Okanogan Highlands Alliance (David Kliegman)

Okanogan Highlands Alliance submits the attached Groundwater Memorandum regarding groundwater quality overview for Echo Bay Key Mill vicinity, Permit No. ST0008033 as it relates to the Key Mill Storage SEIS. The DSEIS should be revised to incorporate the data, information, and interpretations in this memo, including background water quality of the tailings impoundment, and the opinions of the technical experts that reviewed the facility. The experts found and discuss that the liner leaks, that it has leaked for decades, and that water quality monitoring data shows that contaminants from the tailings are and have been present in down gradient surface water. Specifically "Hydrogeo (2005) assumed an underdrain capture rate of 80% of the estimated seepage from the primary liner in their simulations of groundwater conditions below the TSF. This leaves 20% of the tailings seepage (about 700 gallons per day), with a sulfate concentration of 3,300 mg/L, to discharge to groundwater."

Groundwater Memorandum

To: Jacquelyn Nutt, Gary Johnson, Pat Hallinan

Cc: Adriane Borgias, Art Jenkins, Andrew Austreng

From: Llyn Doremus

Date: 8/4/2023

Re: Groundwater Quality overview, Echo Bay Key Mill vicinity, Permit no. ST0008033

Background

Echo Bay Minerals Company operates the Key Mill 94-acre, lined Tailings Storage Facility (TSF) in the North Fork Sanpoil River watershed The TSF impoundment extends from an elevation of 3,000 feet, (north of the North Fork Sanpoil River channel) upslope 200 feet to an elevation of 3,200 feet. The address is 363 Fish Hatchery Road, Republic Washington, (T 37N, R 33 E, Section 26). The TSF has been in operation since 1989, and currently stores approximately 13.2 million tons of mine tailings within a two-hundred-foot-high detention enclosure (AMEC 2006). Proposed changes to operations include adding another 75 feet to the height of the impoundment enclosure and storing another 7.4 million tons of tailings in the TSF. Groundwater downgradient of the TSF groundwater is monitored in wells TP-1, TP-2, TP-3 and TP-2A and reported to Ecology according to the conditions established in State Waste Discharge Permit no. ST0008033.

Hydrogeology

The North Fork Sanpoil River drains the approximately 15 square mile watershed upgradient of the where the Key Mill and TSF are located. The Sanpoil River was gaged from 2005 – 2009, about twenty miles downstream from the Key Mill site, above the confluence of Thirteen Mile Creek (USGS site no. 12433890). The average discharge measured over that period was 41 ft^3/second. Golder monitored discharge in the North Fork Sanpoil River near the Key Mill vicinity recording a range of flows between 1.04 and 9.38 ft^3/second from June to October 2015 (Golder, 2016). Annual average precipitation measured at Curlew from 2019 - 2022 is 19.5 inches (WSU AgWeatherNet).

The Key Mill site is underlain by unconsolidated glacio-fluvial sediments deposited on Eocene O'Brien Formation (tuff interbedded with sedimentary deposits) and Sanpoil volcanics (porphyritic dacite). Two distinct aquifers have formed in the unconsolidated glacio-fluvial sediments, a shallow unconfined aquifer in sand and gravel deposits ranging in thickness from zero to eighty feet and a lower semi-confined aquifer. Hydrogeo (2005) reports that water levels in the shallow unconfined aquifer are between ten and seventy feet below the ground surface (average elevations of 3020 to 3050 feet), and the saturated thickness between 2 and 27 feet. The shallow aquifer accumulates on a lacustrine, low permeability silt-clay layer ten to twenty feet thick, ranging in depth below the ground surface of 50 to 85 feet. Hydrogeo (2001) characterizes this low permeability unit as a leaky barrier to groundwater flow from the shallow unconfined aquifer to the lower semi-confined unit.

Beneath the silt-clay layer the lower, semi-confined, unconsolidated aquifer is composed of fine sands and weathered bedrock and rests on glacial till and volcanic deposits. The groundwater level elevations in the lower semi-confined aquifer are 90 to 110 feet below the ground surface and the saturated thickness ranges from 12 to 34 feet (Hydrogeo, 2005).

Groundwater Characterization

The hydraulic gradient in the shallow unconfined aquifer is generally towards to the south, estimated at 0.1 – 0.14 (Hydrogeo, 2005), discharging to the North Fork Sanpoil River. Springs along the north bank of the North Fork Sanpoil River, south of the TSF, evidence discharge from the shallow aquifer to the River. HydroGeo (2005) calculated a downward vertical component of the hydraulic gradient from the upper unconfined to the lower semi-confined aquifer of 0.68 in the TP-3 vicinity, and 0.74 in the TP-2A vicinity (Hydrogeo, 2007). Aspect (2021) concluded there is little hydraulic connection between the upper and lower transmissive units based on a pump test conducted in TP-3 due to the lack of drawdown detected in the TP-1 and TP-2 monitoring wells during pumping. Neither was drawdown evidenced in TP-2A during the pumping test, which is screened in the same semi-confined lower aquifer as TP-3. Distance from the pumping well appears to have affected monitoring well drawdown during the pumping test more than the hydraulic connectivity between the pumping well and the other monitoring wells.

A paleochannel in the TP-2 vicinity breaches the low permeability silt-clay layer that separates the upper (shallow) and lower aquifers creating a hydraulic link between them (Hydrogeo, 2007). Similar elevations in TP-2A (screened in the lower semi-confined aquifer) as those in TP-1 and TP-2 support the interpretation that there is hydraulic connectivity between the shallow transmissive aquifer and deeper semi-confined aquifer.

The difference in groundwater elevations between TP-2A and TP-3, (water levels measured in TP2A are higher than those measured by TP-3 by 43 to 79 feet between 2006 and 2022), suggests an east to west component of the hydraulic gradient parallel to the flow direction of the North Fork Sanpoil River in the deeper semi-confined aquifer.

Upslope of the TSF the Mill Wet Spring (also termed the Mill Draw Spring) discharges into an infiltration trench constructed at the north margin of the TSF. The upgradient spring evidences groundwater movement from higher (northward) upgradient elevations in the watershed continuing to the south, and below the TSF. Echo Bay analyzed samples spring monthly from March to August 2010 (Mitchum, 2010). Golder reported analyses results for spring samples collected in 2015 (Golder, 2016).

During initial groundwater investigations for TSF construction ten monitoring wells were installed in the TSF vicinity. Golder (1988) installed the first six wells, four accessing the shallow unconfined aquifer: ZB-4, ZB-5, ZB-7, ZB-9, and two screened in the deeper semi-confined aquifer: ZB-8 and ZB-11. Four additional monitoring wells accessing the shallow unconfined aquifer were installed later in 1988: ZB-12, ZB-13, ZB-14, ZB-15 (Hydrogeo, 1988). Groundwater quality data collected following installation of these wells in 1988 provides baseline information on groundwater quality conditions prior to TSF operation.

Groundwater Quality

Baseline groundwater quality data was collected from shallow wells ZB-7, ZB-9, ZB12, ZB-13, and ZB-14 in June 1988. Total dissolved solids (TDS) measured in the five wells ranged from 272 to 318 mg/L, sulfate ranged from 8 – 43 mg/L, and total alkalinity ranged from 194 – 253 mg/L (Hydrogeo, 2005). The ratio of sulfate to the total dissolved solids concentrations measured ranged from 0.03 – 0.14, and alkalinity to TDS ratios of 0.61 to 0.84, in all 1988 groundwater analyses. Samples analyzed in June1988 from the deeper wells (ZB-8 and ZB-11) detected TDS concentrations of 224 and 272 mg/l respectively, sulfate concentrations were 14 and 10 mg/L, with a ratio of sulfate to TDS of 0.06 and 0.04. Alkalinity concentrations were 218 and 180 mg/L respectively, with a ratio of alkalinity to TDS of 0.80 in both wells.

Hydrogeo (2001) interpreted the background conditions from groundwater quality data measured in TP-1, TP-2 and TP-3 as follows: TDS 283 mg/L, sulfate 17 mg/L, chloride 6 mg/L and alkalinity at 212 mg/L, with a sulfate to TDS ratio of 0.08.

The Mill Wet spring (also known as the Money Pit Spring) discharging upgradient of the TSF was sampled five times in 2010 by Echo Bay, with the following results: TDS 199- 285 mg/L; sulfate 11.9 –19.2 mg/L; with a sulfate to TDS ratio of .06 - .08. Golder (2016) analyzed samples from the Mill Wet Spring in 2015, with the following results: TDS 298 mg/L; sulfate 19.5 mg/L; chloride 2.05 mg/L and total alkalinity 229 mg/L. The TDS to sulfate ratio for this sample is .07.

Together the Echo Bay and Golder data indicate that pre-TSF construction groundwater conditions (measured in 1988) were comparable to those measured upgradient of the TSF in the Mill Wet Spring. Groundwater analyses from the Mill Wet Spring, and groundwater (1988) detected TDS concentrations of 199 to 318 mg/L and sulfate concentrations of 8 to 43 mg/L, with sulfate to TDS ratios of 0.4-0.14. Background groundwater quality conditions in the upper unconfined aquifer and the lower semi-confined aquifer were similar prior to TSF operation and are consistent with those measured in the upgradient Mill Wet Spring. Together these data are interpreted to define background groundwater quality.

Tailings Storage Facility Operations and Groundwater Quality

Construction of the TSF in 1989 reduced shallow recharge to groundwater. By 1991 groundwater levels dropped below the bottoms or were close to the bottoms of monitoring wells ZB-4 through ZB-15 (Hydrogeo, 2001). Those monitoring wells were subsequently abandoned, with the four new wells installed (TP-1, TP-2, TP-2A and TP-3) that are currently in use. After ten years of continued TSF interception of groundwater recharge, Hydrogeo reported in 2001 that groundwater quality met the groundwater criteria for all parameters measured in TP-1, TP-2 and TP-3 except TDS and isolated exceedances of manganese and arsenic; nitrate also exceeded the groundwater criteria three times in 1997 and 1998 in TP-2. Groundwater concentrations of TDS and sulfate progressively increased from 1991 to 2000; from 456 to 792 mg/L TDS in TP-1; 292 to 653 mg/L in TP-2. Coincident with the TDS increases, sulfate increased in TP-1 from 18.3 to 162 mg/L, and in TP-2 from 12.8 to 166 mg/L. The SO_4/TDS ratio in TP-1 increased to 0.20 in January 2001, and to 0.25 in TP-2. Total Dissolved Solids concentrations measured in TP-3 between

1993 and 2000 increased slightly, from 197 to 239, and sulfate from 13.8 to 33mg/L, with a slight SO_4/TDS ratio increase from 0.07 to 0.14 (Hydrogeo, 2001).

While construction of the lined TSF in 1989 reduced recharge to the underlying unconsolidated aquifers (upper unconfined and lower semi-confined) and lowered groundwater levels, additional factors merit consideration in assessing the causes for increasing total dissolved solids concentrations detected in the shallow unconfined aquifer. In all three wells increases in TDS were accompanied by an increase in the proportion of sulfate present in groundwater, indicating an increased source of sulfate, most likely from the operation of the TSF. Total alkalinity and chloride concentrations measured in TP-1, TP-2 and TP-3 show an opposite trend to the proportional increases in sulfate concentration between 1991 and 2001. The alkalinity to TDS ratio decreases (TP-1, 0.88 to 0.58; TP-2, 0.66 to 0.38) or remains constant (TP-3 0.66), and the chloride to TDS ratio is constant (between 0.00 and 0.02), supporting the interpretation that another source, besides a higher concentration of natural solids dissolved in a reduced amount of recharging groundwater, is contributing to the increased TDS concentrations.

Groundwater elevations in TP-1, TP-2, TP-2A between 2006 and 2018 generally increased from 3020 to 3033 feet in all three wells, with subsequent decline of 5 feet between 2018 and 2022. TDS and sulfate concentrations in TP-2A decreased from 714 mg/L (TDS) in January 2006 to 634 mg/L in October 2017 and sulfate reduced from 199 to 146, with associated reductions in the SO4/ TDS ration of 0.28 to 0.23. Declines in TP-1 TDS concentration (692 -582 mg/L) and sulfate concentrations (92.2 to 59 mg/L) were also reflected in declines of the SO4/TDS ratio (0.13 to 0.10). TP-2 increases from 2006 to 2018 in TDS (from 519 to 615 mg/L) sulfate (from 103 to 164 mg/L) showed an increase in the SO4/TDS ratio (0.20 to 0.27).

The progressive increase in groundwater elevations in all four monitoring wells between 2006 and 2018 indicate an increase in groundwater recharge, potentially a result of seepage increases from the TSF, or groundwater flow patterns reestablishing below the TSF from previous blockage due TSF construction and loading. A decrease in recharge during this period is counter indicated by the extended period of groundwater elevation increases in all four monitoring wells.

By 2018 groundwater elevations in TP-1, TP-2 and TP-3 had returned to the elevations measured when they were installed (1991 for TP-1 and TP-2, 1993 for TP-3). Although the return of groundwater elevations to pre-TSF elevations might be expected to signal a resumption of the groundwater recharge conditions prior to

TSF construction, the associated coincident return to pre-TSF groundwater quality conditions were not evident in the groundwater quality monitoring data. In January 2018 TDS and sulfate remained elevated as described previously.

TP-3 water levels varied significantly over the monitored period (1993 – present). Between 1993 and 2003, elevations increased in 1993 from 2940 ft to 2968 ft in 1998, decreased to 2943 ft in 2001 and increased again in 2003 to 2952. Between 2005 and 2018 rose water levels rose from 2050 to 2069 ft, and subsequently dropped to 2062 ft by 2022. TDS and sulfate concentrations measured in TP-3 continued to increase progressively over that period with TDS increasing from 197 to 374 mg/L, and sulfate increasing from 14 to 69.2 mg/L, (SO_4 to TDS ratios increasing from 0.07 to 0.18), seemingly independent of the variations in groundwater elevations.

Hydrogeo (2005) assumed an underdrain capture rate of 80% of the estimated seepage from the primary liner in their simulations of groundwater conditions below the TSF. This leaves 20% of the tailings seepage (about 700 gallons per day), with a sulfate concentration of 3,300 mg/L, to discharge to groundwater. Golder (2016) notes in the AKART assessment that seepage through the TSF is a possible contributor to groundwater quality impacts detected in monitoring wells, and that water level rises in TP-1 and TP-2 may be a result of infiltration past the underdrain collection system. However, Golder also acknowledged the limitations of the existing data in unequivocally defining the factors or processes contributing to the observed groundwater level variations.

AKART sources and mitigation

The AKART measures implemented from the Hydrogeo (2005) report include addition of a biologic denitrification treatment system for TSF infiltrate and lining the Mill Site Drainage Sump. The Hydrogeo (2007) model predicted AKART measures implementation would reduce sulfate and nitrate concentrations in TP-1 and TP-2, with concentrations at TP-3 increasing slightly as ground water infiltrated to the lower semi-confined aquifer. The Hydrogeo simulations come close to predicting current conditions in TP-1; TDS concentrations decreased from a high of 900 mg/L in 2010 to 397 mg/L in 2023. For TP-2, the declining trend in TDS concentrations present from 1991 to 2009 reversed and subsequently increased to 521 mg/L in 2023. TP-3 concentrations gradually increased from 1993 to 2003, from 197 mg/L to 433 mg/L, accompanied by a progressively increasing sulfate concentration, and a relatively constant SO_4/TDS ratio of 0.23 -0.25.

The Golder (2016) AKART assessment of the various components of the Key Mill operations titled: *AKART Evaluation: Key Mill and Tailings Storage Facility* evaluated septic effluent, mill site drainage, sump infiltration, ore stockpile runoff, road runoff, leakage from the TSF as sources potentially degrading groundwater at the site. They observed that the biotreatment system effluent sulfate concentrations were equivalent to those in the influent, indicating that sulfate is not being removed during the treatment process. Echo Bay implemented the Golder recommended AKART actions to reduce potential sources of pollutants as listed below:

Source	Action	Implementation
Mill Site Drainage Sump Infiltration	Relocation of offloading area for discharges of concentrated brine into TDF.	Completed October 2015. Liner installed in 2013.
Ore Stockpile Runoff	Remove berms and base material. Construct lined area for ore stockpiles	Berm removal and temporary liner system completed in 2017. Base material removed and permanent lined system completed in 2018.
Ore Stockpile Runoff	Collect and convey runoff to TDF.	Completed in 2017 with ponded water from stockpile pumped to TSF.
Mill Ball Storage Area Runoff	Remove berms and construction fill.	Completed in 2017 (berms) and 2018 (construction fill).
Mill Ball Storage Area Runoff	Collect and convey runoff to TDF.	Completed in 2018 with area recontoured, graded, and placement of cover material.
TDF Underdrain System	Underdrain treatment system improvements including cleaning of media and nutrient dosing adjustments.	Media cleaned in 2017. Nutrient dosing adjusted in 2018 with ongoing adaptive management.
TDF Underdrain System	Reduce volume of water stored in TDF as a means of preventing future leaks.	Completed in 2018 with spray evaporators installed in the TDF.

Aspect Consulting (2019) evaluated the effectiveness of the AKART measures implemented to address four potential source areas: the Mill Sump, Ore Stockpile Area, Mill Ball Storage Area, and the Biotreatment System. They found that implementation of Golder's recommended AKART actions improved the biotreatment system nitrate removal. Nitrate concentrations have subsequently decreased in groundwater. Sulfate concentrations in TP-1 and TP-3 remain elevated. Improvements implemented to reduce TDS concentrations in wells TP-2 and TP-3 were not evident. They attributed increases in recharge during site construction activities as the cause for reductions in TP-1 TDS content, and that reduced infiltration in the TSF area led to increases in TDS content in TP-2. An addendum to the 2019 report entitled *Evaluation of Hydrogeologic Conditions and Water Quality at Monitoring Well TP-3* Aspect (2021) attributed changes to recharge in the TSF areas resulting from reduced infiltration through the TSF covered area as the cause of increasing TDS concentrations detected in TP-2 and TP-3.

Implementation of the AKART measures is likely to have contributed to improved groundwater quality. The groundwater levels decline from 2018 to 2022 in all wells, suggests that infiltration from the Key Mill facilities (resulting from Mill Sump lining, spray evaporators reducing TSF storage volume, Ore Stockpile lining) may have decreased. TDS concentrations detected in TP-1 and TP-2 stabilized by 2018. Afterwards TDS concentrations at TP-1 show a decreasing trend (statistically significant) through 2022, while TP-2 concentrations showed no statistically significant trend from 2017 through 2022, another potential indication that AKART measures were effective at reducing TDS in groundwater. However, TDS concentrations at well TP-3 have steadily increased over the period of record (1993 to 2022) peaking at 466 mg/L in July 2020.

Conclusions

Groundwater elevation declines following the construction of the Tailings Storage Facility in 1989 were associated with increased TDS and sulfate concentrations in groundwater. Subsequent groundwater elevation increases in all four monitoring wells from 2001 and 2018 suggest that that groundwater recharge increased during that period. However, associated declines in TDS and sulfate concentrations that might be expected from an increase in recharge, if in fact a reduction in recharge was the cause of the increasing TDS and SO_4 groundwater concentrations, were not detected. Instead, constituent concentrations increased in all four monitoring wells coincident with the groundwater level rises. The likely contributor to elevated TDS and sulfate concentrations is the seepage through the TSF liner, simulated by Hydrogeo (2005), and postulated by Golder (2016). This interpretation contrasts with the Aspect's (2019) explanation that increase in constituent concentrations (TDS, alkalinity and sulfate) observed in the Key Mill monitoring wells was caused by decreasing groundwater recharge.

The successful implementation of AKART measures to reduce infiltration from Key Mill facilities following the 2005 Mill Sump lining, and 2016 Golder AKART actions have apparently contributed to declines in the TDS content of the shallow unconfined aquifer. The TSF source reduction due to AKART measures provides additional evidence that elevated constituents in groundwater are deriving from the Key Mill operations. However, continued vertical migration from the shallow unconfined aquifer to the lower semi-confined aquifer is transporting TDS and sulfate to the lower semi-confined aquifer, progressively increasing the concentrations of those constituents in TP-3 and TP-2A.

Groundwater sulfate content consistently increases with TDS concentration increases in all four wells, with higher proportions of sulfate present in higher TDS concentration groundwater. The high sulfate concentration of the tailings impounded in the TSF provide additional evidence that infiltration of TSF liner seepage is the source of elevated TDS in groundwater. The only exception is TP-2; sulfate concentration has steadily decreased since 2018. Since then, the SO_4/TDS ratio in TP-2 declined from 0.26 to 0.08, with TDS concentrations remaining relatively constant. Infiltration through the nearby underdrain infiltration gallery may be diluting the groundwater sulfate concentrations measured in TP-2.

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