TECHNICAL MEMORANDUM

DATE August 16, 2018 **Project No.** 923-1000-005.100

TO Mr. Jerome Cruz
Washington State Department of Ecology

CC Landsburg Mine Site PLP Group

FROM Golder Associates Inc. **EMAIL gzimmerman@golder.com**

PRE-REMEDIAL ACTION 1,4-DIOXANE DETECTION AT THE LANDSBURG MINE SITE

1.0 PURPOSE AND SCOPE

This technical memorandum (memo) describes the recent detection of 1,4-dioxane at low concentrations in three groundwater monitoring wells located at the northern end of the Landsburg Mine Site (Site). This memo presents the nature of the detection, establishes that the detection does not present a current risk to human health or the environment, and provides a plan to address the 1,4-dioxane detection that is acceptable to the Washington State Department of Ecology (Ecology), is consistent with the Final Cleanup Action Plan (Ecology 2017a) and ensures the long-term protection of human health and the environment.

2.0 BACKGROUND

The history of the Site, summary of the remedial investigation (RI), feasibility study (FS) and additional environmental investigations completed at the Site, and the cleanup actions selected by Ecology are detailed in the Final Cleanup Action Plan (CAP) (Ecology 2017a).

The remedial actions selected in the CAP include backfilling the trenches where wastes were disposed and capping the backfilled trenches with a low-permeability soil layer to minimize stormwater infiltration to the subsurface. A vegetated layer will be installed over the cap for improved evapotranspiration and erosion control. Surface grading and collection trenches to provide stormwater drainage away from the cap will be installed. Institutional controls including deed restrictions and groundwater use restrictions, fencing and warning signs, and periodic Site inspections and maintenance are also components of the Site remedial actions to ensure long-term protection of human health and the environment. The remedial actions also include installing the infrastructure for contingent groundwater treatment systems at both the north and south ends of the Site. The infrastructure was previously installed at the north end, and the south end will be installed under the CAP remedial actions schedule. The remedial action schedule was included as Exhibit C of the Consent Decree (CD) (Ecology 2017b).

Currently, without the low permeability cap, rain water falls directly into the trenches, and stormwater along adjacent areas of the mine trench enters into the trenches by overland flow. During the rainy season, localized ponding of rainwater in portions of the trench occurs. A portion of the ponded water infiltrates through the soil/mine rock at the bottom of the trench and into the underlying groundwater within the former mine workings. The ponding is temporary and dries up during low rain periods of the year. The selected remedial actions will minimize rainwater and stormwater from entering the trenches in the areas where waste disposal occurred, thus preventing water from infiltrating through the soils and mine rock to the underlying former mine. By reducing the quantity of water entering the mine, the remedial actions will also reduce the total quantity of groundwater flowing through the former mine. Backfilling and capping the trench will also encapsulate the former waste disposal area preventing direct contact by humans and animals.

A supporting document to the CAP is the Compliance Monitoring Plan (CMP) (Ecology 2017c), which describes the groundwater monitoring that will be conducted both during the remedial action and after completion of the remedial actions. The monitoring that will occur during the remedial actions is referred to under Model Toxics Control Act (MTCA) and in the CMP as “protection monitoring,” which is conducted to ensure that human health and the environment are adequately protected during construction and operation of the remedial actions. Additionally, “performance monitoring” will be conducted to confirm that cleanup standards and other performance standards are being met. The monitoring conducted following completion of the remedial action is referred to in the CMP and under MTCA as “confirmational monitoring,” which is conducted to ensure the long-term effectiveness of the remedy.

The CMP establishes trigger levels and appropriate response actions in the event that detection thresholds are encountered during protection monitoring after the remedy required under the Consent Decree is implemented. The design, construction and activation of the contingent groundwater treatment system are required under the CAP and CMP if certain trigger levels are met. Protection monitoring will start at the time when backfilling of the trench starts, which is currently scheduled to start in the spring to summer of 2019. The confirmational monitoring will start at the completion of the remedial actions, which is currently scheduled to occur by the end of 2020.

Remedial actions have not yet started at the Site. Consistent with the schedule in the CAP, a draft Engineering Design Report (EDR) was submitted to Ecology in April 2018 (Golder 2018a). The EDR contains the plans, designs, and procedures to ensure the remedial actions completed at the Site are conducted in a manner that is consistent with the CAP, accepted engineering practices, and the requirements of Washington Administrative Code (WAC) 173-340-400(4)(a). Ecology provided comments on the draft EDR, and these have been incorporated into the final EDR (Golder 2018d). Details of the cleanup action are provided in the EDR.

3.0 INTERIM GROUNDWATER MONITORING

The current groundwater monitoring program is referred to as “interim groundwater monitoring,” and has been conducted semiannually at the site since approximately 2003. The interim groundwater monitoring has been conducted to provide continued monitoring of the Site groundwater quality until the remedial actions and associated compliance monitoring as described in the CAP and CMP are started. The interim groundwater monitoring has included laboratory testing for a comprehensive list of analytes; including: petroleum compounds, volatile (VOC) and semi-volatile organic compounds (SVOC), pesticides, polychlorinated biphenyls (PCBs), and various metals. There were no detections of contaminants that are attributable to mine waste contaminants during any of the monitoring events from 2003 to November 2017.

In response to comments received on the draft Cleanup Action Plan, Ecology added the compound 1,4-dioxane to the suite of analytes listed in the CMP that will be tested for during protection and confirmational monitoring at the Site. Although compliance monitoring will not commence until the selected remedy is implemented, the Landsburg PLP Group elected to add 1,4-dioxane to the list of test analytes included in the current interim groundwater monitoring. 1,4-Dioxane was the only new compound added to the CMP, and starting in November 2017 was the only new compound added to the interim groundwater monitoring program. All other compounds included in the CMP have been tested for at the Site during the RI and during the interim groundwater monitoring conducted since 2003. 1,4-Dioxane is recognized for its use as a stabilizer in some solvents and for its use in many household consumer products such as laundry detergents, shampoos and cosmetics. The common use of 1,4-dioxane combined with its chemical property of high solubility and mobility in groundwater has resulted in low level detections of this compound in groundwater throughout the United States (EPA 2017). In recent years 1,4-dioxane is routinely being added to groundwater testing programs at municipal water systems and at environmental cleanup sites.

The November 2017 interim groundwater monitoring round included analysis for 1,4-dioxane for the first time. All 10 of the Site groundwater monitoring wells and the north and south Portals were sampled and analyzed for: VOCs; (United States Environmental Protection Agency [EPA] Method 8260C), SVOCs including 1,4-dioxane, (EPA Method 8270D), PCBs (EPA 8082A), pesticides (EPA 8081B), priority pollutant metals (EPA Method 6010C/200.8/7470A Series), and a petroleum hydrocarbon identification scan (NWTPH-HCID). Figure 1 shows the location of the Site groundwater monitoring wells.

The analytical results for all test analytes during the November 2017 sampling event were consistent with results during the RI and with all the previous interim groundwater monitoring events conducted since 2003 except that 1,4-dioxane was detected in LMW-2 and LMW-4 at concentrations of 2.0 micrograms per liter (µg/L) and 2.3 µg/L, respectively. Since November 2017 was the first time 1,4-dioxane was tested for at the Site, its detection in LMW-2 and LMW-4 does not necessarily indicate a change in groundwater conditions. The compound 1,4-Dioxane was not detected in any of the other groundwater monitoring wells or in the either of the portal surface water samples, including monitoring well LMW-10 and the north portal, which are located upgradient of LMW-2 and LMW-4.

LMW-2 and LMW-4 were resampled in February 2018 to confirm the November 2017 1,4-dioxane detections. 1,4-Dioxane was detected during the resampling at 2.1 µg/L and 2.3 µg/L in LMW-2 and LMW-4, respectively, similar to the results detected in the November 2017 groundwater monitoring. The Landsburg PLP Group notified Ecology after the November 2017 results were received and validated and after the February 2018 resampling results were received and validated.

4.0 INSTALLATION OF NORTH SENTINEL WELLS

In response to the detection of the 1,4-dioxane in LMW-2 and LMW-4, the Landsburg PLP Group decided to expedite the installation of the four additional groundwater monitoring wells referred to as “sentinel wells” in the CAP. Sentinel wells are groundwater monitoring wells that are located between the waste disposal area and the compliance wells located at the north and south ends of the Site. The wells are referred to as sentinel wells because they will be used as an early warning for impacted groundwater migration. Two of the sentinel wells are located north of where the waste disposal occurred and two will be located south of the former waste disposal area. Figure 1 and the cross-section Figure 2 show the locations of the existing monitoring wells and the new sentinel wells.

In March 2018, a sentinel well installation work plan (Golder 2018b) was submitted to Ecology describing the details for installation of the four additional sentinel wells. Ecology approved the work plan, and the two north sentinel wells were installed during March through May 2018. The northern sentinel wells were installed first to provide data to help evaluate the potential source of the 1,4-dioxane detected in LMW-2 and LMW-4. The process of identifying the potential source of compounds detected in the Site groundwater monitoring wells is referred to in the CAP as “an alternative source evaluation” (CAP, page 46). As shown on Figure 2, the new shallow north sentinel well (LMW-12) was screened within the former mine workings from a depth of 15.5 to 25.5 feet below ground surface (ft. bgs). The new deeper north sentinel well (LMW-13R) was screened within the former mine workings at a depth of 115 to 140 ft. bgs. Existing north sentinel well LMW-10 is screened near the bottom of the coal seam at a depth of 267 to 287 ft. bgs. The attached Table 1 summarizes the groundwater monitoring well construction details. LMW-10, LMW-12, and LMW-13R are located upgradient of northern compliance wells LMW-2 and LMW-4 and downgradient of the former waste disposal area, as shown on Figure 2. If the 1,4-dioxane detected in LMW-2 and LMW-4 is a mine waste contaminant it would also be expected to be detected in LMW-12 and LMW-13R.

The two new north sentinel wells (LMW-12 and LMW-13R) were included in the May 2018 interim groundwater monitoring event. Full results from this monitoring event have been provided to Ecology in a groundwater monitoring report (Golder 2018c). During the May 2018 interim groundwater monitoring, 1,4-dixoane was detected in the new shallow north sentinel well LMW-12 at a concentration of 1.5 µg/L, but was not detected in the new deeper north end sentinel well LMW-13R. The compound was also not detected in the existing deep north sentinel well LMW-10, or in any of the other Site groundwater monitoring wells except LMW-2 and LMW-4. During the May 2018 interim groundwater monitoring, 1,4-dioxane was detected in LMW-2 and LMW-4 at 1.8 and 1.5 µg/L; respectively, which is less than the concentrations that were detected in these wells in the initial sampling in November 2017 and lower than concentrations detected in the February 2018 resampling. Although these are only three distinct events over a six-month period of time, the data indicate the 1,4-dioxane concentrations are not increasing and may actually be decreasing. Table 2 presents a summary of the 1,4-dioxane detections since the start of sampling for the compound in November 2017.

The detection of 1,4-dioxane in the new shallow north sentinel well LMW-12 indicates that the 1,4-dioxane could be coming from the former waste disposal area and could be a mine waste contaminant. However, the absence of detecting 1,4-dioxane in the new deeper north sentinel well LMW-13R is inconsistent with this determination. Only one round of sampling has been conducted of the new sentinel wells and additional evaluation of the detection of this new test compound is required under the alternative source evaluation. The Landsburg PLP Group continues to address the 1,4-dioxane detection pursuant to the CAP, CMP and per Ecology direction to ensure safety to human health and the environment. The remainder of this report provides evaluation of potential risks and proposed actions under the conceptual premise that the low-level concentrations of 1,4-dioxane detected in the north end sentinel well LMW-12 and the north end compliance wells LMW-2 and LMW-4 could be a potential mine waste contaminant.

5.0 CHARACTERISTICS OF 1,4-DIOXANE

1,4-Dioxane was used as a stabilizer in chlorinated solvents (particularly 1,1,1-trichloroethane [TCA]) starting in the 1970s until its use as a stabilizer was phased out in 1995. 1,4-Dioxane is also present as a by-product (meaning it is not added during production of a product, but instead results from various reactions during the production of the product) of various surfactants, resins, PET plastics, chemical food additives, and other compounds that are used in common commercial and household products. Some common household products like laundry detergents, shampoos, and dish soaps have measured concentrations of 1,4-dioxane exceeding 10,000 micrograms per kilogram (µg/kg) (Mohr 2017). The state of New Hampshire detected 1,4-dioxane in car wash soap at a concentration of 760,000 µg/kg. 1,4-Dioxane is released to the environment at sites where TCA or other commercial products containing 1,4-dioxane were released. 1,4-Dioxane is also released to the environment where consumer products like detergents, soaps and shampoos that contain 1,4-dioxane infiltrate to the soil and potentially to the underlying groundwater through private home owner's septic system drainage fields (Massachusetts 2018). Because public waste water treatment systems are often unable to remove 1,4-dioxane from the treated effluent, discharges of 1,4-dioxane to surface water from public waste water treatment plants commonly occurs (Mohr 2017). The wide-spread use 1,4-dioxane as a stabilizer in TCA and in various consumer and commercial products combined with the release of these products to the environment has resulted in 1,4-dioxane being found in groundwater at sites throughout the United States (EPA 2017).

1,4-Dioxane is a synthetic chemical that is completely miscible in water (i.e. it mixes easily with water). Unlike many organic compounds, 1,4-dioxane does not readily absorb to carbon that is present in most soils. The high solubility and weak retardation of the compound in soil results in migration of 1,4-dioxane from soil to groundwater. It is relatively resistant to biodegradation in groundwater compared to chlorinated solvents. Its resistance to degradation and high mobility in groundwater often result in 1,4-dioxane migrating in groundwater greater distances from the source area than most other organic compounds.

Based on laboratory studies on animals, the US Department of Health and Human Services (HHS), considers 1,4-dioxane as reasonably anticipated to be a human carcinogen. HHS indicates in the April 2012 Agency for Toxic Substances and Disease Registry (ASTDR), that the effects of 1,4-dioxane on human health depends on the how much 1,4-dioxane a person is exposed to and the length of exposure (ASTDR 2012). The ASTDR document indicates that the EPA has determined that exposure to 400 µg/L of 1,4-dioxane in drinking water for 10 days is not expected to cause any adverse effect in a child. The National Academy of Science (NAS) and the US Food and Drug Administration have established a maximum concentration of 10,000 micrograms per kilogram (µg/kg) in food additives, products used in dietary supplements, and cosmetics (ASTDR 2012).

There are currently no drinking water levels established by EPA or in Washington State for 1,4-dioxane. The World Health Organization suggests a 50 µg/L drinking water threshold for 1,4-dioxane, whereas the EPA National Center for Environmental Assessment proposed a health-based advisory level of 3 µg/L in tap water (Water Research Foundation, 2014). Under MTCA, Ecology has set a groundwater cleanup level for 1,4-dioxane of 0.435 µg/L. Seventeen other states have established drinking water and groundwater guidelines with acceptable groundwater concentrations ranging from 77 µg/L to 0.25 µg/L. Twelve states have standards that are higher than 3 µg/L for 1,4-dioxane, and six states (including Washington) have cleanup levels for 1,4-dioxane that are lower than 3 µg/L.

1,4-Dioxane breaks down in the atmosphere due to photo-oxidation (EPA 2017). 1,4-Dioxane has low aquatic toxicity as it does not bioaccumulate, biomagnify, or bioconcentrate in the food chain (ATSDR 2012; Mohr 2001). There are no surface water cleanup levels established for 1,4-dioxane in Washington state. At the PSC Georgetown Facility in Seattle, Washington, Ecology established a protection of surface water criteria for 1,4-dioxane, based on human consumption of fish, of 78.5 µg/L (Ecology 2010). The lowest No Observable Effects Concentration (NOEL) for aquatic organisms listed in the EPA EcoTox Database for 1,4-dioxane is 100,000 µg/L (EPA 2018). A MTCA Method B surface water value, calculated using a bioconcentration factor of 0.5 liters per kilogram (Oak Ridge National Laboratory's Risk Assessment Information System [RAIS 2018]) and the oral cancer potency factor listed in Cleanup Levels and Risk Calculation (CLARC) of 0.1 kg-day/mg, results in a MTCA Method B surface water value of 130 µg/L.

6.0 NATURE AND EXTENT OF 1,4-DIOXANE AT THE SITE

6.1 Extent of 1,4-Dioxane at the Site

This section evaluates the current understanding of the horizontal and vertical extent of 1,4-dioxane. As described in Section 3 of this memo, low concentrations of 1,4-dioxane were detected in groundwater monitoring wells LMW-2, LMW-4 and LMW-12, all located at the northern end of the Landsburg Site. The northern portal (Portal #2), LMW-10 and LMW-13R are also located at the north end of the Site, but 1,4-dioxane was not detected in any of these locations. All other Site groundwater wells and water from the south mine portals have also been tested for 1,4-dioxane, and 1,4-dioxane was not detected in any of the other samples.

All of the northern wells – LMW-2, LMW-4, LMW-10, LMW-12, and LMW-13R – are screened across various depth intervals within the former Roger's mine seam workings. Monitoring well construction details are listed in Table 1, and well locations and depths are depicted in Figure 2. LMW-2 and LMW-12 are screened at shallow depths, LMW-13R and LMW-4 are screened at deeper depths within the mine workings, and LMW-10 is screened near the bottom of the former mine workings. The concentrations of 1,4-dioxane detected in LMW-2 and LMW-4 are similar, indicating that near the northern end of the Site the vertical distribution of 1,4-dioxane extends from the top of the water table (located approximately 5 ft. bgs) to at least 210 ft. bgs. 1,4-Dioxane is not detected in LMW-10, whose screen interval starts at a depth of 267 ft. bgs. This would indicate that the vertical extent of 1,4-dioxane reaches non-detectable concentrations (laboratory detection limit of 0.2 µg/L) at a depth shallower than 267 ft. bgs.

Groundwater beneath the waste disposal area within the former Roger's mine seam flows to the north. The new sentinel wells LMW-12 and LMW-13R are located hydrologically downgradient of the former waste disposal area and upgradient of the compliance wells LMW-2 and LMW-4. If the source of the 1,4-dioxane detected in LMW-2 and LMW-4 is the former waste disposal area, one would expect to see higher concentrations of 1,4-dioxane in wells LMW-12 and LMW-13R. 1,4-Dioxane was not detected in LMW-13R during the May 2018 interim groundwater monitoring event and was detected at lower concentrations in LMW-12 than detected in LMW-2 and LMW-4. The absence of 1,4-dioxane in LMW-13R, which is screened at a depth shallower than LMW-4, is also inconsistent with the vertical extent of 1,4-dioxane detected at LMW-2 and LMW-4. Additional groundwater monitoring data collected from the Site monitoring wells will provide further evaluation of 1,4-dioxane concentration trends and potential source areas.

In the northern portion of the Site where 1,4-dioxane was detected, the lateral extent of the 1,4-dioxane is limited to the width of the former Rogers seam. The coal seam itself is approximately 10 to 12 feet wide, but the collapsed width of the Rogers mine is about 15 feet. The geology and hydrogeology of the Site are described within the CAP (Ecology 2017). On the northern end of the Site the coal seam and associated mine workings are oriented nearly vertically. Low permeability sandstone and shale of the Puget Group bedrock are located on the east and west sides of the Rogers coal seam and mine workings. The mined/backfilled Rogers seam is a highly conductive zone for groundwater flow. The fine-grained, vertically bedded Puget Group bedrock strata located to either side of the seam are several orders of magnitude less permeable than the mined out seam. Groundwater flow within the mine flows horizontally to the north to northeast, along the strike through the highly permeable Rogers seam.

North of the Site, groundwater from the Rogers seam discharges to the Cedar River through the glacial sands and gravels that overlie the coal seam and underlie the Cedar River. There are currently no groundwater wells located between the north end of the Site and the Cedar River. The Cedar River is located approximately 600 feet north of LMW-2 and LMW-4. Figures 2 and 3 conceptually depict the coal seams, the low permeability Puget Group sandstone and siltstones located on either side of the coal seams, and the recessional outwash sands and gravel deposits beneath the Cedar River.

6.2 Evaluation of Current Potential Exposure Pathways

The concentrations of 1,4-dioxane detected in groundwater samples collected from LMW-2, LMW-4 and LMW-12 range from 1.5 to 2.3 µg/L. These concentrations exceed the Washington State MTCA Method B groundwater cleanup level of 0.438 µg/L, but are lower than concentrations considered acceptable for drinking water in most of the other states that have promulgated 1,4-dioxane groundwater cleanup or guidance levels (EPA 2017) (see Section 5, above). The concentrations of 1,4-dioxane detected in the three Site wells are significantly less than estimated surface water values that are protective of human health from consumption of organisms (130 µg/L calculated MTCA Method B cleanup level) and significantly lower than concentrations for the protection of aquatic Ecological receptors (100,000 µg/L, EPA 2018). Therefore, the potential exposure pathway to be considered is consumption of groundwater. There are no drinking water wells located on the Site, and the environmental covenants required under the CAP will prevent groundwater use from the Site for any non-remedial purpose. There are also no groundwater wells located downgradient of the Site between the LMW-2 and LMW-4 and the Cedar River. The nearest private well is located approximately 1300 feet west of the Rogers coal seam (Figures 1 and 3), and is not along the downgradient groundwater flow path between the Rogers seam and the Cedar River. The combination of these factors - prevention of drinking water wells on Site and distance/cross-gradient location of nearest private wells - indicates that the low-level detection of 1,4-dioxane in LMW-2, LMW-4 and LMW-12 does not present a current risk to human health or the environment. The following section presents proposed actions to ensure the long-term protection of human health and the environment.

7.0 PLAN TO ADDRESS 1,4-DIOXANE DETECTION

The following actions are proposed to address the recent 1,4-dioxane detection:

- Continue the alternative source evaluation as prescribed in the CAP. The closest private wells located northwest of the Site will be sampled as a precaution. Although the geology and hydrogeology of the Site and surrounding area indicate that groundwater from the Rogers mine discharges to the Cedar River and that groundwater would not flow towards the private wells located northwest of the Site, the Landsburg PLP Group will request access from the nearest private well owners to sample their wells. If access is provided, the wells will be sampled and analyzed for 1,4-dioxane. As indicated in this tech memo, 1,4-dioxane is present in many consumer products and has been found to enter groundwater through private septic system drain fields. The detection of 1,4-dioxane in any private well sample would not automatically indicate the groundwater from the Rogers seam is the source, but would indicate that additional evaluation of the potential source is required. The additional evaluation could include installation of groundwater monitoring wells north of the LMW-2 and LMW-4 to provide empirical data on the lateral extent of 1,4-dioxane in the groundwater downgradient of the Site.

- Complete the remedial actions as described in the CAP. If the 1,4-dioxane is a mine waste contaminant, backfilling and capping of the mine trench area where wastes were disposed will reduce the infiltration of rainwater and stormwater runoff currently entering the trench and subsequently reduce the flux of any 1,4-dioxane in soils to the groundwater within the mine workings. The capping will also reduce the total quantity of water that flows along the mine workings and ultimately discharges to the Cedar River.

- Increase the interim groundwater monitoring frequency of the groundwater monitoring wells located at the north end of the Site to quarterly. Sampling for 1,4-dioxane at the Site first occurred with the November 2017 interim semi-annual groundwater monitoring event. Although the concentrations detected in May 2018 were lower than detected in November 2017, it is not possible to evaluate the long-term concentration trends or seasonal trends with the limited amount of data currently available. The increased monitoring frequency will provide additional data to evaluate 1,4-dioxane concentration trends. Semi-annual interim groundwater monitoring will continue on all other Site groundwater monitoring wells, until compliance monitoring as described in the CMP starts.
- Expedite the installation of the south sentinel wells. The north sentinel wells have already been installed. The two southern sentinel wells required under the CAP will be installed during fall 2018. These wells will provide data on the groundwater quality and provide further clarification of the groundwater gradients.
- Install the south contingent treatment system infrastructure in 2019 versus 2020 as initially provided in the draft EDR schedule.

8.0 SUMMARY

1,4-Dioxane was not tested for at the Landsburg Mine Site prior to finalization of the CD and CAP. The detection of 1,4-dioxane during the recent interim groundwater monitoring events in three groundwater monitoring wells located at the northern end of the Site is new data that was not available at the time the CD and CAP were prepared. Evaluation of the 1,4-dioxane detections indicates that the low-level detections do not present a risk to human health or the environment. Although the closest private wells northwest of the site are not located along the downgradient groundwater flow path from the Site, testing of these wells is proposed to ensure protection and evaluate potential alternative sources. Groundwater monitoring frequency of the northern Site groundwater monitoring wells has been increased to quarterly to provide additional concentration trend data and to monitor for other potential highly mobile volatile organic compounds. Implementation of the remedial actions required under the CD and CAP are proceeding. The backfilling, capping and stormwater diversion remedial actions are designed to reduce infiltration of water through the former waste disposal area and potential flux of contaminants to the groundwater within the former mine workings. If the 1,4-dioxane is a mine waste contaminant, these remedial actions will serve to attenuate the concentrations currently detected in the northern portion of the Site and will reduce the overall of volume of groundwater discharging through the former mine workings.

GOLDER ASSOCIATES INC.

Gary L. Zimmerman
Principal

GLZ/DJM/sb

Attachments:
Tables
Figures

v:\projects_1992 projects\923-1000\1,4-dioxane detect\1,4-dioxane-action letter\final\9231000-005-tm-rev0-1,4-dioxane-final-081618.docx

9.0 REFERENCES

Agency for Toxic Substances and Disease Registry (ATSDR). 2012. “Toxicological Profile for 1,4-Dioxane.” www.atsdr.cdc.gov/toxprofiles/TP.asp?id=955&tid=199. April.

Golder Associates Inc. (Golder). 2018a. Draft Report. Engineering Design Report Landsburg Mine Site. Prepared for the Washington State Department of Ecology. Redmond, Washington April 27.

Golder 2018b. Draft Report. Sentinel Well Installation Work Plan. Prepared for the Washington State Department of Ecology. Redmond, Washington March 5.

Golder 2018c. Landsburg Mine Site Interim Groundwater Monitoring Results – May 2018. Prepared for the Landsburg PLP Steering Committee. Redmond, Washington. August 14.

Mohr, T.K.G. 2001. “1,4-Dioxane and Other Solvent Stabilizers White Paper.” Santa Clara Valley Water District of California. San Jose, California. June 14.

Mohr, T.K.G., Santa Clara Valley Water District. 2017. Presentation to the Groundwater Resources Association of California. Sacramento, California. October 3.

Oak Ridge National Laboratory’s Risk Assessment Information System (RAIS). 2018. Toxicity Values Database. https://rais.ornl.gov/cgi-bin/tools/TOX_search?select=chem.

U.S. Environmental Protection Agency (EPA). 2017. Technical Fact Sheet – 1,4-Dioxane November 2017. EPA 505-F-17-011. Washington DC.

EPA 2018. ECOTOX Database: Aquatic Report for 1,4-Dioxane. January 31.

Washington State Department of Ecology (Ecology) 2010. Final Cleanup Action Plan, PSC Georgetown Facility, Seattle, Washington. Prepared for Burlington Environmental, LLC. April 28.

Ecology. 2017a. Exhibit B of the Consent Decree - Final Cleanup Action Plan Landsburg Mine Site MTCA Remediation Project, Ravensdale, Washington. Prepared by Golder Associates Inc. June 7.

Ecology 2017b. Consent Decree, Landsburg Mine Site MTCA Remediation Project, Ravensdale, Washington. Filed in King County Superior Court. November 6.

Ecology 2017c. Exhibit D of the Consent Decree – Compliance Monitoring Plan Landsburg Mine Site MTCA Remediation Project, Ravensdale, Washington. Prepared by Golder Associates Inc. June 7.

Water Research Foundation. 2014. 1,4-Dioxane White Paper.

Tables

Table 1: Landsburg Mine Site Groundwater Monitoring Wells Construction Summary

Well ID	Coordinates		Installation Date	Measuring Point Elevation (ft)	Borehole Depth (ft)	Borehole Diameter (inches)	Well Casing Diameter (inches)	Well Materials	Depth to Top of Screen (ft)	Depth to Bottom of Screen (ft)	Screen Slot Size (inches)	Depth to Top of Filter Pack (ft)	Comments
	Northing	Easting											
LMW-1	138279.4	1354991.4	1/23/1994	765.16	180	8	4	Stainless/PVC	162	177	0.02	158	In area of gangway that connects mine fault off-set
LMW-1A	138322.87	1354997.2	2/7/1994	759.51	220	8	2	PVC	129	149	0.02	n/a	Only for water levels
LMW-2	139076.87	1355972.6	2/11/1994	617.73	46	8	4	Stainless/PVC	28	38	0.02	25	Shallow north compliance
LMW-3	135192.23	1353220.4	11/22/2004	656.75	76	8	4	Stainless/PVC	50	65	0.02	47	Shallow south compliance
LMW-4	139122.48	1355864.9	2/19/1994	619.26	233	8	4	Stainless/PVC	195	210	0.02	210	Deep north compliance
LMW-5	135206.05	1353141.3	12/8/2004	658.27	247	8	4	Stainless/PVC	232	242	0.02	232	Deep south compliance
LMW-6	138772.683	1714004.8	1/13/1994	632.33	106	8	4	Stainless/PVC	91	106	0.02	83	Frasier Coal Seam
LMW-7	138055.1	1355483.6	1/10/1994	771.51	254	8	4	Stainless/PVC	240	254	0.02	n/a	Landsburg Coal Seam
LMW-8	135074.898	1353229.4	4/7/2004	646.97	15	9	2	PVC	7.5	13	0.02	6	Representative of Portal #3 discharge
LMW-9	135727.33	1353324	4/14/2004	743.99	160	9	2	PVC	149	159	0.02	144	Southern Sentinel Well mid-depth
LMW-10	139054.3	1355787.9	5/11/2004	618.87	450	9	4	PVC	267	287	0.02	258	Deep, near bottom of mine, northern end
LMW-11	TBD	TBD	8/24/2005	801.87	707	9	4	Stainless/PVC	697	707	0.02	688	Deep, near bottom of mine, south end
P-2	135117.598	1353212.7	4/16/2004	651.37	70	9	2	PVC	39	44	0.02	*n/a	Temporary piezo into Portal #3
LMW-12	TBD	TBD	3/14/2018	TBD	30	8	4	PVC	15.5	25.5	0.02	11	North Portal shallow Sentinel Well
LMW-13R	TBD	TBD	5/15/2018	TBD	151	8	4	PVC	115	140	0.02	110	North Portal deep Sentinel Well

Note
* No filter pack was installed in P-2 due to the open mine shaft at 39 feet to 44 feet. The casing was removed, and the native material collapsed around the well to 15 feet below ground surface.
TBD = to be determined. Well coordinates and measuring point elevations will be determined by a professional surveyor.

Table 2: Groundwater 1,4-dioxane detections since November 2017

ANALYTE	MTCA Level B	UNITS	LMW-2	LMW-2	LMW-2	LMW-4	LMW-4	LMW-4	LMW-12	LMW-13R
			11/30/2017	2/9/2018	5/24/2018	11/30/2017	2/9/2018	5/24/2018	5/23/2018	5/23/2018
1,4-Dioxane	**0.438**	ug/L	**2.0**	**2.1**	**1.8**	**2.3**	**2.3**	**1.5**	**1.5**	0.2 U

Notes:

U - The analyte was not detected above the method detection limit of 0.2 ug/L .

µg/L = micrograms per liter

May-2018 Sampling Results

Analyses performed by EPA Method 8270

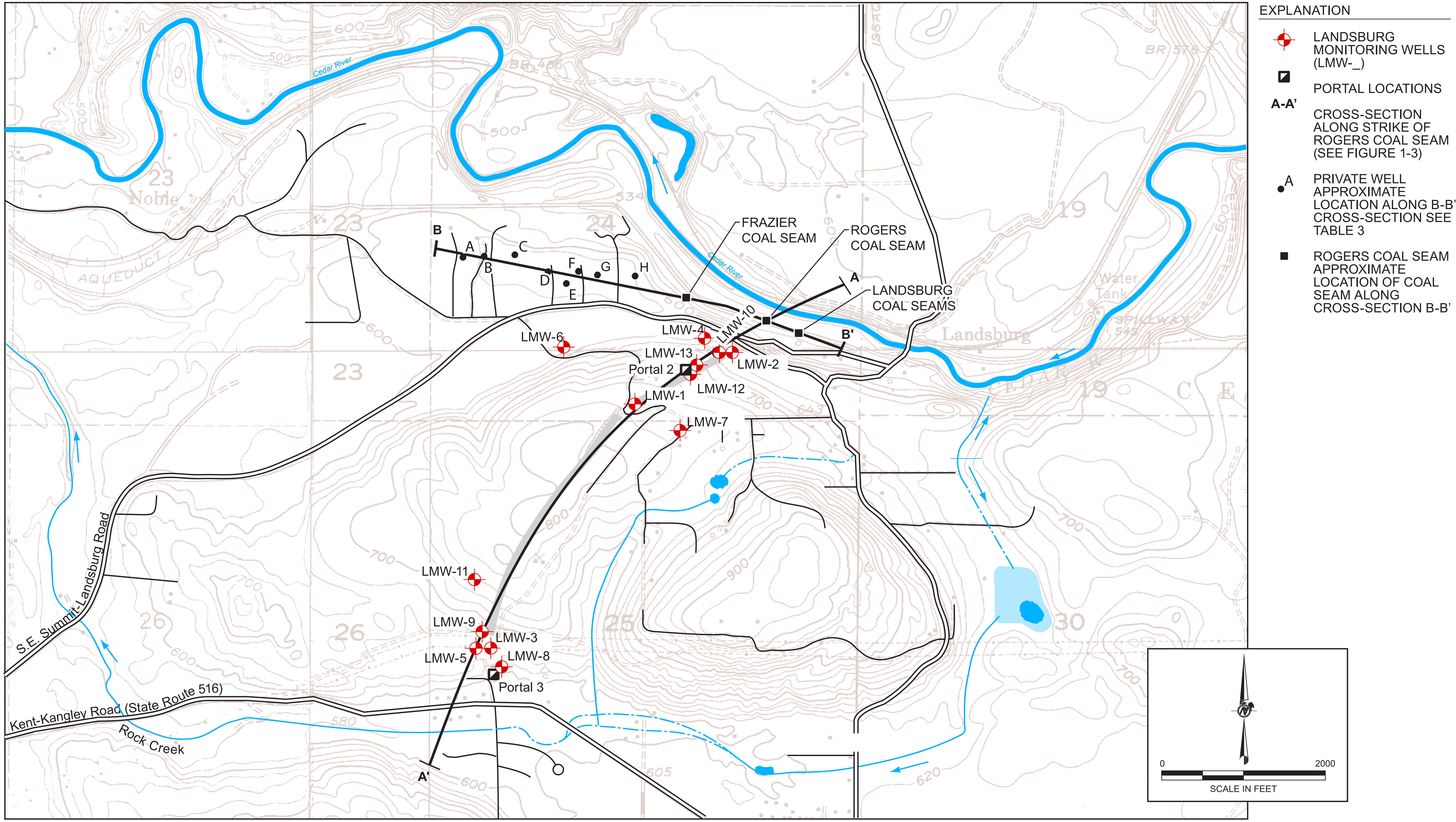
Groundwater samples from all other Site groundwater monitoring wells were analyzed for 1,4-Dioxane during the November and May interim groundwater monitoring events
1,4-Dioxane was not detected in any of the other Site groundwater monitoring wells or in samples collected from the north and south portals.

Table 3: Summary of Private Wells Located Along Cross-Section B - B' on Figure 3.

Well ID (Figures 1 and 3)	Well Owner/Tenant(s) at the time of RI	Address	Water Supply Source For (# of) Homes	Water Supply Source For (# of) People (approx.)	Well Specifications Date Installed	Well Specifications Depth (ft)	Well Specifications Depth to Water (ft BGS)	Well Log Available	Comments
A	Unknown	26022 SE 252nd ST Ravensdale, WA 98031	1		Jun-82	160	148	Yes	
B	William J. Doyle	26108 SE 252nd St Ravensdale, WA 98051	1	2	Jun-82	169	152	Yes	
C	Kevin Satre	26202 SE 252nd St Ravensdale, WA 98031	1	4	Aug-90	138	104	Yes	
D	Paul Drillevich	26318 SE Summit Landsburg Rd Ravensdale, WA 98031	1	2	Aug-77	44	30	Yes	
E	Chris Morris	17224 SE 265th St Ravensdale, WA 98031	1	1	Oct-80	38	20	Yes	
F (PW-3)*	Well 429641 Tenants	25005 - 265th AV SE Ravensdale, WA 98031	4	11	Aug-87	51	25	Yes	Elev - 617.08 N-140,049.071 : E-1,713,890.354
G	LS Kombol Trust	26600 Summit Landsburg Road Ravensdale, WA 98051	0	0	Jun-16	172	143	Yes	
H (PW-4)*	Landsburg Estates Greg Putnam	25041 - 267th AV SE Ravensdale, WA 98031	8	18	Apr-78	167	127	Yes	Elev - 618.53 N-139,946.902 : E-1,714,848.720

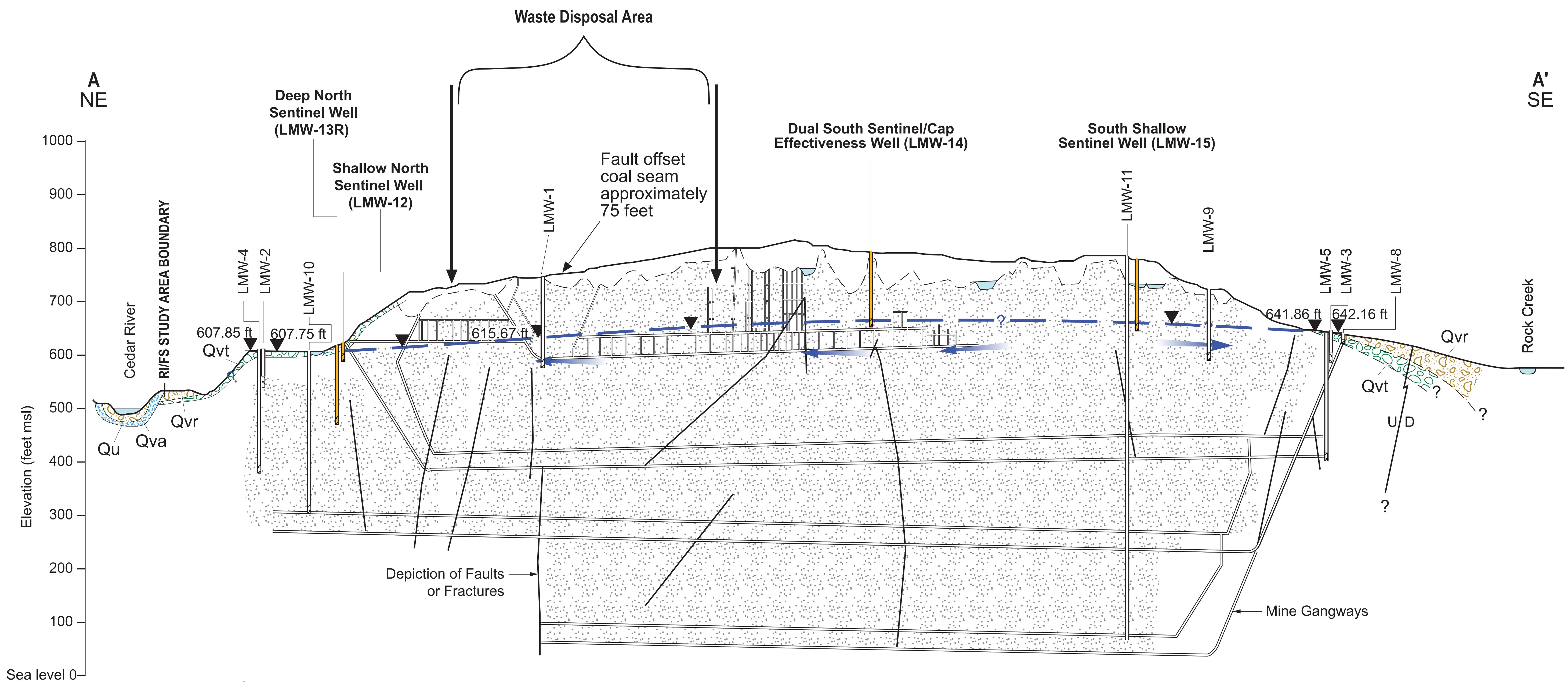
Notes:
NA - Unable to obtain information
* - These wells were included in the groundwater sampling program conducted during the remedial investigation.
Northings and Eastings are listed in the comments section for sampled private wells. The locations reference Washington state plane coordinates.

Figures



BASE MAP FROM USGS 7.5' TOPOGRAPHIC QUADRANGLES "CUMBERLAND" AND "HOBART".

CLIENT	LANDSBURG MINE SITE PLP GROUP
CONSULTANT	GOLDER
YYYY-MM-DD	2018-08-03
PREPARED	REDMOND
DESIGN	
REVIEW	
APPROVED	
PROJECT	LANDSBURG MINE SITE
TITLE	**SITE FEATURES AND MAP VIEW FOR LANDSBURG CROSS-SECTION**
PROJECT No.	923-1000.005
PHASE	1000
FIGURE	1



EXPLANATION

Potentiometric surface

Outline of trench bottom

Water Level (ft. amsl) 2/23/94

Qvt Till, compact mixture of gravel occasional boulders in clayey silty sand matrix

Sandstone

Surface water feature

Anticipated collapsed zone within mine

Qu Drift, till, fluvial sand and gravel, lacustrine sand, silt, clay and peat

Qvr Recessional outwash, well sorted sand and pebble-cobble

Qva Advanced outwash pebble-cobble gravel may include very fine sand

Monitoring Interval

Groundwater Flow Direction

Sources for the Geology and Mine Information:
J.E. Luzier 1969; surficial geology
State of Washington, Water Well reports
Mine Superintendant's Records
Landsburg Well Logs

NOTE: Vertical to horizontal scale ratio is 2.5:1
Wells are project normal into the strike of the Cross-Section A-A'

Assuming groundwater discharge at the north and south end of mine.

0 500
FEET

CLIENT
LANDSBURG MINE SITE PLP GROUP

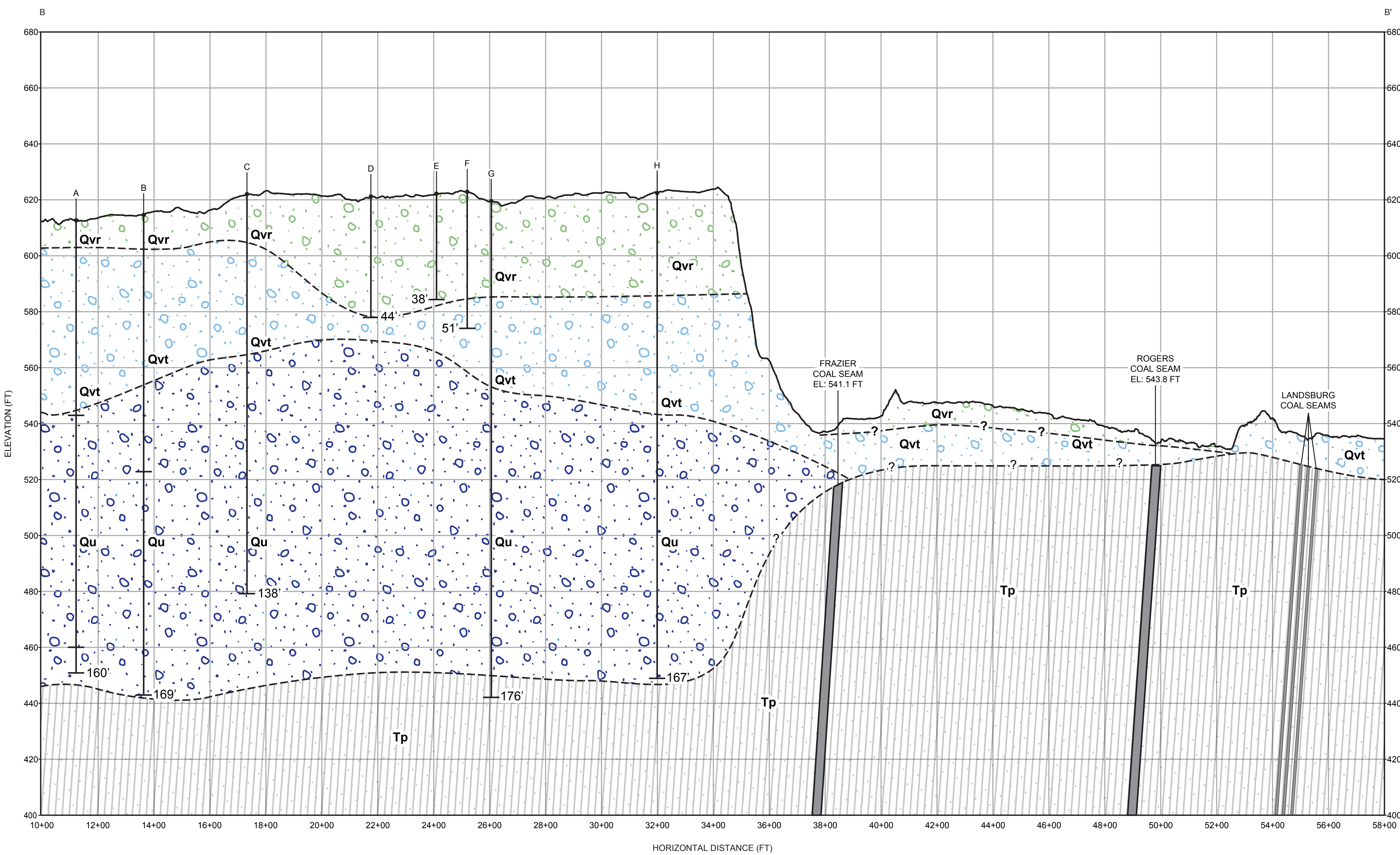
PROJECT
LANDSBURG MINE SITE

CONSULTANT
GOLDER

YYYY-MM-DD 2018-08-03
PREPARED REDMOND
DESIGN
REVIEW
APPROVED

TITLE
CROSS-SECTION ALONG STRIKE AT COAL SEAM CROSS-SECTION A-A'

PROJECT No. 923-1000.005
PHASE 1000
FIGURE 2



VERTICAL SCALE: 1" = 20' (0, 20, 40 FEET)

HORIZONTAL SCALE: 1" = 200' (0, 200, 400 FEET)

EXPLANATION

- Tp (UNDIFFERENTIATED PUGET GROUP) - SANDSTONE INTERBEDDED SHALE AND COAL
- Qu (PRE-VASHON DRIFT) - TILL, FLUVIAL SAND AND GRAVEL, LACUSTRINE SAND, SILT, CLAY, AND PEAT
- Qvt (TILL) - COMPACT MIXTURE OF GRAVEL, OCCASIONAL BOULDERS IN CLAYEY SILTY SAND MATRIX
- Qvr (RECESSIONAL OUTWASH) - WELL SORTED SAND AND PEBBLE-COBBLE
- A PRIVATE WELL LOCATION AND DEPTH FROM DRILLERS BOREHOLE LOGS

Sources for the Geology and Mine Information:

- J.E. Luzier 1969; surficial geology
- State of Washington, Water Well reports
- Landsburg Well Logs

NOTE:
Wells are projected normal into the strike of the Cross-Section C-C'.
Cross-sections are inferred from limited data and should be considered approximate.

CLIENT	LANDSBURG MINE SITE PLP GROUP	PROJECT	LANDSBURG MINE SITE
CONSULTANT	GOLDER	TITLE	CROSS-SECTION B-B`
YYYY-MM-DD	2018-08-03	PROJECT No.	923-1000.005
PREPARED	REDMOND	PHASE	1000
DESIGN		FIGURE	3
REVIEW			
APPROVED			