KENDRA KAISER, PhD[1]

Expert Witness Report

SEPTEMBER 11, 2023

PREPARED FOR PROTESTANT NEZ PERCE TRIBE

BEFORE THE DEPARTMENT OF WATER RESOURCES OF THE STATE OF IDAHO

In the Matter of Applications for Permit Nos. 77-14377, 77-14378, 77-14379;
Applications for Transfer Nos. 85396, 85397, 85398, 85399;
and Application for Exchange 85538
In the Name of Perpetua Resources Idaho, Inc.

[1] Associate Research Faculty, Boise State University; B.S. Soil & Water Science, Montana State University (2011); Ph.D., Watershed Hydrology & Biogeochemistry, Duke University (2017).

Hydrology Expert Report

Effect of Perpetua Resources' Water Right Applications on Surface Water Quantity and Groundwater Levels in the East Fork South Fork Salmon River Watershed

I. INTRODUCTION

Protestant Nez Perce Tribe requested that I review and evaluate the effect of water right applications submitted by Perpetua Resources Idaho, Inc. ("Perpetua") to the Idaho Department of Water Resources on the flow regime in the headwaters of the East Fork South Fork Salmon River ("EFSFSR"). The purpose of this report is to summarize my analysis of Perpetua's hydrologic modeling and provide my analysis of existing and proposed hydrologic conditions in the EFSFSR headwaters.

In preparing this report, I reviewed Perpetua's applications for permit nos. 77-14377, 77-14378, and 77-14379; applications for transfer nos. 85396, 85397, 85398, and 85399; and application for exchange 85538, along with the following documents Perpetua provided through the administrative protest proceeding in support of their applications: Site-Wide Water Balance Model ("SWWB") Revised Proposed Action ModPRO2 Report (BC, 2021b); Stibnite Hydrologic Site Model ("SHSM") Refined Proposed Action (ModPRO2) Report (BC, 2021a); SGP Water Right Diversion Rate and Storage Volume Technical Memo (BC, 2020); Surface Hydrology Report (Rio ASE, 2019); Stibnite Gold Project Water Quantity Specialist Report (USFS, 2022);[2] Water Application Report (2021); and Site-Wide Water Balance Sensitivity Analysis (Perpetua, 10/1/2021). I also reviewed Perpetua's June 27, 2022, technical memorandum appended to an August 2, 2022, letter from the Idaho Governor's Office of Species Conservation and Idaho Department of Fish and Game to James Cefalo, Regional Manager, Idaho Department of Water Resources; comments from BAS Groundwater Consulting (December 22, 2022; filed as comments by Save the South Fork Salmon River on the Forest Service's Draft Supplemental Environmental Impact Statement for the proposed Stibnite Gold Project; *see* Appendix C); and relevant scientific information, which I have listed in the report's "References" section.

This report provides my analysis of existing and proposed hydrologic conditions in the EFSFSR headwaters under two scenarios: 1) Perpetua's proposed water rights and 2) the withdrawal scenario proposed by Perpetua in its June 27, 2022, technical memorandum referenced above ("Perpetua's Proposed Conditions").

As a result of my review, I have concluded:

- Perpetua's assessment of the effect of their proposed water rights on surface water and groundwater does not sufficiently evaluate or take into account future climate change conditions.

[2] Perpetua disclosed this report to the Tribe during discovery. It can be found at bates stamp no. PRI0012144.

- Perpetua's SWWB Model does not reflect the full potential effects of their water right because they do not model the scenario under which they divert the maximum amount of water sought under their water right applications.
  - If Perpetua's total water rights (10.43 cfs) were used (assuming a 1:1 groundwater to surface water connection, as Perpetua assumes in the June 27, 2022, technical memorandum appended to the August 2, 2022, letter to James Cefalo, Regional Manager, Idaho Department of Water Resources), the EFSFSR would go dry during low flow conditions in the months August through March.
- Perpetua's analysis and figures provided in their SWWB Model Revised Proposed Action ModPRO2 Report (10/2021) obscure the true effect of water diversions on EFSFSR streamflow.
- Perpetua's "no action" SWWB Model output predicts higher low flow statistics than those calculated from historic observations.
- Due to Perpetua's failure to account for climate change there could be less water in the EFSFSR during low flows and less groundwater than Perpetua has predicted, and they could have underpredicted the amount of time it will take for groundwater levels to rise.
- Perpetua's Proposed Conditions would result in the EFSFSR dropping below 7 cfs from August through March each year, based on historical data. This conclusion does not take into account changing conditions due to climate change effects.
- Perpetua's Proposed Conditions place the proposed point of quantification for the water right condition below the confluence of Sugar Creek. This location makes it difficult to accurately determine the effect of Perpetua's proposed water rights on flows in the EFSFSR.
- In order to accurately and reliably monitor flows in the EFSFSR, I recommend that a monitoring location be sited directly below the point of diversion on the EFSFSR (above Perpetua's proposed fish passage tunnel) so that the effect of diversions upstream of this point and at that point on streamflow can be directly quantified. I also recommend that current streamflow monitoring locations should remain in place where possible to maintain a consistent hydrologic record.

II. BACKGROUND

Perpetua's water right applications for permit numbers 77-14377, 77-14378, and 77-14379; applications for transfer nos. 85396, 85397, 85398, and 85399; and application for exchange 85538 are for a total of 10.43 cfs of surface water/groundwater and 0.96 cfs of groundwater. I provide a summary of their water rights in Appendix A. It is important to note that Perpetua's application for permit 77-14378, totaling 9.6 cfs, combines surface and groundwater withdrawals without indicating the source, quantity, or timing of either. Also, two of the application's purposes, dust suppression (0.7 cfs) and excess dewatering water (4.3 cfs) will be affected by changing climatological conditions. Application for permit 77-14378 does not cover the dewatering well networks that will be required for mining the pits, although this dewatering will also affect surface water and groundwater conditions.

Perpetua characterizes the hydrology of the EFSFSR headwaters using summary statistics of flow conditions (Rio ASE, 2019) at multiple U.S. Geological Survey ("USGS") gages (Table 1, Appendix B) and through the use of three water models. The SHSM and associated model output integrate outputs from the Meteoric Water Balance and SWWB Model to forecast dewatering rates, diversions, and hydrologic drawdown in the EFSFSR headwaters. Perpetua's predicted effect on streamflow is variable depending on which USGS gage is referenced in the model output.

The Meadow Creek USGS gage (No. 13310850) is located high in the watershed near the Tailings Storage Facility, the EFSFSR above Meadow USGS gage is located above the confluence with Meadow Creek (No. 13310800) near the proposed employee housing, and the EFSFSR above Sugar USGS gage is located above the confluence of the EFSFSR with Sugar Creek (No. 13311250) and below all of Perpetua's proposed points of diversion. The Johnson Creek USGS gage (no. 13313000) is located on a tributary to the EFSFSR, which joins the EFSFSR near the Village of Yellow Pine, below Perpetua's proposed points of diversion. Perpetua used this gage to extend the period of record at other monitoring stations in the headwaters of the EFSFSR, and I use it below to show climate change impacts on streamflow.

Table 1: USGS gages, site numbers and duration of record

Site Name	Site Number	Start	End
EFSFSR above Meadow	13310800	2011-09-17	2023-07-10
Meadow Creek	13310850	2011-09-16	2023-08-09
EFSFSR at Stibnite	13311000	1986-10-01	active
EFSFSR above Sugar	13311250	2011-09-15	active
Sugar Creek	13311450	2011-09-17	active
Johnson Creek	13313000	1986-10-01	active

III. TECHNICAL ASSESSMENT OF PERPETUA'S MODELS

This section highlights my concerns regarding Perpetua's SWWB Model and SHSM.

A. Perpetua's use of historical data (2004 – 2017), rather than predicted future climatological conditions, in their SHSM limits the statistical validity of the model's predicted streamflows.

Perpetua's SWWB[3] Sensitivity Analysis (Perpetua, 10/1/2021) used two alternative precipitation scenarios that scale total precipitation to 110% and 85% of historical conditions. Perpetua states that these alternative streamflow conditions can be treated as a proxy for streamflow changes due to climate change (BC, 2021b). This is incorrect. Scaling total precipitation to 110% and 85% of historical conditions does not account for the complex ways in which climate change will affect the type and timing of precipitation in Idaho and how those changes will affect flow regimes (Abatzoglou et al., 2021).

The climate change sensitivity analysis Perpetua provided shows the 10th and 90th percentiles for additional freshwater needs under these two scenarios. Perpetua did not provide, however, the summary statistics or data, and the figures are not sufficiently detailed to assess impacts at low flows. Perpetua also did not provide any information to support its conclusion that "...streamflow impacts are similar on the extreme wet and dry ends of the scale" (BC, 2021b, p. 15). Perpetua uses its Meteoric Water Balance[4] to quantify surface water runoff and groundwater recharge for inputs to the SHSM.[5] The Meteoric Water Balance assumes that 50% of April precipitation falls as rain and 50% as snow, 70% of October precipitation falls as rain and 30% as snow, and that all of November through March precipitation falls as snow (BC, 2021a, p. 2-5). This assumption is problematic because these percentages of precipitation phase (rain versus snow) are not projected to remain static; they are projected to change, and there is data that can be used to quantify the actual precipitation phase statistics.

Total annual precipitation is not predicted to change significantly in the Pacific Northwest due to climate change (Figure 1), but the seasonality of this precipitation is expected to change (Klos et al., 2015). We have already seen an increase in maximum daily precipitation in the spring (March – May, 1911 – 2011) in the Pacific Northwest and increased warming has led to declining snowpack as of April 1st of each year (Abatzoglou et al., 2021). For example, the average April 1st snow water equivalent at the SNOTEL[6] site closest to Perpetua's proposed points of diversion (Seesech Summit) has declined from 31.8 inches to 30.4 inches from 1981 through 2010 and 1991 through 2020, respectively (NRCS accessed 09/08/2023). Moreover, research using the

---

[3] SWWB quantifies the consumptive water use needs of the project.

[4] Meteoric Water Balance: Generates monthly meteorological data, groundwater recharge rates and surface water runoff volumes.

[5] SHSM - Simulates groundwater and surface water to forecast dewatering rates, diversions, and hydrologic drawdown.

[6] "SNOTEL is an automated near real-time data collection network that provides mid- to high-elevation hydroclimatic data from mountainous regions of the western United States. A standard SNOTEL station provides snow water equivalent, snow depth, precipitation, and temperature data. The SNOTEL network is maintained by the USDA Natural Resources Conservation Service Snow Survey and Water Supply Forecasting Program." Available at: https://www.drought.gov/data-maps-tools/nrcs-snotel-and-snow-course-data.

observational streamflow record from across the Pacific Northwest shows a reduction in total annual streamflow, particularly in the driest portion of the year (Luce et al., 2009) and decreases in minimum annual streamflow (Kormos et al., 2016). This is in part due to recent warmer and drier summers, which have increased atmospheric water demand over the past five decades (Abatzoglou et al., 2014).

As a result of climate change, snowpacks are projected to decline in the Pacific Northwest, multi-year snow droughts will become more common, snowmelt will occur earlier, and, in conjunction with higher evapotranspiration, late summer streamflow will likely be lower than in the historical record. Air temperatures will increase another 2 to 3˚F by 2050 and between 6 to 11˚F by 2100 (Abatzoglou et al., 2021). This will have a significant impact on streamflow and water temperature in the EFSFSR.

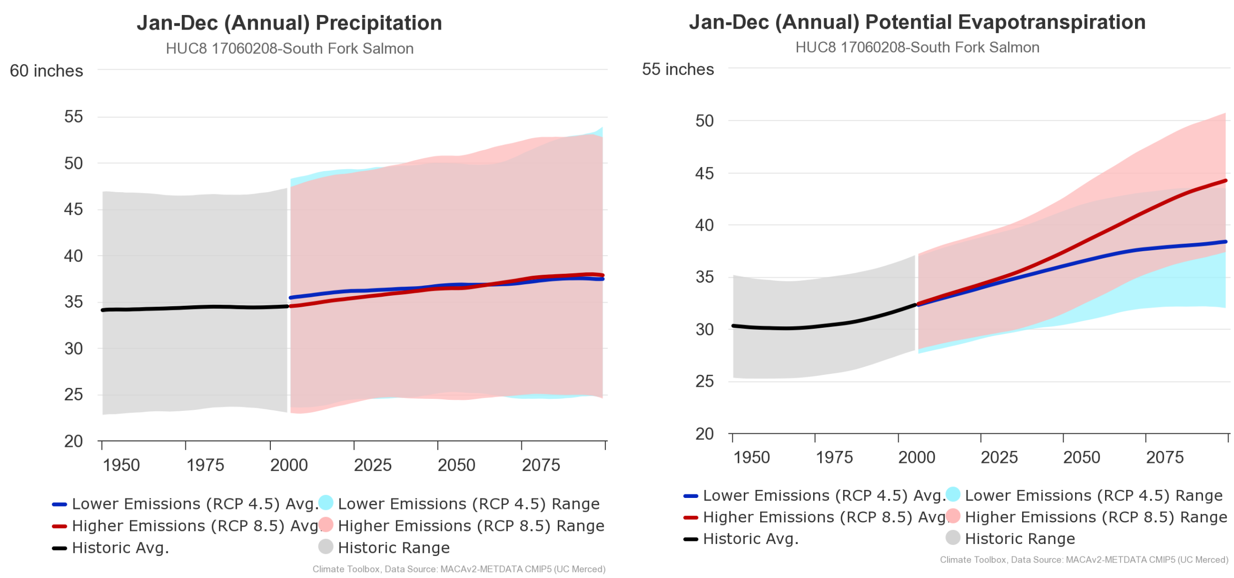


Figure 1: Forecasted future annual precipitation in the South Fork Salmon Basin showing a slight increase and potential evapotranspiration showing an increasing trend (Hegewisch and Abatzoglou, accessed 09/08/2023).

In order to better understand how changing temperatures and precipitation regimes will affect streamflow patterns in the EFSFSR, I downloaded projected streamflow time series data for the Johnson Creek USGS gage. This time data series was generated from 10 global climate change models using the MACA downscaling methodology and VIC-P3 hydrologic model for the representative concentration pathway 4.5 (lower intermediate scenario) and 8.5 (highest emission scenario). Figure 2 below shows distributions of daily streamflow under historical conditions (1950 – 2023), under forecasted conditions for the next 20 years (2024 – 2044), and for forecasted conditions through the end of the century (2045 – 2100). The key takeaway of Figure 2 is that low streamflows, those below 10 cfs in particular, become more common in the next twenty years (as seen by the green line on the graphs).

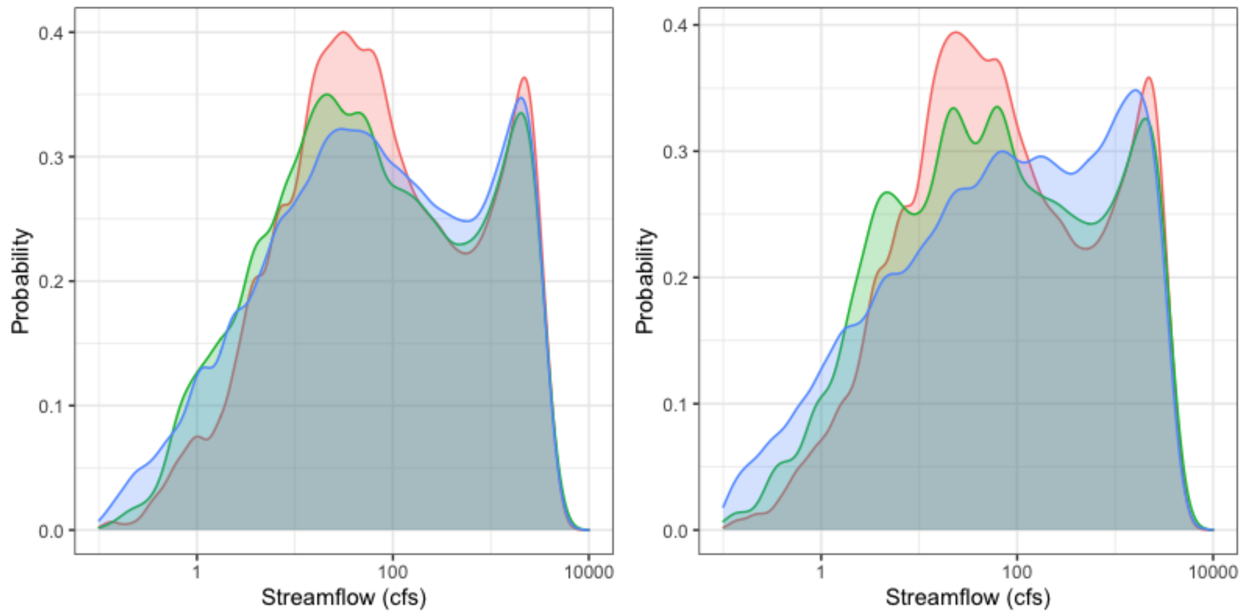


Figure 2: Distributions showing the probability of daily streamflow at Johnson Creek under historic conditions, future conditions from 2024-2044, and future conditions from 2045-2100 **left:** RCP 4.5, **right:** RCP 8.5.

Perpetua's decision to scale total precipitation to 110% and 85% of historical conditions is not sufficient to account for changes in temperature or type and seasonality of precipitation in the future. Future climate projections (including evapotranspiration, temperature, precipitation, and streamflow) are available from the 4 km resolution MACA models (Abatzoglou & Brown 2012). Perpetua should have used forecasted precipitation and temperature from the MACA models as input data to the Meteoric Water Balance, which, in turn, is input data to their SWWB Model and the SHSM. MACA provides downscaled products for 20 global climate change models. Using each of these datasets would allow Perpetua to develop robust uncertainty bounds around potential impacts to stream flow, groundwater levels, and evaporative demand. Perpetua could also use this dataset to determine the proportion of water precipitation that falls as rain or snow for each month.

B. Various structural components of Perpetua's MODPRO2 groundwater model should be improved and should include additional sensitivity and uncertainty[7] analysis to fully assess the effect of their proposed water rights on streamflow and groundwater levels.

My ability to quantify effects from Perpetua's water right applications on streamflow and groundwater levels is limited by components of their SHSM Refined Proposed Action (ModPRO2) Report (BC, 2021a) and the associated MODFLOW 6 groundwater model. Comments from BAS Groundwater Consulting do an excellent job of outlining the multiple structural components of Perpetua's groundwater model and its associated sensitivity or uncertainty analysis that should be

[7] Sensitivity analysis examines how model results change when model parameters change (e.g., testing a value between 0.01 and 10); uncertainty analysis is a way to quantify the degree of confidence in the input data, assumptions, parameters, or model output.

improved. I summarize BAS Groundwater Consulting's conclusions below and appended their comments here as Appendix C.

- The model domain is not large enough to capture the impact of mine dewatering, as the drawdown contours provided in MODPRO2 intersect the model boundary (Figures 4-4 and 4-5; BC, 2021a). The contours showing the impact of groundwater withdraws continue beyond the model boundary, meaning the model cannot capture the full impacts of dewatering as those impacts are cut off at the model boundary.

- The model layers may also be too thick to capture vertical hydraulic gradients that are important for quantifying surface water-groundwater connectivity or vertical movement of groundwater near open pits. The structure and characteristics of these layers may result in subsurface routing that is not representative of the actual groundwater flow paths.

- Perpetua uses the MODFLOW's Streamflow routing package to simulate streamflows, but they use a constant streamflow depth of 2 feet (BC, 2021a). The model will hold this depth constant, so if there is more than 2 feet of water in the stream (e.g., during the snowmelt period), the model will force water to exchange with the subsurface at a higher rate than would be expected if the depth of water in the stream was greater. Perpetua should conduct a sensitivity analysis to test the impact of the assumption of constant streamflow depth on the modeling results.

- Perpetua failed to represent various structural features (e.g., faults and fractures) in the model domain, with associated sensitivity testing (Appendix C). For example, the model showed that the Meadow Creek Fault Zone did not impact pit dewatering, but Perpetua did not conduct an uncertainty analysis showing how the Meadow Creek Fault Zone might affect the timing and location of groundwater discharge to the river post-mining. Perpetua did not include other features in their modeling effort (e.g., West End Fault Zone and blast zone), and the model output shows Midnight Basin's hydraulic conductivity[8] to be lower than observed (Table 3-2, BC 2021a). Additional sensitivity and uncertainty analysis would need to be done to understand how these parameters would affect pit dewatering estimates and associated groundwater fluxes and flow paths.

- The SHSM Refined Proposed Action (ModPRO2) Report (BC, 2021a) shows that water levels near the Yellow Pine Pit are underestimated in the model (by an unknown amount, as it is not quantified in Figure 4-15 of the model report) and that the model does not represent the seasonal variability in the bedrock monitoring wells. The latter may suggest that the modeled storage is too high, or modeled hydraulic conductivity is too low, meaning that the model does not represent the strength of the connection between shallow groundwater and the stream. This has implications for understanding how groundwater pumping affects streamflow and the rate of recovery of the groundwater table after mining.

[8] Hydraulic conductivity characterizes how easily fluid moves through porous material or fractured rock. When hydraulic conductivity is high, fluid can move through the material faster than lower hydraulic conductivity.

- Lastly, Perpetua does not provide calibrated water budget values to assess how well the model represents the conceptual water budget, which is a basic standard of groundwater modeling (American Society for Testing and Materials (ASTM) D5490; *See* Appendix C).

In summary, in order to adequately assess the effect of Perpetua's proposed water rights on streamflow and groundwater, various components of their groundwater model and model output (BC, 2021a) need clarification and testing through additional uncertainty and sensitivity analysis. Perpetua's model domain is too close to areas of impact, model layers may be insufficient to capture accurate hydraulic gradients, and the calibration should be either improved or show sensitivity analysis for hydraulic conductivities. Additional summary information, such as the calibrated water balance components, should be added to validate that the model accurately represents the system.

C. Perpetua's SHSM "No Action" scenario predicts higher low flows than currently observed at multiple locations.

Perpetua's SHSM predicts higher low flows than in the historical observational record (*See* Figure 3 below).

Perpetua provides simulated[9] streamflow data using the SHSM in Appendix A of their SHSM Refined Proposed Action (ModPRO2) Report (BC, 2021a). The Model Calibration section says that the model "sufficiently reproduces the timing and magnitude of the measured hydrographs at all gage locations" (p. 4-9) referring to figures that show measured versus simulated flow from 2012 to 2020 (Figures 4-4 through 4-8). Model evaluation criteria provide an objective mechanism to determine if the model represents the system well, but there are many alternative options for model assessment criteria, which are often selected based on the objectives of the modeling effort (e.g., Pfannerstill et al., 2014 compare 15 alternative criteria). The model evaluation criteria Perpetua uses, the Root Mean Square Error ("RMSE"), is known to overemphasize how well models predict flood peaks, which masks poor model performance in low streamflow periods. Because application of a single performance criteria is insufficient to capture all relevant hydrologic processes, the scientific community has created many alternatives to improve model calibration for higher certainty in modeled low streamflow periods (Pfannerstill et al., 2014, Pushpalatha et al., 2012). The summary statistics and figures in the SHSM Refined Proposed Action (ModPRO2) Report (BC, 2021a) do not provide complete information on model performance at low flows. For example, calibration statistics (which characterize how well model predictions compare to observations) are only provided for the base flow period (November – February); this misses a critical time of year (August – September) when streamflows are low and evapotranspiration is high.

To quantify how well the SHSM performs at low flows, I calculated the monthly 95% exceedance flow using Perpetua's simulated streamflow data under their "No Action" scenario (Table B-8: Meadow Creek 13310850 and B-11: EFSF above Sugar Creek 13311250, BC, 2021a) and compared it to the observed USGS record for those sites (See Figure 3 and Table 2 below). This comparison shows that Perpetua predicts low streamflows to be up to 305% higher than they actually are. This corresponds with Table 4-6 of the SHSM (Baseflow Calibration Statistics at the

[9] Simulated is used interchangeably with "modeled."

USGS gages from November - February) where the Minimum Residual (difference between simulated and observed) for the EFSFSR above Sugar Creek can be up to -4.96 cfs in December, at which time the 95% exceedance at that site is 9.04 cfs. This means that Perpetua's model could simulate the flow to be 13 cfs, or 133% of the actual flow. Although the calibration statistics Perpetua provided (RMSE) suggest that the model performs well, the magnitude of difference at low flows suggests otherwise. This, in conjunction with other results that are sufficiently vague (e.g., simulated basin yield does not capture the important seasonal variability in streamflows) prevent me from assessing actual effects on surface water and groundwater.

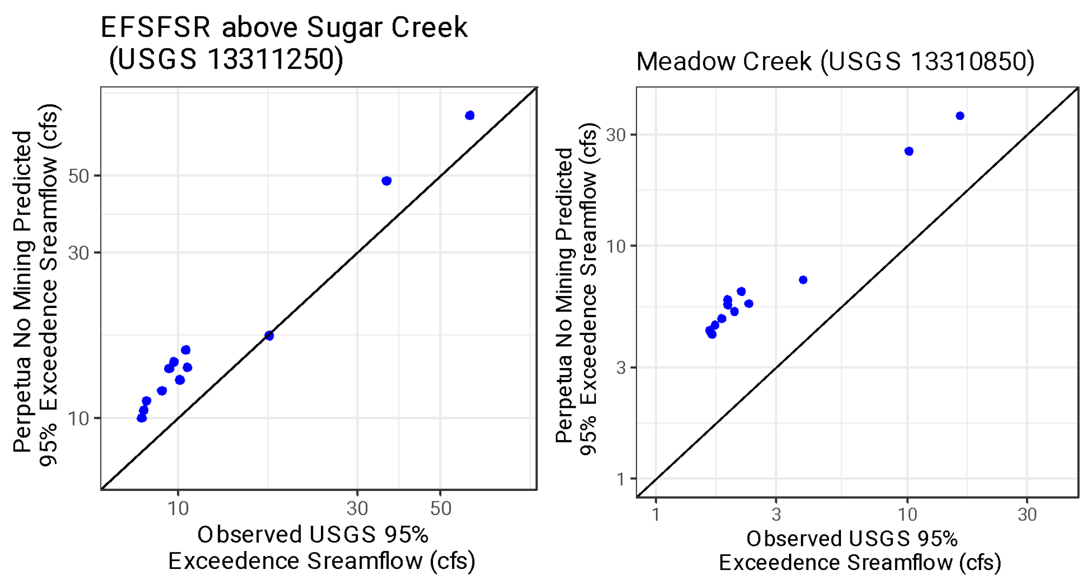


Figure 3: Observed versus predicted low flows (95% exceedance) at the EFSFSR gage above Sugar Creek and at Meadow Creek. The black line is a 1:1 line; if the model matched observations perfectly all points would fall on the line. Low flows predicted by Perpetua's No Action model are consistently higher than the observed low flows at the USGS gages. Axes are logged to show both low and high flows in one figure.

Table 2: Percent difference in low flows between Perpetua's No Action Model and observed data at USGS gages. Greater than 100% denotes months where the model predicts higher flows than the observed data at USGS gages and less than 100% denotes months where the model predicts lower flows than the observed data at USGS gages.

Month	EFSFSR above Sugar (USGS 13311250)	Meadow Creek (USGS 13310850)	Sugar Creek (USGS 13311450)
January	136%	266%	138%
February	130%	265%	137%
March	125%	249%	125%
April	132%	240%	104%
May	125%	223%	124%
June	134%	250%	89%
July	99%	185%	99%

August	150%	291%	124%
September	149%	305%	139%
October	147%	288%	130%
November	127%	255%	128%
December	132%	267%	140%

IV. PROJECTED EFFECTS OF PERPETUA'S PROPOSED WATER RIGHTS AND CONDITIONS ON EFSFSR STREAMFLOW & GROUNDWATER

The following sections provide: A) Analysis of Perpetua's modeled streamflow statistics to quantify impacts at low flows using data they provided in Appendix B of the SHSM Refined Proposed Action (ModPRO2) Report (BC, 2021a), and B) a summary of the effects Perpetua's water rights will have on groundwater based on the SHSM Refined Proposed Action (ModPRO2) Report (BC, 2021a), and the Stibnite Gold Project Water Quantity Specialist Report (USFS, 2022).

A. Analysis of Perpetua's modeled streamflow statistics and potential effects of proposed water withdrawals on surface water.

The hydrologic regime in the EFSFSR is characterized by an accumulation of snow during winter months, which melts and results in peak streamflow from May to June, and declines through October, in conjunction with high evapotranspiration from the terrestrial landscape (Figure 4). Flows decline further during winter months and streams often freeze due to low temperatures. Streamflows can vary by two orders of magnitude, which requires additional figures and analysis to understand the variability during low streamflow conditions.

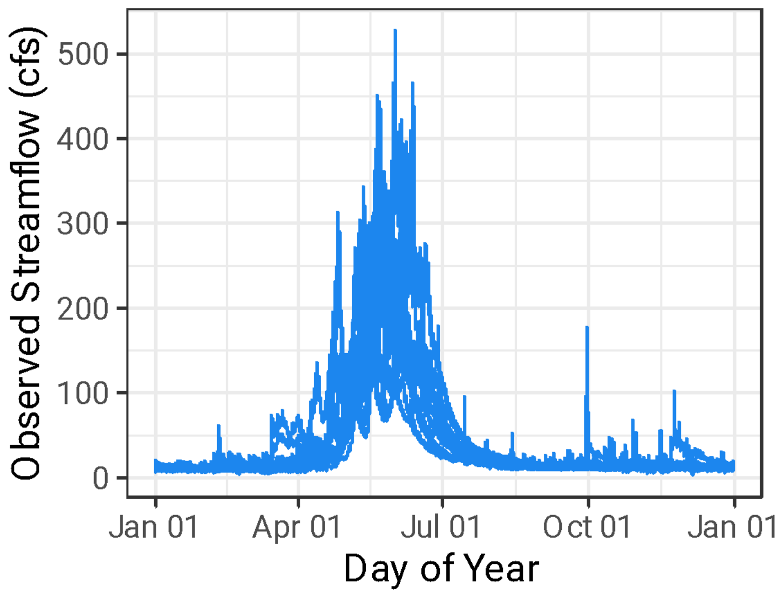


Figure 4: Annual hydrographs for the EFSFSR above Sugar Creek

Perpetua uses the SHSM to show the effects of water diversions under its proposed water rights and its mining operations on both surface and groundwater flows. Perpetua, however, omits important information necessary to accurately quantify these effects, particularly at low streamflows. First, Perpetua does not model the effect that withdrawing their full water right of 10.43 cfs would have on surface flows. Perpetua acknowledges that "[t]he maximum value for these diversion rates are not currently modeled to coincide [and] timing of peak demand by source may change based on annual weather patterns and mine sequencing" (Letter to Keen, 2021, BC, 2020).

Application for permit number 77-14378 is for 9.6 cfs (with no delineation for maximum surface water diversion from the EFSFSR). Application for transfer number 85396 (from water right 77-7122) is 0.33 cfs, and application for transfer number 85398 (from water right 77-7293) and application for exchange number 85538 are 0.25 cfs each. These applications total 10.43 cfs. Although portions of the 9.6 cfs water right may also be withdrawn from groundwater wells, Perpetua assumes in their June 27, 2023, technical memo (appended to the August 2, 2022, letter to James Cefalo, Regional Manager, Idaho Department of Water Resources) that those withdrawals will have a 1:1 impact on surface water flows.

Perpetua characterizes their water diversions in many ways throughout various documents. For example, Table 1 in their June 27, 2023, technical memo shows the peak rate of diversion to be 9.6 cfs and the average to be 3.0 cfs. In contrast, the Figure 6-20 of the SWWB Model Revised Report (BC, 2021b) shows up to 4.46 cfs in mine year 1. Given that Perpetua never modeled the effect that withdrawing their full water right of 10.43 cfs and Perpetua's various representations of how much water they will withdraw for their mine, I considered the instantaneous use of the total water right of 10.43 cfs at any point in the year (Table 3).

I used data obtained from the USGS gage on the EFSFSR above its confluence with Sugar Creek (13311250), as this is the most downstream gage on the EFSFSR and thus the best USGS gage for accurately assessing the effect of Perpetua's proposed water withdrawals. In Perpetua's June 27, 2023, Proposed Conditions letter, Perpetua states that placing the point of quantification below the confluence of Sugar Creek and the EFSFSR "provides a meaningful metric for the Project" without further explanation. This location makes calculating the impact on the EFSFSR alone more difficult. The addition of Sugar Creek streamflows at the point of quantification obscures the impact of Perpetua's water use on the EFSFSR. In the Boise River Basin, the Water District 63 watermaster recently installed real-time monitoring equipment on all PODs from the Boise River to more accurately capture diversion rates.

Next, I used the observed 12-year USGS record (2011 - 2023) to quantify low streamflow statistics. The low flow analysis that Perpetua uses to summarize historic conditions in the Project Area Hydrology report (Rio ASE, 2019) uses two methods to extend the hydrologic record: 1) the MOVE.3 methodology to extend the record to 86 years (1929 – 2017) for the 10-year recurrence low flows; and 2) a ratio method to extend the average daily discharge for 24 years (1993 - 2017). Creating a longer time series is statistically useful to quantify the likelihood of streamflow conditions. Based on the analysis[10] provided in Rio ASE, 2019, the summary statistics from the shorter USGS record are well aligned with the extended historic records analyzed. Regardless, the analysis in the Rio ASE, 2019 report, shows a 10% likelihood 7-day duration low flow of 5.9 cfs at the EFSFSR above Sugar Creek (Table 5-1, Rio ASE, 2019), and the 95% exceedance flow is 5 to 8 cfs during the flow periods for various fish species (Table 6-2), both of which are much lower than Perpetua's "No Action" SHSM output.

Following my approach outlined above, I summarize low flow statistics from Perpetua's SHSM output (both mining and no action) and historic observations at the EFSFSR gage above the confluence with Sugar Creek in Table 3 below. I calculated 95% exceedance values from the historic observational data and compared it to the "No Action" SHSM output to quantify the differences between the modeled and observed low flow conditions in the EFSFSR. I also quantified the same low flow statistics for the Mining SHSM output, and the impacts of using the full water right and the conditioned water right on the EFSFSR using the observed low flow statistics.

[10] Table 6-2 of the RioASE report shows that the relative error of estimating these daily low flows using the ratio methodology is either zero or predicts the low flows to be lower than observed.

Table 3: Summary of low flow statistics at the EFSFSR gage from Perpetua's SHSM output, low flow statistics from historic USGS data, calculated use of full water right (10.43 cfs) with and without the OSC condition, and historic monthly minimum for comparison.

East Fork South Fork Salmon River above Sugar Creek (USGS 13311250)						
	Monthly 95% Exceedance Flows (cfs)					Historic Minimum (2011-2023)
Month	Mining SHSM	No Action SHSM	Historic Observations (2011-2023)	Full Water Right	Full Water Right with Condition	
January	8.7	11.2	8.2	0	5.5	7.5
February	8.4	10.5	8.1	0	5.5	6.9
March	9.3	10	8	0	5.4	6.9
April	13.4	14	10.6	0.1	6.7	8.5
May	72.3	74.7	59.9	49.4	49.4	22.9
June	43	48.3	35.9	25.5	25.5	26
July	13.6	17.3	17.5	7.1	7.1	13.3
August	12	15.7	10.5	0	6.6	9.9
September	11.7	14.5	9.7	0	6.4	9.4
October	10.8	13.9	9.5	0	6.2	9
November	10.4	12.9	10.1	0	6.8	8.2
December	9.3	12	9	0	6.1	7

1. **The streamflow regime will be disproportionately impacted during low flow periods, even when applying Perpetua's Proposed Conditions.**

Table 3 above shows that if total water right is used, the stream will go dry during low flow conditions (August – March). If the water right is conditioned in accordance with Perpetua's June 27, 2023, Proposed Conditions[11] (once flows drop below 25 cfs, leave 80% of streamflow remaining below confluence of EFSFSR and Sugar Creek), the EFSFSR at Stibnite would drop below 7 cfs once flows below the confluence of the EFSFSR and Sugar Creek drop below 17 cfs. Without minimum streamflow protections beyond those in the Perpetua's Proposed Conditions,

[11] Perpetua's Proposed Conditions calculate "20% unimpaired streamflow" based on the sum of two streams, which is then subtracted from the EFSFSR alone because that is the location of the Points of Diversion. This obscures impacts on the EFSFSR alone.

the affected stream reaches will drop below 7 cfs from August to March, before considering climate change effects.

B. Summary of the predicted effects Perpetua's water rights will have on groundwater levels using Perpetua's SHSM, the Payette National Forest's Water Quantity Specialist Report, and the comments found in Appendix C.

Groundwater levels will remain impacted permanently from Perpetua's proposed water withdrawals, but I cannot assess the magnitude of the impact given the modeling limitations provided above in Section II.B and without more information related to how much water Perpetua intends to pull under their proposed water rights from specific shallow and deep wells and. Groundwater recharge will change over time due to the mine features, which adds additional variability through time. As a result, I summarize below the effects that Perpetua predicts its water right applications will have on groundwater levels in its SHSM, and the effects the Forest Service predicts in its Water Quantity Specialist Report for the Draft Supplemental Environmental Impact Statement for the proposed Stibnite Gold Project.

According to the Forest Service's Supplemental Draft Environmental Impact Statement[12] for the proposed Stibnite Gold Project, the fully lined tailings storage facility ("tailings storage facility ("TSF")") and TSF Buttress and lined Yellow Pine pit and Hanger Flats pit backfills "would alter local groundwater recharge and flow permanently" in the 430 acres they cover because the liners would decrease groundwater recharge and result in increased surface water runoff while likely lowering local groundwater levels (USFS, 2022). Modeling shows that the regional groundwater levels are likely to rebound once groundwater pumping stops, but the rate of this rebound is uncertain given the lack of sensitivity analysis on Perpetua's modeled hydraulic conductivities. The simulated groundwater drawdown for the Yellow Pine Pit is the deepest at the end of mine Year 5 (550 ft, Figure 4-4, Brown & Caldwell, SHSM) and recovers by Mine Year 12. The West End Pit has a maximum groundwater dewatering during Mine Year 12 (400 ft) and is not anticipated to recover until 50 years afterward. At the end of mine year 112, a drawdown of 200 ft remains between the West End and Yellow Pine pits. The modeled groundwater elevations shown in the SHSM Refined Proposed Action (ModPRO2) Report (08/2021) provide the difference between the no action and proposed action model scenarios. The average model calibration error is 9 feet (BC, 2021a), making the minimum drawdown contour of 10 feet particularly uncertain. This means that if the model predicted a 9 feet drawdown it may be up to 18 feet, which is not shown in the model output.

Lowering groundwater levels during operations and post-closure will decrease instream flows. The specific impact on streamflows beyond the mining period is challenging to quantify, however, given the above-mentioned limitations in Perpetua's SHSM and lack of uncertainty analysis. There are also 93 seep and spring locations in the project area that could be affected by lower groundwater levels. The effect on seeps and spring is unknown, however, because it is unclear from which part of the aquifer the seeps and springs and associated wetlands are receiving water (USFS, 2022).

[12] Available at: https://usfs-public.app.box.com/v/PinyonPublic/file/1052214209080.

VI. CONCLUSIONS

- Perpetua's SWWB Model does not reflect the full potential effect of their proposed water rights on surface water because they never model the scenario under which they divert the maximum amount of water sought under their water right applications. This means that instantaneous streamflows in the EFSFSR could be lower than shown in any of the figures provided in their reports and could potentially be zero cfs, even without consideration of climate change effects.

    - If Perpetua's total water rights (10.43 cfs) were used (assuming a 1:1 groundwater to surface water connection, as Perpetua assumes in the June 27, 2022, technical memorandum appended to the August 2, 2022, letter to James Cefalo, Regional Manager, Idaho Department of Water Resources), the EFSFSR would go dry during low flow conditions in the months August through March.

- Perpetua's analysis and figures provided in their SHSM and SWWB Revised Proposed Action ModPRO2 Report (BC, 2021b) obscure the potential impacts of water diversions on the EFSFSR.

    - Model calibration statistics are only provided for November through February, and the corresponding figures do not allow for evaluation of impacts at low flows. Given the complex nature of the proposed actions, this makes evaluating long term impacts on surface water and groundwater challenging. Clear and detailed figures and summary statistics that focus on low-flow periods of time in particular are necessary.

- Perpetua's "no action" SHSM output does not produce summary statistics similar to historic conditions during low flows. Rather, it predicts low flows will be higher than flows actually observed at USGS gages.

    - This suggests that the model does not accurately capture low flows, which means the effect of using their full water right on the EFSFSR could be larger than predicted.

- Due to Perpetua's failure to account for climate change there could be less water in the EFSFSR during low flows and less groundwater than Perpetua has predicted, and they could have underpredicted the amount of time it will take for groundwater levels to rise.

    - Perpetua's SWWB Model does not incorporate forecasted input variables (e.g., precipitation and temperature) using anticipated climate change scenarios to predict surface and groundwater flows in the headwaters of the EFSFSR. Instead, they scale total precipitation in their SWWB Model Sensitivity Analyses. This approach fails to capture how a changing climate will affect the seasonality of precipitation and total evapotranspiration. Changes in temperature and precipitation patterns are predicted to result in lower late summer streamflows. This is not captured in the SWWB Model or the SHSM.

- If Perpetua's Proposed Conditions were implemented (i.e., leave 80% of streamflow remaining below confluence of EFSFSR and Sugar Creek, once flows drop below 25 cfs), the EFSFSR at Stibnite would drop below 7 cfs from August through April (once flows below the confluence of the EFSFSR and Sugar Creek drop below 17 cfs).

- Perpetua's Proposed Conditions place the proposed point of quantification for the water right condition below the confluence of Sugar Creek. This location makes it difficult to accurately determine the effect of Perpetua's proposed water rights on flows in the EFSFSR.

- In order to accurately and reliably monitor flows in the EFSFSR, I recommend that a monitoring location be sited directly below the point of diversion on the EFSFSR (above Perpetua's proposed fish passage tunnel) so that the effect of diversions upstream of this point and at that point on streamflow can be directly quantified. I also recommend that current streamflow monitoring locations should remain in place where possible to maintain a consistent hydrologic record.

VIII. REFERENCES:

Abatzoglou J.T. and Brown T.J. 2012. A comparison of statistical downscaling methods suited for wildfire applications. *International Journal of Climatology*, 32, 772-780. https://rmets.onlinelibrary.wiley.com/doi/full/10.1002/joc.2312.

Abatzoglou, J. T., Rupp, D. E., Mote, P. W. 2014. Seasonal Climate Variability and Change in the Pacific Northwest of the United States. *Journal of Climate*, 27(5): 2125-2142. https//doi.org/10.1175/JCLI-D-13-00218.1.

Abatzoglou, J. T., Marshall, A. M., Harley, G. L. 2021. Observed and Projected Changes in Idaho's Climate. *Idaho Climate-Economy Impacts Assessment*. James A. & Louise McClure Center for Public Policy Research, University of Idaho. Boise, ID.

Brown and Caldwell, 2020. Technical Memorandum, "SGP water Right Diversion Rate and Storage Volume."

Brown and Caldwell (2021a). August 2021. Stibnite Hydrologic Site Model Refined Proposed Action (ModPRO2) Report.

Brown and Caldwell (2021b). October 2021. Final Stibnite Gold Project Site-Wide Water Balance Model Refined Proposed Action (ModPRO2) Report.

Climate Toolbox (accessed Sept. 8, 2023). https://climatetoolbox.org/tool/future-time-series.

Chegwidden, O.S., B. Nijssen, D.E. Rupp, P. W. Mote. 2017. Hydrologic Response of the Columbia River System to Climate Change [Data set]. Zenodo. http://doi.org/10.5281/zenodo.854763.

Hegewisch, K.C., Abatzoglou, J.T. Future Time Series' web tool. Climate Toolbox (accessed on Sept. 9, 2023). https://climatetoolbox.org/.

Klos, P. Z., and Coauthors, 2015. Indicators of Climate Change in Idaho: An Assessment Framework for Coupling Biophysical Change and Social Perception. *Wea. Climate Soc.*, **7**, 238–254, https://doi.org/10.1175/WCAS-D-13-00070.1.

Kormos, P. R., Luce, C. H., Wenger, S. W., Berghuijs, W. R. 2016. Trends and Sensitivities of Low Streamflow Extremes to Discharge Timing and Magnitude in Pacific Northwest Mountain Streams. *Water Resources Research*.

Luce, C. H. and Z. A. Holden. 2009. Declining Annual Streamflow Distributions in the Pacific Northwest United States, 1948-2006. *Geophysical Research Letters*. NRCS, https://wcc.sc.egov.usda.gov/nwcc/site?sitenum=740.

RioASE. 2019. Surface Water Hydrology Report. Midas Gold Idaho, Inc., Appendix C: Project Area Hydrology.

Letter to Shelley Keen, Water Allocation Bureau, IDWR (Oct. 15, 2021), Subject Additional Information for Application for Permit by Perpetua Resources Idaho, Inc. (bates number PRI0004873).

Office of Species Conservation (OSC) letter to Officer Cefalo. (Sept. 2022) Technical Assistance Request for Stibnite Gold Project Water Right Application from Mike Edmonson (OSC) and Amber Christofferson (IDFG) with attached Request for Technical Assistance Review from Perpetua Resources (Jul. 27, 2023).

Perpetua Resources, Site-Wide Water Balance Sensitivity Analyses (10/1/2021).

Pfannerstill M, Guse B, Fohrer N. 2014. Smart low flow signature metrics for an improved overall performance evaluation of hydrological models. *Journal of Hydrology*, 510:447–458. https://doi.org/10.1016/j.jhydrol.2013.12.044.

Pushpalatha R, Perrin C, Moine NL, Andréassian V. 2012. A review of efficiency criteria suitable for evaluating low-flow simulations. *Journal of Hydrology*, 420–421:171–182. https://doi.org/10.1016/j.jhydrol.2011.11.055.

USFS. 2022. Stibnite Gold Project. Water Quantity Specialist Report. Prepared by: USDA Forest Service, Payette National Forest. Aug. 2022.

Appendix A

Summary of Water Rights

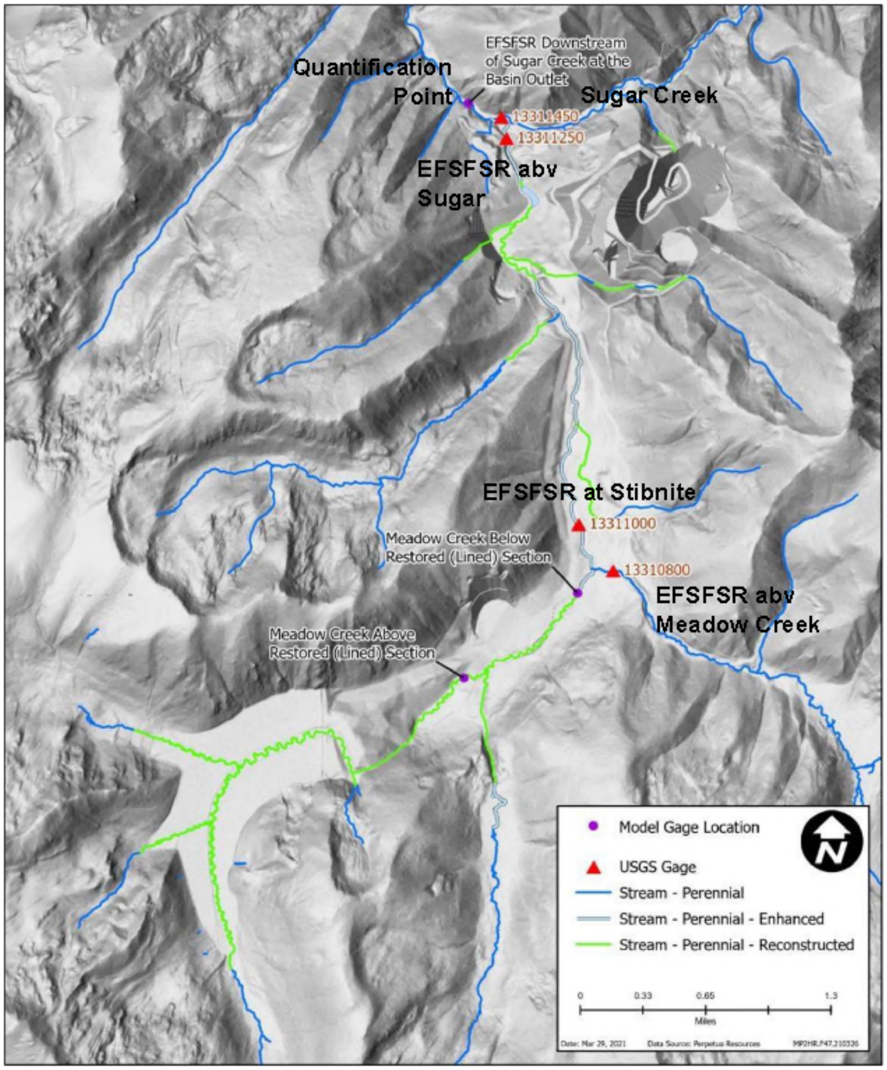
Water Right	Rate	Volume	Purpose	POD Details
77-14377	0.2 cfs		Domestic (employee housing)	4 wells at 500 feet, 8" diameter
77-14378	9.6 cfs	600 AF	industrial and diversion to storage, for improvement storage and industrial from storage	50 wells, 10 stormwater runoff ponds, underdrain from tailings storage facility, underdrain from buttress, and surface water from EFSFS; proposed at 1,000 ft with diameter of 6,8,10,12 inch; well drilled in 1988 and 2011; up to 210 ac-ft of detained contact water (no water right)
77-14379	0.06 cfs		domestic (Truck Shop)	# wells; 72 feet, 14" diameter, 2012, EFSF abv meadow ~ 500 ft from stream
Transfer 85396: wr 77-7122	0.33 cfs	7.1 AF	diversion to storage, mining and mining from storage	Surface water EFSFS
Transfer 85397: wr 77-7285	0.5 cfs	30.2 AF	mining, diversion to storage, mining storage and mining from storage	13 wells (Between TSF and Hangar Flats)
Transfer 85398: wr 77-7293	0.25 cfs	20 AF		Surface water EFSFS
Transfer 85399: wr 77-7141	0.20 cfs	11.4 AF	domestic	4 wells (PODs shown are the exact same as in 77-14377 for employee housing)
Exchange 85538	0.25 cfs	20 AF		Surface water from Hennessey Creek into EFSFSR above Yellow Pine Pit; water will be diverted only at times when an equal

				amount of water is available at the original point of diversion
Total Surface Water	10.43 cfs	677.3 AF		
Ground-water only	0.96 cfs	41.6 AF		

* 0.5 cfs was determined as the amount that could be drawn from the well network in Meadow Creek Valley without adverse effects on Meadow Creek from the groundwater flow model (BC 2021b; SWWB Model report p. 6-21)

* The surface water diversion need is shown as up to 2000 gpm (4.45 cfs) in Mine Year 1 (Figure 6-20, SWWB Model report, p 6-23), 1500 gpm in Mine Year 2 and 11 (3.3 cfs).

Appendix B


EFSFSR Downstream of Sugar Creek at the Basin Outlet
Quantification Point
Sugar Creek
13311450
13311250
EFSFSR abv Sugar
EFSFSR at Stibnite
13311000
Meadow Creek Below Restored (Lined) Section
13310800
EFSFSR abv Meadow Creek
Meadow Creek Above Restored (Lined) Section
Model Gage Location
USGS Gage
Stream - Perennial
Stream - Perennial - Enhanced
Stream - Perennial - Reconstructed
0
0.33
0.65
1.3
Miles

Appendix C

DATE December 22, 2022

TO Save the South Fork Salmon

FROM Betsy Semmens, RG **EMAIL betsy@basgc.com**

EXECUTIVE SUMMARY

The modeling effort undertaken to estimate the impacts of proposed mining on the groundwater and surface water system near Stibnite, Idaho has been improved for the MODPRO2 evaluation compared to the MODPRO evaluation in 2019 and 2020. The sensitivity and uncertainty testing appear to have been expanded with the modeling done for the MODPRO2 and better support was provided in the modeling report for the model input parameters chosen for the MODPRO2 model.

There remain unaddressed comments from the MODPRO modeling that apply to the MODPRO2 modeling, as well as new comments on the MODPRO2 groundwater modeling effort. The MODPRO2 model needs additional clarification, testing, and potential improvement before predictions of groundwater and streamflow impacts can be made and conclusions can be formed. These concerns include spatial calibration bias, a model domain that is too close to areas of impacts, model layering that may be inadequate to estimate vertical hydraulic gradients, model layer geometry that may adversely affect model results, and a lack of testing major geologic structures in the area, to name a few. These concerns should be addressed and potentially corrected to improve upon the model's ability to predict impacts.

One of the largest concerns of the MODPRO2 modeling is the lack of correlation of what the model results mean in terms of potential impacts to sensitive ecosystems. The modeling results are presented in terms of a) drawdown of the water table during and after mining at discrete times, b) modeled predictions of the recovery of streamflow after mining, and c) percentage of abundance of particles (flow paths) from the three pits (two backfilled and one pit lake) that will report to various stretches of different streams, creeks, and rivers. Furthermore, drawdown impacts are only shown for a minimum evaluation of the 10-foot drawdown contour, and sensitive ecosystems may be impacted at levels below this threshold. The model predicted impacts should be equated to volumes of impacted groundwater and rates of impacted groundwater movement to sensitive downstream ecosystems, rather than only in the context of groundwater and surface water drawdown and recovery.

The general impact of modifying the model to address the comments in this letter could potentially change model predictions such as:

- groundwater flow directions and interaction with surface water during and after mining,
- estimated depth to groundwater and impacts of groundwater mounding beneath or within facilities and generated geochemistry, and
- estimates of groundwater discharge to the open pits which could, in turn, influence estimates of ultimate pit lake level, the amount of and impacts from groundwater pumping for makeup water, and the geochemistry of seepage during and after mining.

TECHNICAL REVIEW OF MODPRO2 MODFLOW 6 MODEL

I am a hydrogeologist with over 25 years of experience in consulting with an emphasis in numerical groundwater modeling. I have a Bachelor of Science in Geology from the University of Minnesota and a Master of Science in Geology from Northern Arizona University. I am the owner of BAS Groundwater Consulting, Inc., located in Colorado, and am a Past-President of the Colorado Groundwater Association. I am a Registered Geologist in Idaho (PGL-1656), Arizona (40167), Utah (11242390-2250), and Wyoming (PG-4118). I have personally constructed and calibrated dozens of numerical groundwater flow models, including for the mining industry, and used those models for predictions of impacts from mining activities and system recovery post-closure. I also have experience providing third-party reviews of groundwater models including as a contracted reviewer by state agencies in Arizona and Kansas.

I was involved with the initial review of the groundwater modeling conducted in support of the original modified proposed action (MODPRO) report. For that effort, I reviewed the following:

- Draft Environmental Impact Statement (*Stibnite Gold Project, Draft Environmental Impact Statement*, United States Department of Agriculture, August 2020 (DEIS, 2020),
- *Final Stibnite Gold Project, Hydrologic Model Existing Conditions*, *April 27, 2018* (BC 2018a),
- *Revised Final Stibnite Gold Project, Hydrologic Model Proposed Action, October 5, 2018* (BC 2018b),
- *Stibnite Gold Project, Hydrologic Model Sensitivity Analysis, December 2019* (BC 2019a),
- *Final Stibnite Gold Project Modified PRO Alternative Modeling Report, September 2019* (BC 2019b),
- *Golden Meadows Project Overburden Geotechnical Investigation, June 2012* (SRK 2012),
- *Stibnite Gold Project Water Resources Summary Report, June 30, 2017* (BC 2017),
- *Groundwater Hydrology Baseline Study, Stibnite Gold Project, Final. June 2017 (*SPF 2017),
- *Final Workplan: Hydrologic Model of the Upper Watershed of the East Fork of the South Fork of the Salmon River, Stibnite, Idaho. October 23, 2017* (JSAI 2017),
- Existing Conditions model – file name: *Midas_ExistingCond.gwv,* and associated MODFLOW-NWT input files,
- Life of Mine model without mining – file name: *Midas_NoAction_AvgPrecip.gwv* and associated MODFLOW-NWT input files,
- Life of Mine model with mining – file name: *Midas_MineOps_AvgPrecip.gwv* and associated MODFLOW-NWT input files, and
- Instructions provided with the model files – file name: *Midas MODFLOW Hydro Model Readme.doc*

I have reviewed documents that have been submitted since 2020 in support of the modified refined proposed action (MODPRO2). The following is a list of the documents that I have reviewed for the MODPRO2 modeling:

- *Draft Stibnite Hydrologic Site Model Particle Tracking Technical Memo*, *to Alan Hasiam, VP Permitting, Perpetua Resources, from Mark Porter, Principal Hydrogeologist, Brown and Caldwell, dated July 12, 2020 (BC 2020),*
- *Hydrologic Site Model Refined Proposed Action (MODPRO2) Report, August 2021 (BC 2021a),*
- *Draft Stibnite Hydrologic Site Model (SHSM) Sensitivity Analysis, September 2021 (BC 2021b)*
- *Draft Aquifer Test Report RTC SGP Hydrogeologic Data Adequacy Review Technical Memorandum to Alan Haslam, VP Permitting, Perpetua Resources Idaho Inc., from Brad Hart, Brown and Caldwell, dated September 1, 2021 (BC 2021c),* and
- *Final 2022 Drilling and Aquifer Testing Work Plan, June 2022 (BC 2022)*

Two additional references are cited in this technical memorandum:

- Naylor, P. 2012, *Review of Known Hydrogeologic Conditions at the Midas Gold – Golden Meadows Project Area. Technical Memorandum, MWH Global*
- Rygh, J., 2015*, Analysis of the Potential Effects to Groundwater Resources from the Proposed Golden Meadows Exploration Project. 2015 Revision*

Many of the comments that I provided in 2020 on the original MODPRO modeling appear to have been addressed by Brown & Caldwell, Stantec, and/or the U.S. Forest Service in the modeling conducted for the MODPRO2. An overarching comment that I had on the original MODPRO modeling was the lack of sensitivity and uncertainty analysis testing and documentation on the modeled parameters and assumptions. The sensitivity and uncertainty testing appear to have been expanded with the modeling done for the MODPRO2 (BC 2021b) and better support was provided in the modeling report for the model input parameters chosen for the MODPRO2 model (BC 2021c). Unaddressed comments from the MODPRO modeling that apply to the MODPRO2 modeling, or new comments on the MODPRO2 groundwater modeling effort are provided below.

1. Model Domain

The modeled contours of drawdown for MODPRO2 reach the model boundary downgradient of the Yellow Pine pit, as shown on Figures 4-4 and 4-5 (BC 2021a). This indicates that the model boundary is too close to the pits to allow proper testing of the impacts of dewatering the pit. Exterior model boundaries should be located far enough from the features of interest, so they do not impact the predictive results. The radial nature of groundwater discharge to these open pits cannot properly be simulated if the model boundary encroaches upon the pit. The model-predicted results of pit dewatering, namely the amount of groundwater capture in the Yellow Jacket and potentially West End pits, the extent of drawdown of the groundwater table, and the impacts to streamflow may all be affected by the model boundary influencing the model's results.

2. Model Grid

The MODFLOW 6 model grid has a quadtree refinement around major washes and the Meadow Creek Fault Zone (MCFZ), but the modeling report (BC 2021a) has no discussion of grid refinement around the pits. Stage-Area and Stage-Volume curves (collectively referred to here as SAS curves) are provided on Figures 3-7 and 3-8 (BC 2021a). It is assumed that this figure shows the SAS curves for pit shell topography based on the mine plans and not the modeled SAS curves that represent the geometry of the planned pits in the model grid. Regardless, a comparison of the topographic-based SAS curves to the modeled SAS curves should be provided to show how the planned pit geometries are represented with the model grid. The uses of the MODFLOW Lake (LAK) package to represent the pit lake in the West End pit and the MODFLOW Drain (DRN) package to represent dewatering in the Yellow Pine, West End, and Hangar Flats pits rely on the model grid to represent the pit geometries.

For the calculations of pit dewatering the drain elevation representing the pit depth is applied to the entire model cell and in this way the pit geometry and subsequent groundwater discharge to the pit can be over- or underestimated by the model. The post-mining simulations in the Yellow Pine and Hangar Flats pits apply hydraulic conductivity and specific yield values to represent backfill materials in model cells within the pits and these adjusted property values are applied to the entire volume of the model cell. In this way, the pit backfill materials also can be over- or underestimated by the model. For the calculations of pit lake development in the West End pit, the MODFLOW LAK package performs a water balance between the infill rates (groundwater, runoff, and precipitation) and the outflow rates (evaporation and groundwater flow-through (if applicable)) to estimate the pit lake level at defined time intervals. The pit lake level grows until the combined inflow rates are balanced by the combined outflow rates and the equilibrated, ultimate pit lake level is determined. The entire model cell (area and layer thickness) assigned with a LAK boundary condition contributes to the calculation of volume and area, and therefore the model grid (cell dimensions and layer thickness) have a significant impact on the resulting modeled estimate of pit lake filling.

The modeling report (BC 2021a) notes that the bottom of model layer 4 was adjusted in model cells representing the pit bottoms, but this does not guarantee that the volumes and areas of the pits are represented closely in the model grid. If the modeled volume is significantly different than the pit topographic designs, the modeled flux of groundwater to the pits during dewatering and the filling rate of the pit lakes can be in error. If the modeled area of the pit at various elevations is significantly different than the pit topographic designs, the modeled evaporation will be in error. These inconsistencies will lead to errors in estimating the volume of groundwater discharge to the open pits and the rate of pit lake formation and ultimate pit lake levels.

3. Model Layering

The model is described in the modeling report (BC 2021a) as having five layers. Model layers 1 and 2 represent alluvial and overburden materials and have a combined thickness to represent mapped alluvial thickness in the mine area and a combined thickness of 15 feet outside of these areas. The area and thickness of alluvial and overburden materials is not shown in the modeling report and should be shown on figures to clearly communicate the modeled thickness of this important lithological unit that yields most of the groundwater to the Hangar Flats pit and the water to planned groundwater extraction wells.

Model layer 3 is described in the modeling report as being 20 feet thick, model layer 4 is 120 feet thick, and model layer 5 is 980 feet thick (BC 2021a). The deeper model layers (layers 4 and 5) are significantly thicker than the upper model layers and were set as thickness from the top of model layer 1 which was defined with a topographic digital elevation model (DEM) surface. From this process it follows that there may be vertical discontinuity between model cells. Vertical discontinuity occurs when there is a steep change in layer elevations and relatively thin model layers resulting in a model cell from a deeper model layer laying vertically adjacent to a model cell from a shallower model layer. This can result in errors during particle tracking with particles becoming “stuck” in the vertically displaced cell.

The model layering should be shown in cross sections on figures to allow the reader to understand the geometry of the modeled system. The cross sections should show the ultimate pit bottoms to communicate the relationship between the layering and the mine pits.

Showing the model layers in cross section with the pit bottoms is important because the model was simulated, for the most part, with one value of hydraulic conductivity for each model layer, and with decreasing bedrock hydraulic conductivity with deeper model layers. Descriptions of the model particle tracking results of post-mining conditions in the West End pit lake (BC 2020) report that water losses from the pit lake to groundwater occur first in model layer 5. Model layer 5 was simulated with a significantly lower value of hydraulic conductivity throughout most of the model domain (0.03 feet per day (ft/d)) than in the upper model layers and if the model cells in the bottom elevations of the West End pit (model layer 4) were in adjacent communication with model cells in model layer 5, this might affect the model-estimated groundwater flow paths and ultimate discharge to rivers. In other words, water from the West End pit may be forced to move through the lower hydraulic conductivity materials of model layer 5, not because this represents the true nature of the potential groundwater flow paths but because of an artifact of the model layer geometry. Furthermore, if the area of the West End pit has a combined thickness of 15 feet for the alluvial and overburden materials (model layers 1 and 2), the overall thickness of model layers 1 through 4 in the pit area is approximately 155 feet (15 feet (model layers 1 and 2) plus 20 feet (model layer 3) plus 120 feet (model layer 4)). Of the nine reported values of hydraulic conductivity in the area of the West End pit that measured at depths greater than 155 feet, five have values greater than 0.03 ft/d (the value of hydraulic conductivity modeled in model layer 5), (Table 3-2, BC 2021a).

Additionally, the model layering may be too coarse/thick to adequately simulate vertical hydraulic gradients that may be important for model predictions of water exchange between groundwater and the streams or infiltration of seepage from mining activities. There was discussion in the original MODPRO modeling report that the model did not calibrate well to a pump test in the Gestrin well because the model layering is a “poor analog of the test conditions” because the pumping well and observation wells have well screens that are only about 10 feet long and model layer 1 is “approximately 190 feet thick near the pumping well” (BC 2018a). Appendix A of SPF, 2017 provides monitor well construction information and most monitor wells have screen lengths of approximately 10 feet. Model layers 1 and 2 in the modified MODPRO2 model vary in thickness between 15 and greater than 250 feet and model layer 5 (the layer beneath the pit bottoms) is 980 feet thick. The model-calculated groundwater elevation is averaged vertically over the thickness of each layer, and it has not been shown that the model layering is sufficiently discretized to represent the vertical movement of groundwater typically found near open pits nor the hydraulic gradients needed to properly model the exchange of groundwater with surface water.

A sensitivity analysis and a predictive uncertainty analysis should be conducted specifically of the area of the West End pit to demonstrate the sensitivity of the model calibration in this local area and pit lake estimates and subsequent flow paths from the West End pit to the assumption of lower hydraulic conductivity with depth below the pit bottom. Furthermore, a discussion and cross sections of the model layering with pit bottoms should be included in the modeling report clarifying that vertically disconnected cells do not occur from the model layering (if applicable) or have not impacted particle tracking results (if applicable and if this is true). If particles appear to be “stuck” in vertically disconnected cells the model layering should be adjusted to alleviate this condition. A discussion should be added to the modeling report of modeled vertical hydraulic gradients beneath the pit bottoms along with a justification that the layer thicknesses are appropriate to simulate these gradients.

4. Simulation of the Rivers

The model simulates streamflow using MODFLOW’s Streamflow Routing (SFR) package. A constant depth was assumed for the streams (ICALC = 0), and the modeling report indicates that the depth was assumed to equal 2 feet in all streams (Section 4.3.2, BC, 2018a). This depth may be too small to property represent the actual stream depth for some portions of the streams and portions of the year, such as early summer when snowmelt runoff is high, and this overall assumption may be too restrictive to allow for appropriate representation of the stream geometry because the model will hold the depth constant while exchanging streamflow with the underlying aquifer. Stream geometry is important because the stream stage is used to calculate the hydraulic gradient with the underlying aquifer and thus impacts the exchange of water between the aquifer and the stream, a major component of the model calibration and an important predictive result of the future models. At the very least the assumption of stream depth should have been tested in the model sensitivity analysis along with other options for defining stream characteristics, such as defining a Manning’s coefficient from literature values for comparable settings or conducting stream bathymetry surveys (ICALC = 1 or 4). Given that two main conclusions made from modeling of the mining and post-mining periods is the impact of mining on the amount of streamflow and the time, post-closure, until streamflow is restored, the stream characteristics should have been thoroughly tested in the sensitivity analysis.

5. Modeled Geologic Structures

The modified MODPRO2 model included two geologic structures: the MCFZ which was modeled as an aquitard with low hydraulic conductivity, and the Gestrin Feature, which was modeled with locally high hydraulic conductivity. The presence of the MCFZ was tested with model runs where this feature was removed, and the conclusion was that the presence of the MCFZ as an aquitard in the model domain did not influence the model-estimated pit dewatering volumes. However, the uncertainty of the model predicted post-mining flow paths on the inclusion of this aquitard was not discussed in the modeling report. Such uncertainty analyses should be conducted to demonstrate if the model estimated of post-mining flow paths from the pits are influenced by this regional barrier to groundwater flow. The MCFZ as a low permeability feature could impact the timing and location of groundwater discharge to various reaches of the river, which is one of the major conclusions of the post-mining modeling effort.

The Gestrin feature was calibrated in a separate effort through manual calibration techniques. Presumably this resulted in an understanding of the sensitivity of the model calibration to the manner in which this feature is represented in the model (higher permeability). This understanding should form the basis of testing the Gestrin feature in an uncertainty analysis for mining impacts, and this should be included in the modeling report. Furthermore, it is mentioned in several documents (BC 2021a, 2022) that aquifer testing within the bedrock is impractical in the low permeability bedrock setting because of unsustainable flows and that packer testing is a more reliable method of obtaining estimates of hydraulic conductivity. However, this argument should not apply to the alluvial materials and it appears that limited successful aquifer testing has been conducted in the alluvial materials (limited to the Gestrin pumping well test in 2013 and inconsistent testing in 2019). Given that the alluvial unit yields almost all of the water to the Hangar Flats pit, and will supply water to extraction wells for mine operations, this alluvial unit should have further hydraulic testing conducted to support modeling of the Gestrin feature and modeled permeability in general.

Lastly, it does not appear that other structural features were included or tested in the model. A discussion and justification should be added to the modeling report to explain why other structural features (e.g. faults and fractures) were deemed unnecessary for representation in the model domain. An example is the West End Fault Zone (WEFZ) around which wells have shown artesian conditions and a well drilled into the fault zone produced high yield (approximately 50 gallons per minute (gpm)) (Naylor 2012 *in* Rygh, 2015). The WEFZ may be a barrier to flow across the fault trace but permeable along it or show different conditions in different areas of the fault, and this may be an important control for estimates of pit dewatering and pit lake development. If the areas of higher suspected permeability along the WEFZ are included in the area of higher hydraulic conductivity modeled in the Midnight Basin (see next bullet), then this should be explained in the modeling report along with an explanation of how these higher permeabilities can represent the artesian conditions observed in the area. Additionally, it does not appear that a blast zone was included in the model to represent the locally increased permeability around the pits from blasting of the native rocks. This area can be important to appropriately estimate pit dewatering with the model.

6. **Midnight Basin**

The area of Midnight Basin was modeled with a generally higher value of hydraulic conductivity (relative to adjacent bedrock) to represent vertical bedding and fracturing observed in the area. The modeled hydraulic conductivity ranges from 0.15 to 0.5 ft/d in model layers 4 and 5, yet field data in the area (Table 3-2, BC 2021a) show hydraulic conductivity values higher than this (0.12 to 5.9 ft/d). Therefore, the sensitivity analyses conducted for the model in general do not test a high enough range of values of hydraulic conductivity for this area. Additionally, the higher values of hydraulic conductivity in the Midnight Basin area alone should be tested in a separated sensitivity and uncertainty analysis given the potential for this permeable area to impact pit dewatering estimates in both the West End and Yellow Pine pits and the predicted flow through groundwater fluxes and flow paths.

7. **Model Calibration**

The modeling report states that there is no bias to the model calibration, and that the model showing both over and underestimated water levels and a balance of calibration residuals (BC 2021a). However, review of the provided spatial plots of calibration residuals (Figure 4-15, BC 2021a) shows that there is a spatial bias in the calibration, with water levels near the Yellow Pine pit consistently underestimated in the model (modeled water level is too low). This underprediction of water levels at the downgradient end of the model domain (Yellow Pine pit area) could influence ultimate, predicted flowpaths of impacted groundwater from the pits (BC, 2020) as well as rates of pit dewatering and streamflow impacts. This area of spatial bias in the model calibration residuals should be corrected.

Additionally, the transient hydrographs of measured and modeled water levels in bedrock wells (Figures 4-16 through 4-21, BC 2021a) show that the model underpredicts seasonal fluctuations in the bedrock monitoring wells, potentially implying that the modeled hydraulic conductivity is too low, disallowing enough connection of those model layers with the shallow groundwater and streamflow systems, the modeled storage is too high, or other mechanisms of the bedrock groundwater system are inappropriately simulated.

There is also a general bias in the model calibration that the modeled streamflow is typically higher than the measured streamflow, particularly at lower stream flows. This is shown on the graphs of modeled and measured streamflows at individual gage locations (Figures 4-4 through 4-8, BC 2021a) with the blue (modeled) line above the black (measured) line in the low flow months. If the model consistently overestimates streamflow, this may impact estimates of available surface water to satisfy mill demand and underestimate the amount of groundwater required as pumped make up water. This in turn could impact the predictions of drawdown in certain areas.

The discussion of model calibration does not include an evaluation of the calibrated model's replication of the measured vertical hydraulic gradients at the site. The modeling report provides cross sections of the alluvial and bedrock groundwater systems and the vertical hydraulic gradients between the two (Figure 1-2, BC 2021a), and mentions that two new pairs of paired alluvial/bedrock monitoring wells were installed at the site (MGI-19-OW1A and 1B, and 2A and 2B) (BC 2021a,c) yet the model's reproduction of vertical gradients is not provided. Appropriately representing downward hydraulic gradients in areas of recharge and upward hydraulic gradients in areas of discharge (such as beneath gaining reaches of the rivers and beneath the open pits during dewatering) is important to show that overall flow paths are appropriate (one of the predictive modeling results presented in BC 2020) and that the modeled discharge fluxes are appropriate (a major result of the predictive modeling results of pit dewatering and streamflows in BC 2021a). The modeling report should be amended to present the modeled vertical hydraulic gradients, and to show that these are appropriate to represent the conceptualized groundwater system.

Lastly, the calibrated modeled water budget is not presented in the modeling report, as discussed in the next bullet.

8. Modeled Water Budgets

A calibrated water budget was not provided for the model calibration. Components of the conceptual water budget, derived from the meteoric water balance were provided in the modeling report (BC 2021a) but the resulting calibrated water budget was not provided to allow confirmation that the model adequately represents the total expected amount of water and its movement between the various components of the model. Providing a calibrated water budget and presenting it in the context of how well, or not well, it represents the conceptual water budget is a basic standard of groundwater modeling (American Society for Testing and Materials (ASTM) D5490).

Similarly, while a large amount of modeled flow information is provided for various components of the Proposed Action predictive model (simulated streamflows, groundwater discharges to open pits by geologic unit, etc) (BC 2021a), a summarized water budget that can be easily compared to the calibrated model water budget and the conceptual model water budget was not provided. Additionally, the pit filling curve for the West End pit is provided (Figure 5-1, BC 2021a) but not the modeled fluxes for each component of the pit lake simulation (runoff, evaporation, and precipitation over time), hindering review and understanding of the modeled predictions. Providing these components of the pit lake water balance allows for review that the evaporation is consistent with the pit geometry, and that mass balance errors are not present in the pit lake (may be indicated by oscillating values).

9. Modeled Impacts from Mining

The MODPRO2 modeling only presents impacts to groundwater from mining as the modeled change to water levels (represented as drawdown) and modeled change to baseflow (BC 2021a), and the modeled percentage of particles that report to each downgradient stream reach post mining (BC 2021b). Comments on the post-mining modeling conducted for the MODPRO2 model are as follows:

- The volume of impacted water from the backfilled pits and the West End pit lake that blends with groundwater was not quantified and the volumes of impacted groundwater that reach downgradient stream reaches was not estimated.
- Particle tracks were not shown to illustrate the groundwater flow paths of impacted mine water and timing was not presented to show how long it will take for impacted groundwater to reach sensitive downstream ecosystems.
- Only the model-predicted 10-year drawdown contours of the water table, calculated as the difference between the modeled groundwater elevations determined from a no-action model scenario and the proposed action model scenario, is shown in the modeling report (BC 2021a), because it is noted that the absolute average model calibration error is 9 feet and model predicted drawdown impacts less than 10 feet are "highly uncertain". Drawdown of the water table less than 10 feet may be critical impacts to sensitive ecosystems that rely upon spring discharges and/or baseflow. It is recommended that the 1-foot drawdown contour be included in modeling figures of impacts with an assessment of the uncertainty of those estimates, and spatial calibration bias at the downgradient end of the model domain (at Yellow Pine pit) be corrected for improved estimates of impacts.
- Model-predicted drawdown of the water table is presented as contours at specific post-mining timeframes that coincide with mining milestones (years 5 and 12 when "significant changes in dewatering occur", year 70 when West End pit lake reaches maximum stage, and year 112 at the end of the predictive modeling). However, drawdown impacts in groundwater can propagate through low permeability bedrock systems, beyond when pit dewatering reaches a maximum. The maximum extent of the 1-foot and 10-foot drawdown contours should be blended for various mining times to show the maximum extent of drawdown impacts regardless of mining year. The downgradient boundary of the model domain may need to be adjusted to incorporate the entire area of potential impacts from mining.
- Model estimated contours of groundwater elevations should be shown for key times to allow the reader to understand the model-predicted groundwater flow paths. Only showing contours of the relative drawdown of the water table does not allow the reader to understand where flow-through conditions at the pits occur.

10. Information to Include in the Modeling Report

The modeling report should be edited to include key information to help the reviewer understand the modeling approach and results. Specifically, the modeling report figures should have common features shown on each to orient the reviewer and allow for understanding of spatial relationships. These common features should include, at a minimum:

- Outlines of the proposed open pits,
- Major washes and tributaries labeled (to ease the location of Midnight Basin, for example),

- The MCFZ, and
- The outer perimeter of the model domain

The general impact of modifying the model to address the comments in this letter could potentially change model predictions such as:

- groundwater flow directions and interaction with surface water during and after mining,
- estimated depth to groundwater and impacts of groundwater mounding beneath or within facilities and generated geochemistry, and
- estimates of groundwater discharge to the open pits which could, in turn, influence estimates of ultimate pit lake level, the amount of and impacts from groundwater pumping for makeup water, and the geochemistry of seepage during and after mining.

1.0 CONCLUSIONS

The modeling effort undertaken to estimate the impacts of proposed mining on the groundwater and surface water system near Stibnite, Idaho has been improved for the MODPRO2 evaluation compared to the MODPRO evaluation in 2019 and 2020. The MODPRO2 model needs additional clarification, testing, and potential improvement before predictions of groundwater and streamflow impacts can be made and conclusions can be formed. Spatial calibration bias, a model domain that is too close to areas of impacts, model layering that may be inadequate to estimate vertical hydraulic gradients, model layer geometry that may adversely affect model results, and a lack of testing major geologic structures in the area, to name a few, should be addressed and potentially corrected to improve upon the model's ability to predict impacts. The model predicted impacts should be equated to volumes of impacted groundwater and rates of impacted groundwater movement to sensitive downstream ecosystems, rather than only in the context of groundwater and surface water drawdown and recovery. Groundwater impacts less than the currently delineated minimum of 10-feet of drawdown should be assessed to properly evaluate the potential impacts to sensitive downstream ecosystems.

Sincerely,

Betsy Semmens

Betsy Semmens, R.G.