	**10**
Date:	9/8/2015	Design Grout Mix	**1.52**
Job Number:	860080		
Superintendent:	Frank Kalata	Page	**1/2**
Location:	Mead, WA		

HBI-1A, HBI-1B

Sample Time	**Neat Grout SG**
9:45	1.52
13:00	1.53
14:30	1.52

Drill Time		**Drill Depth (ft)**	
Start	End	Start	End
8:16	9:40	0	160.7

Panel	**Jet Time**		**Jet Depth (ft)**	
	Start	End	Start	End
B	9:40	10:31	160.7	134.7
A	10:42	11:21	160.7	134.7

Panel	Jet Grout Volume	Grout Flow
B	4807 gal	137 gpm
A	4285 gal	137 gpm

Spoils Samples Taken

Panel	**Time**	**Quantity**	**Depth (ft)**	**SG**
A	11:01	5	152.8	1.64

Comments:

HBI-1A: Reamed @ 152.8'.
HBI-1B: Reamed @ 153.6', 143.3', and 140.5'

HAYWARD BAKER
Geotechnical Construction

Jet Grout Panel Report
Project: Kaiser Mead NPL

Client:	Hydrometrics	Panels Completed to Date:	**10**
Date:	9/8/2015	Design Grout Mix	**1.52**
Job Number:	860080		
Superintendent:	Frank Kalata	Page	**2/2**
Location:	Mead, WA		

HBI-3A, HBI-3B

Sample Time	**Neat Grout SG**
15:00	1.52
15:20	1.52
16:15	1.52
16:30	1.52

Drill Time		**Drill Depth (ft)**	
Start	End	Start	End
12:54	14:17	0	161.1

Panel	**Jet Time**		**Jet Depth (ft)**	
	Start	End	Start	End
B	14:17	15:20	161.1	134.7
A	15:39	16:34	161.1	134.7

Panel	Jet Grout Volume	Grout Flow
B	5027 gal	137 gpm
A	4924 gal	137 gpm

Spoils Samples Taken

Panel	**Time**	**Quantity**	**Depth (ft)**	**SG**
B	14:50	7 (2 for Hydrometrics)	155.1	1.6

Comments:

HBI-3A: Reamed @ 160.2'
HBI-3B: Reamed @ 155.4' and 152.9'

HAYWARD BAKER
Geotechnical Construction

Jet Grout Panel Report
Project: Kaiser Mead NPL

Client:	Hydrometrics	Panels Completed to Date:	**12**
Date:	9/9/2015	Design Grout Mix	**1.52**
Job Number:	860080		
Superintendent:	Frank Kalata		
Location:	Mead, WA		

HBI-7A & HBI-7B

Sample Time	**Neat Grout SG**
9:30	1.52
10:10	1.52
13:45	1.52

Drill Time		**Drill Depth (ft)**	
Start	End	Start	End
7:50	9:36	0	160.7

Panel	**Jet Time**		**Jet Depth (ft)**	
	Start	End	Start	End
B	9:36	10:17	160.7	134.7
A	10:21	13:15	160.7	134.7

Panel	Jet Grout Volume	Grout Flow
B	4013 gal	137 gpm
A	3961 gal	137 gpm

Spoils Samples Taken

Panel	**Time**	**Quantity**	**Depth (ft)**	**SG**
A	13:30	7 (2 for Hydrometrics)	155.7	1.55

Comments:

HBI-7B: Cleaned basket @ 143.5'
HBI-7A: 11:10 - 12:39 Tripped out to clean clogged nozzles.

HAYWARD BAKER
Geotechnical Construction

Jet Grout Panel Report
Project: Kaiser Mead NPL

Client:	Hydrometrics	Panels Completed to Date:	**14**
Date:	9/10/2015	Design Grout Mix	**1.52**
Job Number:	860080		
Superintendent:	Frank Kalata		
Location:	Mead, WA		

HBI-9A & HBI-9B

Sample Time	**Neat Grout SG**
9:45	1.52
10:45	1.52

Drill Time		**Drill Depth (ft)**	
Start	End	Start	End
7:21	9:42	0	160.4

Panel	**Jet Time**		**Jet Depth (ft)**	
	Start	End	Start	End
B	9:42	10:34	160.4	134.7
A	10:45	11:44	160.3	134.7

Panel	Jet Grout Volume	Grout Flow
B	4309 gal	137 gpm
A	4367 gal	137 gpm

Spoils Samples Taken

Panel	**Time**	**Quantity**	**Depth (ft)**	**SG**
A	11:05	5	147.1	1.61

Comments:

HBI-7B: Cleaned basket @ 145.0'
HBI-9A: Waiting on batch plant to catch up @ 146.1'

HAYWARD BAKER
Geotechnical Construction

Jet Grout Panel Report
Project: Kaiser Mead NPL

Client:	Hydrometrics	Panels Completed to Date:	**18**
Date:	9/11/2015	Design Grout Mix	**1.52**
Job Number:	860080		
Superintendent:	Frank Kalata	Page	**1/2**
Location:	Mead, WA		

HBI-11A, HBI-11B

Sample Time	**Neat Grout SG**
9:00	1.52
9:30	1.52
9:45	1.52

Drill Time		**Drill Depth (ft)**	
Start	End	Start	End
8:08	8:54	0	160.7

Panel	**Jet Time**		**Jet Depth (ft)**	
	Start	End	Start	End
B	8:54	9:34	160.7	134.7
A	9:41	10:53	160.7	134.7

Panel	Jet Grout Volume	Grout Flow
B	4522 gal	137 gpm
A	4180 gal	137 gpm

Spoils Samples Taken

Panel	**Time**	**Quantity**	**Depth (ft)**	**SG**
B	9:25	5	141.8	1.55

Comments:

HBI-11A: Water issues @ 150.4'
HBI-11B: Jet grouting report does not show correct graphs. Driller's computer was still in drilling mode during jet grouting.
HBI-11A,B: Jet grout reports do not show actual grout pressure.

HAYWARD
BAKER
Geotechnical Construction

Jet Grout Panel Report
Project: Kaiser Mead NPL

Client:	Hydrometrics	Panels Completed to Date:	**18**
Date:	9/11/2015	Design Grout Mix	**1.52**
Job Number:	860080		
Superintendent:	Frank Kalata	Page	**2/2**
Location:	Mead, WA		

HBI-2A, HBI-2B

Sample Time	**Neat Grout SG**
16:00	1.52
16:10	1.52
17:00	1.52

Drill Time		**Drill Depth (ft)**	
Start	End	Start	End
12:07	14:21	0	157.19

Panel	**Jet Time**		**Jet Depth (ft)**	
	Start	End	Start	End
B	14:21	16:31	157.1	134.7
A	16:37	17:22	157.1	134.5

Panel	Jet Grout Volume	Grout Flow
B	4213 gal	137 gpm
A	3690 gal	137 gpm

Spoils Samples Taken

Panel	**Time**	**Quantity**	**Depth (ft)**	**SG**
B	16:22	5	142.7	1.62

Comments:

HBI-2A: Various issues @ 147.9'
HBI-2B: Reamed @ 156.8' and 153.7'
HBI-2A,B: Jet grout reports do not show actual grout pressure.

HAYWARD BAKER
Geotechnical Construction

Jet Grout Panel Report
Project: Kaiser Mead NPL

Client:	Hydrometrics	Panels Completed to Date:	**22**
Date:	9/14/2015	Design Grout Mix	**1.52**
Job Number:	860080		
Superintendent:	Frank Kalata	Page	**1/2**
Location:	Mead, WA		

HBI-4A, HBI-4B

Sample Time	**Neat Grout SG**
10:15	1.52
10:50	1.52
11:00	1.52

Drill Time		**Drill Depth (ft)**	
Start	End	Start	End
7:53	9:47	0	160.8

Panel	**Jet Time**		**Jet Depth (ft)**	
	Start	End	Start	End
B	9:47	10:38	160.8	134.7
A	10:45	11:31	160.8	134.7

Panel	Jet Grout Volume	Grout Flow
B	3751 gal	136 gpm
A	4023 gal	136 gpm

Spoils Samples Taken

Panel	**Time**	**Quantity**	**Depth (ft)**	**SG**
B	10:27	5	145	1.64

Comments:

HBI-4A: Vaccuum issues @ 142.5'

Jet Grout Panel Report
Project: Kaiser Mead NPL

Client:	Hydrometrics	Panels Completed to Date:	**22**
Date:	9/14/2015	Design Grout Mix	**1.52**
Job Number:	860080		
Superintendent:	Frank Kalata	Page	**2/2**
Location:	Mead, WA		

HBI-5A, HBI-5B

Sample Time	**Neat Grout SG**
14:57	1.52
15:50	1.52
16:00	1.52

Drill Time		**Drill Depth (ft)**	
Start	End	Start	End
12:23	14:44	0	160.4

Panel	**Jet Time**		**Jet Depth (ft)**	
	Start	End	Start	End
B	14:44	15:36	160.4	134.7
A	15:47	16:27	160.4	134.6

Panel	Jet Grout Volume	Grout Flow
B	4383 gal	136 gpm
A	4545 gal	136 gpm

Spoils Samples Taken

Panel	**Time**	**Quantity**	**Depth (ft)**	**SG**
A	16:00	5	153	1.66

Comments:

HBI-5A: Basket cleaned @ 146.9'
HBI-5: Rotated panel A CCW 30 degrees, then rotated 65 degrees CW and jetted panel B

HAYWARD BAKER
Geotechnical Construction

Jet Grout Panel Report
Project: Kaiser Mead NPL

Client:	Hydrometrics	Panels Completed to Date:	**26**
Date:	9/15/2015	Design Grout Mix	**1.52**
Job Number:	860080		
Superintendent:	Frank Kalata	Page	**1/2**
Location:	Mead, WA		

HBI-8A, HBI-8B

Sample Time	**Neat Grout SG**
9:30	1.52
10:00	1.52

Drill Time		**Drill Depth (ft)**	
Start	End	Start	End
7:56	9:30	0	160.5

Panel	**Jet Time**		**Jet Depth (ft)**	
	Start	End	Start	End
B	9:30	10:07	160.5	134.7
A	10:13	11:01	160.5	134.5

Panel	Jet Grout Volume	Grout Flow
B	4096 gal	137 gpm
A	3847 gal	137 gpm

Spoils Samples Taken

Panel	**Time**	**Quantity**	**Depth (ft)**	**SG**
B	10:00	5	141	1.63

Comments:

HBI-8: Rotated panel set 8 degrees CW from original orientation.

HAYWARD BAKER
Geotechnical Construction

Jet Grout Panel Report
Project: Kaiser Mead NPL

Client:	Hydrometrics	Panels Completed to Date:	**26**
Date:	9/15/2015	Design Grout Mix	**1.52**
Job Number:	860080		
Superintendent:	Frank Kalata	Page	**2/2**
Location:	Mead, WA		

HBI-R, HBI-R1

Sample Time	**Neat Grout SG**
14:15	1.52
15:20	1.52

Drill Time		**Drill Depth (ft)**	
Start	End	Start	End
12:48	14:25	0	160.4

Panel	**Jet Time**		**Jet Depth (ft)**	
	Start	End	Start	End
R	14:25	15:03	160.4	134.9
R1	15:08	15:39	160.4	150.1

Panel	Jet Grout Volume	Grout Flow
R	4074 gal	137 gpm
R1	1929 gal	137 gpm

Spoils Samples Taken

Panel	**Time**	**Quantity**	**Depth (ft)**	**SG**
R	14:58	5	140	1.64

Comments:

HBI-R: Chose a borehole location 1'10" to the right and 1' up from the original HBI-1 borehole.
HBI-R: Due to deviation, we rotated 15 degrees CCW and jetted HBI-R.
HBI-R1: Due to concerns with the possible gap at the bottom of HBI-2, we rotated CW 30 degrees and jetted a 10 ft panel (starting at the bottom) at a pull rate of 20 cm/min.

Attachment C –
Laboratory Test Results

HWA GEOSCIENCES INC.
Geotechnical Engineering • Hydrogeology • Geoenvironmental • Inspection and Testing

October 30, 2015
HWA Project No. 2014-069-23

Hayward Baker
11180 East Marginal Way South
Tukwila, Washington 98168

Attention: Mr. Dylan Fisher

Subject: **SOIL LABORATORY TESTING REPORT**
Permeability Testing on Soil Cement

Dear Mr. Fisher:

As requested, HWA GeoSciences Inc. (HWA) performed laboratory permeability tests for the above referenced project. Herein we present the results of our laboratory analyses, which are summarized on the attached reports on Figures 1 through 6. The laboratory testing program was performed in general accordance with your instructions and appropriate ASTM Standards as outlined below.

SAMPLE INFORMATION: Twelve soil cement samples were delivered to our laboratory for testing on September 25, 2015 by Hayward Baker personnel. The samples were delivered in 3x6 inch plastic cylinder molds. For purposes of expediency only six of the twelve sample were tested. The samples tested were designated "HBI-1, HBI-3, HBI-6, HBI-8, HBI-10, and HBI-12" by the Client.

HYDRAULIC CONDUCTIVITY OF SOIL (FLEXI-WALL TRIAXIAL CHAMBER METHOD): The hydraulic conductivity (also commonly referred to as coefficient of permeability) of each submitted sample was measured in general accordance with method ASTM D-5084. Each sample was removed from its plastic mold, trimmed, measured and weighed prior to placement into the testing apparatus. Saturation was induced by subjecting the test specimen to a flow gradients ranging from 9.7 to about 26.7 generated by a back-pressure differential of 5 psi within a triaxial pressure chamber. Testing was conducted until inflow was nearly equal to outflow and the hydraulic conductivity was relatively steady. The test results are presented in detail on Figures 1 through 6.

o • o

CLOSURE: Experience has shown that test values on soil and other natural materials vary with each representative sample. As such, HWA has no knowledge as to the extent and quantity of material the tested samples may represent. No copy should be made of this report except in its entirety.

21312 30th Drive SE
Suite 110
Bothell, WA 98021-7010
Tel: 425.774.0106
Fax: 425.774.2714
www.hwageo.com

We appreciate the opportunity to provide laboratory testing services on this project. Should you have any questions or comments, or if we may be of further service, please call.

Sincerely,

HWA GEOSCIENCES INC.

Jessica Herrera
Materials Laboratory Manager

Steven Greene, L.G., L.E.G.
Vice-President

Attachments:

Figures 1 through 6	Hydraulic Conductivity Test Reports

Hydraulic Conductivity Test Report

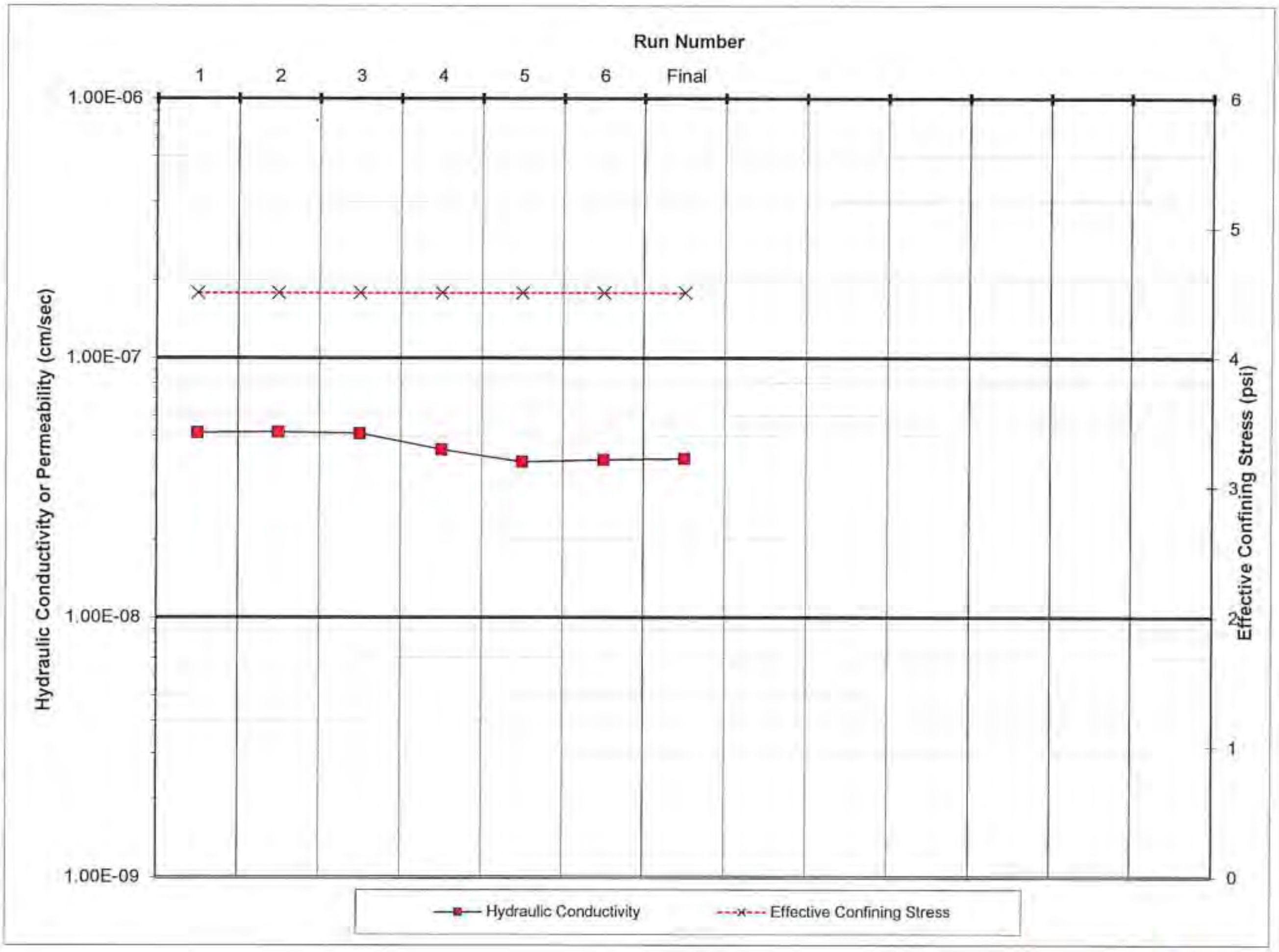
Method ASTM D 5084

HWA GEOSCIENCES INC.

Project	
Client	Hayward Baker
Project number	2014-069
Date	10/14/2015
Technician	DW
Sample point	HBI-1
Sample number	N/A
Sample depth	N/A
Sample description	Soil Cement

Assumed Specific Gravity	2.65		
Initial Sample Area (cm2)	46.32	Final Sample Area (cm2)	46.32
Initial Sample Length (cm)	14.22	Final Sample Length (cm)	14.22
Initial Sample Volume (cc)	658.7	Final Sample Volume (cc)	658.4
Initial moisture (%)	53.8	Final moisture (%)	55.2
Initial wet unit wt. (pcf)	101.9	Final wet unit weight (pcf)	102.9
Initial dry unit wt. (pcf)	66.2	Final dry unit weight (pcf)	66.3
Initial void ratio	1.496	Final void ratio	1.495
Initial porosity	0.599	Final porosity	0.599
Initial saturation (%)	95.3	Final saturation (%)	97.9

Run No.	Hydraulic Conductivity (cm/s)	Running Average of 4 Readings (cm/s)	Maximum % Deviation from Average (should be less than 25%)	Flow Ratio (0.75 to 1.25 required)	Effective Confining Stress (psi)	Other Information
1	5.1E-08	n.a.		1.30	4.5	Maximum Gradient
2	5.2E-08	n.a.		1.14	4.5	25.7
3	5.1E-08	n.a.		1.21	4.5	Minimum Gradient
4	4.4E-08	5.0E-08	10.7%	1.05	4.5	22.0
5	4.0E-08	4.7E-08	15.0%	1.08	4.5	Max. Back Pressure (psi)
6	4.0E-08	4.4E-08	16.3%	1.00	4.5	63.0
Final	4.1E-08	4.1E-08	7.2%	1.21	4.5	Min. Back Pressure (psi)
						63.0



Checked by:

FIGURE: 1

Hydraulic Conductivity Test Report

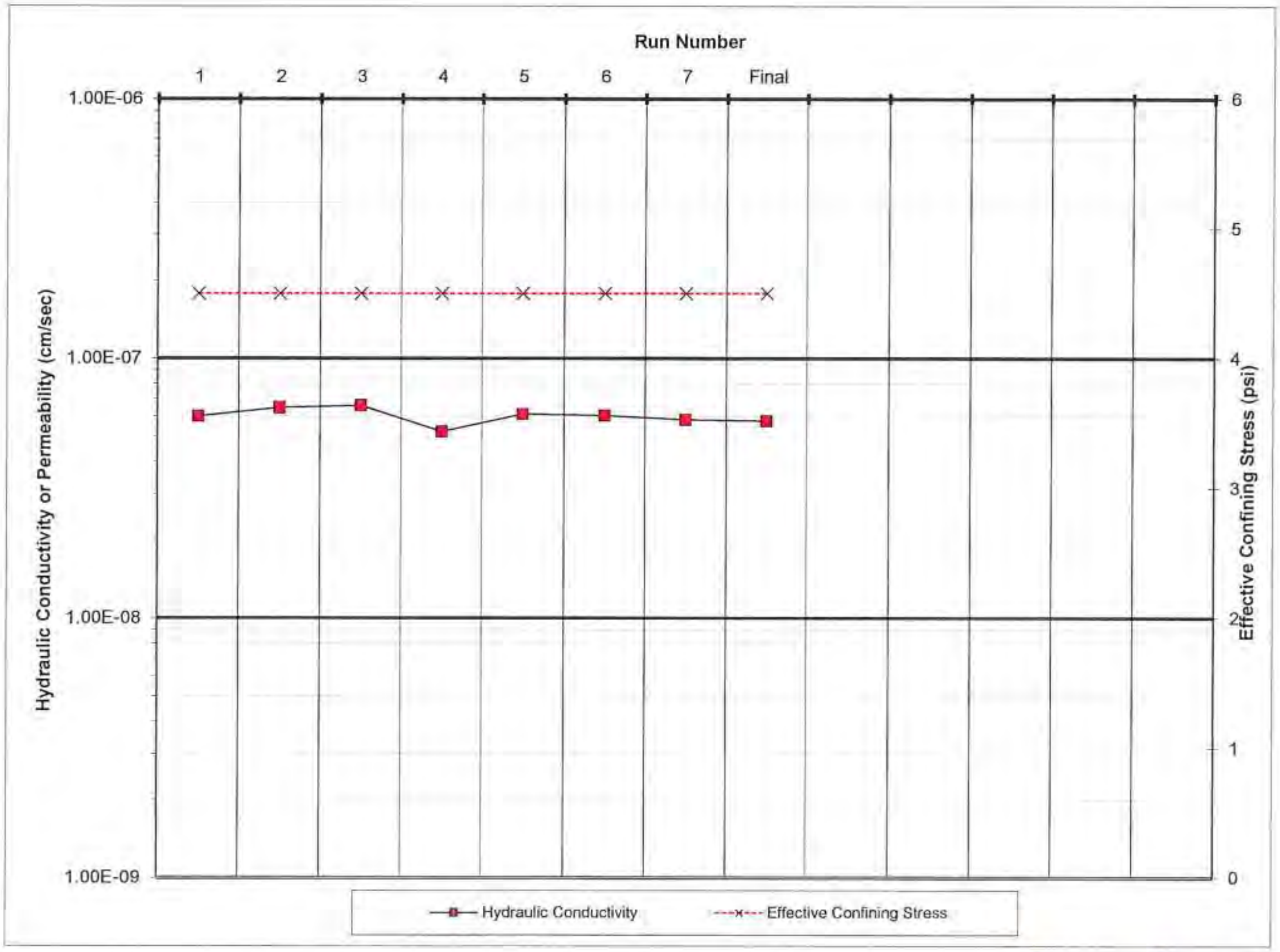
Method ASTM D 5084

HWA GEOSCIENCES INC.

Project	
Client	Hayward Baker
Project number	2014-069
Date	10/19/2015
Technician	DW
Sample point	HBI-3
Sample number	N/A
Sample depth	N/A
Sample description	Soil Cement

Assumed Specific Gravity	2.65		
Initial Sample Area (cm2)	46.29	Final Sample Area (cm2)	44.99
Initial Sample Length (cm)	14.16	Final Sample Length (cm)	14.14
Initial Sample Volume (cc)	655.6	Final Sample Volume (cc)	635.9
Initial moisture (%)	50.2	Final moisture (%)	52.1
Initial wet unit wt. (pcf)	99.8	Final wet unit weight (pcf)	104.2
Initial dry unit wt. (pcf)	66.4	Final dry unit weight (pcf)	68.5
Initial void ratio	1.489	Final void ratio	1.413
Initial porosity	0.598	Final porosity	0.586
Initial saturation (%)	89.3	Final saturation (%)	97.7

Run No.	Hydraulic Conductivity (cm/s)	Running Average of 4 Readings (cm/s)	Maximum % Deviation from Average (should be less than 25%)	Flow Ratio (0.75 to 1.25 required)	Effective Confining Stress (psi)	Other Information
1	6.0E-08	n.a.		0.80	4.5	Maximum Gradient
2	6.5E-08	n.a.		0.81	4.5	26.7
3	6.6E-08	n.a.		0.91	4.5	Minimum Gradient
4	5.2E-08	6.1E-08	13.9%	0.62	4.5	22.2
5	6.1E-08	6.1E-08	14.3%	0.84	4.5	Max. Back Pressure (psi)
6	6.0E-08	6.0E-08	12.7%	0.89	4.5	63.0
7	5.8E-08	5.8E-08	9.8%	0.89	4.5	Min. Back Pressure (psi)
Final	5.7E-08	**5.9E-08**	3.1%	0.85	4.5	63.0



Checked by:

FIGURE: 2

Hydraulic Conductivity Test Report

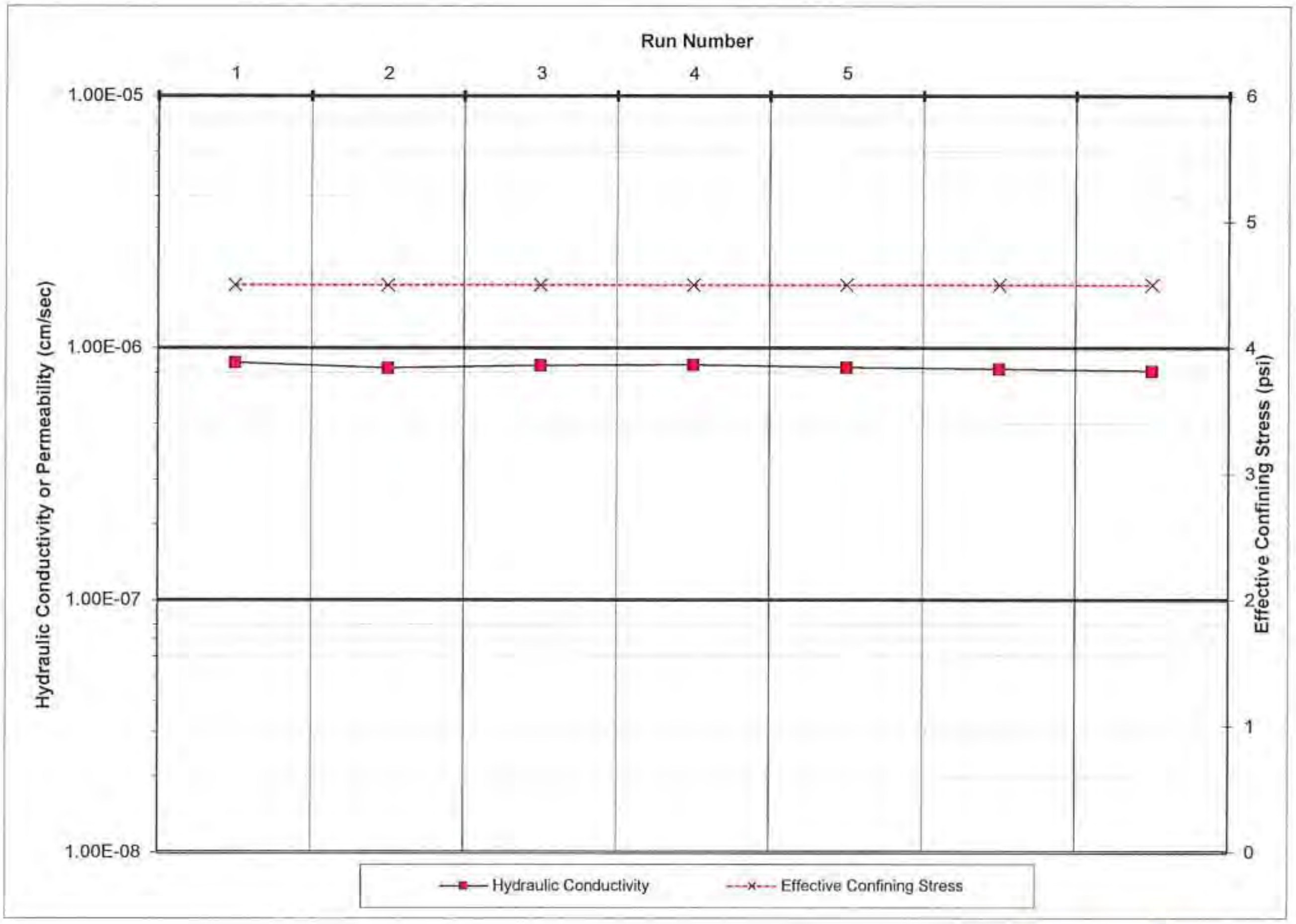
Method ASTM D 5084

HWA GeoSciences Inc.

Project	
Client	Hayward Baker
Project number	2014-069
Date	10/14/2015
Technician	DW
Sample point	HBI-6
Sample number	N/A
Sample depth	N/A
Sample description	Soil Cement

Assumed Specific Gravity	2.65		
Initial Sample Area (cm2)	46.40	Final Sample Area (cm2)	46.40
Initial Sample Length (cm)	14.14	Final Sample Length (cm)	14.09
Initial Sample Volume (cc)	656.1	Final Sample Volume (cc)	653.6
Initial moisture (%)	34.4	Final moisture (%)	36.0
Initial wet unit wt. (pcf)	109.6	Final wet unit weight (pcf)	111.5
Initial dry unit wt. (pcf)	81.6	Final dry unit weight (pcf)	81.9
Initial void ratio	1.028	Final void ratio	1.018
Initial porosity	0.507	Final porosity	0.504
Initial saturation (%)	88.6	Final saturation (%)	93.7

Run No.	Hydraulic Conductivity (cm/s)	Running Average of 4 Readings (cm/s)	Maximum % Deviation from Average (should be less than 25%)	Flow Ratio (0.75 to 1.25 required)	Effective Confining Stress (psi)	Other Information
1	8.8E-07	n.a.		1.00	4.5	Maximum Gradient
2	8.3E-07	n.a.		1.11	4.5	26.0
3	8.5E-07	n.a.		1.07	4.5	Minimum Gradient
4	8.6E-07	8.5E-07	2.5%	1.00	4.5	23.5
5	8.4E-07	8.4E-07	1.6%	1.04	4.5	Max. Back Pressure (psi)
6	8.3E-07	8.4E-07	2.1%	0.99	4.5	63.0
Final	8.1E-07	8.3E-07	3.1%	1.00	4.5	Min. Back Pressure (psi)
						63.0



Checked by:

FIGURE: 3

Hydraulic Conductivity Test Report

Method ASTM D 5084

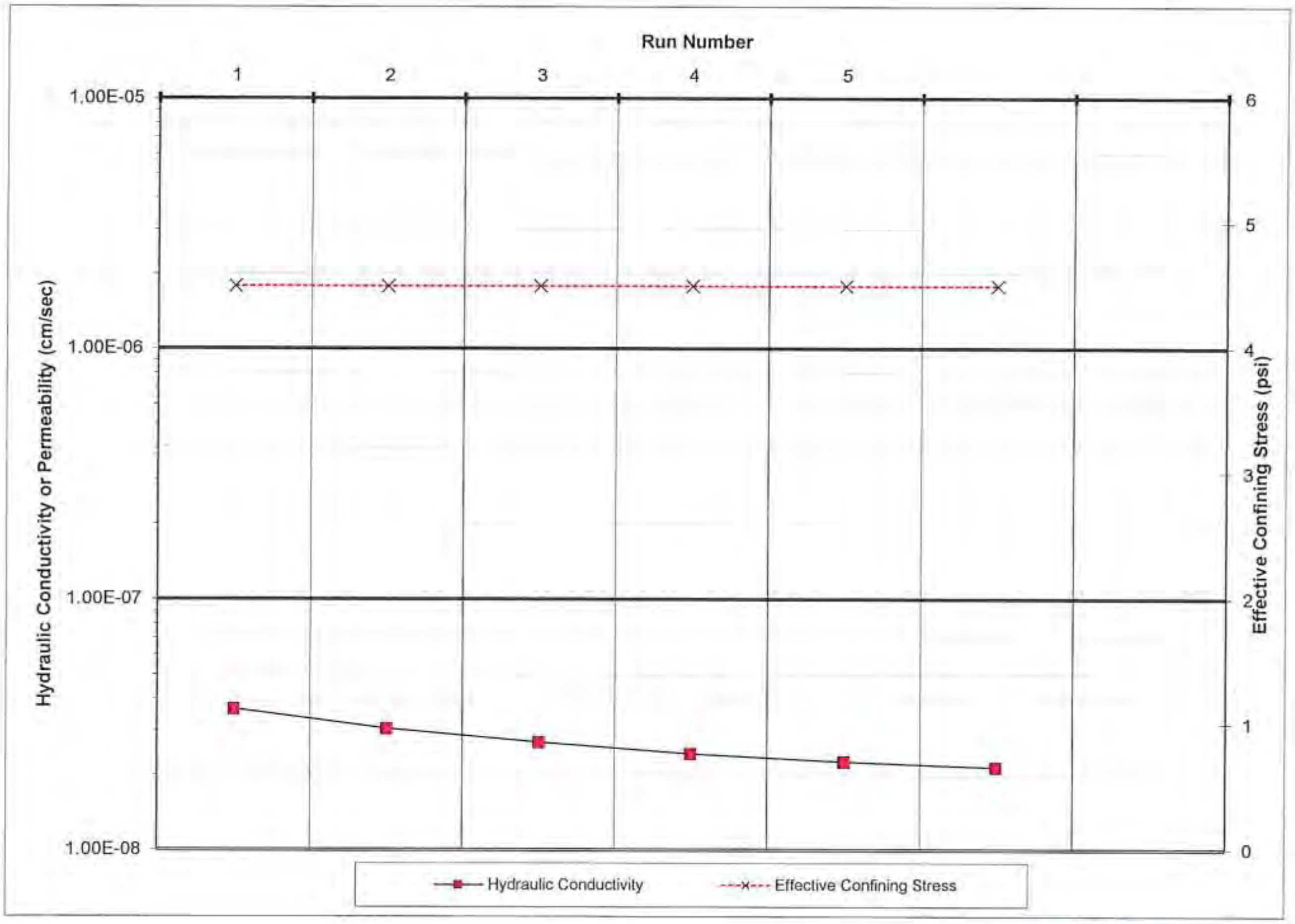
HWA GEOSCIENCES INC.

Project	
Client	Hayward Baker
Project number	2014-069
Date	10/14/2015
Technician	DW
Sample point	HBI-8
Sample number	N/A
Sample depth	N/A
Sample description	Soil Cement

Assumed Specific Gravity	2.65		
Initial Sample Area (cm2)	44.97	Final Sample Area (cm2)	45.58
Initial Sample Length (cm)	14.01	Final Sample Length (cm)	13.96
Initial Sample Volume (cc)	629.8	Final Sample Volume (cc)	636.5
Initial moisture (%)	39.9	Final moisture (%)	42.5
Initial wet unit wt. (pcf)	105.4	Final wet unit weight (pcf)	106.2
Initial dry unit wt. (pcf)	75.3	Final dry unit weight (pcf)	74.6
Initial void ratio	1.196	Final void ratio	1.218
Initial porosity	0.545	Final porosity	0.549
Initial saturation (%)	88.5	Final saturation (%)	92.4

Run No.	Hydraulic Conductivity (cm/s)	Running Average of 4 Readings (cm/s)	Maximum % Deviation from Average (should be less than 25%)	Flow Ratio (0.75 to 1.25 required)	Effective Confining Stress (psi)
1	3.7E-08	n.a.		0.94	4.5
2	3.1E-08	n.a.		0.94	4.5
3	2.7E-08	n.a.		1.03	4.5
4	2.4E-08	3.0E-08	23.7%	1.02	4.5
5	2.2E-08	2.6E-08	17.3%	1.03	4.5
Final	2.1E-08	**2.4E-08**	13.2%	1.05	4.5

Other Information
Maximum Gradient 26.2
Minimum Gradient 23.5
Max. Back Pressure (psi) 63.0
Min. Back Pressure (psi) 63.0



Checked by:

FIGURE: 4

Hydraulic Conductivity Test Report

Method ASTM D 5084

HWA GEOSCIENCES INC.

Project	
Client	Hayward Baker
Project number	2012-069
Date	10/6/2015
Technician	JH
Sample point	HBI-10
Sample number	N/A
Sample depth	N/A
Sample description	Soil Cement

Assumed Specific Gravity	2.65		
Initial Sample Area (cm2)	46.38	Final Sample Area (cm2)	46.48
Initial Sample Length (cm)	14.49	Final Sample Length (cm)	14.45
Initial Sample Volume (cc)	671.8	Final Sample Volume (cc)	671.8
Initial moisture (%)	32.4	Final moisture (%)	33.3
Initial wet unit wt. (pcf)	109.9	Final wet unit weight (pcf)	110.7
Initial dry unit wt. (pcf)	83.0	Final dry unit weight (pcf)	83.1
Initial void ratio	0.992	Final void ratio	0.991
Initial porosity	0.498	Final porosity	0.498
Initial saturation (%)	86.6	Final saturation (%)	89.0

Run No.	Hydraulic Conductivity (cm/s)	Running Average of 4 Readings (cm/s)	Maximum % Deviation from Average (should be less than 25%)	Flow Ratio (0.75 to 1.25 required)	Effective Confining Stress (psi)	Other Information	
1	1.7E-08	n.a.		0.50	3	Maximum Gradient	
2	1.5E-08	n.a.		0.67	3	25.3	
3	1.6E-08	n.a.		0.60	3	Minimum Gradient	
4	1.5E-08	1.6E-08	10.8%	1.50	3	9.7	
5	1.6E-08	1.5E-08	4.7%	0.60	3	Max. Back Pressure (psi)	
6	1.4E-08	1.5E-08	9.3%	0.60	3	63.0	
7	1.3E-08	1.5E-08	9.8%	0.63	3	Min. Back Pressure (psi)	
8	1.1E-08	1.4E-08	17.8%	0.57	3	46.0	
9	1.1E-08	1.2E-08	13.6%	0.78	4.5		
10	9.1E-09	1.1E-08	20.3%	0.60	4.5		
11	8.9E-09	9.9E-09	12.7%	0.73	4.5		
12	9.4E-09	9.5E-09	10.9%	1.00	4.5		
13	9.4E-09	9.2E-09	3.7%	0.69	4.5	Terminated after 20 days.	230
14	8.3E-09	9.0E-09	7.9%	1.00	4.5		247
15	6.3E-09	8.3E-09	24.5%	0.64	4.5		264
16	7.7E-09	7.9E-09	20.5%	1.00	4.5		281
17	8.0E-09	7.6E-09	16.8%	0.62	4.5		298
18	6.7E-09	7.2E-09	12.3%	0.60	4.5		315
19	6.4E-09	7.2E-09	11.0%	0.75	4.5		332
20	5.7E-09	6.7E-09	19.2%	0.64	4.5		349
21	5.9E-09	6.2E-09	8.5%	0.75	4.5		366
Final	5.7E-09	5.9E-09	8.3%	0.67	4.5		383

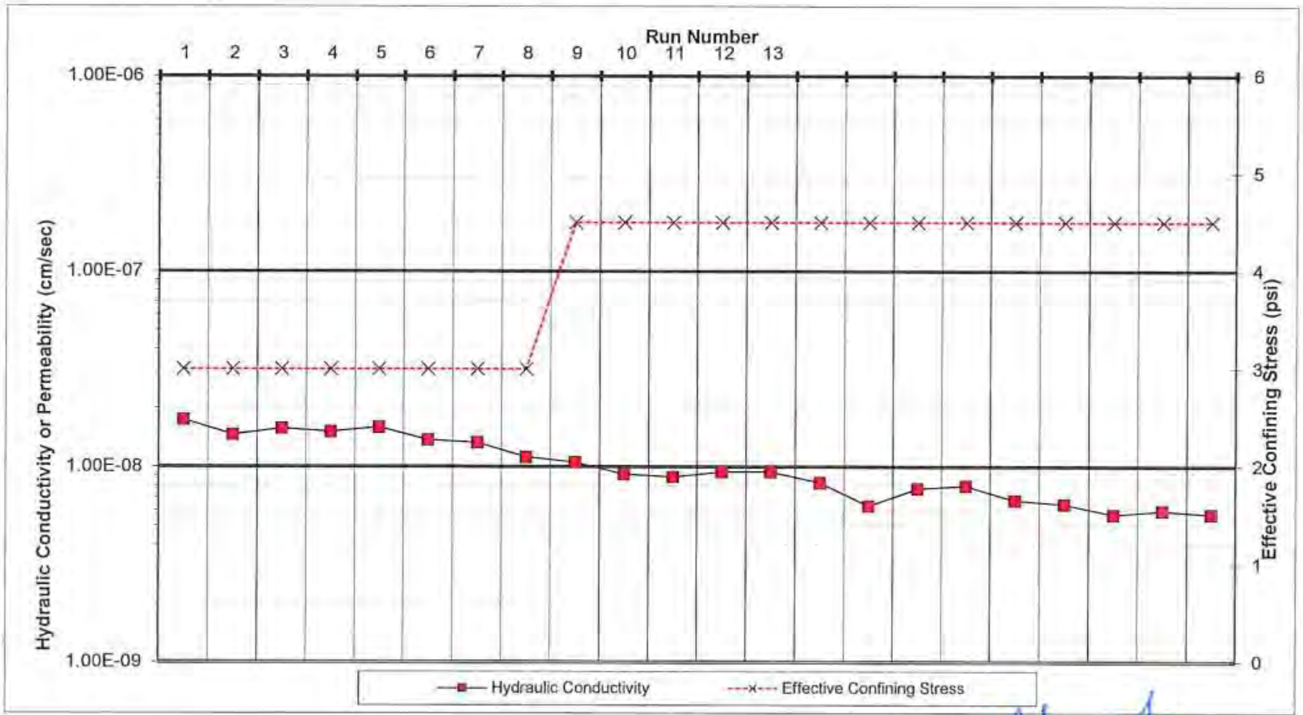


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FIGURE: 5

Hydraulic Conductivity Test Report

Method ASTM D 5084

HWA GEOSCIENCES INC.

Project	Hydrometrx: Mead, Washington
Client	Hayward Baker
Project number	2012-069
Date	10/6/2015
Technician	JH
Sample point	HB-12
Sample number	N/A
Sample depth	N/A
Sample description	Soil Cement

Assumed Specific Gravity	2.65
Initial Sample Area (cm2)	45.72
Initial Sample Length (cm)	14.17
Initial Sample Volume (cc)	647.9
Initial moisture (%)	27.4
Initial wet unit wt. (pcf)	108.4
Initial dry unit wt. (pcf)	85.1
Initial void ratio	0.943
Initial porosity	0.485
Initial saturation (%)	77.1

Final Sample Area (cm2)	45.06
Final Sample Length (cm)	14.11
Final Sample Volume (cc)	635.8
Final moisture (%)	30.9
Final wet unit weight (pcf)	113.5
Final dry unit weight (pcf)	86.7
Final void ratio	0.907
Final porosity	0.475
Final saturation (%)	90.2

Run No.	Hydraulic Conductivity (cm/s)	Running Average of 4 Readings (cm/s)	Maximum % Deviation from Average (should be less than 25%)	Flow Ratio (0.75 to 1.25 required)	Effective Confining Stress (psi)	Other Information
1	4.6E-09	n.a.		1.00	4.5	Maximum Gradient
2	2.6E-09	n.a.		0.57	4.5	25.9
3	2.8E-09	n.a.		0.67	4.5	Minimum Gradient
4	2.5E-09	3.1E-09	47.5%	0.67	4.5	24.7
5	2.5E-09	2.6E-09	7.2%	0.67	4.5	Max. Back Pressure (psi)
6	2.5E-09	2.6E-09	8.2%	0.43	4.5	63.0
7	2.3E-09	2.5E-09	5.1%	0.80	4.5	Min. Back Pressure (psi)
Final	1.8E-09	**2.3E-09**	20.3%	0.71	4.5	63.0

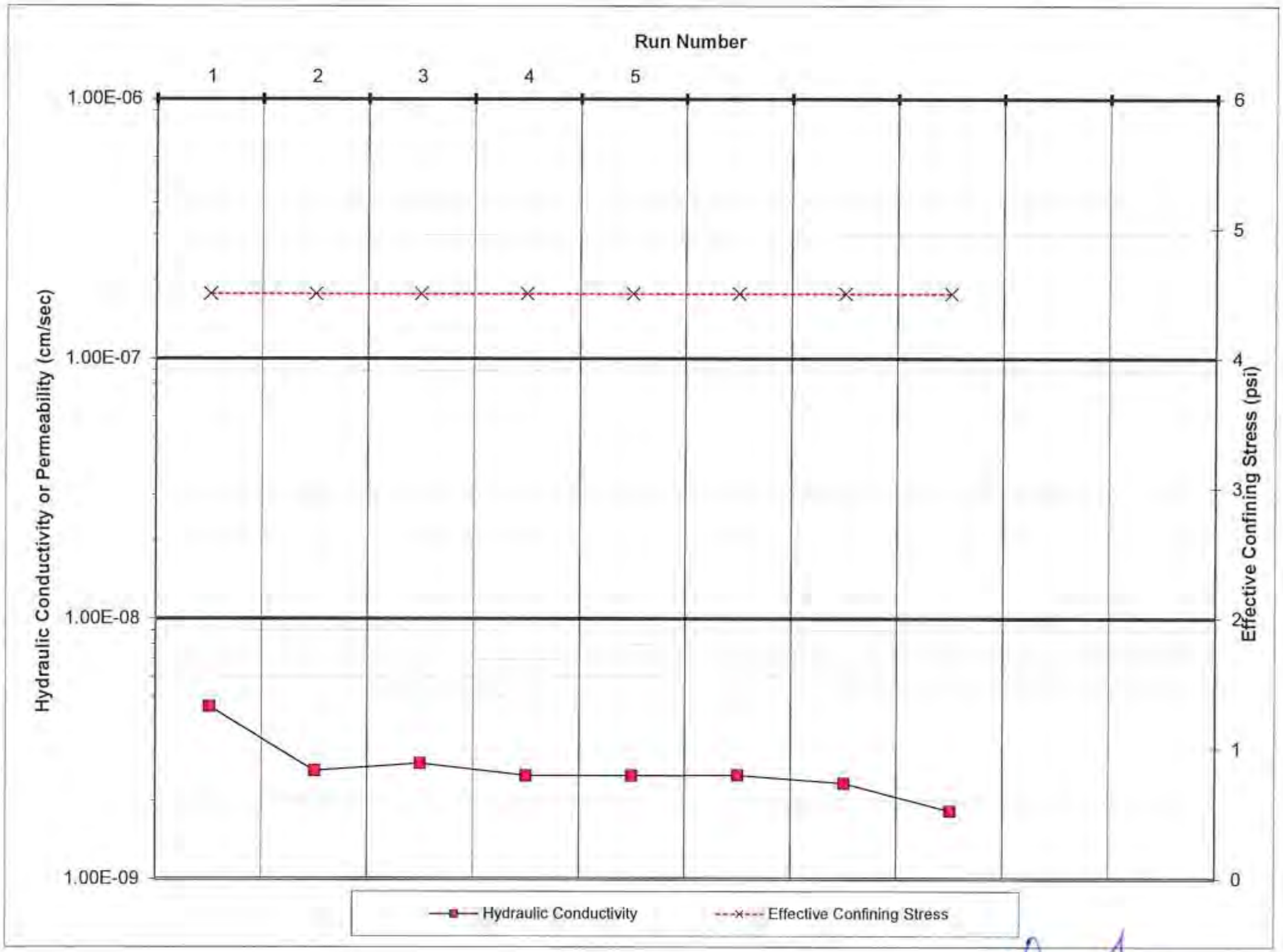

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FIGURE: 6

Kaiser Mead NPL

HAYWARD
BAKER

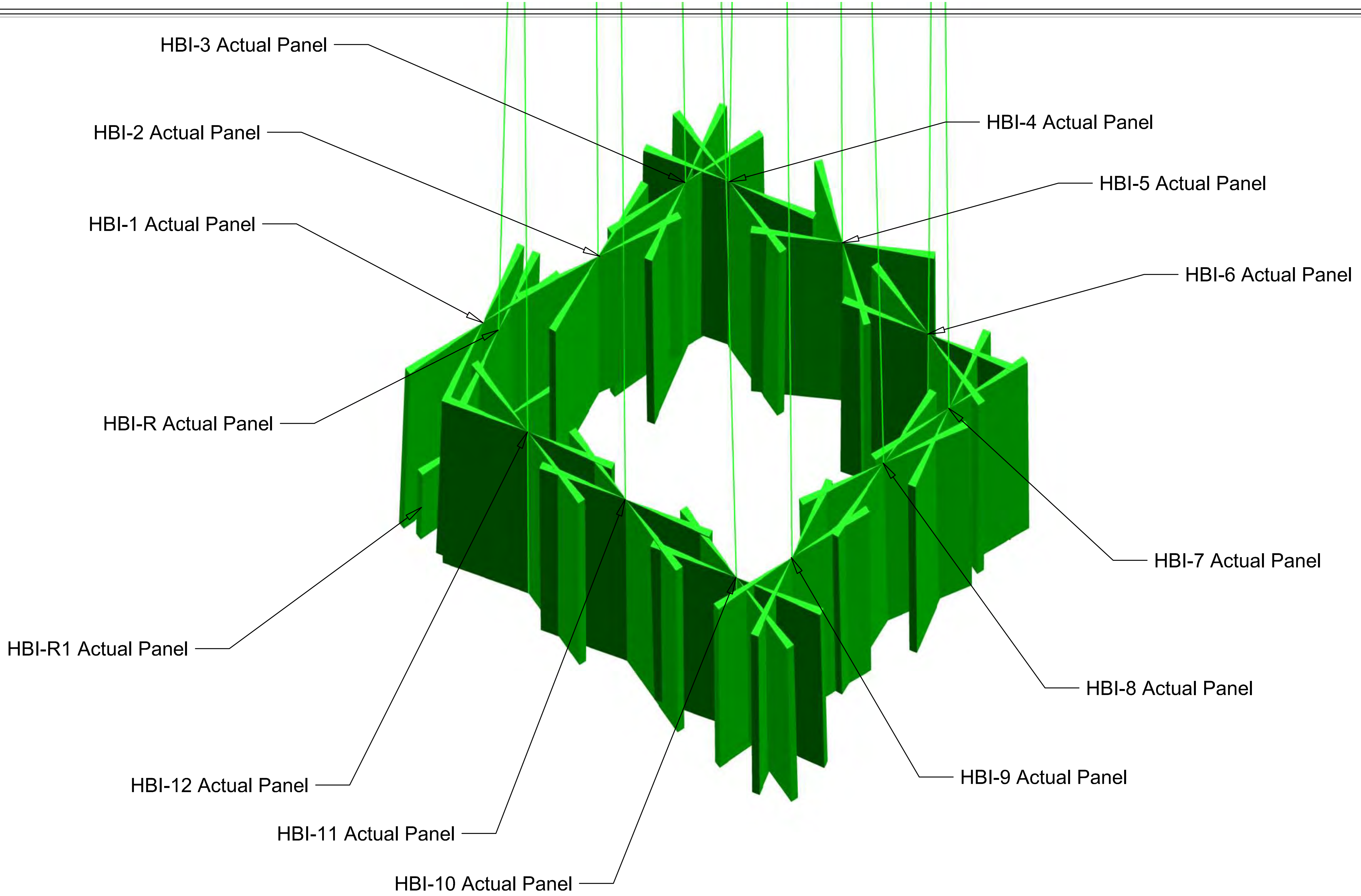
Daily Quality Control Report

Client: Hydrometrix
Project Location: Mead, WA
ORA Report No: 319237
HBI Job No: 860080

Spoils Sample Log

Field Data							Break Dates	Compressive Strength Results			
Date	Borehole Number	Panel ID	Time Sampled	Depth Sampled	Specific Gravity	Sampled By	28	Actual Break Date	Age	Strength (psi)	Strength (psi)
9/1/2015	HBI-10	B	13:30	145.0	1.81	TC	9/29/2015	9/29/2015	28	1730	1840
9/2/2015	HBI-12	B	14:20	150.5	1.78	TC	9/30/2015	9/30/2015	28	2200	2150
9/3/2015	HBI-6	A	11:43	154.4	1.75	TC	10/1/2015	10/1/2015	28	1940	1900
9/8/2015	HBI-1	A	11:01	152.8	1.64	TC	10/6/2015	10/6/2015	28	950	980
9/8/2015	HBI-3	B	14:50	155.1	1.6	TC	10/6/2015	10/6/2015	28	880	930
9/9/2015	HBI-7	A	13:30	155.7	1.55	TC	10/7/2015	10/7/2015	28	580	590
9/10/2015	HBI-9	A	11:05	147.1	1.61	TC	10/8/2015	10/8/2015	28	1520	1530
9/11/2015	HBI-11	B	9:25	141.8	1.55	TC	10/9/2015	10/9/2015	28	1180	1110
9/11/2015	HBI-2	B	16:22	142.7	1.62	TC	10/9/2015	10/9/2015	28	2060	1880
9/14/2015	HBI-4	B	10:27	145.0	1.64	TC	10/12/2015	10/12/2015	28	2010	2040
9/14/2015	HBI-5	A	16:00	153.0	1.66	TC	10/12/2015	10/12/2015	28	1980	2040
9/15/2015	HBI-8	B	10:00	141.0	1.63	TC	10/13/2015	10/13/2015	28	1470	1570
9/15/2015	HBI-R	R	14:58	140.0	1.64	TC	10/13/2015	10/13/2015	28	1560	1550

Attachment D – 3D As-Built



REVISIONS

REV No.		DATE	BY
	DESIGN CHANGE DUE TO POOR SOIL CONDITIONS	DATE 11/20	BY: MAR

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KELLER

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SHEET TITLE
Kaiser Mead NPL
Jet Grout Pilot Test As Built

PROJECT NAME
Kaiser Mead NPL

PROJECT ADDRESS
Spokane, WA

HB PROJECT NUMBER
860080

ISSUE DATE
Feb. 15, 2016

SCALE
NTS

DRAWING / SHEET NUMBER
HBI-1AB

SHEET 1 OF 1

Rev0

Final Construction Report for Kaiser Mead NPL

FEBRUARY 15, 2016

GERONDALE, ADAM

HAYWARD BAKER
A Keller Company

KELLER

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Table of Contents

1.0 Introduction

1.1 Location of Project

The project site was located at the old Kaiser Aluminum site in Spokane County, WA. The site was previously owned and operated by Kaiser Aluminum from the 1940's until it was closed in 2000.

1.2 Background

Since the closure of the Aluminum processing facility The Mead Custodial Trust was developed to evaluate and implement remedial actions to address groundwater contamination at the previous site of the smelter. As part of the remedial actions Hayward Baker Inc. (HBI) was contracted to install a "pilot test" groundwater cutoff wall in order to evaluate the effectiveness of a cutoff wall to divert groundwater around the source of contamination, thereby reducing the concentration of contaminants in the groundwater to acceptable levels.

2.0 Geotechnical Conditions

The site geotechnical conditions consisted of fine to coarse sand with traces of gravels and interbedded seams of clay/silt from the ground surface to approximately 160 feet below grade surface (bgs). Beyond 160 feet bgs a stiff clay layer identified as the A-zone aquitard was encountered. At the time of the explorations groundwater was found to be between 140 and 155 below grade surface.

3.0 Scope of Work

The project plans initially identified 2 different locations and geometries for the pilot test section. Option 1, was 90 lf of wall located in the southern portion of the site. Option 2 was an "L" shaped wall with 45 foot long sides located in the northern portion of the site. Since the purpose of the pilot test was to ultimately determine the permeability of the pilot test wall a square box having 22.5' long sides was ultimately chose as the final geometry. A square box was chosen because it allowed the interior wells which were installed prior to the cutoff wall construction to be fully enclosed in the wall and isolated from the exterior wells. The box was constructed from the top of the aquitard to approximately 135 feet below grade surface which corresponded to 10 feet above the high water table of the aquifer.

4.0 Construction Methodology

Construction of a partial cutoff wall at the depths specified for this project posed several construction challenges. Cutoff walls can be constructed using several different techniques from trencher technologies, column mixing, excavation and replacement, or several other grouting technologies. Because this project required a cutoff wall at depths greater than 100 feet and the desire was only to provide water cutoff in the bottom portion of the drill hole, the jet grouting technology was selected.

4.1 Jet Grouting

Jet Grouting is a grouting technique that utilizes high pressure grout injection to erode and mix the in situ soils. Jet grouting is typically installed using 1 of 4 methods:

- Single System- Grout slurry is pumped through the rod and forced horizontally through a nozzle using high pressures to erode and mix the subsurface soils.
- Double system- A two phase internal rod system is used to supply grout and air into two different concentric horizontal nozzles. The grout is injected and forced through the nozzles at high pressures and the air is used to shroud the grout slurry and increase erosion efficiency.
- Triple System- Grout slurry, air and water are pumped through different lines into the monitor. High velocity air and water are used to erode the subsurface soils while the grout slurry is pumped at lower pressure through horizontal nozzles below the erosion jets to backfill the hole.
- HBI's proprietary Super Jet: Enhanced double fluid jet grouting technology using proprietary jet grout rods.

For this project HBI's super jet technology was utilized.

In addition to multiple methods jet grouting can be installed in a wide array of different geometries. The most common geometry is column jet grouting where the jet grout rods are rotated 360 degrees during the installation process to create circular in situ columns.

Two geometries were initially considered. The first geometry proposed was the column geometry discussed above. The second geometry and the one that was selected by the owner was to create double panel sets. Jet grout panels are constructed using the same installation parameters as column jet grouting with the only difference being that the tooling is not rotated or only rotated in small sectors during construction. Double panels are created by first drilling to design depth. Once at design depth the nozzles are properly aligned and high pressure grouting is initiated. While injecting high pressure grout the drill string is slowly withdrawn. Upon completion of the first panel the drill string is drilled back to design depth. At design depth the nozzles are rotated between 45 and 90 degrees and the construction process is repeated.

5.0 Construction Sequence

5.1 Pre-production Test Section

Prior to the start of the production work 2-test panel sets were installed adjacent to the work area. The test panels were installed from approximately 4 feet below grade surface to 15 feet below grade surface. Two sets of parameters were tried during the test panel construction in order to determine the most appropriate parameters for construction. Table 1 shows the two different parameter sets used for the test panels.

After installation and 24 hours of cure time the test panel sets were exhumed and measured to verify the intended geometry was created.

Table 1: Jet Grouting Test Parameters

Test Panel Parameters		
	T-1	T-2
Pull Speed [cm/min]	40	30
RPM	0	0
Grout Flow [GPM]	125	125
Grout Pressure [bar]	400	400
Nozzle Size [mm]	5.0 x2	5.0x2

Exhumation of the test panels revealed that both panel sets met or exceeded the length required by HBI's design. Ultimately HBI chose to use 30 cm/min for the production pull rate. This provided a level of conservatism and would also account for the differences in soil densities near the surface versus 160' below grade.

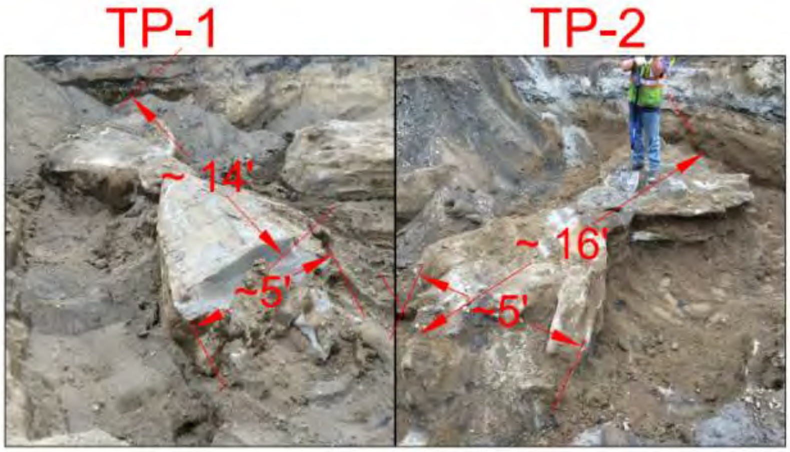


Figure 1: Test Panels Exhumed

5.2 Construction Sequence

Each panel set was preceded by a predrilling rig. Predrill holes were drilled using the duplex method. Duplex drilling utilized an outer temporary steel casing and an inner drill rod to advance the drill hole. Each predrill hole was drilled to design depth and backfilled with a cement/bentonite mix. The predrilled holes acted like pilot holes for the jet grout tooling and allowed easy advancement of the jet grout tooling. After the holes were backfilled the jet grout drill rig would then advance the jet grout tooling to design depth. Upon reaching design depth a down the hole inclinometer was lowered down the inner annulus of the jet grout tooling. After measuring the inclination jet grouting commenced.

Panel sets were installed in an alternating fashion with every third panel being constructed per pass around the box perimeter. Typically jet grouting is mixed in a wet on wet fashion, but the size of the box and the proximity of the two drill rigs to each did not allow for this during the test phase.

6.0 Process and System Description

6.1 Equipment Description

The jet grouting system generally consisted of:

1. Predrill rig
2. Batch plant
3. High Pressure Pump
4. Jet grout drill rig
5. Jet grout tooling

6.1.1 Predrill Rig

Hayward Baker utilized a Hutte 605 drill rig for the predrilling operations. The Hutte drill is a tieback style, hydraulic crawler drill with dual rotary heads. The drill was outfitted with an outer 10.75” diameter temporary steel casing and an inner 4” API rod. The drill tooling used a drag style bit and external flushing of a bentonite/cement slurry to drill the casing to design depth.

Figure 2: Predrilling

6.1.2 Batch Plant

Grout was batched onsite using a jet valve mixing system. Raw cement product was stored in a 350 barrel vertical silo and was delivered to the jet vales using an auger feed system. At the jet valves grout was proportioned with the appropriate amount of water and stored in a 500 gallon holding tank. Cement was delivered to site in bulk via truck and trailer. Bentonite was delivered to site in 50 pound bags and held in a 500 gallon storage tank.

6.1.3 High Pressure Pump

Grout was delivered to the jet grout rig via a Gardner Denver D2000 High pressure pump. The pump is a piston pump capable of delivering grouting at flows in excess of 100 gallons per minute and pressure over 5000 psi.

6.1.4 Jet Grout Drill

Figure 3: KB6 Drill Rig

The KB-6 jet grout drill manufactured specifically for the jet grouting application by HBI's parent company was utilized for this project. The drill was tooled up with HBI's super jet tooling, rotary drill head, and data acquisition.

6.1.5 Data Acquisition

HBI's proprietary data acquisition (DAQ) software was used to monitor and record the jet grout parameters. Additionally the DAQ system allowed the project parameters to be inputted into a computer that automatically controlled the drill. The DAQ system recorded the installation data in graphical format**.** Through a series of sensors grout pressure, duration, depth, RPM, withdrawal rate, specific gravity, volume and treated length were recorded for each individual panel.

6.2 Operations Description

6.2.1 Schedule

Mobilization to site began on August 24th, 2015 with equipment preparations and batch plant erection. Following mobilization two test panel sets were constructed on August 27th, 2015. After analyzing the test panels, production commenced and proceeded at a rate of 1-2 panel sets per shift.

6.2.2 Production Parameters

After the testing phase the following production parameters were set for the box construction:

- Pull Rate: 30 cm/min
- RPM: 0
- Operating Pressure: 5800 psi
- Nozzle Size: 2-5mm

6.2.3 Batching Grout

Grout consisted of Portland Type I/II cement sourced locally and was portioned with potable water at a water to cement ratio of 1:1 w:c. This grout mixture yielded a grout with a specific gravity of 1.52. No other additives such as plasticizer were used in the grout mix.

Predrill grout was also batched onsite and consisted of a mix of cement, bentonite, and potable water. The predrill grout was mixed at the following proportions:

- Cement: 150 lbs
- Bentonite: 25 lbs
- Water: 50 gal

6.2.4 Drilling

Predrill holes were advanced using a 10.75” temporary steel casing and a 4” inner drill string. Initially the intent of the predrilling was to advance a temporary steel casing to the top of the treatment zone in order to create a pilot hole for the jet grouting to commence. This method was subsequently abandoned after jet grouting the first hole because the drill casing became stuck and could not be removed. The remainder of the predrilling used an external flush of cement/bentonite to advance the casing. After drilling to full depth the drill holes were backfilled with cement/bentonite.

Jet grout drilling used a drag style drill bit to advance the jet grout tooling to depth. The KB-6 drill rig was capable of advancing the jet grout tooling to a depth of 96 feet before additional rill rods needed to be added.

6.2.5 Grouting

As described in section 4.1, jet grouting using the super jet technology was selected to create double panel sets for the cutoff wall. Upon reaching the design tip elevation the drill rig operator would initiate high pressure grout flow. Once the grout reached the intended pressure the operator would initiate the data acquisition system which automatically controlled rotation and withdrawal rate.

The panel orientation for the pilot test section offset each panel 15 degrees from the boxes’ horizontal axis. Offsets were placed in the layout to confirm nozzle orientation during construction. Additionally the KB6 drill had proximity sensors mounted on the drill head that allowed the operator to set an orientation of the nozzles at the surface, and once at depth, orient them based upon this initial mark.

6.2.6 Spoils Management

Jet grout spoils were immediately contained within the work zone through the use of sand berms. Spoils were then transported to an onsite disposal facility using a vacuum system. The vacuum system allowed the spoils to be continually captured near the point of discharge and immediately transported to the onsite disposal area without the use of trucks or support equipment.

Figure 4: Spoils Management

7.0 Quality Control/ Quality Assurance

7.1 Column Inclination

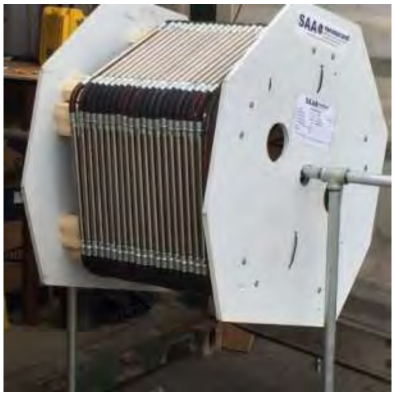


Figure 5: SAA Inclinometer

As discussed above column inclination was critical in the QA/QC process. The planned panel spacing required that drill holes be drilled within 1% of vertical at worst case. In order to verify this a Shape Accel Array tool was used to measure the down the hole inclination. Using this data HBI was able to create a 3D as-built of the box geometry on a per column basis. Using the 3D modeling slight adjustments to the orientation of the nozzles and panel locations were made to ensure proper interlocking.

The measured drill hole deviations for the 13 panel sets that were installed during the pilot test program ranged from 3.06% to 0.31% from vertical at the bottom of the hole. With the exception of panel set HBI-1 which encountered an obstruction during drilling (discussed further in section 8.2) drill hole deviation was on average about 1% from vertical at the bottom of the hole.

Table 2: Drill Hole Deviation Measurements

Column No.	Depth [ft]	% Deviation	Depth [ft]	% Deviation
HBI-1	160.76	3.06%	134.74	2.56%
HBI-2	157.18	1.49%	134.78	1.28%
HBI-3	161.19	1.04%	134.81	0.87%
HBI-4	160.83	0.79%	134.74	0.66%
HBI-5	160.43	1.05%	134.74	0.88%
HBI-6	161.45	0.31%	134.71	0.26%
HBI-7	160.73	0.64%	134.75	0.54%
HBI-8	160.43	1.60%	134.74	1.34%
HBI-9	160.40	0.93%	134.78	0.78%
HBI-10	159.35	1.12%	134.97	0.95%
HBI-11	160.69	0.62%	134.78	0.52%
HBI-12	160.50	0.38%	134.71	0.32%
HBI-Remedial	160.43	1.34%	134.97	1.13%

Generally speaking drill hole verticality was in line with what was anticipated by HBI. By modeling the as-built panel locations, HBI was able to identify if the drill hole deviation would cause gaps in the box and make adjustments to the wall layout in almost real time. For example during the construction of panel HBI-5, the drill hole had deviated away from the box alignment and our modeling indicated that it would not intersect the adjacent panels. In order to mitigate this the panel orientation for HBI-5 was opened up from the planned 26 degrees to 61 degrees.

7.2 Sampling

Wet grab samples were retrieved from the spoils at the surface. A set of 6- 3”x6” cylinders were retrieved per panel set. Samples were partially cured onsite prior to being transported to a third party laboratory for testing. Cylinders were broke in accordance with ASTM C-39 in order to obtain the unconfined compressive strength. Wet grab samples had strengths between 700 and 2200 psi.

Permeability testing was conducted in accordance with ASTM D-5084. The project required the permeability of the box to be 1 x 10^{-6} cm/s of less. In order to obtain early permeability information six samples from six different panel sets were tested in accordance with ASTM D-5084. Permeability of the obtained samples ranged from 5×10^{-9} cm/s to 8×10^{-7} cm/s which was much lower than required.

7.3 Layout & Nozzle Orientation

Panel locations were initially surveyed and staked out to within +/- 0.2 feet. During construction HBI maintained the layout using offset marks placed prior to construction.

In addition the box alignment was demarcated on the ground for reference and to ensure appropriate nozzle orientation.

7.4 Bottom of Cutoff Wall

One key element in the drilling was to identify when the jet grout tooling had reached the depth of the A-zone aquitard in order to prevent punching through into the underlying aquifer. Since the A-zone aquitard was only anticipated to be 1-2 feet thick, HBI utilized pre-installation boring data and our Data Acquisition software to monitor for increased drilling resistance at depth to identify the A-zone aquitard.

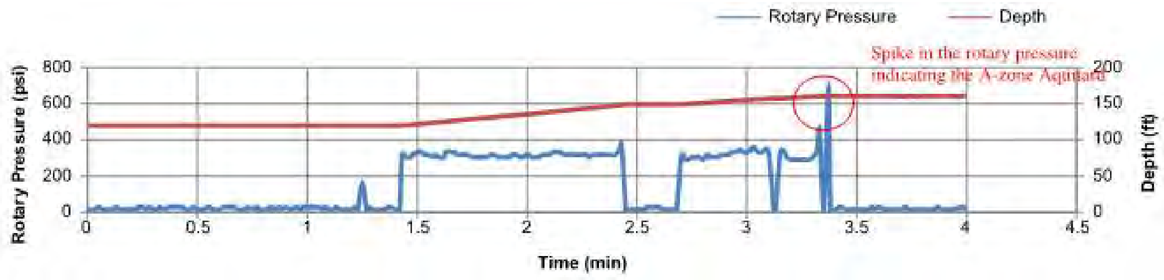


Figure 6: DAQ Drilling Report

Monitoring the changes in soil density by the drilling operation required calibration of the depth to the aquitard using the adjacent borehole logs and our DAQ system. Using the adjacent borehole log the drill rig operator was able to identify the subtle changes in the drilling energy as they related to drilling through the sands and into the thin clay layer.

7.5 Grout Mix

The specific gravity of the grout mix being injected was constantly monitored using a mass flowmeter placed on the recirculation line of the agitank. In addition the grout batcher would periodically measure the grout specific gravity using a Baroid Mud Balance to ensure the accuracy of the mass flow meter.

7.6 Grouting Parameters

Jetting grouting parameters were controlled and monitored in real time using HBI's proprietary data acquisition system, discussed in section 6.1.5. To ensure the data acquisition was calibrated correctly the jet grout parameters were also manually verified. The pull rate was measured by marking two lines on the drill mast 1 foot apart and then timing how long it took a third mark on the drill tooling to travel that 1 foot.

The pump flow rate was calibrated by filling a 55 gallon drum with water in the Seattle HBI yard prior to shipping.

8.0 Lessons Learned

8.1 Drilling

As discussed briefly in section 6.2.4 the intention of predrilling each hole was to create a pilot hole to lower the jet grout tooling in and to provide a safe haven to add drill rods and prevent nozzle plugging. It was originally planned to use a temporary 10.75” steel casing that would be left in place until the completion of the jet grouting and then removed. This however was not possible because the jet grouting process would cause the casing to become grouted in place. This could have been avoided by using a slightly bigger casing and grouting in place a PVC sleeve to serve as the pilot hole.

The other alternative to the PVC sleeve would be to predrill each hole to depth and backfill with cement/bentonite, similar to what was done for a large portion of the test section.

The drilling material was problematic because the coarse sands created a large amount of skin friction between the casing and soils. Due to the friction caused by the coarse sands internal flushing of the casing was not possible.

8.2 Obstructions

While drilling panel HBI-1 an obstruction was encountered near surface at a depth of approximately 15 feet below grade. The obstruction caused the drill hole to deviate 3% from vertical at the bottom of the hole and required a remedial panel to be installed. Due to the box formation and the fact that the out of plumb panel was located on the corner of the box only 1 remedial panel was required. During a full scale production however it is possible that 1-2 remedial panels will be required to ensure wall continuity. For the full scale production it would be prudent to have an array of different production parameters to create various panel lengths to minimize added costs due to having to install remedial panels. This could be completed with another shallow test section utilizing a wider array of production parameters.

8.2.1 Panel HBI-2

During the drilling of panel HBI-2 refusal of the drilling equipment was achieved roughly 3 feet short of the Aquitard depth. Visual observation of the drill spoils indicated that grout was present at the bottom of the drill hole. The modeling of the HBI-2 and HBI-3 indicated that the panel sets had deviated toward each other. Based upon this it was thought that a portion of panel set HBI-3 had a migrated into the area where HBI-2 was to be constructed. HBI-2 was then constructed from the maximum depth the drill could achieve.

After analyzing the grouting and drilling data it appeared that panel HBI-2 and HBI-3 would have proper interlock due to the presence of gourt at the bottom of the drill hole. However at the intersection of HBI-1 and HBI -2 there would be a potential gap between the bottom of panel HBI-2 and the top of the aquitard. Since Panel HBI-1 deviated due an obstruction a remedial panel was required.

8.2.2 Remedial Panel HBI-R

The purpose of the remedial panel was twofold:

1. Fill in the gap in the box left by the deviation of HBI-1;
2. Fill in the potential soil gap below HBI-2 and provide interlock;

Using our 3D model we plotted a potential remedial location and nozzle orientation. Additionally the drill hole inclination data was used to serve as a baseline for verticality to further help select location and orientation. Based upon this model the remedial panel was laid out, drilled, and grouted.

Using our model it was determined that in order to provide interlock the panels would need to be roughly 12 feet long to provide interlock, which was consistent with our design. However due to the potential soil gap below HBI-2, a larger 14 foot panel would need to be created. In order to achieve a larger panel the pull rate was slowed during the construction of the leg of the remedial panel that would intersect HBI-2. HBI slowed the pull rate from 30 cm/min to 20 cm/min to deliver the additional erosional energy and create a larger panel.

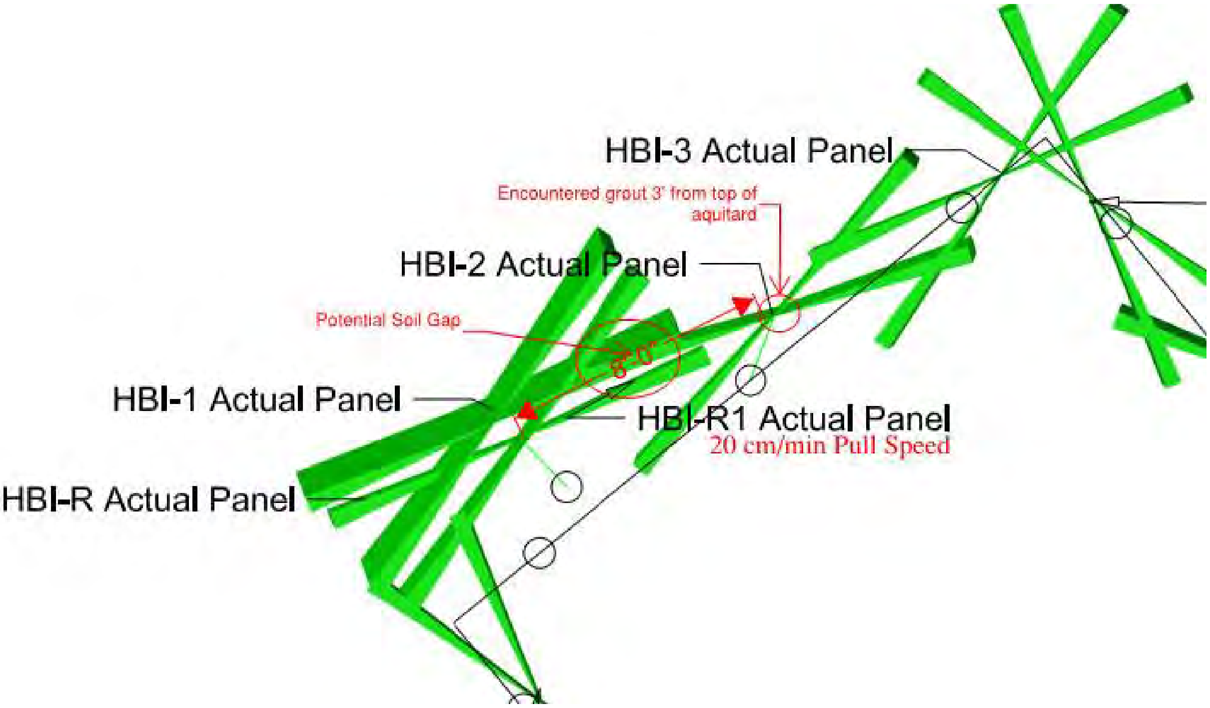


Figure 7: Partial As-Built

9.0 Conclusion

Jet grouting commenced on August 24th, 2015 and was completed on September 15th, 2015. In total 13 (12 planned and 1 remedial) panel sets were installed. Through the construction of the pilot test program, Hayward Baker was able to gain valuable knowledge on the subsurface strata which will be invaluable in the production of the full scale water cutoff wall. Additionally, by moving to a full scale operation there will be a more continuous work flow that will make it possible to mix the panels in a wet on wet fashion which will further help with the continuity at the interlock of each panel set.

Through incorporation of lessons learned and modifying the work procedures slightly a full scale water cutoff wall using panel jet grouting is a viable method. The construction of the pilot test program allowed for both preliminary test data on this method and has also allowed Hayward Baker to gain valuable information specifically about the site to use in the full scale production.

10.0 Attachments

Attachment A - Contractor Daily Site Report Packages
Attachment B - Contractor Field Logs
Attachment C - Lab Test Results
Attachment D - As-Built 3D Model

APPENDIX C

GROUT SAMPLE PERMEABILITY TEST RESULTS

Budinger
& Associates

Geotechnical Engineering
Environmental Engineering
Construction Materials Testing
Subsurface Exploration
Special Inspection

Proudly serving the Inland Northwest for over 30 years

October 21, 2015

Antonio Chavez, PE
Hydrometrics, Inc.
2736 White Pines Drive
Coeur d'Alene, ID 83815

Project Number X15417

PROJECT: **Grout Curtain Monitor Well Development**
Spokane, WA

SUBJECT: **Results of Laboratory Testing**
Report #2

At your request, we provided laboratory testing services for the subject project. Services were limited to the performance of specific laboratory tests, selected at your discretion.

For this period our involvement was limited to laboratory testing of four samples delivered to us on October 8, 2015. Laboratory tests were performed in general accordance with methods listed on the attached *Laboratory Summary, Hydraulic Conductivity Test Results,* and *Particle Size Distribution Report* sheets.

If you have any questions, please call.

Respectfully Submitted,
BUDINGER & ASSOCIATES, INC.

Terri J. Ballard

Terri J. Ballard
Mgr. Laboratory Services

TJB/kh
Addressee – 2
Attachments:
- Soilcrete- Laboratory Summary (1 page)
- Hydraulic Conductivity Test Results (4 pages)

SOILCRETE
LABORATORY SUMMARY

	Units	Test Methods	Spec				
LABORATORY NUMBER				15-5535	15-5536	15-5537	15-5538
CLIENT NUMBER				HBI-12	HBI-6	HBI-3	HBI-7
PERMEABILITY (Flexible Wall)	cm/sec	ASTM D5084	1.0×10^{-6}	4.5×10^{-7}	4.1×10^{-7}	1.9×10^{-6}	3.9×10^{-7}

Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter
ASTM D 5084
Test Results

Project No.: X15417
Sample ID: HBI-12
Tested By: TB
Sampled By: Client
Laboratory No: 15-5535

Project Location: Grout Curtain Monitor Well Development
Sample Description: #1 Soilcrete
Initial Dry Density: 84.1 pcf
Initial/Final Moisture Content:
Date Tested: 10/8/15

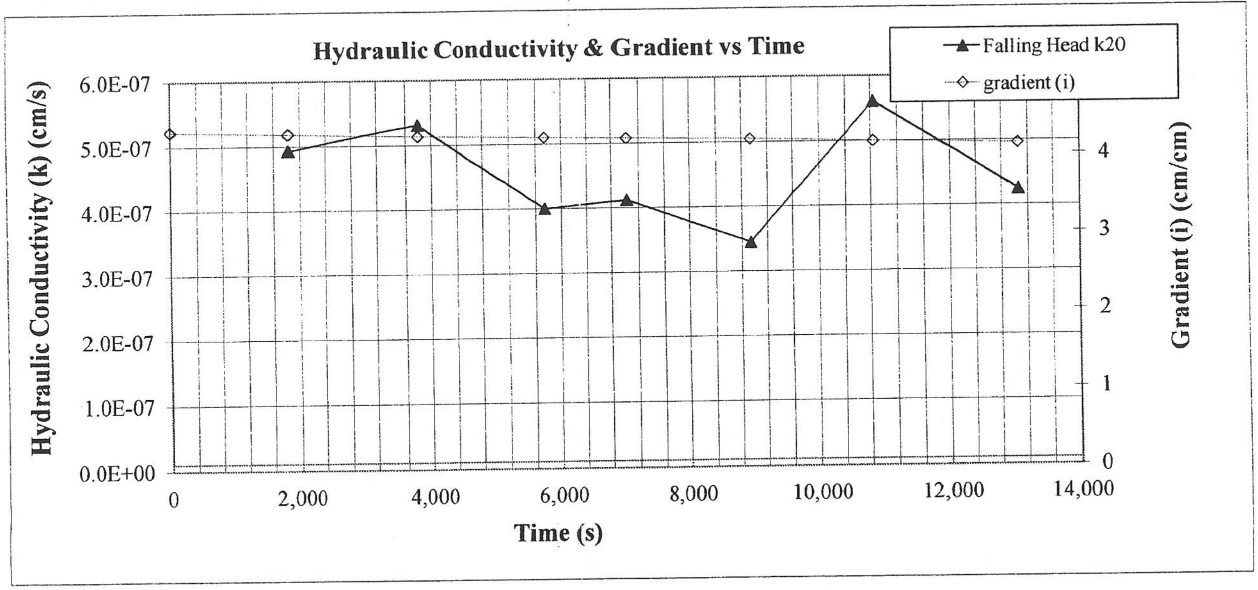
Remolded
X Undisturbed

Register 1 Chamber 49.0 (psi)
Register 3 Upper 48.0 (psi)
Register 2 Lower 48.3 (psi)

$a_{\text{influent burrett}}$ 0.981 cm^2
$a_{\text{effluent burret}}$ 0.981 cm^2
Length, L_f 10.262 cm
Area, A_f 45.300 cm^2

Date	Time (s)	Lower (Red) Pore Pressure (psi)	Upper (Black) Pore Pressure (psi)	Temperature		Burette Readings		Incremental Flow			Head Difference h (t) (cm)	Gradient	Constant Head k_{20} (cm/sec)	**Falling Head k_{20} (cm/sec)**
				°C	R_T	Upper V_U (t) (cc)	Lower V_L (t) (cc)	Inflow (lower) (cc)	Outflow (upper) (cc)	Ratio In/Out				
10/8/2015	0	46.30	46.00	20.5	0.992	23.60	0.45				44.7	4.4		
	1827	46.30	46.00	20.5	0.992	23.40	0.60	0.15	0.20	0.7	44.4	4.3	4.8E-07	**4.9E-07**
	3780	46.30	46.00	20.5	0.992	23.20	0.80	0.20	0.20	1.0	43.9	4.3	5.2E-07	**5.3E-07**
	5741	46.30	46.00	20.5	0.992	23.10	1.00	0.20	0.10	2.0	43.6	4.3	3.9E-07	**4.0E-07**
	7018	46.30	46.00	20.5	0.992	23.00	1.10	0.10	0.10	1.0	43.4	4.2	4.0E-07	**4.1E-07**
	8935	46.30	46.00	20.5	0.992	22.90	1.25	0.15	0.10	1.5	43.2	4.2	3.4E-07	**3.5E-07**
	10837	46.30	46.00	20.5	0.992	22.70	1.45	0.20	0.20	1.0	42.8	4.2	5.5E-07	**5.6E-07**
	13055	46.30	46.00	20.5	0.992	22.50	1.60	0.15	0.20	0.8	42.4	4.1	4.2E-07	**4.2E-07**
												k_{20}=	4.4E-07 cm/s	**4.5E-07 cm/s**

Permeant liquid: standard water



Calculations meeting ASTM D 5084:
Constant Head Method A ______
Falling HeadMethod B ______
Falling HeadMethod C X
Constant Rate of Flow Method D ______
Constant Head Method E ______
Falling HeadMethod F ______

Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter
ASTM D 5084
Test Results

Project No.: X15417
Sample ID: HBI-6
Tested By: TB
Sampled By: Client
Laboratory No: 15-5536

Project Location: Grout Curtain Monitor Well Development
Sample Description: #2 Soilcrete
Initial Dry Density: 81.6 pcf
Initial/Final Moisture Content:
Date Tested: 10/7/15

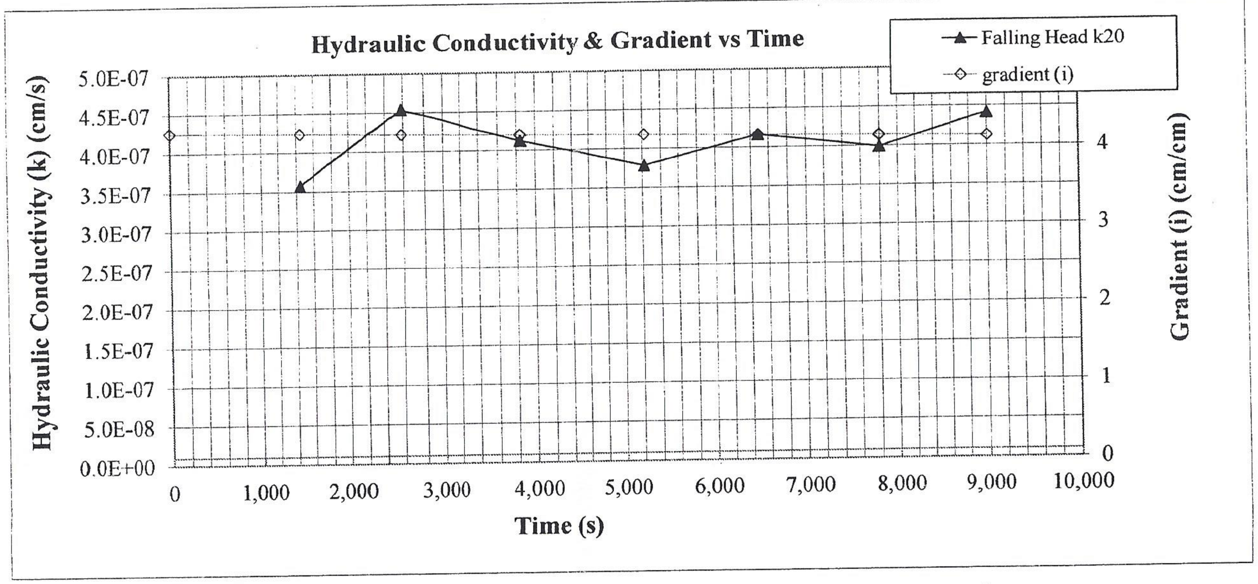
Remolded
X Undisturbed

Register 1 Chamber 48.0 (psi)
Register 3 Upper 46.0 (psi)
Register 2 Lower 46.3 (psi)

a influent burrett 0.981 cm²
a effluent burret 0.981 cm²
Length, L_f 10.338 cm
Area, A_f 46.214 cm²

Date	Time (s)	Lower (Red) Pore Pressure (psi)	Upper (Black) Pore Pressure (psi)	Temperature		Burette Readings		Incremental Flow			Head Difference h (t) (cm)	Gradient	Constant Head k_{20} (cm/sec)	Falling Head k_{20} (cm/sec)
				°C	R_T	Upper V_U (t) (cc)	Lower V_L (t) (cc)	Inflow (lower) (cc)	Outflow (upper) (cc)	Ratio In/Out				
10/7/2015	0	46.30	46.00	20.5	0.992	23.20	0.70				44.0	4.3		
	1440	46.30	46.00	20.5	0.992	23.10	0.80	0.10	0.10	1.0	43.8	4.2	3.5E-07	**3.6E-07**
	2580	46.30	46.00	20.5	0.992	23.00	0.90	0.10	0.10	1.0	43.6	4.2	4.5E-07	**4.5E-07**
	3840	46.30	46.00	20.5	0.992	22.90	1.00	0.10	0.10	1.0	43.4	4.2	4.0E-07	**4.1E-07**
	5220	46.30	46.00	20.5	0.992	22.80	1.10	0.10	0.10	1.0	43.2	4.2	3.7E-07	**3.8E-07**
	6480	46.30	46.00	20.5	0.992	22.70	1.20	0.10	0.10	1.0	43.0	4.2	4.1E-07	**4.2E-07**
	7800	46.30	46.00	20.5	0.992	22.60	1.30	0.10	0.10	1.0	42.8	4.1	3.9E-07	**4.0E-07**
	9000	46.30	46.00	20.5	0.992	22.50	1.40	0.10	0.10	1.0	42.6	4.1	4.3E-07	**4.4E-07**
												k_{20}=	4.0E-07 cm/s	**4.1E-07 cm/s**

Permeant liquid: standard water



Calculations meeting ASTM D 5084:
Constant Head Method A ______
Falling HeadMethod B ______
Falling HeadMethod C X
Constant Rate of Flow Method D ______
Constant Head Method E ______
Falling HeadMethod F ______

Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter
ASTM D 5084
Test Results

Project No.: X15417
Sample ID: HBI-3
Tested By: TB
Sampled By: Client
Laboratory No: 15-5537

Project Location: Grout Curtain Monitor Well Development
Sample Description: #3 Soilcrete
Initial Dry Density: 66.6 pcf
Initial/Final Moisture Content:
Date Tested: 10/8/15

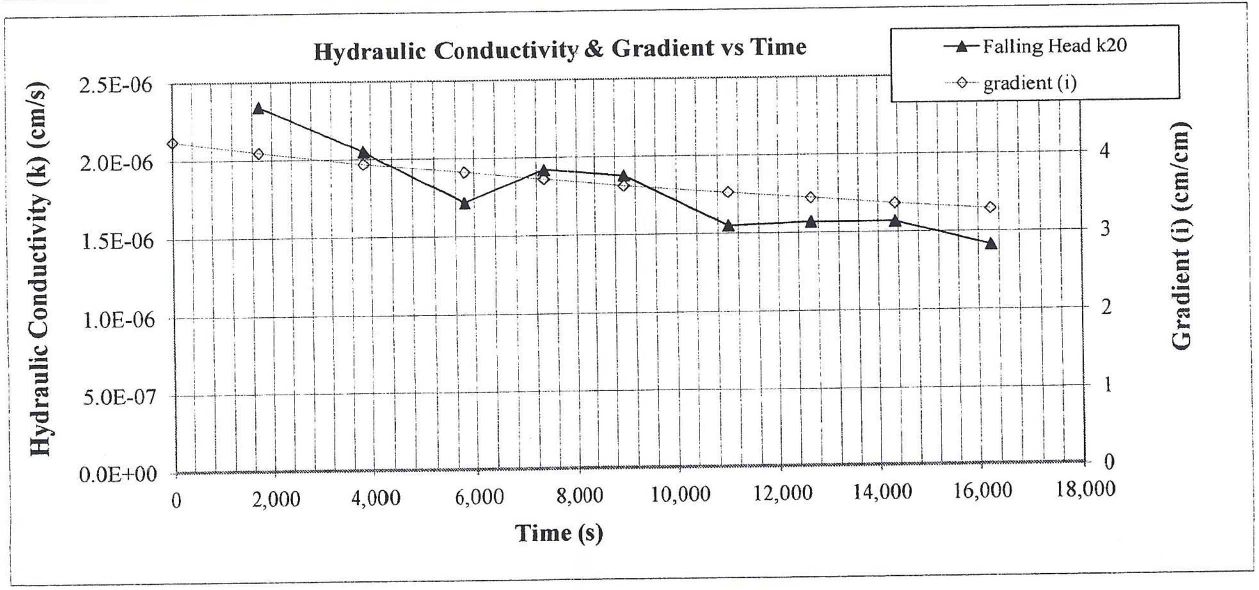
Remolded
X Undisturbed

Register 1	Chamber	59.0	(psi)
Register 3	Upper	58.0	(psi)
Register 2	Lower	58.3	(psi)

$a_{\text{influent burrett}}$	0.981	cm^2
$a_{\text{effluent burret}}$	0.981	cm^2
Length, L_f	10.262	cm
Area, A_f	45.604	cm^2

Date	Time (s)	Lower (Red) Pore Pressure (psi)	Upper (Black) Pore Pressure (psi)	Temperature		Burette Readings		Incremental Flow			Head Difference h (t) (cm)	Gradient	Constant Head k_{20} (cm/sec)	Falling Head k_{20} (cm/sec)
				°C	R_T	Upper V_U (t) (cc)	Lower V_L (t) (cc)	Inflow (lower) (cc)	Outflow (upper) (cc)	Ratio In/Out				
10/9/2015	0	46.30	46.00	19.9	1.007	23.20	1.20				43.5	4.2		
	1730	46.30	46.00	19.9	1.007	22.50	2.00	0.80	0.70	1.1	42.0	4.1	2.3E-06	**2.3E-06**
	3849	46.30	46.00	19.9	1.007	21.75	2.80	0.80	0.75	1.1	40.4	3.9	2.0E-06	**2.0E-06**
	5793	46.30	46.00	19.9	1.007	21.20	3.40	0.60	0.55	1.1	39.3	3.8	1.7E-06	**1.7E-06**
	7344	46.30	46.00	19.9	1.007	20.70	3.90	0.50	0.50	1.0	38.2	3.7	1.9E-06	**1.9E-06**
	8974	46.30	46.00	19.9	1.007	20.20	4.40	0.50	0.50	1.0	37.2	3.6	1.8E-06	**1.9E-06**
	11004	46.30	46.00	19.9	1.007	19.70	4.90	0.50	0.50	1.0	36.2	3.5	1.5E-06	**1.6E-06**
	12649	46.30	46.00	19.9	1.007	19.30	5.30	0.40	0.40	1.0	35.4	3.4	1.5E-06	**1.6E-06**
	14334	46.30	46.00	19.9	1.007	18.90	5.70	0.40	0.40	1.0	34.6	3.4	1.5E-06	**1.6E-06**
	16245	46.30	46.00	19.9	1.007	18.50	6.10	0.40	0.40	1.0	33.8	3.3	1.4E-06	**1.4E-06**
												k_{20}=	1.7E-06 cm/s	**1.9E-06 cm/s**

Permeant liquid: standard water



Calculations meeting ASTM D 5084:

Constant Head Method A	
Falling HeadMethod B	
Falling HeadMethod C	X
Constant Rate of Flow Method D	
Constant Head Method E	
Falling HeadMethod F	

Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter
ASTM D 5084
Test Results

Project No.: X15417
Sample ID: HBI-7
Tested By: TB
Sampled By: Client
Laboratory No: 15-5538

Project Location: Grout Curtain Monitor Well Development
Sample Description: #4 Soilcrete
Initial Dry Density: 56.6 pcf
Initial/Final Moisture Content:
Date Tested: 10/13/15

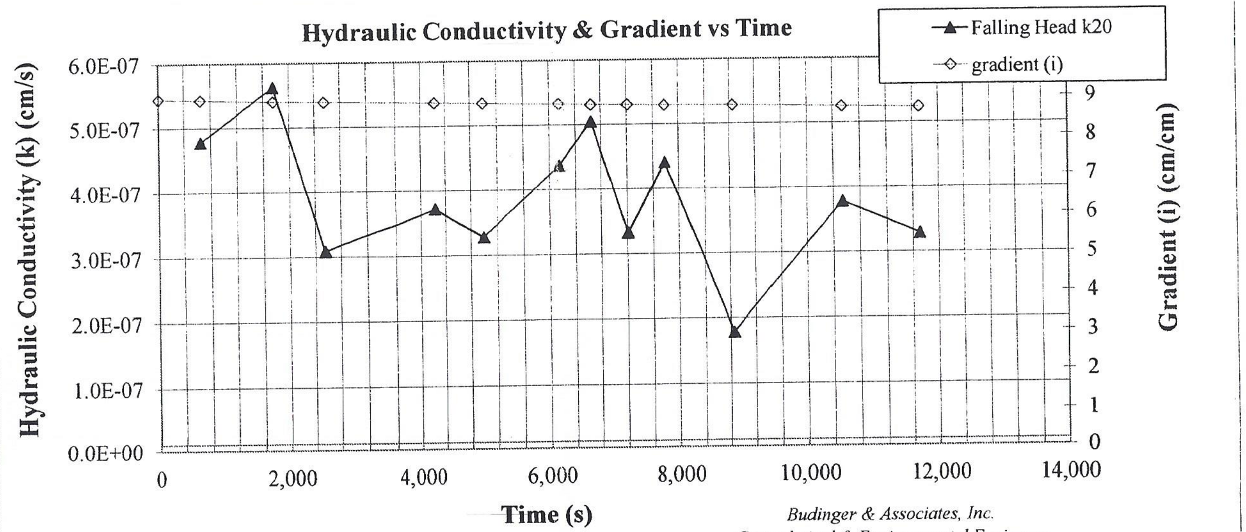
Remolded
X Undisturbed

Register 1	Chamber	45.0	(psi)
Register 3	Upper	43.0	(psi)
Register 2	Lower	44.0	(psi)

$a_{\text{influent burrett}}$	0.981	cm^2
$a_{\text{effluent burret}}$	0.981	cm^2
Length, L_f	10.287	cm
Area, A_f	45.604	cm^2

Date	Time (s)	Lower (Red) Pore Pressure (psi)	Upper (Black) Pore Pressure (psi)	Temperature		Burette Readings		Incremental Flow			Head Difference h (t) (cm)	Gradient	Constant Head k_{20} (cm/sec)	Falling Head k_{20} (cm/sec)
				°C	R_T	Upper V_U (t) (cc)	Lower V_L (t) (cc)	Inflow (lower) (cc)	Outflow (upper) (cc)	Ratio In/Out				
10/13/2015	0	44.00	43.00	20.2	1.000	23.35	0.80				93.4	9.1		
	645	44.00	43.00	20.2	1.000	23.20	0.90	0.10	0.15	0.7	93.1	9.1	4.7E-07	**4.8E-07**
	1745	44.00	43.00	20.2	1.000	22.90	1.10	0.20	0.30	0.7	92.6	9.0	5.5E-07	**5.6E-07**
	2550	44.00	43.00	20.2	1.000	22.80	1.20	0.10	0.10	1.0	92.4	9.0	3.0E-07	**3.1E-07**
	4227	44.00	43.00	20.2	1.000	22.60	1.50	0.30	0.20	1.5	91.9	8.9	3.6E-07	**3.7E-07**
	4990	44.00	43.00	20.2	1.000	22.50	1.60	0.10	0.10	1.0	91.7	8.9	3.2E-07	**3.3E-07**
	6140	44.00	43.00	20.2	1.000	22.30	1.80	0.20	0.20	1.0	91.3	8.9	4.3E-07	**4.4E-07**
	6640	44.00	43.00	20.2	1.000	22.20	1.90	0.10	0.10	1.0	91.1	8.9	4.9E-07	**5.0E-07**
	7209	44.00	43.00	20.2	1.000	22.10	1.95	0.05	0.10	0.5	90.9	8.8	3.3E-07	**3.3E-07**
	7783	44.00	43.00	20.2	1.000	22.00	2.05	0.10	0.10	1.0	90.7	8.8	4.3E-07	**4.4E-07**
	8850	44.00	43.00	20.2	1.000	21.90	2.10	0.05	0.10	0.5	90.6	8.8	1.7E-07	**1.8E-07**
	10533	44.00	43.00	20.2	1.000	21.70	2.40	0.30	0.20	1.5	90.0	8.8	3.7E-07	**3.8E-07**
	11700	44.00	43.00	20.2	1.000	21.50	2.50	0.10	0.20	0.5	89.7	8.7	3.2E-07	**3.3E-07**
												k_{20}=	3.8E-07 cm/s	**3.9E-07 cm/s**

Permeant liquid: standard water



Budinger & Associates, Inc.
Geotechnical & Environmental Engineers
Construction Materials Testing & Special Inspection

Calculations meeting ASTM D 5084:

Constant Head Method A	
Falling HeadMethod B	
Falling HeadMethod C	X
Constant Rate of Flow Method D	
Constant Head Method E	
Falling HeadMethod F	

APPENDIX D

HAYWARD BAKER FULL SCALE COST ESTIMATE

Hayward Baker Inc.

11180 E Marginal Way S
Tukwila, WA 98168
Tel: 206-223-1732
Fax: 206-223-1733

HAYWARD
BAKER
A Keller Company

June 13, 2016

Hydrometrics
2736 White Pines Dr.
Couer d' Alene, ID 8815
208-660-8549

Attn: Antonio Chavez
Submitted via email: achavez@hydrometrics.com

Subject: Kaiser Mead NPL – Mead, WA
Groundwater Cutoff Full Scale Wall

Hayward Baker Inc. (HBI) is pleased to present this proposal to construct a ground water cutoff wall in accordance with the means and methods employed during the 2015 Pilot Test Program. This proposal includes our scope of work, inclusions, exclusions, schedule, pricing, and our General Terms and Conditions which would become part of any contract between us. This proposal is based upon the following:

- Pilot Test Bid Documents received via Email January 16th, 2015;
- Wall alignment provided via email April 27, 2016;
- Powerline Height provided via email May 16, 2016 from Mari Rosales;

Scope of Work

HBI's will utilize the same means and methods utilized in the pilot test program to construct the full scale water cutoff wall. HBI's scope is specifically understood to be as follows:

- Double panel jet grouting to construct 3,950 linear foot cutoff wall;
  - 498 Total Panel Sets
- Predrilling each location;
- Treatment from the top of the aquitard to 10 feet above the high water line;
  - 35 foot treatment length
- Drilling depths anticipated: 150 to 175 feet;
  - 84,636 LF of drilling
- Handling and onsite disposal of spoils;
  - Spoils volume is anticipated to be on the order of 35,000 cyd
- Permeability testing of wet grab spoils samples;
- QA/QC, submittals, and daily reporting pertaining to our scope of work;

Note: Drilling quantity and depths based upon Depths.pdf provided via email on April 11, 2016.

Jet Grouting

HBI will utilize the same panel geometry and spacing to construct the full scale cutoff wall that was used in the Pilot Test Program. 12' long double panels constructed using the super jet technique will be installed every 8 feet along the wall alignment. Grout will be site batched using Portland Type I cement and clean potable water at a 1:1 by weight water to cement ratio.

Prior to the insertion of the jet grout tooling each location will be predrilled with a separate drill rig. Drilling will be completed using rotary duplex drilling where a temporary steel casing and inner rod are advanced to the design elevation. Once the drill holes are completed they will be backfilled with a weak cement-bentonite grout and will serve as a pilot hole for the jet grout tooling.

Jet grout tooling will be advanced to the top of the aquitard layer where the nozzles will be oriented and jet grouting will commence. Upon completion of the first panel the jet grout nozzles will be reoriented and the tooling plunged into the previously constructed panel. Upon completion of the second panel the tooling will be removed completely from the drill hole and the process repeated at the next location. Spoils will be diverted to a series of waste pits dug adjacent to the wall alignment. From there the spoils will be given time to harden and dug out and disposed of onsite. We have assumed that spoils can be disposed of at the same location used during the test section.

As in the Pilot Test Program, HBI will provide a soil-cement material with a permeability less than or equal to 1×10^{-6} cm/s. Permeability will be verified through triaxial permeability testing of samples molded from spoils return at the surface. Given the inherent variability of the subsurface profile, we cannot guarantee overall permeability of the wall in situ. While we assume that overall in situ permeability will be similar to the results of the Pilot Test Program, and thus acceptable, should additional panel installation or other work be required to achieve the design intent HBI will invoice and be paid for this work.

Spoils Handling

HBI will direct the flow of wet jet grout spoils form each location into a series of waste pits constructed along the wall alignment. Spoils will be contained in the waste pits and given sufficient time to cure. After the spoils have hardened, HBI will excavate the pits and move the spoils material to the waste disposal area utilized in the test section.

HBI has planned to end dump spoils into the waste area utilized in the test section with a standard 5-8 cubic yard dump truck. Any further handling or grading of the spoils to facilitate additional placement of spoils is assumed to be done by others.

Pricing and Schedule

Schedule

HBI has priced this work based upon the mobilization of 2 complete jet grouting units and 2 predrilling units working simultaneously. Based upon this we estimate the work will take approximately 9-11 months working 8-10 hour shifts, Monday through Friday, single shift during day light hours. HBI may work occasional Saturdays at our discretion.

Based upon the schedule duration above and the actual start date work may need to be conducted during the winter months. Local Spokane weather for the winter season is variable but cold winter temperatures can have an impact on the overall efficiency of the jet grouting process. HBI has not made provision for winter impacts at this time as we are not fully aware of the intended schedule start.

Pricing

Item	Description	Quantity	UOM	Bid Price
1	Additional Geotechnical Investigation	1	LS	$500,000
2	Full Scale Cutoff Wall	1	LS	$13,785,000
		Total		$14,285,000

Item 1: Provision of 20 SPT holes with sampling every 5 feet to further define the soil profile along the wall alignment.

Item 2: Provision of full scale cutoff wall inclusive of mobilization in accordance with the means and methods utilized in the pilot test program and the scope of work defined above;

EXCLUSIONS

Exclusions applicable to all options:

1. Provision and maintenance of a flat stable dry working platform for an 50 ton drill moving under its own power, including any surface compaction and re-compaction of the working surface as work progresses;
2. Provision of 4-5 10,000 SF flat, level and compacted laydown areas;
3. Locating, protecting, restoring, monitoring, and removing utilities and adjacent structures as necessary to complete our work without delay. HBI will maintain a current one call ticket number;
4. Provision of unlimited headroom within the treatment area except as noted below;
    - Note: HBI acknowledges the transmission powerlines that intersect the wall alignment and has made provisions for the installation of 40 low headroom panel sets with a drill rig with a 20 foot tall drill mast;
5. Site access for daily material deliveries and mobilization. Material delivery shall be pas through (no backing required) within 50 feet of the batch plant area;
6. Provision of water to within 100 feet of our batching area at 300 gpm and 100 psi;
7. Protection/restoration of all surfaces, hardscapes, etc., including grading & patching;
8. Layout from which HBI can precisely establish our individual column locations;
9. Provision of an onsite spoils disposal area accessible by an excavator and standard dump truck. Any spoils regrading and stockpiling shall be done by others;
10. Any equipment decontamination in excess of pressure washing the equipment at an onsite designated location;
11. Any work related to post treatment verification, coring or pump testing;
12. Any work or costs as they pertain to handling, removing or disposing of contaminated soils;
13. Any and all vibration and/or settlement monitoring;
14. Any and all work or planning related to sediment and water control;
15. Removal of any pavement, concrete, timber, debris or any other obstructions;
16. Traffic control as necessary to complete each scope of work, including any signage, flaggers, maintenance, street cleaning, barricades, permits etc.
17. Winter impacts;
18. Permits, fees, taxes, and bonds. Please note HBI can provide bonding at a cost of $4/$1000.
19. Any work not specifically included.

The pricing above assumes the work can be completed in a single mobilization, without delay. Any delays which are beyond the control of HBI, including delays due to site access and encountering obstructions shall be billed at a cost of $ 900/hr.

Summary

We look forward to working with you on this project. Should you have any questions regarding any of the information contained in this proposal please do not hesitate in contacting us at 206-223-1732.

Sincerely,
Hayward Baker Inc.

Adam Gerondale
Project Manager

Attachments: General Terms and Conditions (3 pages)

GENERAL TERMS AND CONDITIONS

A. FACILITIES BY OTHERS

The following facilities and services are to be provided to HBI by others free of all costs to HBI:

Site Access: Preparation and maintenance of clear, well drained, uninterrupted access ways and level working platform suitable for HBI equipment moving under its own power. Access includes unlimited overhead clearance and adequate ramps at suitable levels and should be available to us at the time and to the extent necessary to suit our operations.

Site Work: The work under this proposal does not include any excavation, grading or sealing work required on the site to establish a working platform or to restore the site to the original or finished grade. All such work is to be furnished by others in a timely manner, so as not to impede the progress of the work or cause damage to the finished work.

Site Security: Provide a secure site by means of fencing, lights and night watchmen, as required.

Traffic Control: All pedestrian and vehicular traffic control including signs and barricades, if and when required for our work and equipment and material deliveries.

Noise and Dust Control: Provide and maintain noise abatement measures/devices (e.g. sound walls), if required. Provide and maintain ventilation and/or dust control barriers etc., if required.

Support of Adjacent Ground and Structures: Any necessary protection of existing structures, utilities, or roadways.

Utilities: All existing above and below ground utilities, which may be affected by the work, shall be located and exposed, probed, removed, or relocated. The extent and location of adjacent utilities and services left in place shall be clearly and accurately marked out on site and shown to an HBI representative prior to the commencement of work. HBI cannot accept responsibility for any damage to any such utilities not thus indicated. Furthermore, it is possible that damage may occur as a result of heave, settlement or intrusion caused by grout material due to the unforeseeable condition of the ground or utility. For this reason, HBI cannot accept responsibility for damages thus caused. The General Contractor shall contact the underground service locating organization as required.

Layout: Any survey and field layout necessary to perform our operations. Any post construction survey of HBI's work shall be performed by others.

Sanitary Facilities: On-site sanitary facilities for the use of HBI employees.

Permits and Easements: All permits and easements required to legally perform the work.

Site Yard: An area shall be provided on site, adjacent to our work, for our equipment, storage yard, workshop, and site office.

Testing & Inspection: Required instrumentation, movement monitoring, site/building condition surveys, laboratory or field materials testing or construction/materials inspection services beyond those which are included under Scope. Existing condition surveys of buildings, utilities, and facilities shall be taken after site preparation/demolition and prior to commencement of HBI's work.

Excavation and Spoil Removal: All necessary storage and disposal, including solid and liquid waste materials resulting from our work.

Water Supply: Clean potable water supply at hydrant pressure and flow provided within 100ft of our work.

Restoration and Protection: Protect and restore all pavements, surfaces, finishes, landscape, hardscape, utilities, or any other element, directly or indirectly affected by our work.

Security: Site security during nights and on weekends.

B. PROGRESSION OF WORK

HBI's proposal is based upon carrying out the work in an unobstructed manner, working 8 to 10 hour shifts, Monday through Friday, in a single uninterrupted visit to the site. Delays or suspensions of HBI's operations which are due to reasons not within the control of, or not caused by the fault of HBI, shall be compensated at the standby rate for each unit. This includes delays due to dealing with subsurface obstructions

C. PAYMENT TERMS

1. Progress payments will be submitted monthly and shall be payable within 30 days of the invoice date.
2. All amounts due, will be paid in full within 30 days of completion of HBI's work regardless of the anticipated project completion date. NO RETENTION SHALL APPLY.
3. An interest charge of 1 percent per month and all costs of collection, including reasonable attorney's fees and court costs, will be added to overdue accounts.
4. In the event payment is withheld for reason not the fault of or within the direct control of HBI then payment shall be made at the time and in the amount originally scheduled.

D. OTHER CONDITIONS

Standard Term of Subcontract: Our proposal is based upon performing the Work under a standard form of contract (either AIA form A401 or AGC form 640), or purchase order, with this proposal as the prevailing contract document.

Hazardous Material: In the event that HBI encounters any material on the site, as defined in 29CFR1910, which has not been rendered harmless, HBI shall immediately stop work in the area affected and report the condition in writing to the Owner and Engineer. To the fullest extent permitted by law, the Owner and Contractor shall indemnify and hold harmless HBI, their agents, consultants, and employees from and against all claims, damages, losses and expenses, including but not limited to attorney fees arising out of or resulting from performance of the work in the affected area.

Bonds: The cost of a bond premium is not included in our contract price.

Liquidated Damages: Hayward Baker shall not be liable or responsible for any liquidated damages, delay damages, or time-related penalties arising from the work.

Changed Conditions: If the ground, structure, or site conditions differ from those offered at the time of bidding and referred to in this proposal, HBI reserves the right to obtain an equitable price adjustment to compensate for extra work and impacts as a result of the changed condition.

Confidentiality: All specifications, drawings and technical data submitted by HBI are to be treated as confidential and shall not be disclosed to any third party without express written consent of HBI. Such information shall remain HBI's property and be returned to HBI upon demand.

<u>Liability</u>: No liability can be accepted by us, nor shall we accept as in any way our responsibility defects of any kind whatsoever arising from a cause which is outside our immediate control or knowledge, or for any fault in the junction between our work and subsequent work carried out by others.

<u>Indemnity</u>: Subject to the terms of the Liability Clause above, and to the correct soil conditions having been provided to us prior to our work, we shall indemnify and hold harmless the Owner and Architect and their agents and employees from and against all claims, damages, losses and expenses, including attorneys' fees, arising out of or from the performance of the work, provided that any such claim, damage, loss or expense (1) is attributable to bodily injury, sickness, disease or death, or to injury to or destruction of tangible property (other than the work itself) including the loss of use resulting therefrom, and (2) is caused in whole or in part by any negligent act of HBI, its Subcontractor, anyone directly or indirectly employed by anyone of them or anyone for whose acts any of them may be liable. Regardless of whether or not it is caused in part by a party indemnified hereunder, the limit of our Liability shall be $1,000,000.00. Notwithstanding this article HBI shall be responsible to defend, indemnify, insure, and hold harmless only to the extent of its negligence. Notwithstanding all articles, which include indemnity and insurance obligations, HBI shall indemnify, hold harmless, defend and insure Contractor and other named parties only to the extent of the negligence of HBI.

<u>Force Majeure</u>: HBI cannot accept any liability for default or delay in the completion of the work when caused by strike, riot, war, or Act of God or other similar circumstances beyond HBI's control.

<u>Insurance</u>: HBI will provide the following insurance with limits as shown. No railroad insurance is included. HBI must be covered as an additional insured or covered under a railroad blanket policy.

1. Comprehensive General Liability:	$1,000,000.00
(Combined Single Limit, Bodily Injury	
and Property Damage)	
2. Automobile Liability:	$500,000.00
(Combined Single Limit, Bodily Injury	
and Property Damage)	
3. Workman's Compensation	STATUTORY

<u>Exclusions</u>: Any items of work not specifically included in this proposal shall not be the responsibility of HBI.

<u>Labor Affiliation</u>: Project shall be manned with union employees under current job specific agreements. Local prevailing wages shall apply.

<u>Period of Acceptance</u>: This proposal is offered for acceptance for a period of 30 days.

APPENDIX H

DISPROPORTIONATE COST ANALYSIS TABLES

APPENDIX H. DISPROPORTIONATE COST ANALYSIS SCORING TABLES

Remedial Alternative	**Protectiveness (30%)**	**Permanence (25%)**	**Long-Term Effectiveness (25%)**	**Short Term Risk Management (10%)**	**Technical and Administrative Implementability (10%)**	**Environmental benefit score**	**30 yr cost ($ Millions, NPV)**	**80 yr cost ($ Millions, NPV)**
	Overall protectiveness of human health and the environment, including the degree to which existing risks are reduced, time required to reduce risk at the facility and attain cleanup standards, on-site and off-site risks resulting from implementing the alternative, and improvement of the overall environmental quality.	The degree to which the alternative permanently reduces the toxicity, mobility, or volume of hazardous substances, including the adequacy of the alternative in destroying the hazardous substances, the reduction or elimination of hazardous substance releases and sources of releases, the degree of irreversibility of waste treatment process, and the characteristics and quantity of treatment residuals generated.	Long-term effectiveness includes the degree of certainty that the alternative will be successful, the reliability of the alternative during the period of time that hazardous substances are expected to remain on-site at concentrations that exceed cleanup levels, the magnitude of residual risk with the alternative in-place, and the effectiveness of controls required to manage treatment residues or remaining wastes. The following types of cleanup action components may be used as a guide, in descending order, when assessing the relative degree of long-term effectiveness: reuse or recycling; destruction or detoxification; immobilization or solidification; on-site or off-site disposal in an engineered, lined, and monitored facility; on-site isolation or containment with attendant engineering controls; and institutional controls and monitoring.	The risk to human health and the environment associated with the alternative during construction and implementation, and the effectiveness of measures that will be taken to manage such risks.	Ability to be implemented including consideration of whether the alternative is technically possible, availability of necessary off-site facilities, services and materials, administrative and regulatory requirements, scheduling, size, complexity, monitoring, and integration with existing facility operation and other current or potential remedial actions.			
MNA	This alternative provides no increase in overall protectiveness of either human health or the environment from current conditions; this alternative does not decrease off-site transport of contamination; it has the longest time to achieve cleanup standards and does not remove any contaminants that may act as on-going sources.	This alternative does not reduce toxicity or mobility or volume of hazardous substances relative to current conditions; there are no wastes or treatment residuals generated.	This alternative is the lowest in the long-term effectiveness hierarchy.	Short term risks associated with this alternative are the lowest of the alternatives evaluated.	This alternative is the most technically and administratively implementable. It consists of remedial action components that are regularly implemented at cleanup sites.	3.6	$ 0.7	$ 1.5
	2	2	2	10	10			
Grout Wall	This alternative provides additional overall protectiveness by limiting off-site transport of contamination. It significantly decreases the time to achieve cleanup levels at the compliance wells.	The alternative does not destroy or reduce the toxicity or volume of hazardous substances; rather, it slows the release of secondary source contamination by limiting the amount of groundwater flowing through secondary source materials in the subsurface. Those secondary sources are then released over a longer period but at lower concentrations. Approximately 27,000 tons of waste materials are generated during installation but there would be no on-going waste materials produced following initial construction.	There is some uncertainty that the wall could be constructed with a low enough defect rate to function as predicted in reducing flow through source materials. Once built, a wall that achieved its design goals would remain effective in reducing the rate of off-site transport of contamination for the long term with no maintenance. However, on-site isolation is lower on the long-term effectiveness hierarchy than remedial options that destroy or detoxify, or those that dispose of hazardous substances in an engineered, lined and monitored facility.	Construction of a grout wall of this size would require use of heavy equipment, and proper management and off-site hauling of wastes. Risks posed by these activities can be reasonably controlled by construction health and safety planning.	The materials, facilities, and services needed to construct the wall are available. Construction of the wall could be coordinated with existing facility operations. Given the necessary depth of the wall and uncertainty about subsurface obstructions, very close monitoring of critical construction parameters would be needed to ensure that the wall met its objective in terms of the effective defect rate achieved.	6.1	$ 29.0	$ 30.1
	7	5	5	8	7			
Wetland EC 100 gpm	This alternative provides a major improvement in overall protectiveness by greatly reducing the time to achieve cleanup levels at the compliance line and by removing a large amount of contaminant mass (which may act as an on-going source) from the subsurface. Pumping this flow rate is expected to result in complete capture of the plume. The on- and off-site risks associated with implementation are manageable with proper design and operation. An appropriately designed and constructed treatment wetland would provide the additional environmental benefit of a significant reduction of the nitrate associated with the plume.	This alternative would destroy cyanide, thus permanently reducing its toxicity. Fluoride would be removed in sludge, processed and disposed in an off-site facility. While the capture of fluoride in the sludges is not irreversible, proper operation of the off-site disposal facility will ensure it is not reintroduced to the environment. The wetland option would produce less on-going waste than the other options considered for cyanide removal. This alternative would remove a relatively large amount of contaminants from the subsurface that could act as on-going source materials.	There is a relatively high degree of certainty that a pump and treat system using wetland treatment and electrocoagulation would perform to expectations. The magnitude of residual risk with this alternative in-place would be low. With proper maintenance and operation this alternative is deemed reliable and following local, state and federal requirements for waste management will effectively reduce risk from treatment residuals. The alternative would destroy cyanide and use off-site disposal for fluoride-bearing treatment wastes. Destruction of hazardous substances is ranked high in the long-term effectiveness hierarchy. Disposal in an off-site, engineered, lined and monitored facility ranks above on-site isolation and MNA with institutional controls.	The short-term risk to human health and the environment during construction and implementation is low. Construction/implementation would use common equipment and techniques and risks can be managed using best practices for health and safety.	The ability to implement the alternative is good. Wetland systems take more time to develop and optimize than physical/chemical treatment systems. A wetland sized to treat 100 gpm would require acquisition of additional property but integration with other site constraints is otherwise possible. This alternative would require a field pilot to verify wetland design elements.	8.6	$ 55.8	$ 123.4
	10	8	8	9	7			

APPENDIX H. DISPROPORTIONATE COST ANALYSIS SCORING TABLES

Remedial Alternative	Protectiveness (30%)	Permanence (25%)	Long-Term Effectiveness (25%)	Short Term Risk Management (10%)	Technical and Administrative Implementability (10%)	Environmental benefit score	30 yr cost ($ Millions, NPV)	80 yr cost ($ Millions, NPV)
	Overall protectiveness of human health and the environment, including the degree to which existing risks are reduced, time required to reduce risk at the facility and attain cleanup standards, on-site and off-site risks resulting from implementing the alternative, and improvement of the overall environmental quality.	The degree to which the alternative permanently reduces the toxicity, mobility, or volume of hazardous substances, including the adequacy of the alternative in destroying the hazardous substances, the reduction or elimination of hazardous substance releases and sources of releases, the degree of irreversibility of waste treatment process, and the characteristics and quantity of treatment residuals generated.	Long-term effectiveness includes the degree of certainty that the alternative will be successful, the reliability of the alternative during the period of time that hazardous substances are expected to remain on-site at concentrations that exceed cleanup levels, the magnitude of residual risk with the alternative in-place, and the effectiveness of controls required to manage treatment residues or remaining wastes. The following types of cleanup action components may be used as a guide, in descending order, when assessing the relative degree of long-term effectiveness: reuse or recycling; destruction or detoxification; immobilization or solidification; on-site or off-site disposal in an engineered, lined, and monitored facility; on-site isolation or containment with attendant engineering controls; and institutional controls and monitoring.	The risk to human health and the environment associated with the alternative during construction and implementation, and the effectiveness of measures that will be taken to manage such risks.	Ability to be implemented including consideration of whether the alternative is technically possible, availability of necessary off-site facilities, services and materials, administrative and regulatory requirements, scheduling, size, complexity, monitoring, and integration with existing facility operation and other current or potential remedial actions.			
Wetland EC 50 gpm	Provides improvement in overall protectiveness by reducing the time to achieve cleanup levels at the compliance line and by removing significant contaminant mass from the subsurface. The on- and off-site risks associated with implementation are manageable with proper design and operation. The wetland treatment would provide reduction of nitrate in the treated water. This alternative would not provide full plume capture.	This alternative would destroy cyanide, thus permanently reducing its toxicity. Fluoride would be removed in sludge, processed and disposed in an off-site facility. While the capture of fluoride in the sludges is not irreversible, proper operation of the off-site disposal facility will ensure it is not reintroduced to the environment. The wetland option would produce less on-going waste than the other options considered for cyanide removal. This alternative would remove a significant amount of contaminants from the subsurface that could act as on-going source materials. While similar to the above alternative, benefits in this category are reduced because the full plume would not be captured and treated. There is a corresponding reduction in the amount of treatment waste produced.	There is a relatively high degree of certainty that a pump and treat system using wetland treatment and electrocoagulation would perform to expectations. The magnitude of residual risk with this alternative in-place would be higher than for the alternative above because the full plume would not be captured and treated. With proper maintenance and operation this alternative is deemed reliable and following local, state and federal requirements for waste management will effectively reduce risk from treatment residuals. There would be less waste generated by this alternative due to the lower capture rate. The alternative would destroy cyanide and use off-site disposal for fluoride-bearing treatment wastes. Destruction of hazardous substances is ranked high in the long-term effectiveness hierarchy. Disposal in an off-site, engineered, lined and monitored facility ranks above on-site isolation and MNA with institutional controls.	The short-term risk to human health and the environment during construction and implementation is low. Construction/implementation would use common equipment and techniques and risks can be managed using best practices for health and safety.	The ability to implement the alternative is good. Wetland systems take more time to develop and optimize than physical/chemical treatment systems. A wetland sized to treat 50 gpm would likely be possible in the footprint of the property owned by the Trust and could be implemented within other site constraints. This alternative may require a field pilot to verify wetland design elements.	6.8	$ 28.4	$ 60.7
	7	6	6	9	8			
Wetland EC 25 gpm	Provides a modest improvement in overall protectiveness by reducing the time to achieve cleanup levels at the compliance line and by removing contaminant mass from the subsurface. The on- and off-site risks associated with implementation are manageable with proper design and operation. The wetland treatment would provide reduction of nitrate in the treated water. This alternative would capture less of the plume than the alternative above and thus the anticipated benefits in this category are reduced.	This alternative would destroy cyanide, thus permanently reducing its toxicity. Fluoride would be removed in sludge, processed and disposed in an off-site facility. While the capture of fluoride in the sludges is not irreversible, proper operation of the off-site disposal facility will ensure it is not reintroduced to the environment. The wetland option would produce less on-going waste than the other options considered for cyanide removal. This alternative would remove some contaminants from the subsurface that could act as on-going source materials. While similar to the above alternative, benefits in this category are reduced because less of the plume would be captured and treated. There is a corresponding reduction in the amount of treatment waste produced.	There is a relatively high degree of certainty that a pump and treat system using wetland treatment and electrocoagulation would perform to expectations. The magnitude of residual risk with this alternative in-place would be higher than for the alternative above because it would capture and treat less of the plume. With proper maintenance and operation this alternative is deemed reliable and following local, state and federal requirements for waste management will effectively reduce risk from treatment residuals. There would be less waste generated by this alternative than the alternative above due to the lower capture rate. The alternative would destroy cyanide and use off-site disposal for fluoride-bearing treatment wastes. Destruction of hazardous substances is ranked high in the long-term effectiveness hierarchy. Disposal in an off-site, engineered, lined and monitored facility ranks above on-site isolation and MNA with institutional controls.	The short-term risk to human health and the environment during construction and implementation is low. Construction/implementation would use common equipment and techniques and risks can be managed using best practices for health and safety.	The ability to implement the alternative is good. Wetland systems take more time to develop and optimize than physical/chemical treatment systems. A wetland sized to treat 25 gpm would fit in the footprint of the property owned by the Trust and could be implemented within other site constraints. Because of the smaller scale, a field pilot would likely not be recommended for this alternative.	5.2	$ 14.8	$ 30.5
	5	4	4	9	8			

APPENDIX H. DISPROPORTIONATE COST ANALYSIS SCORING TABLES

Remedial Alternative	Protectiveness (30%)	Permanence (25%)	Long-Term Effectiveness (25%)	Short Term Risk Management (10%)	Technical and Administrative Implementability (10%)	Environmental benefit score	30 yr cost ($ Millions, NPV)	80 yr cost ($ Millions, NPV)
	Overall protectiveness of human health and the environment, including the degree to which existing risks are reduced, time required to reduce risk at the facility and attain cleanup standards, on-site and off-site risks resulting from implementing the alternative, and improvement of the overall environmental quality.	The degree to which the alternative permanently reduces the toxicity, mobility, or volume of hazardous substances, including the adequacy of the alternative in destroying the hazardous substances, the reduction or elimination of hazardous substance releases and sources of releases, the degree of irreversibility of waste treatment process, and the characteristics and quantity of treatment residuals generated.	Long-term effectiveness includes the degree of certainty that the alternative will be successful, the reliability of the alternative during the period of time that hazardous substances are expected to remain on-site at concentrations that exceed cleanup levels, the magnitude of residual risk with the alternative in-place, and the effectiveness of controls required to manage treatment residues or remaining wastes. The following types of cleanup action components may be used as a guide, in descending order, when assessing the relative degree of long-term effectiveness: reuse or recycling; destruction or detoxification; immobilization or solidification; on-site or off-site disposal in an engineered, lined, and monitored facility; on-site isolation or containment with attendant engineering controls; and institutional controls and monitoring.	The risk to human health and the environment associated with the alternative during construction and implementation, and the effectiveness of measures that will be taken to manage such risks.	Ability to be implemented including consideration of whether the alternative is technically possible, availability of necessary off-site facilities, services and materials, administrative and regulatory requirements, scheduling, size, complexity, monitoring, and integration with existing facility operation and other current or potential remedial actions.			
Iron Precip EC 100 gpm	This alternative provides a major improvement in overall protectiveness by greatly reducing the time to achieve cleanup levels at the compliance line and by removing a large amount of contaminant mass (which may act as an on-going source) from the subsurface. Pumping this flow rate is expected to result in complete capture of the plume. The on- and off-site risks associated with implementation are manageable with proper design and operation.	Under this alternative, fluoride and cyanide would be captured in treatment sludges and disposed in an off-site facility. While the capture of contaminants in treatment sludges is not irreversible, proper operation of the off-site disposal facility will ensure contaminants are not reintroduced to the environment. Iron precipitation will generate more waste than a wetland treatment system. This alternative would remove a relatively large amount of contaminants from the subsurface that could act as on-going source materials.	There is a high degree of certainty that a pump and treat system using iron precipitation for cyanide removal and electrocoagulation for fluoride treatment would perform to expectations. The magnitude of residual risk with this alternative in-place would be low. With proper maintenance and operation this alternative is deemed reliable and following local, state and federal requirements for waste management will effectively reduce risk from treatment residuals. Off-site disposal would be used for cyanide and fluoride-bearing treatment wastes. Disposal of hazardous substances in an off-site, engineered, lined and monitored facility ranks above on-site isolation and MNA with institutional controls but below options that destroy contaminants.	The short-term risk to human health and the environment during construction and implementation is low. Construction/implementation would use common equipment and techniques and risks can be managed using best practices for health and safety.	The ability to implement the alternative is very good. The treatment technologies are proven and the equipment needed is readily available from vendors. Engineering designers would likely be able to work with vendors to spec equipment without the need for pilot testing. The needed systems would fit within the property footprint.	8.0	$ 71.3	$ 152.9
	9	7	7	9	9			
Iron Precip EC 50 gpm	Provides improvement in overall protectiveness by reducing the time to achieve cleanup levels at the compliance line and by removing significant contaminant mass from the subsurface. The on- and off-site risks associated with implementation are manageable with proper design and operation. This alternative would not provide full plume capture.	Under this alternative, fluoride and cyanide would be captured in treatment sludges and disposed in an off-site facility. While the capture of contaminants in treatment sludges is not irreversible, proper operation of the off-site disposal facility will ensure contaminants are not reintroduced to the environment. Iron precipitation will generate more waste than a wetland treatment system. This alternative would remove a significant amount of contaminants from the subsurface that could act as on-going source materials. While similar to the above alternative, benefits in this category are reduced because less of the plume would be captured and treated. There is a corresponding reduction in the amount of treatment waste produced.	There is a high degree of certainty that a pump and treat system using iron precipitation for cyanide removal and electrocoagulation for fluoride treatment would perform to expectations. The magnitude of residual risk with this alternative in-place would be higher than for the alternative above because the full plume would not be captured and treated. With proper maintenance and operation this alternative is deemed reliable and following local, state and federal requirements for waste management will effectively reduce risk from treatment residuals. There would be less waste generated by this alternative than the alternative above due to the lower capture rate. Off-site disposal would be used for cyanide and fluoride-bearing treatment wastes. Disposal of hazardous substances in an off-site, engineered, lined and monitored facility ranks above on-site isolation and MNA with institutional controls but below options that destroy contaminants.	The short-term risk to human health and the environment during construction and implementation is low. Construction/implementation would use common equipment and techniques and risks can be managed using best practices for health and safety.	The ability to implement the alternative is very good. The treatment technologies are proven and the equipment needed is readily available from vendors. Engineering designers would likely be able to work with vendors to spec equipment without the need for pilot testing. The needed systems would fit within the property footprint.	6.1	$ 39.1	$ 83.1
	6	5	5	9	9			

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Remedial Alternative	Protectiveness (30%)	Permanence (25%)	Long-Term Effectiveness (25%)	Short Term Risk Management (10%)	Technical and Administrative Implementability (10%)	Environmental benefit score	30 yr cost ($ Millions, NPV)	80 yr cost ($ Millions, NPV)
	Overall protectiveness of human health and the environment, including the degree to which existing risks are reduced, time required to reduce risk at the facility and attain cleanup standards, on-site and off-site risks resulting from implementing the alternative, and improvement of the overall environmental quality.	The degree to which the alternative permanently reduces the toxicity, mobility, or volume of hazardous substances, including the adequacy of the alternative in destroying the hazardous substances, the reduction or elimination of hazardous substance releases and sources of releases, the degree of irreversibility of waste treatment process, and the characteristics and quantity of treatment residuals generated.	Long-term effectiveness includes the degree of certainty that the alternative will be successful, the reliability of the alternative during the period of time that hazardous substances are expected to remain on-site at concentrations that exceed cleanup levels, the magnitude of residual risk with the alternative in-place, and the effectiveness of controls required to manage treatment residues or remaining wastes. The following types of cleanup action components may be used as a guide, in descending order, when assessing the relative degree of long-term effectiveness: reuse or recycling; destruction or detoxification; immobilization or solidification; on-site or off-site disposal in an engineered, lined, and monitored facility; on-site isolation or containment with attendant engineering controls; and institutional controls and monitoring.	The risk to human health and the environment associated with the alternative during construction and implementation, and the effectiveness of measures that will be taken to manage such risks.	Ability to be implemented including consideration of whether the alternative is technically possible, availability of necessary off-site facilities, services and materials, administrative and regulatory requirements, scheduling, size, complexity, monitoring, and integration with existing facility operation and other current or potential remedial actions.			
Iron Precip EC 25 gpm	Provides a modest improvement in overall protectiveness by reducing the time to achieve cleanup levels at the compliance line and by removing significant contaminant mass from the subsurface. The on- and off-site risks associated with implementation are manageable with proper design and operation. This alternative capture less of the plume than the alternative above and thus the anticipated benefits in this category are reduced.	Under this alternative, fluoride and cyanide would be captured in treatment sludges and disposed in an off-site facility. While the capture of contaminants in treatment sludges is not irreversible, proper operation of the off-site disposal facility will ensure contaminants are not reintroduced to the environment. Iron precipitation will generate more waste than a wetland treatment system. This alternative would remove some contaminants from the subsurface that could act as on-going source materials.	There is a high degree of certainty that a pump and treat system using iron precipitation for cyanide removal and electrocoagulation for fluoride treatment would perform to expectations. The magnitude of residual risk with this alternative in-place would be higher than for the alternative above because less of the plume would not be captured and treated. With proper maintenance and operation this alternative is deemed reliable and following local, state and federal requirements for waste management will effectively reduce risk from treatment residuals. There would be less waste generated by this alternative than the alternative above due to the lower capture rate. Off-site disposal would be used for cyanide and fluoride-bearing treatment wastes. Disposal of hazardous substances in an off-site, engineered, lined and monitored facility ranks above on-site isolation and MNA with institutional controls but below options which destroy contaminants.	The short-term risk to human health and the environment during construction and implementation is low. Construction/implementation would use common equipment and techniques and risks can be managed using best practices for health and safety.	The ability to implement the alternative is very good. The treatment technologies are proven and the equipment needed is readily available from vendors. Engineering designers would likely be able to work with vendors to spec equipment without the need for pilot testing. The needed systems would fit within the property footprint.	4.5	$ 22.5	$ 47.3
	4	3	3	9	9			