Predictions of Groundwater Inflows to the Underground Mine Workings at the Idaho-Maryland Mine

Prepared
for
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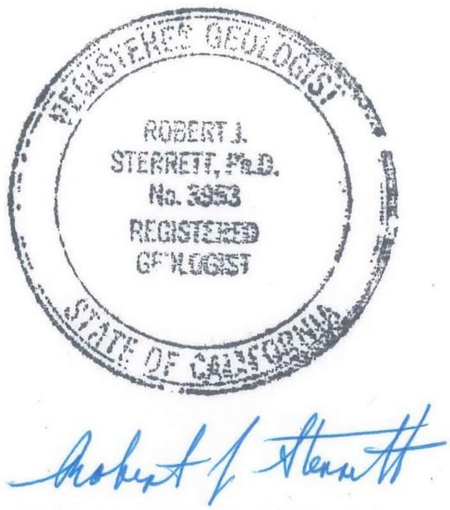
LIST OF ABBREVIATIONS

3-D	three-dimensional
amsl	above mean sea level
bgs	below ground surface
cfs	cubic feet per second
ft	feet
ft/day	feet per day
ft^3/day	cubic feet per day
gpm	gallons per minute
HSA	hydrologic study area
IMMC	Idaho-Maryland Mining Corporation
K	hydraulic conductivity (L/t); the ability of a rock or soil unit to transmit water
K_x and K_y	horizontal hydraulic conductivity
K_z	vertical hydraulic conductivity
LOM	life of the mine
NID	Nevada Irrigation District
S_s	specific storage
S_y	specific yield
USGS	United States Geological Survey

CERTIFICATION

The work that is described in this report has been undertaken under the direction of the registered geologist whose stamp and signature appear below.



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EXECUTIVE SUMMARY

Itasca Denver, Inc. (Itasca) prepared this report for Rise Grass Valley Inc. (Rise) to summarize the study related to groundwater flow modeling for the Idaho-Maryland Mine (the Mine). The main objectives of the groundwater flow model are to predict the following:

1. The inflow rates to the future mine workings based on the mine plan,
2. The potential effects of mining on groundwater levels, and
3. The potential reduction of baseflows of selected nearby creeks as the result of future mining.

The following tasks were conducted for the Mine:

1. Review and analyze available data;
2. Develop a conceptual hydrogeologic model based on the data analysis;
3. Construct a three-dimensional (3-D) groundwater flow model and calibrate the model to the available data;
4. Predict groundwater inflows to the underground mine workings, the drawdown of the water table, and potential reduction of baseflow of the key creeks due to pumping for mining; and
5. Perform sensitivity analyses of various input parameters to the model to assess their effects on the predicted inflow rates and drawdowns.

Based on the data analysis, Itasca developed a conceptual hydrogeologic model. The key hydrogeologic components and their relationships with future mining operations are summarized below:

1. Deep Groundwater Recharge: Because of the low hydraulic conductivities (*K*s) of the various rock units at the depths of future mining, the effect of recharge on the inflow rates to the deep mine workings is anticipated to be minor.
2. Geologic Setting: The main hydraulic parameter of the geologic units that controls the inflow rates to the mine workings is *K*. Because the *K* values decrease with depth, the inflow rates to the future mine workings are anticipated to be relatively low, given the size of the underground workings, as a result of mining in the low-*K* rocks.

3. Geologic Structures: Past mining records and hydrogeologic investigations suggest that there are no permeable faults in the mining area and thus limited pathways for groundwater inflow.
4. Mining: Because the underground mining occurs in saturated rock, groundwater inflows to the mine workings will occur through groundwater seepage. The seepage to the mine workings in low-permeability rock can usually be managed by underground pumping.
5. Regional Groundwater Flow: Regional groundwater will be the main source of groundwater seepage into the Mine. Because of the low *K* of the rock units and the estimated low inflow rates to the mine workings (based upon the low *K* of the rock units), the effects of mining on regional groundwater flow are expected to be limited to the mining area.
6. Surface Water: The surface water within the mining area could provide recharge to the existing, shallow mine workings. Because the future mine workings are in deep, low-*K* rock, the future contributions of surface water to mine inflows are estimated to be low.
7. Seasonal Variation of Groundwater Inflow to Mine Workings: Groundwater inflow rates to the historical Idaho-Brunswick Mine were reported to be low during the dry season and high during the rainy season. Itasca judges that the variations were likely due to surface-water inflows (surface-water runoff) through vertical workings (e.g., shafts). The seasonal variations of groundwater inflow to the mine workings are temporal and do not represent stable groundwater inflow conditions to future mining.

Using the hydrogeologic conceptual model and the available data, Itasca developed a 3-D finite-element numerical groundwater flow model of the Mine and the surrounding area. The model was calibrated to groundwater levels for the pre-historical-mining condition and during the historical mining operations. The model was further calibrated to the recovery of groundwater levels after the cessation of historical mining operations.

The calibrated model was used to predict the inflow rates to the future mine workings, the potential effects of mining on shallow groundwater levels, and the potential reduction of baseflows within selected creeks as the result of future mining. Sensitivity analyses were conducted to assess the sensitivity of predicted inflows, groundwater drawdowns, and baseflows of selected nearby creeks to changes in values for the various input parameters that are used in the model. Such parameters include the *K* values of the key geologic units, the presence of faults, recharge, and potential change of mine plans.

Based on the analyses of the available data and the results of the groundwater flow model predictions, Itasca provides the following conclusions:

1. The groundwater flow model is reasonably calibrated to the measured inflow rates to the historical Idaho-Brunswick Mine, groundwater levels in the flooded Union Hill Mine and historical Idaho-Brunswick Mine, and baseflow rates at the South Fork of Wolf Creek and Wolf Creek. In addition, the calibrated model reasonably simulates groundwater levels in a variety of domestic wells, as well as the vertical hydraulic gradient from the shallow water-bearing zone to the historical mines.
2. The groundwater flow model predicts that the maximum and the stable mine-inflow rates are approximately 1,100 and 900 gallons per minute (gpm), respectively, based on the future mine plan that Rise provided, which is approximately 200 to 400 gpm in addition to the inflow rate of approximately 700 gpm to the historical Idaho-Brunswick Mine as measured in 1956. These predicted inflow rates are annual average rates.
3. The groundwater drawdown due to dewatering for future mining is largely confined to within the mineral rights boundary.
4. The reductions of the average baseflow rates in the South Fork of Wolf Creek and Wolf Creek are approximately 0.1 cubic feet per second (cfs) and 0.75 cfs, respectively, at the end of mining compared to the 2019 average baseflows.
5. The predicted inflow rates and baseflows of nearby creeks are not sensitive to the *K* values of the transition zone and faults. The transition zone is a zone that appears to have increased *K* values due to weathering and stress release but not as high of *K* as the shallower bedrock and alluvial units. The shallow units have increased *K* due to stress release as a result of erosion, weathering, and the fact that alluvium may have higher *K* values than unweathered bedrock.
6. The recharge rate applied to the model has limited effect on the predicted inflow rates to future mining. But the recharge rate affects baseflows of nearby creeks and the extent of groundwater drawdown. Higher recharge would lead to greater baseflows of nearby creeks and a smaller area of drawdown. Conversely, lower recharge would lead to lower baseflows of nearby creeks and a larger area of drawdown.
7. The predicted inflow rates, groundwater drawdown, and baseflows of nearby creeks are not sensitive to significant expansion of mining within the known mineralized system at depths greater than approximately 1,000 feet below ground surface because of the low *K* of the deeper bedrock within the mining zone.

Itasca has the following recommendations:

1. Rise should plan to collect hydrogeologic data according to the project stages. The key data are groundwater levels with depth and flow rates pumped from the Mine.
2. Prior to the dewatering of the Mine, monitoring wells and piezometers need to be installed for the measurement of water levels. The critical reason for the installation of piezometers and monitoring wells prior to dewatering of the Mine is to measure the hydraulic responses over time at these monitoring points. As the Mine pumps groundwater from the mine workings, groundwater levels will decline in the surrounding rock, and the measurements of water levels in the wells/piezometers will document the groundwater-level changes.
3. The water-level data can be used to update the groundwater flow model to improve the confidence of the model.
4. It is expected that the actual mining areas will change from the modeled mining areas due to vein geometry and discoveries, which will only be known after extensive underground exploration is completed in the future. Itasca recommends that the groundwater flow model be updated periodically after dewatering commences. Updated modeling would incorporate changes to the long-term mining plan, data from monitoring wells, and measured pumping rates.

1.0 INTRODUCTION

Itasca Denver, Inc. (Itasca) prepared this report for Rise Grass Valley Inc. (Rise) to summarize the study related to groundwater flow modeling for the Idaho-Maryland Mine (the Mine). The main objectives of the groundwater flow model are to predict the following:

1. The inflow rates to the future mine workings based on the mine plan provided by Rise,
2. The potential effects of mining on groundwater levels, and
3. The potential reductions of baseflows of selected nearby creeks as the result of future mining.

The Mine is located in Nevada County, California, and is close to the city limits of the city of Grass Valley. The surface-land property of the Mine encompasses approximately 175 acres with two industrial sites for future mining: Centennial industrial site and Brunswick industrial site, as shown in Figure 1-1. Within the mineral rights boundary (as shown in Figure 1-1), there are five historical mines: Union Hill, Old Idaho, Old Brunswick, New Idaho, and New Brunswick. The maximum depth of the historical mines is approximately 3,300 feet (ft) below ground surface (bgs), or -530 ft above mean sea level (amsl). The historical mining produced a total of 2,414,000 ounces of gold from 1866 to 1955 (Rise 2019a). These mine workings are currently flooded by groundwater.

The output of the groundwater flow model will be used as input for the preparation of a use permit application for commencing full-scale underground mining activities (Rise 2019a). The tasks completed by Itasca include the following:

1. Review and analyze available data;
2. Develop a conceptual hydrogeologic model based on the data analysis;
3. Construct a three-dimensional (3-D) groundwater flow model and calibrate the model to the available data;
4. Predict groundwater inflows to the underground mine workings, the drawdowns of the water table, and potential reductions in baseflows of the key creeks due to mining; and

5. Perform sensitivity analyses of selected input parameters to the model to assess their effects on the calculated inflow rates, groundwater drawdowns, and potential impacts to baseflows in streams.

2.0 GENERAL HYDROGEOLOGIC CONDITIONS

Itasca received previous investigation reports on areas in or near the Mine area, which included surface geology, hydrogeologic investigations, operational reports of historical mines, and groundwater well completion information. The relevant information is summarized in this section.

2.1 CLIMATE AND GROUNDWATER RECHARGE

The climate of the Mine area is temperate with moderate precipitation. Precipitation data have been recorded from 1893 to September 1966 for the Grass Valley 2 station based on data from the Western Regional Climate Center. The average annual precipitation (both as rain and snow) is approximately 53 inches, as reported on the Western Regional Climate Center website (http://wrcc.dri.edu/Climate) for Grass Valley, CA. Groundwater recharge in the area was estimated as 10 to 12 inches per year (Kopania 2019, pers. comm.).

2.2 GEOLOGIC SETTING AND STRUCTURES

Based on the geologic map of the Chico quadrangle, California (Saucedo and Wagner 1992), as shown in Figure 2-1, the Mine site lies on the Sierra Nevada and is underlain by mafic intrusive and metamorphic rocks of Paleozoic and Mesozoic ages; metavolcanics, epiclastic, and ultramafic rocks of Jurassic age; granitic rocks of Jurassic and Cretaceous age; pyroclastic rocks of Tertiary age; and alluvium of Quaternary age (Clark 1976; Page et al. 1984). The granitic (igneous origin) and metamorphic rocks are hard and dense and yield little water to wells except when a wellbore intersects fractures or weathered portions of these geologic units. (Page et al. 1984). It should be noted that Figure 2-1 does not have a high graphic resolution because it is based on a figure from Saucedo and Wagner (1992). However, Figure 2-1 is sufficient for illustration purposes in this report.

Based on historical geological mapping of the underground mine workings and core drilling completed by Rise, the historical Brunswick and Union Hill mining areas occur within meta-andesite rocks (termed as "Brunswick Porphyrite Block"), and the historical Idaho and nearby Eureka and

Maryland Mines are mostly located within mafic intrusive and metamorphic rocks, including gabbro and serpentinite (Rise 2019a). In addition, fine-grained meta-sediments (slates, argillite) of the Mariposa Formation and Tertiary-aged andesite volcanic rocks are present to the east and southwest of the Brunswick Porphyrite Block. The Tertiary-aged andesite deposits are typically less than a few hundred feet thick, forming a relatively thin mantle that obscures the underlying bedrock geology and faulting (Rise 2019a). These geologic units in the Mine area are presented in Figure 2-2.

As the cross sections in Figures 2-1 and 2-2 show, the geologic units were folded along sub-vertical directions. Both the volcanic and metamorphic rocks are more weathered and fractured in the shallow portion and competent below the weathered zone (Clark 1976; Todd 2007).

In the Mine area, geologic structures are poorly exposed on the surface but were intersected in the underground workings and drill holes (Rise 2019b, pers. comm.). As shown in Figure 2-2, two main faults, Fault 6-3 and the Morehouse Fault, generally have a strike direction of northwest-southeast. Both faults dip to the northeast, with Fault 6-3 dipping 70 degrees northeast and the Morehouse Fault dipping 40 degrees northeast (Rise 2019b, pers. comm.). Another fault, identified as the Idaho fault zone, generally follows the northern boundary of the Brunswick Porphyrite Block (Rise 2019a). The Idaho fault zone was not delineated in the 3-D geologic model by Rise. The Idaho fault system is coincident with the mined Idaho veins that are incorporated into the model. On the left-hand side of Figure 2-2, the Morehouse Fault and Fault 6-3 are projected to the land surface; however, in cross section, these faults may not extend to the surface.

2.3 DEWATERING RATES FROM THE HISTORICAL MINES

The Mine area had been mined intermittently from 1863 to 1956 under various operations. The elevations and estimated mine lives, along with the measured flow rates for the historical mines, are presented in Table 2-1. The spatial extents (both horizontal and vertical) of the historical mines are shown in Figure 2-3.

The Old Idaho Mine (Idaho #1) was mined from 1863 to 1914 to a depth of approximately 2,200 ft bgs, or 317 ft amsl. After the mine drifts reached the bottom of the Old Idaho Mine, the average groundwater pumping rate from the mine was approximately 290 gallons per minute (gpm), based on the pumping-rate record. The flow rate was 250 gpm for 10 months of the year and 500 gpm for the remaining two months during the rainy season (Mines and Mineral Resources of Nevada County 1920). This variation in pumping rates shows that surface-water inflows through shafts or other workings, along with shallow recharge through the shallow fractured rock units, is temporal.

The Old Brunswick Mine was mined intermittently between 1880 and 1915 (Rise 2019a). The only available estimated pumping rate was in 1933, when the mine was flooded. Therefore, the pumping rate in 1933 did not represent the average groundwater inflow rate to the mine during operation.

The New Brunswick Mine and the New Idaho Mine were expansions of the Old Brunswick and Old Idaho Mines, respectively, and were connected to the old mines. These two mines continued operation until 1956. The New Brunswick Mine drifts reached a bottom elevation of -530 ft amsl, and the New Idaho Mine had a bottom elevation of approximately -400 ft amsl. The two mines were connected in 1941 at the B2300 ft level (500 ft amsl). James Askew Associates (1991) reported that the average groundwater inflow rate to these historical mines was approximately 680 gpm, ranging from a low inflow rate of 500 gpm during the dry season to a high inflow rate of 1,200 gpm at the end of the rainy season. As mentioned above, these variations are more likely due to surface-water inflows through vertical workings along with shallow recharge through the higher hydraulic conductivity (*K*) surficial geologic materials.

South of the historical Idaho-Brunswick Mine, there was a small mine named the Union Hill Mine, which was closed in 1918 and has been flooded since then. The Union Hill Mine is not connected to the historical Idaho-Brunswick Mine but is in close proximity to the Brunswick Mine. In 1956, the water level at the Union Hill Mine was reported to be within 20 ft of the top of the shaft (Clark 2005), which suggested that the complete dewatering of the adjacent mine workings (historical Idaho-

Brunswick Mine) resulted in no more than 20 ft of water-level decline in the Union Hill Mine. The water level in the Union Hill Mine would not be higher than the surface elevation of the shaft. The top of the Union Hill Mine is at approximately 2,666 ft amsl with a measured water level of approximately 2,665 ft amsl in 2019 (Kopania 2019, pers. comm.). At the same time (as of 2019), the flooded New Brunswick shaft had a water level of approximately 2,497 ft amsl. The water level in the Union Hill shaft was approximately 160 ft higher than the water level in the historical Idaho-Brunswick Mine (Vector 1992), suggesting that there is a poor hydraulic connection between these two mines.

2.4 HYDRAULIC CONDUCTIVITIES AND GROUNDWATER LEVELS IN DOMESTIC WELLS

The well completion reports provided well yields for the domestic wells in the vicinity of the Mine property. As illustrated in Figure 2-4, the yield of the wells generally decreases with depth, mainly as the result of decreasing fracture intensity with depth. In analyzing the yield of groundwater wells in southwestern Nevada County, Page et al. (1984) concluded that the fractured rocks generally occur above a depth of 215 ft bgs. Similarly, in the vicinity of the Mine property, the domestic wells with a depth shallower than 215 ft tended to produce more water, while the deeper wells generally produced less than 5 gpm (Vector 1992). Fractures tend to close with depth due to vertical loading stresses.

Figure 2-5 shows the estimated *K* with depth. The *K* values in Figure 2-5 demonstrate a decreasing trend with depth (Todd 2007; Kopania 2019, pers. comm.). Figure 2-5a is based on well completion reports from 334 wells that are within an area of 18 square miles in the vicinity of the Idaho-Maryland Mine. Figure 2-5b is derived from well completion reports near the Rise mineral rights boundary based on the estimated transmissivity values from Kopania (2019, pers. comm.) and the saturated thickness of each well. Though the units of *K* differ in these two figures (a *K* value of 1 ft/day is equal to a *K* value of 7.48 gpd/ft^2), both figures show the decreasing trend with depth and the same order of magnitude of *K* values.

There are no estimated *K* values for the faults. Rise (2019b, pers. comm.) indicated that the faults did not show significant fractured zones, as observed in cores that were obtained by drilling and in historic mapping and reports (Bateman 1948), and may be less permeable than the surrounding rocks (Vector 1992; Todd 2007). The Idaho, 6-3, and Morehouse Faults are premineralized faults (Vector 1992; Todd 2007).

The relevant information from wells with groundwater-level measurements in the Mine area is summarized in Table 2-2. The wells that are listed under the "Todd 2007 Well ID" column in Table 2-2 have water-level measurements periodically from 1994 to 2007. The rest of the wells only have measured water levels during drilling or after well completion. The locations of wells with coordinates are presented in Figure 2-6. Analyses of water levels in the domestic wells suggested that shallower wells had higher water levels than the deeper wells (Todd 2007). In addition, the measured water levels in domestic wells near the historical Idaho-Brunswick Mine are more than 90 ft higher than the water level in the mine void (Sierra-Pacific 1995; Todd 2007; Rise 2019b, pers. comm.).

The Idaho-Maryland Mining Corporation (IMMC) and its predecessors monitored water levels in approximately 79 private domestic wells from 1995 to 2001 and again from 2003 to 2007. The water levels in the private domestic wells have seasonal fluctuations that may range from 10 ft to 50 ft between wet and dry seasons of the year but remain relatively consistent from year to year within each individual well. During the monitoring period, several years had below normal rainfall (2001, 2004, and 2007), multiple years had above normal rainfall (1995–1998 and 2006), and several years had near normal rainfall (1999, 2000, 2002, 2003, and 2005). The annual rainfall amounts are shown in Figure 3-4 of the EMKO (2020) report. Despite large variations in annual rainfall from year to year, the seasonal water-level cycles in individual wells remain consistent and the overall water levels shown on the hydrographs for each well do not fluctuate based on wet or dry climatic cycles. The IMMC hydrographs are included in Appendix B of the EMKO (2020) report.

Based on the lack of changes in the individual well hydrographs between wet and dry climatic cycles, the amount of recharge appears to be consistent from year to year and is not affected substantially by drought or wet cycles (EMKO 2020). The consistent annual recharge may be due to the limitations of recharge in fractured bedrock, where the annual rainfall amount may be greater than the capacity of the fractures to accept additional flow. In this situation, increases or decreases in the annual rainfall due to climatic cycles do not have appreciable effects on the amount of water that can be recharged because the capacity of the fractures to transmit water in the subsurface is near its maximum. Thus, there may not be a substantial variation in recharge to the water-bearing geologic materials in the project area. Nevertheless, the sensitivity of the model to changes in recharge has been evaluated.

In contrast to the seasonal water-level variations of 10 to 50 ft in the domestic wells, water levels measured in the New Brunswick shaft over the past 17 years have only fluctuated by about 7 ft (with the exception of one outlier), as shown in Figure 3-7 of the EMKO (2020) report. In addition, where more than one measurement per year has been made in the shaft, there is no clear wet and dry season variability, unlike in the domestic wells. These observations indicate that there are not specific connections (e.g., via fractures) between the domestic wells and the underground mine workings.

The measured water levels in Table 2-2 mostly reflect water levels measured more than 24 years after the cessation of historical mining operations. Only the water levels from those wells located outside of the historical mining area were used in the pre-historical-mining model calibration, as labeled in Table 2-2. Model calibrations will be discussed in Section 4.0.

2.5 BASEFLOW RATES IN THE CREEKS

In the Mine area, streamflow rates were measured in April 2019 and August 2019 at the discharge location of the South Fork of Wolf Creek and at the Centennial Bridge culvert of Wolf Creek (or Wolf Creek), as shown in Figure 2-6. In addition to the natural creeks, there is the Nevada Irrigation District

(NID) Canal in the mine area. The discharge rate from the NID Canal to Wolf Creek was available for the period of January 2018 to April 2019. Measured streamflow rates and the discharge rate from the NID Canal are listed in Table 2-3.

In August 2019, the measured flow rate in the South Fork of Wolf Creek at the discharge location was approximately 1.0 cubic foot per second (cfs). This flow rate is lower than the measured flow rate of 6.5 cfs in April 2019 because the April measured value may include the runoff contribution from snowmelt, rainfall, and overland flow. Because the baseflow is defined as the discharge from the groundwater system, the lower flow rate is considered to be closer to the groundwater discharge. Therefore, the baseflow rate in the South Fork of Wolf Creek is assumed to be approximately 1 cfs.

Measured streamflow rates in Wolf Creek and the NID Canal are only available in April 2019. The difference between the flow rate from the creek and that from the NID Canal (the measured flow rate in Wolf Creek deducts the flow rate released from the NID Canal) is 31.9 cfs. Because April is considered part of the snowmelt/rainy season, the baseflow of Wolf Creek should be lower than 31.9 cfs. Thus, without additional data available, Itasca assumed that the baseflow rate is lower than 31 cfs (Kopania 2019, pers. comm.).

2.6 GROUNDWATER FLOW

The groundwater flow direction within the hydrologic study area (HSA) generally follows the topography from northeast to southwest (Figure 2-7). The HSA is described in Section 4.0. Due to the presence of the current flooded mine void, groundwater near the historical mine area flows toward the Mine area and discharges through the draining points in the west. The entire mine void is connected and has nearly the same water level, which is close to the elevation of the drains (e.g., East Eureka Shaft Drain, Eureka Drain) located at the west of the historical mine area. The locations of the historical mine shafts and drains are shown in Figure 2-6. Table 2-4 includes the estimated drain elevations in 2019 based on the LIDAR data and topographic map (Kopania 2019, pers. comm.).

3.0 CONCEPTUAL HYDROGEOLOGIC MODEL

This section describes the main components of the conceptual hydrogeologic model that may affect the inflow rates to the future mine workings as well as the potential effects on groundwater levels. Because the underground mine workings are flooded under the current condition and will be pumped dry prior to the start of mining, it is beneficial to present the conceptual models under the current condition and the future mining condition, as shown in Figures 3-1 and 3-2, respectively. The key hydrologic components that may affect the inflow rates to the mine workings and have an effect on groundwater and surface-water resources at the conceptual level are the following:

1. Deep Groundwater Recharge: Because of the low *K*s of the various rock units at the depths of future mining, the effect of recharge on the inflow rates to the deep mine workings is anticipated to be minor.
2. Geologic Setting: The main hydraulic parameter of the geologic units that controls the inflow rates to the mine workings is *K*. Because the *K* values decrease with depth, the inflow rates to the future mine workings are anticipated to be relatively low, given the size of the underground workings, as a result of mining in the low-*K* rocks.
3. Geologic Structures: Past mining records and hydrogeologic investigations suggest that there are no permeable faults in the mining area and thus limited pathways for groundwater inflow.
4. Mining: Because the underground mining occurs in saturated rock, groundwater inflows to the mine workings will occur through groundwater seepage. The seepage to the mine workings in low-permeability rock can usually be managed by underground pumping.
5. Regional Groundwater Flow: Regional groundwater will be the main source of groundwater seepage into the Mine. Because of the low *K* of the rock units and the estimated low inflow rates to the mine workings (based upon the low *K* of the rock units), the effects of mining on regional groundwater flow are expected to be limited to the mining area.
6. Surface Water: The surface water within the mining area could provide recharge to the existing, shallow mine workings. Because the future mine workings are in deep, low-*K* rock, the future contributions of surface water to mine inflows are estimated to be low.
7. Seasonal Variation of Groundwater Inflow to Mine Workings: Groundwater inflow rates to the historical Idaho-Brunswick Mine were reported to be low during the dry season and high during the rainy season. Itasca judges that the variations were likely due to surface-water inflows (surface-water runoff) through vertical workings (e.g., shafts). The seasonal

variations of groundwater inflow to the mine workings are temporal and do not represent stable groundwater inflow conditions to future mining.

Figure 3-1 shows the schematic illustration of the conceptual hydrogeologic model of the Mine area (from northwest to southeast; the location is shown in Figure 2-3). The water level in the mine workings is lower than the water table of the shallow groundwater system as of the current condition (2019). With the given data set, it appears that the hydraulic connection between the shallow groundwater and the mine workings is relatively poor.

Figure 3-2 shows the conceptual groundwater flow conditions for future mining. Similar to Figure 3-1, inflows from the shallow groundwater system and regional groundwater to different mine workings will occur. The inflow rates will be controlled by the *K*s of the various rock units. Water within the Mine will be removed by in-mine pumps to maintain dry working conditions.

4.0 GROUNDWATER FLOW MODEL

The groundwater flow model that was constructed for this investigation utilizes the numerical code *MINEDW*, which was developed by Itasca (2012) to solve 3-D groundwater flow problems with an unconfined (or phreatic) surface using the finite-element method. *MINEDW* is a commercial software that was thoroughly reviewed by Sandia National Laboratories (Corbet et al. 1998) and is approved by the Nevada Division of Environmental Protection for use in permitting applications (NDEP 2018). *MINEDW* has been used successfully at more than 100 mine sites located throughout the world and in diverse hydrogeologic and climatic conditions. The code has been in use for approximately 30 years, and its predictions have been validated by field data collected over many years. Additional information regarding the code *MINEDW* is contained in Appendices A and B.

4.1 MODEL DOMAIN AND DISCRETIZATION

Figure 2-7 shows the HSA for the groundwater flow model that was used for this project and forms the boundaries of the model. The HSA encompasses watershed boundaries and creeks. The primary reasons for selecting the boundaries of the HSA are as follows:

1. To link, if possible, the model boundaries to the natural hydrologic boundaries, such as watershed boundaries and rivers; and
2. To ensure that the model domain is sufficiently large in order to minimize potential artificial boundary effects on the numerical simulations and predictions. Stresses (water-level drawdowns), such as pumping from a mine, should not reach the boundaries of the model. Because the rock units have low permeability in this project, Itasca does not anticipate that the hydraulic effects induced by mining operations will reach the model boundaries.

The eastern boundary of the HSA is a watershed divide (Sierra crest), while the other three sides are rivers/creeks. The western boundary is the Feather River, the northern boundary is the North Yuba River and South Fork Feather River, and the southern boundary is the Rubicon River and Raccoon Creek. The dimensions of the HSA are approximately 40 miles from north to south and 60 miles from east to west. The general topography, location of the Mine's mineral rights boundary, extent of the model domain, and creeks/rivers are shown in Figure 2-7.

The topographic elevations within the HSA are based on LIDAR data and United States Geological Survey (USGS) elevation data that were provided by Rise. The topographic elevations range from 24 to 8,595 ft amsl within the model domain, with the lowest elevation at the southwest corner and the highest at the southeast corner. The bottom elevation of the model in the Mine area is -3,445 ft amsl, which is approximately 1,200 ft below the future mine workings (Rise's future mine plan).

The groundwater model domain encompasses approximately 2,810 square miles, and the finite-element grid contains 324,448 nodes and 626,386 elements within 31 layers (Figures 4-1 and 4-2). The element grid is finely discretized in the Mine area to achieve the following objectives:

1. To refine the numerical solutions of hydraulic heads and flows near the area of flow convergence (for example, in the area of the Mine); and
2. To more accurately represent the detailed geologic settings of the mining area, the underground mine workings, and the future mine plan.

In addition, the model element grids have also been discretized to represent major rivers and creeks, geologic structures (e.g., faults), domestic wells, and the major features of the historical mines and mine plan (i.e., the shafts and drifts). As shown in Figure 4-1, in the immediate mining area, the minimal horizontal length of an element is about 20 to 25 ft. Within the area where detailed information for the mineral rights boundary (which includes the historical mine, surface land boundary, wells, and nearby creeks and canals) is available, the horizontal length of the element is approximately 50 ft. Within the local watershed area, the element size is up to 500 ft horizontally. Outside of these three refined areas, the element size is as large as 5,000 ft.

Figure 4-2 displays the layout of the model layers in the Mine area in a cross-sectional view. The elevations of the model layers were generally set flat, based on the elevations of drifts/raises from both the historical mines and the future mine plan. In total, there are 31 model layers, with the historical and future mine workings mainly being simulated from model layers 4 to 28. Outside of the Mine area, the elevations of the layers follow the variations of topography. The upper seven layers in the areas with higher ground-surface elevations have greater thickness than the areas with lower ground-surface elevations. The thickness and top elevation for each layer in the Mine area are listed in Table 4-1. The bottom three layers are assigned to represent the deep rock units below the future mine zone. These three thick layers were used to minimize the boundary effects from the no-flow model boundary condition assigned to the model bottom.

4.2 MODEL BOUNDARIES

The boundary conditions and assigned specified-head values are presented in Figure 4-3. Model boundaries along the watersheds to the east (primarily the crest of the Sierra Nevada) were assumed to be no-flow boundary conditions. The nodes that are associated with the rivers located at the western (Feather River), southern (Rubicon River and Raccoon Creek), and northern (North Yuba River and South Fork Feather River) boundaries of the model were assigned with a specified-head (also referred to as constant-head) boundary condition that reflects the elevation of the river at that location. The constant-head elevations of the nodes along the Rubicon River and North Yuba River to the east (high-topographic-elevation area) were assigned to be lower than the river elevations based on the model calibration because the rivers at these high-topographic-elevation areas are most likely above the water table.

4.3 SIMULATION OF HYDROLOGIC FEATURES

4.3.1 Simulation of Hydrostratigraphic Units

In the finite-element method, hydraulic properties are assigned to the elements, and hydraulic heads and fluxes are associated with nodes; therefore, every element in the model was assigned to a hydrogeologic zone, as depicted in Figure 4-1 for Layer 4 (upper bedrock units) of the model. The top elevation of this layer is approximately 2,600 ft amsl in the Mine area. Each hydrogeologic zone is assigned with horizontal (K_x and K_y, based on x and y axes) and vertical (K_z; z axis) hydraulic conductivities, specific storage (S_s), and specific yield (S_y). S_y is only utilized when the water table is located within the element.

Itasca incorporated 103 hydrogeologic zones into the model; the assigned hydraulic properties after the model calibration are summarized in Table 4-2. Based on the model calibration, all of the geologic units were assigned with an anisotropy ratio (i.e., a K_x/K_z value) of 10. The description of the model calibration is provided in Sections 4-5 and 4-6.

As discussed in Section 2.4, the *K* values of the geologic units decrease with depth. Vertically, six main sub-units were assigned in the model for each geologic unit to simulate the decrease of the *K* values along the depth.

1. Fractured rocks – from the ground surface to 215 ft bgs;
2. Transition zone – from 215 to 300 ft bgs;
3. Upper bedrock – from 300 to 2,000 ft bgs;
4. Middle bedrock – from 2,000 to 4,000 ft bgs;
5. Lower bedrock – from 4,000 to 5,000 ft bgs; and
6. Deep bedrock – lower than 5,000 ft bgs.

Page et al. (1984) suggested that the rocks, except the alluvium and weathered top units, in the study area have similar hydraulic properties. The initial *K* values of the upper three sub-units (depths are less than 2,000 ft bgs) and lower three sub-units were assigned with reference values for fractured and unfractured igneous and metamorphic rocks, respectively (Freeze and Cherry 1979).

Because there is no measured storativity value, and the groundwater inflow rate in the long term (stable condition) is generally not sensitive to the storativity of the tight, hard-rock water-bearing zones, the same storativity values (S_s and S_y) were assigned to different bedrock units in the model;

a S_s of 5×10^{-6} ft^{-1} was assigned, and the S_y was 0.005 (Freeze and Cherry 1979). The alluvial unit and river-bed sediments were assigned with a S_s of 5×10^{-5} ft^{-1} and a S_y of 0.05.

4.3.2 Simulation of Rivers and Creeks

In addition to the constant-head boundary representing the rivers along the model boundaries, all of the major rivers/creeks that are located within the HSA (Figure 4-3) were incorporated into the model and simulated in the stream-routing package within *MINEDW*. The elevations of riverbeds in the area were based on the LIDAR data or topographic elevations from the USGS via Rise. The stream-routing package simulates interactions between a routed river and an aquifer. The routed-river function uses Manning's equation to calculate the flow in an open channel. A given reach of the river is represented by a node and corresponding reach length. Each reach is connected to the next reach by sequencing the nodes from upstream to downstream. River–groundwater system interactions are simulated by comparing the head in the groundwater system to the head in the river over time and by transferring water across the riverbed accordingly (Itasca 2012). Besides riverbed elevations, the parameters for the stream-routing package also include riverbed *K* (based on the *K* values of the top hydrogeologic units in which streams are located), the length (calculated distance between model stream nodes) and width of the river/stream (assumed as 5 to 100 ft for the creeks and rivers roughly based on Google Earth measurements), and Manning's coefficient (0.02, a value for natural streams with an earth channel). It should be noted that the riverbed units and orientation of bedrock fractures are not uniform. However, the *K* value used for one river reach is the effective value of the whole reach, and the *K* values of the riverbed are mainly controlled by the conductivities of the alluvial materials beneath the riverbed. The *K* values used within the model are within acceptable published ranges and are based on the model calibration to the measured baseflow values. The uncertainty of the simulations is considered in the calibrated *K* values and is thus judged by Itasca to be minor.

4.3.3 Simulation of Precipitation and Recharge

The long-term average precipitation for the Mine area was estimated to be 53 inches per year based on precipitation records summarized by the Western Regional Climate Center. Groundwater recharge was estimated to be 10 to 12 inches per year in the Grass Valley area (Kopania 2019, pers. comm.). In the HSA, the precipitation is high in the high-elevation areas to the east and low in the valley (west); however, due to the variation in geologic units and the depth of weathering, the proportion of the precipitation that recharges to the groundwater system is probably much higher to the west than that to the east, suggesting that the recharge is not directly proportional to the precipitation. Therefore, in the groundwater flow model, a uniform rate of 12 inches per year was assigned to the entire model domain. The impact of precipitation on predicted inflows to future mining is discussed in Section 5.4.

The recharge to the groundwater system was applied to the first saturated node of the model. Though recharge does not occur over the entire year, Itasca simulated the recharge as a long-term average for the model simulations. Due to limited data available for calibration of seasonal variation, the semi-annual fluctuation (dry-wet seasons) of recharge was not incorporated into the model simulations.

4.4 SIMULATION OF UNDERGROUND MINE WORKINGS

The underground mine workings at the Mine include the historical Idaho-Brunswick Mine (including the Old Idaho, Old Brunswick, New Idaho, and New Brunswick Mines) and future mining. These workings comprise drifts, raises, and shafts. The extents are from the ground surface to a depth of 3,300 ft bgs. The vertical distance between levels is approximately 100 ft.

The historical mine workings were simulated using 9,344 drain nodes, and the future mining operation was simulated with 3,888 additional drain nodes. Drain nodes that were associated with the mine drifts and shafts remain numerically active until the end of mining. The starting times of the drain nodes were assigned gradually based on mine schedules and the elevations (from shallow to deep). Backfilling of the mined areas with cemented-paste backfill (CPB) was not simulated in the model. Based on Itasca's other project experience, the effect of backfilling using CPB will likely reduce the amount of seepage into the Mine. As such, Itasca's model could overestimate the amount of inflows and drawdowns.

Drain nodes were used to simulate the discharge of groundwater to the underground mine workings through the utilization of the following relationship:

$$Q = CL\,(H_s - H) \;\; if \;\; H > H_s$$

and (1)

$$Q = 0 \;\; if \;\; H \leq H_s$$

where:

Q = groundwater discharge to the drain nodes [cubic feet per day (ft^3/day)],

H_s = specified elevation of a mine working node [ft],

H = calculated hydraulic head [ft], and

CL = the so-called leakance factor, assigned either an assumed value or one estimated from the following equation:

$$CL = \frac{f \cdot K \cdot D_2 \cdot D_3}{D_1} \tag{2}$$

where:

K = hydraulic conductivity of the drain node material [feet per day (ft/day)],

D_1, D_2, D_3 = generic dimensions related to the size of the individual element to which any particular drain is associated [ft], and

f = a factor that accounts for the effect of non-Darcian flow, the actual size of the excavation relative to the grid size, and the shape of the excavation.

The model simulated the historical Idaho-Brunswick Mine from the top to the bottom of the mine workings with the following mining-operational schedules:

- Old Idaho: 1863–1914
- Old Brunswick: 1880–1915
- New Brunswick: 1933–1956
- New Idaho: 1919–1956

The schedule was assumed based on the general mine sequence for the purposes of model calibration (Table 2-1). It should be noted that the schedule does not affect simulated groundwater inflows to the mine workings because the model simulation was focused on matching the inflow rates to the historical mines near the end of mining (e.g., flow rates to the Old Idaho Mine in 1919 and to the Idaho-Brunswick Mine in 1956), when the entire mines were near fully dewatered.

The horizontal and vertical extents of these historical mines are shown in Figure 2-3. Over the entire simulation period of the historical mining, the flooded Union Hill Mine area was simulated as a special geologic unit with high K (8,000 ft/day) and high porosity (50%). The assumed porosity value was based on the estimation of the mine void relative to the model element size in the Mine area. For example, the size of model elements is generally from 20 to 25 ft in the Mine area, while the mine workings had a width of approximately 10 ft; then an assumed porosity of 50% would normalize the ratio of the mine void relative to the size of the model elements with the consideration of mine-working connections.

4.5 SIMULATION OF PRE-HISTORICAL-MINING CONDITIONS

No groundwater levels are available for the model calibration of pre-historical-mining groundwater conditions. Itasca assumed that current water levels outside of the Mine area are close to those of the pre-historical-mining condition after more than 60 years of recovery. This assumption is supported by the available hydrographs from domestic wells (Todd 2007), which show that groundwater levels were generally stable from 1994 to 2007 with seasonal variations. The simulation of pre-historical-mining groundwater conditions was completed by calibrating the model to the observed water levels from the selected wells in Table 2-2. The model calibration focused on the wells with hydrographs (Todd 2007) because these wells were considered to have more reliable groundwater levels than the first water hits or reported water levels during drilling. Figure 4-4 shows the simulated and measured groundwater levels. The comparison between the simulated and measured hydraulic heads (groundwater levels) of the wells with hydrographs (blue squares) suggests that the simulated hydraulic heads reasonably agree with the measured hydraulic heads.

The simulated water levels deviate at some wells whose water levels were the first water hits measured during drilling or after well installation. For example, wells W76 (the very right dot in Figure 4-4) and W77 were in the same location; the first water hit of well W76 was 2,952 ft amsl, but the static water level for well W77 was 2,739 ft amsl, more than 210 ft lower. On the other hand, the static water level at well W70 of 2,769 ft amsl was 140 ft higher than its first water hit during drilling (2,629 ft amsl). These significant differences between the first-hit and static water levels at the same locations suggested that some of the reported water levels during drilling may not represent stable water levels of the water-bearing zone. Therefore, it is not possible for the model to match all the water levels from the first water hit.

The contours (500-ft contour interval) of the simulated water table are shown in Figure 4-5 in plan view. Water-table contours in this figure show that the shallow groundwater flow direction is toward the west/southwest, which is consistent with field observations and the conceptual model.

The baseflow rates at the South Fork of Wolf Creek and Wolf Creek were calibrated to the values that are summarized in Section 2.5. The simulated baseflow rates for the South Fork of Wolf Creek and Wolf Creek are 1.0 cfs and 21.9 cfs, respectively. The simulated baseflow rate for Wolf Creek is lower than the measured value because the measured value was obtained in April and thus may include surface-water runoff due to precipitation.

4.6 SIMULATION OF HISTORICAL MINING

Using the simulated groundwater levels from the pre-historical-mining simulation as the initial groundwater condition, Itasca conducted transient model calibrations by matching the change of groundwater levels at the Union Hill Mine and groundwater inflows to the historical mines. The simulations were conducted for the following two periods:

1. Mining Period: from 1918, when the Union Hill Mine ceased operation, to 1956, when the New Idaho and New Brunswick Mines ended operation; and
2. Recovery Period: from 1957 to 2019, during which the historical mines were flooded.

Figure 4-6 shows the simulated groundwater flow rates in comparison with the measured inflow rates to both the Old Idaho Mine (1919) and the Idaho-Brunswick Mine (1956). The simulated values are close to the average of the measured values and within the ranges of measured values. It should be noted that the reported high inflow rates were for the rainy season, which likely included the surface-water runoff into the mines.

In the recovery period, the simulated groundwater levels from the end of the mining period were used as the initial groundwater levels for the model simulation of the recovery of the groundwater system from 1957 to 2019. The historical mine openings were simulated with a zone with high *K* (8,000 ft/day) and high porosity (50%).

The simulated water levels in comparison with the limited measured water levels at both the Union Hill Mine and the New Brunswick Mine are shown in Figure 4-7. It should be noted that the assumed start date and actual excavation of different mines may not be accurate in the model; however, this minor difference in the mining schedule will not affect the model calibration result due to the long duration of mining activities and the long time period for groundwater recovery (since at least 1957). During the operation of the historical mines, the measured water level in the Union Hill Mine declined less than 20 ft to approximately 2,646 ft amsl (Clark 2005) when the Brunswick Mine was at the complete dewatering stage at a depth of approximately 1,500 ft below the measured water level in the Union Hill Mine. Such a large water-level difference could only be simulated by assigning the slate unit near the Morehouse Fault and the Union Hill Mine with a relatively smaller *K* value than the surrounding volcanic rocks based on the model calibration. Within the mineral rights boundary, the slate unit was only found in the Union Hill Mine area (Rise 2020, pers. comm.). Figure 4-7 shows that the model reasonably replicated the measured water levels at the mines during both the mining (one data point in 1956) and since the year 2003, when recovery had occurred.

As discussed in the previous sections, measured groundwater levels from the domestic wells are not available since 2007. However, it is reasonable to assume that these groundwater levels are somewhat stable with the exception of seasonal fluctuations, as no major pumping (stresses) has occurred since 2007. The simulated water levels at the end of the recovery period were compared to the ranges of measured water levels in these wells from 1994 to 2007 (Todd 2007), as shown in Figure 4-8. The locations of the wells in Figure 4-8 are highlighted in Figure 2-6. The comparison between simulated and measured groundwater levels is shown in Figure 4-9, which shows that the simulated hydraulic heads in 2019 reasonably agree with the measured groundwater levels representing the recovered water levels (Table 2-2) after the cessation of the historical mining operations. Also presented in Figure 4-8 is the simulated water level and measured water level at the New Brunswick shaft, which represents the water level of the flooded mine. The following observations are made from Figure 4-8:

1. The simulated groundwater levels are within the ranges of measured water levels;
2. The simulated mine-water level is essentially the same as the measured water level; and
3. The water levels in domestic wells are generally higher than the water level of the New Brunswick shaft. Because the underground mine workings are connected, the water level in the New Brunswick shaft is probably the same as in the underground workings.

The *K* values derived from the groundwater flow model calibration are summarized in Table 4-2. Figure 4-10 shows that the simulated horizontal *K* values of different geologic units are within the ranges of the estimated *K* values and literature values.

5.0 PREDICTIVE SIMULATIONS

The predictive numerical simulations were conducted to assess the potential inflows to the mine workings, the effect on nearby domestic wells, and the potential effects on the creeks in the Mine area during mine development and production between the assumed years of 2020 and 2045 (Year 1 to Year 25), which is the current mine plan. The footprint of the mine workings is shown in Figure 5-1 for every 5 years of the 25-year mining plan.

5.1 PREDICTED INFLOWS TO THE MINE

The simulation of future mining was assumed to start with the initial condition of when the underground mine workings were pumped dry, which would be similar to the hydraulic condition in 1956, when the historical Idaho-Brunswick Mine operation ended. Therefore, the simulated groundwater levels in 1956 were used as the initial condition for the predictive numerical model simulations. The average recharge used in the model calibrations was also assigned in the predictive model simulation. The pumping of existing mine-void water was not simulated with the model for the following reasons:

1. It can be better calculated using the analytical solution (volume/pumping rate = time to deplete current mine water); and
2. The groundwater flow model is only designed to simulate the groundwater flow through porous media based on Darcy's law, not the pipe flow in the mine workings during the dewatering of the flooded mine workings.

Using the calibrated groundwater flow model, Itasca simulated the future mine plan as drain nodes to predict the inflow rates to the future mine workings. The predicted inflow rates in Figure 5-2 suggest the following:

1. Total inflow to the entire Mine will reach a maximum value of approximately 1,100 gpm based on the future mine plan.
2. The stable predicted inflow rate is approximately 900 gpm.

3. The future mining will induce about 200 to 400 gpm of inflow in addition to that encountered during the historical mining operation, when the inflow rate was approximately 700 gpm to the historical Idaho-Brunswick Mine in 1956.

Figure 5-2 shows the instantaneous increase (or spike) of the predicted inflow rates. These "spikes" were the result of a combination of the following reasons:

1. The mining was simulated on a monthly interval instead of an hourly interval. Subsequently, all the drain nodes for the planned mined area of the respective month are numerically "turned on" instantaneously. This will numerically introduce the excessive release of groundwater from storage, which, in reality, would release gradually from the rock over the monthly interval.
2. The grid size of the model mesh, which is larger than the actual workings, may also result in a numerical effect.

The estimated stable flow rate of 900 gpm does not include seasonal increased flows that have been documented by Rise. As such, during the rainy season, total pumping would probably be in excess of 900 gpm, perhaps in the range of 1,400 to 1,500 gpm. This estimate is based on the observation that the rainy season flows would increase by approximately 500 gpm for the historical Idaho-Brunswick Mine. The additional pumping during the rainy season will have little effect on the average long-term predicted water levels, as the excess inflows are due to surface-water runoff and percolation.

5.2 PREDICTED GROUNDWATER DRAWDOWN DUE TO MINING ACTIVITIES

Figure 5-3 shows the simulated drawdown of the water table under the current condition relative to the pre-historical-mining condition. The current condition is defined as the year 2019. As shown in Figure 5-3, because of the presence of the historical mine void, drawdown exists between the 2019 groundwater levels and pre-historical-mining water levels. Therefore, the assessment of the potential incremental effects on the groundwater levels should be relative to the 2019 water level, not the pre-historical-mining water levels.

Figure 5-4 shows the simulated drawdown of the groundwater levels by the end of future mining relative to the 2019 water levels. As shown in the figure, the drawdowns of the water table are generally within the mineral rights boundary. This is due to the low-*K* rocks where the deep mining will occur. One will note in this figure and in subsequent figures that the drawdown isopleths are contoured to 1-, 5-, and 10-ft intervals. The predicted contours are based upon the numerical groundwater flow model and the assumptions inherent in the model. Actual, in-field measured water levels may be different from the predicted water levels due to heterogeneities in the hydrogeologic system. The 10-ft drawdown isopleth has been widely used to predict a general area of hydrogeologic impact from mine dewatering and to recognize the uncertainties of groundwater flow modeling. The model is not designed to simulate seasonal or annual changes resulting from variations in groundwater recharge associated with variations in precipitation and groundwater recharge that would occur over the model simulation period. In addition, in many areas within the study area, changes in groundwater levels of less than 10 ft can be difficult to distinguish from natural seasonal and annual fluctuations in groundwater levels.

Figures 5-5 and 5-6 show the 10-ft and 5-ft drawdown extents, respectively, 10 years and 25 years after mining began relative to the 2019 water levels. Both figures illustrate that the extents of the 5-ft and 10-ft drawdown do not expand noticeably as the mining progresses. Again, this is mainly due to the low-*K* rocks where deep mining will occur.

5.3 PREDICTED EFFECTS TO CREEKS NEAR THE MINE DUE TO MINING ACTIVITIES

The mining activities may lower the water table and may reduce the groundwater discharge to surface-water features such as creeks near the Mine. Figure 5-7 shows the predicted baseflow rates at the South Fork of Wolf Creek and Wolf Creek over the life of the mine (LOM). As shown in Figure 5-7, the baseflow rate in the South Fork of Wolf Creek is predicted to reduce by approximately 0.1 cfs at the end of future mining from the simulated current condition of 0.94 cfs (as of 2019). The baseflow in Wolf Creek is predicted to reduce by 0.75 cfs at the end of mining from the simulated flow rate of 21.9 cfs for the year 2019.

5.4 SENSITIVITY ANALYSES

Itasca conducted the following sensitivity analyses to assess the key parameters that would affect the inflow rates:

1. Scenario 1 – Increase the *K* values of the transition zones by 5 times;
2. Scenario 2 – Increase the *K* values of the faults (6-3 and Morehouse) by one order of magnitude (10 times);
3. Scenario 3 – Exclude the faults (6-3 and Morehouse) in the model;
4. Scenario 4 – Increase the recharge rate by 50% (18 inches per year);
5. Scenario 5 – Decrease the recharge rate by 50% (6 inches per year); and
6. Scenario 6 – Extend the planned mining for an additional 40 years to mine additional ore.

Figure 5-8 shows the predicted potential inflow rates for Scenarios 1 through 5 in comparison with the Base-Case Scenario depicted in Figure 5-2. Figure 5-9 shows the extent of the 5-ft drawdown contour lines relative to the Base-Case Scenario for Scenarios 1 through 5. The predicted baseflow rates for the South Fork of Wolf Creek and Wolf Creek at the end of mining are summarized in Table 5-1. The following observations can be made from these two figures and Table 5-1:

1. In Scenario 1, the predicted stable total groundwater inflow to the mine workings in the time period of years 20 to 25 would be approximately 970 gpm, which is approximately 8% higher than the predicted 900 gpm for the Base-Case Scenario. Therefore, the predicted inflow rate is not very sensitive to the *K* value of the transition zones because the mining occurs in the low-*K* rock that is approximately 2,000 ft below the transition zones. The change of 5-foot drawdown extent is within 1, 000 ft relative to the Base-Case Scenario.
2. As shown in Table 5-1, the baseflow rate in the South Fork of Wolf Creek is predicted to increase by approximately 0.1 cfs (for Scenario 1) at the end of mining compared with the Base Case. The baseflow in Wolf Creek increases by approximately 0.5 cfs. Scenario 2 shows that increasing *K* values of the two faults by 10 times will increase the stable inflow rate to approximately 1,100 gpm in the time period of 20 to 25 years, which is approximately 20% higher than the inflow rate of the Base-Case Scenario. It should be noted that the lateral extents of the faults are limited to the mining area in the model. If the faults were extended through the entire model domain, the simulated inflow rates would be more sensitive to the *K* values of the faults than those presented in Figure 5-8. However, past mining and

exploration operations did not encounter permeable faults. Similar changes of the 5-ft drawdown contour extent to those of Scenario 1 are observed for this scenario.

For baseflows, both Wolf Creek and the South Fork of Wolf Creek have the same value as the Base Case, which are calibrated values for baseflows in the two streams, indicating that the *K* values of the faults have no impact on baseflows.

3. Scenario 3 shows that the simulated inflow rate will increase by approximately 6% to approximately 960 gpm in the 20- to 25-year time period without the inclusion of the less permeable faults. Figure 5-9 shows the effect of the exclusion of the faults on the extent of the 5-ft drawdown isopleth. The isopleth is within 800 ft of the Base-Case Scenario.

   The simulated baseflows for Wolf Creek and the South Fork of Wolf Creek are unchanged from the Base Case.

4. Scenario 4 shows that the simulated groundwater inflows to the mine workings will increase by approximately 3% to 925 gpm if the recharge rate in the model domain is increased by 50%. The extent of the 5-ft drawdown is much smaller than in the Base-Case Scenario by as much as 4,000 ft. The relatively low *K* of the deep bedrock limits the downward flow of water; recharge mainly affects the shallow groundwater table. The increase of recharge rate compensates for the drawdown of the water table due to the dewatering of the Mine and thus leads to smaller drawdown areas.

   With the higher recharge rate, the simulated baseflows of Wolf Creek and the South Fork of Wolf Creek increased by 9.5 cfs (45% increase) and 0.4 cfs (50% increase), respectively, over the calibrated Base Case.

5. Scenario 5 shows that the simulated groundwater inflows to the mine workings will decrease by approximately 3% to 870 gpm if the recharge rate in the model domain is decreased by 50%. The extent of the 5-ft drawdown isopleth is larger than in the Base-Case Scenario, as decreased recharge impacts the shallow water-bearing zones more than the deep zone. The 5-ft drawdown isopleth is generally still within the mineral-rights boundary.

   The simulated baseflows of Wolf Creek and the South Fork of Wolf Creek were decreased by 9.7 cfs (46% decrease) and 0.4 cfs (50% decrease), respectively, with the lower recharge rate used from the calibrated Base Case.

The inflows and drawdowns for Scenario 6 were simulated for the potential mine expansion. In Scenario 6, the groundwater flow model simulated an additional 40 years of mining, which accounts for the expansion of the mine workings. The additional mine plan is shown as “Potential Expansion of the Future Mine Plan” in Figure 5-10. The expansions in Scenario 6 would represent a major discovery of parallel veins, similar to those mined historically in the Brunswick Mine, within the known mineralized system. These expansions are modeled to depth below the Idaho and Brunswick Mines and below the "Mitchell Crosscut," which extends past the main mine workings to the north on the 1,000-ft level.

The model simulated the additional mine plan with additional drain nodes in the mine plan area. These drain nodes were "turned on" gradually from Year 26 to Year 65 on a monthly basis from the bottom to the top. As shown in Figure 5-11, the predicted stable groundwater inflow rates to the mine workings increased to approximately 1,200 gpm and then decreased to approximately 1,000 gpm at the end of new mining (Year 65) from 900 gpm at the end of the original mine plan (Year 25). Figure 5-11 shows that the inflow rate reached as high as 1,600 gpm. The "numerical spike" in predicted groundwater inflow rate (from 1,000 gpm to 1,600 gpm within a month) to the Mine is due to the artifact of the release of groundwater storage from thick model layers that represent the additional mining zone. Because the initial model grid discretization did not anticipate the simulation of the deep mining interval of the potential future mine expansion, whose bottom elevation (approximately -3,154 ft amsl) is more than 900 ft lower than the lowest elevation of the original mine plan in the Base-Case Scenario, the numerical release of groundwater storage from the thick model layers is greater than what would probably occur in the smaller mine workings. Therefore, the numerical spike of the inflow rate related to the thick model layers will not occur under field conditions. As also shown in Figure 5-11, the predicted inflow rate decreases from Year 50 to the end of mine life mostly due to the depletion of groundwater storage. The predicted inflow at the end of potential future mining is likely the stable groundwater inflow rate to the mine workings. Hence, the potential expansion of the mine plan increases the stable inflow rate by approximately 12% compared to the Base-Case Scenario. Itasca judged that the current model discretization is adequate for the sensitivity analysis. However, the model discretization will be refined for the updated mine plan in the future if the deep mining as simulated in this sensitivity analysis occurs.

As shown in Figure 5-12, the 5-ft drawdown contour extent of Scenario 6 at the end of potential additional mining (to Year 65) relative to the 2019 water level expands less than 500 ft from that of the Base-Case Scenario. The drawdown contour of the Base-Case Scenario is at the end of the original planned future mining (Year 25) relative to the 2019 water level. The comparison of drawdown contours between Scenario 6 and the Base-Case Scenario suggests that the added potential mining will not lead to large incremental drawdowns as the mining progresses because the mining activities occur in deep, low-*K* rocks.

Under Scenario 6, the predicted baseflows for both Wolf Creek and the South Fork of Wolf Creek have the same values as in the Base Case, which is due to the minor changes of the phreatic surface.

6.0 CONCLUSIONS AND RECOMMENDATIONS

Based on the data analyses, existing data, and groundwater flow model, Itasca provides the following conclusions:

1. The groundwater flow model is reasonably calibrated to the measured inflow rates to the historical Idaho-Brunswick Mine, groundwater levels in the flooded Union Hill Mine and historical Idaho-Brunswick Mine, and baseflow rates at the South Fork of Wolf Creek and Wolf Creek. In addition, the calibrated model reasonably simulates groundwater levels in a variety of domestic wells, as well as the vertical hydraulic gradient from the shallow water-bearing zone to the historical mines.
2. The groundwater flow model predicts that the maximum and the stable mine-inflow rates are approximately 1,100 and 900 gpm, respectively, based on the future mine plan that Rise provided, which is approximately 200 to 400 gpm in addition to the inflow rate of approximately 700 gpm to the historical Idaho-Brunswick Mine as measured in 1956. These predicted inflow rates are annual average rates.
3. The groundwater drawdown due to dewatering for future mining is largely confined to within the mineral rights boundary.
4. The reductions of the average baseflow rates in the South Fork of Wolf Creek and Wolf Creek are approximately 0.1 cubic feet per second (cfs) and 0.75 cfs, respectively, at the end of mining compared to the 2019 average baseflows.
5. The predicted inflow rates and baseflows of nearby creeks are not sensitive to the *K* values of the transition zone and faults. The transition zone is a zone that appears to have increased *K* values due to weathering and stress release but not as high of *K* as the shallower bedrock and alluvial units. The shallow units have increased *K* due to stress release as a result of erosion and weathering.
6. The recharge rate applied to the model has limited effect on the predicted inflow rates to future mining. But the recharge rate affects baseflows of the South Fork of Wolf Creek and Wolf Creek and the extents of groundwater drawdowns. Higher recharge would lead to greater baseflows within the two creeks and a smaller area of drawdown. If recharge is reduced, there is a reduction in baseflows in the two creeks and an expansion in the extents of groundwater drawdowns.
7. The predicted inflow rates, groundwater drawdown, and baseflows of nearby creeks are not sensitive to significant expansion of mining within the known mineralized system at depths greater than approximately 1,000 ft bgs. This is due to the fact that the mining will occur in low-*K* rocks that limit the amount of water to the mine.

8. The model is constructed based on the available data. Because of the fractured nature of the intermediate and deeper geologic units, one may argue that unknown fractures may impact the results of the modeling. Fractures or geologic discontinuities decrease with depth due to the weight of overlying geologic materials. The mining will occur in the deeper geologic units where the fractures, if present, are closed or have smaller apertures, which will not transmit significant quantities of water. The scenarios addressed in the modeling cover a wide range of probable situations that may be encountered and the potential impacts to groundwater levels and surface-water baseflows. As discussed below, Itasca recommends a rigorous groundwater monitoring program to assess how the hydrogeologic system responds to mining, whether the measured results are within those modeled under the various scenarios.

Itasca has the following recommendations:

1. Rise should plan to collect hydrogeologic data according to the project stages. The key data are groundwater levels with depth and flow rates pumped from the Mine.
2. Prior to the dewatering of the Mine, monitoring wells and piezometers need to be installed for the measurement of water levels. The critical reason for the installation of piezometers and monitoring wells prior to dewatering of the Mine is to measure the hydraulic responses over time at these monitoring points. As the Mine pumps groundwater from the mine workings, groundwater levels will decline in the surrounding rock, and the measurements of water levels in the wells/piezometers will document the groundwater-level changes.
3. The water-level data can be used to update the groundwater flow model to improve the confidence of the model.
4. It is expected that the actual mining areas will change from the modeled mining areas due to vein geometry and discoveries, which will only be known after extensive underground exploration is completed in the future. Itasca recommends that the groundwater flow model be updated periodically after dewatering commences. Updated modeling would incorporate changes to the long-term mining plan, data from monitoring wells, and measured pumping rates.

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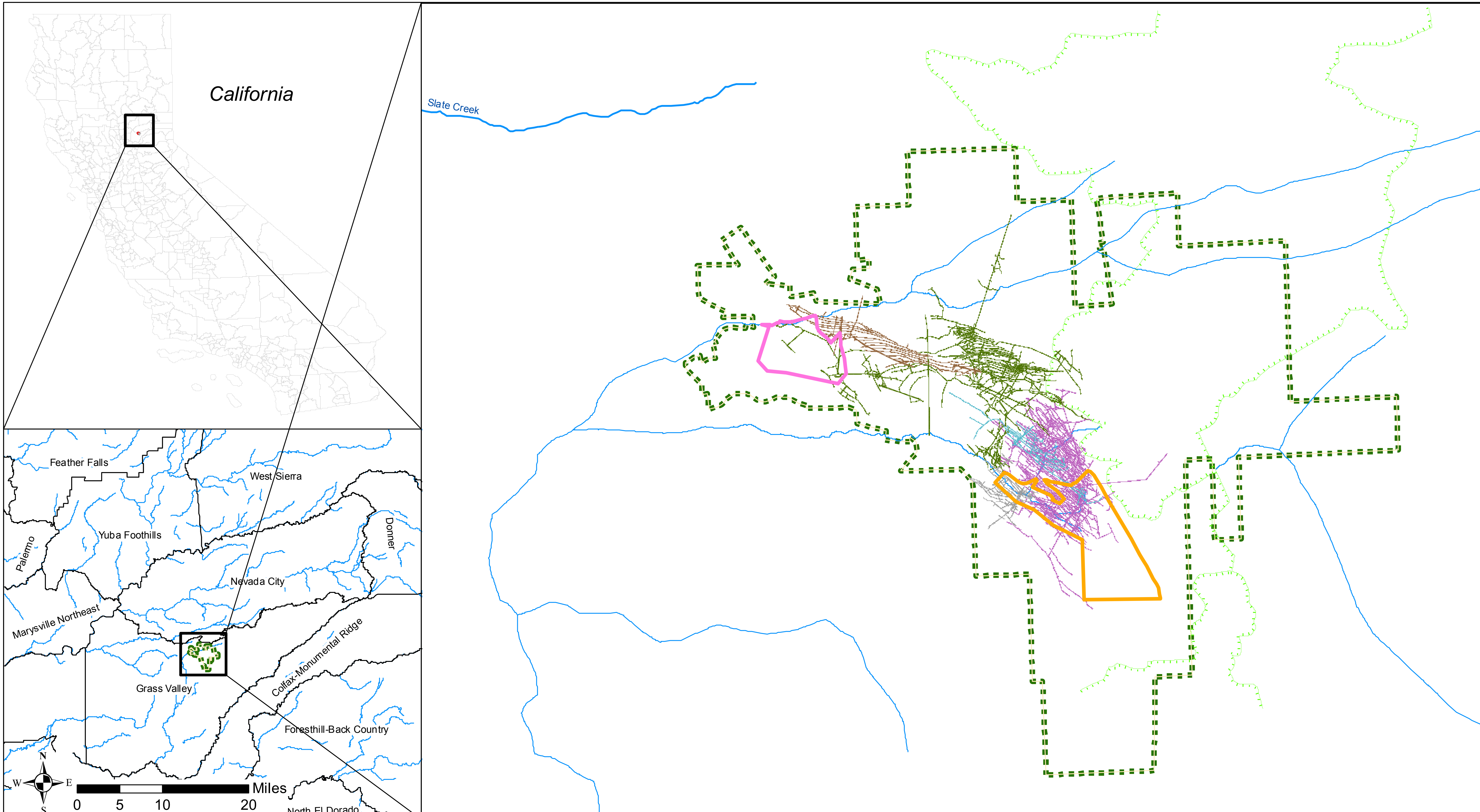

Legend

Other Site Features
- NID Canals
- Creeks
- Mineral Rights Boundary

Historical Mine Workings
- New Brunswick
- New Idaho
- Old Brunswick
- Old Idaho
- Union Hill

Surface Land Boundary
- Brunswick Industrial Site
- Centennial Industrial Site

N

0 2,000 4,000 Feet

PROJECT NO.	4091
BY	DD
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DRAWING NAME	Figure 1 Basemap
DRAWING DATE	Feb. 26, 2020
REVISION DATE	

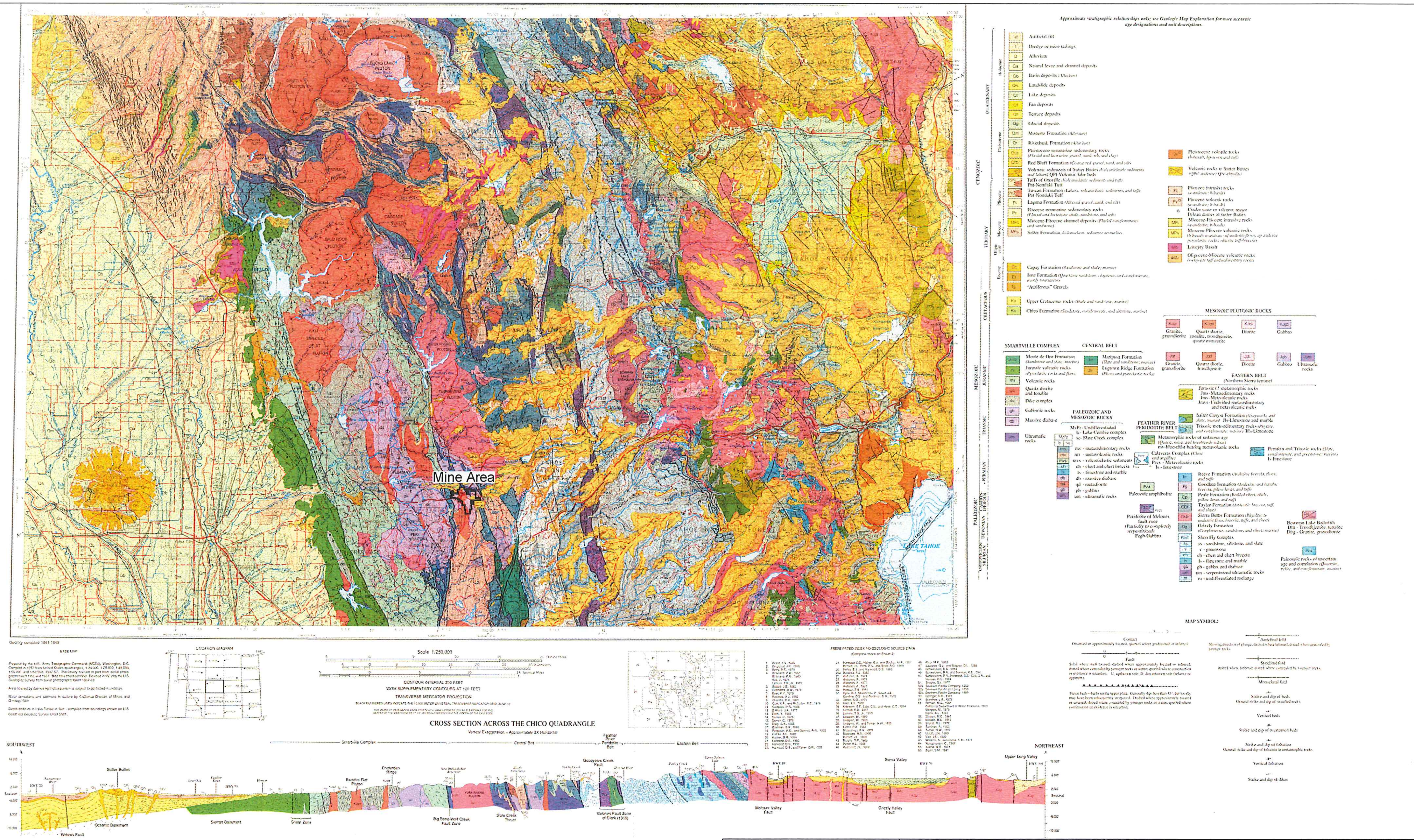
ITASCA Denver, Inc.

Locations of the Historical Mines, Mineral Rights Boundary, and Surface Features

CLIENT: Rise Grass Valley Inc.

FIGURE NO. 1-1

E:\Projects\4091_Rise_grass_valley\Work\mxd\Figures\Figure 1 Basemap.mxd



Source: Saucedo and Wagner (1992)

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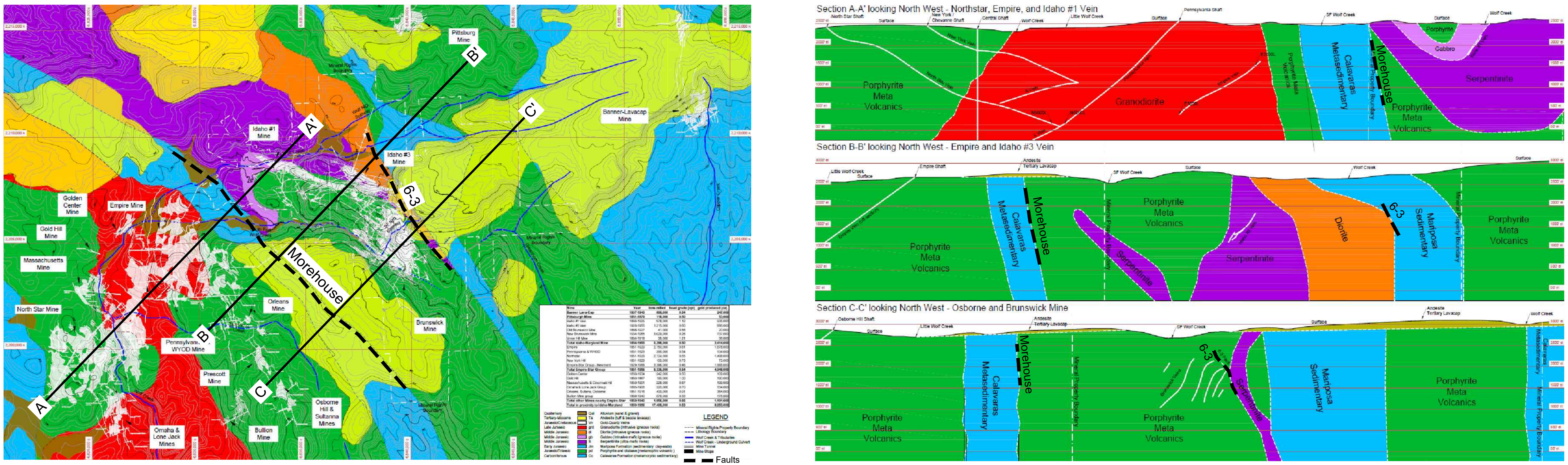
DRAWING DATE	27 FEB 2020
REVISION DATE	

ITASCA™ Denver, Inc.

Regional Surface Geology and Cross Section

CLIENT: Rise Grass Valley Inc.

FIGURE NO. 2-1



NOTE: The locations of the faults were approximately interpolated based on the 3-D geological model (Rise 2019a).

Source: Rise (2019a)

PROJECT NO.	4091-19
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DRAWING DATE	27 FEB 2020
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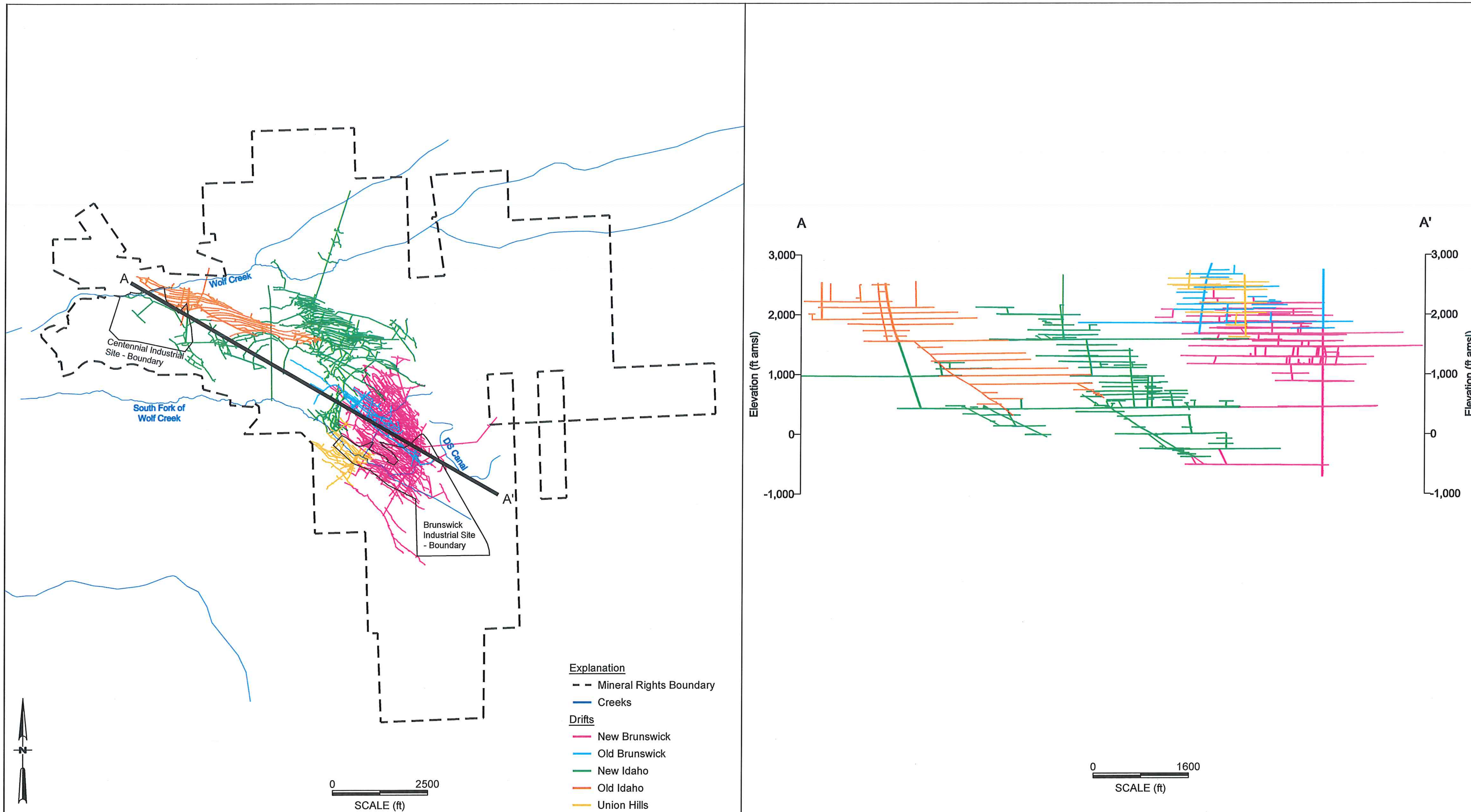
ITASCA™ Denver, Inc.

Geologic Setting at the Idaho-Maryland Mine

CLIENT: Rise Grass Valley Inc.

FIGURE NO. 2-2



PROJECT NO.	4091-19
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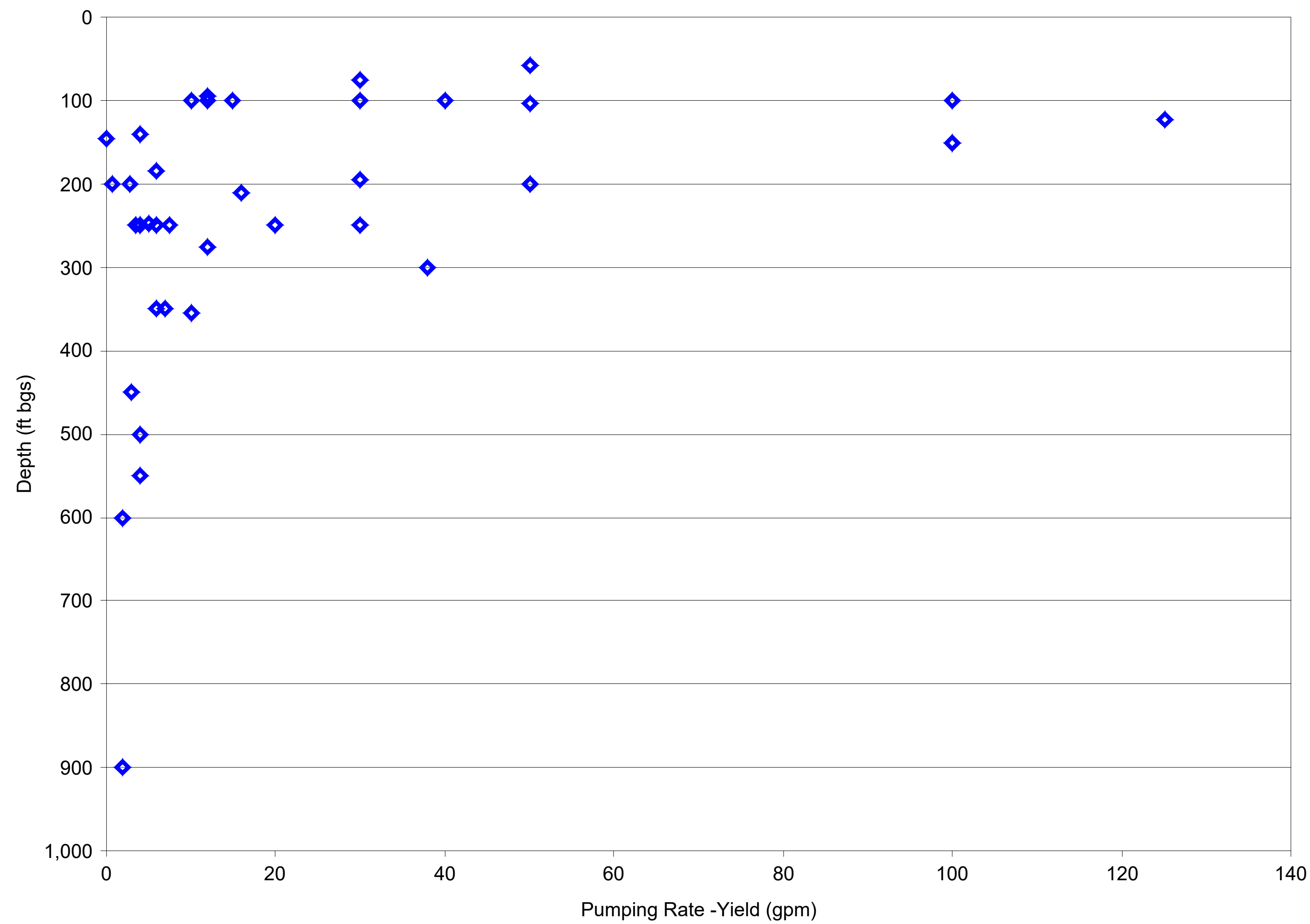
DRAWING NAME	MINES
DRAWING DATE	27 FEB 2020
REVISION DATE	

ITASCA™ Denver, Inc.

Spatial Extents of the Historical Mines

CLIENT: Rise Grass Valley Inc.

FIGURE NO. 2-3



Source: EMKO (2019 pers. comm.)

PROJECT NO.	4091–19
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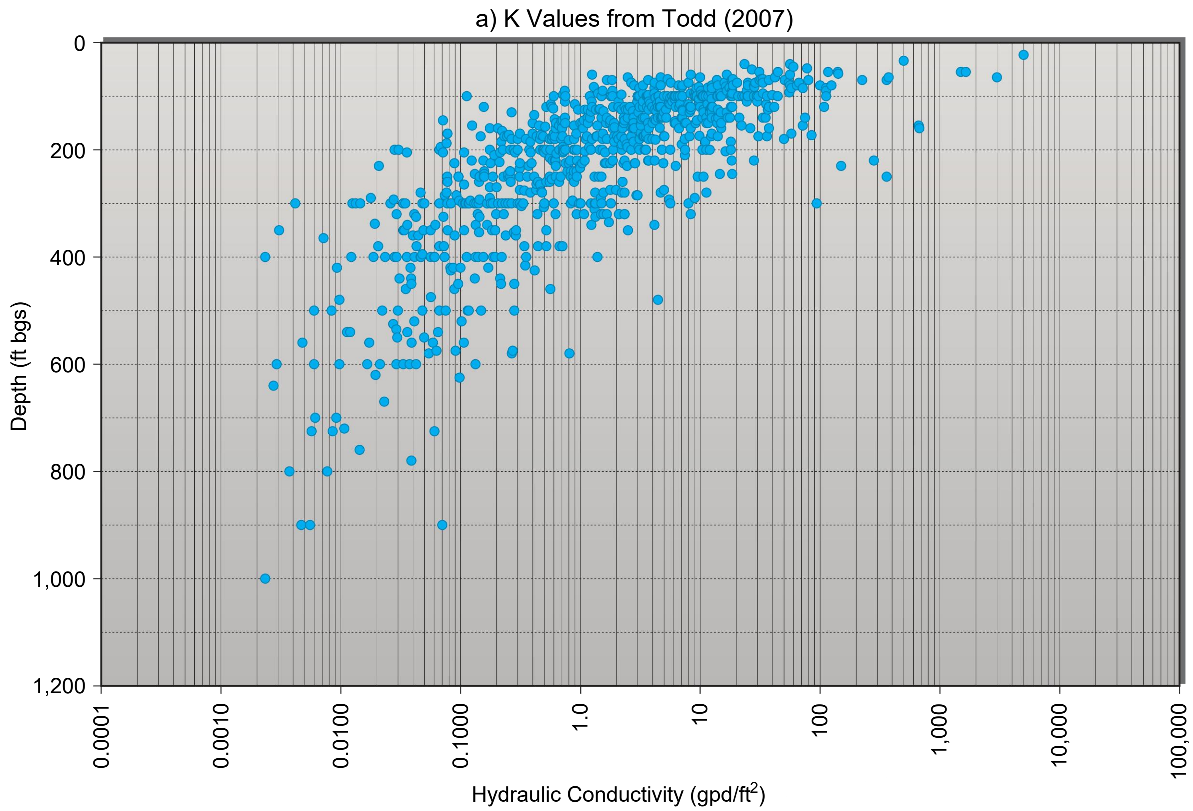
DRAWING NAME	YIELD
DRAWING DATE	27 FEB 2020
REVISION DATE	

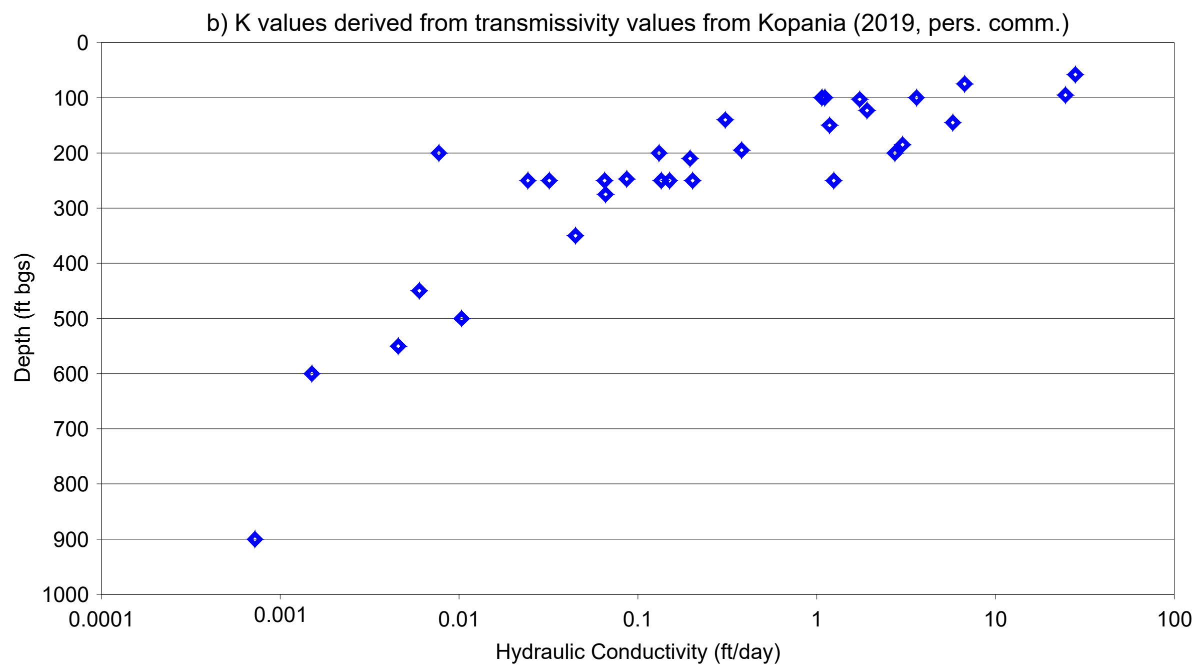
ITASCA™ Denver, Inc.

Well Yield versus Depth of Wells

CLIENT: Rise Grass Valley Inc.

FIGURE NO. 2-4





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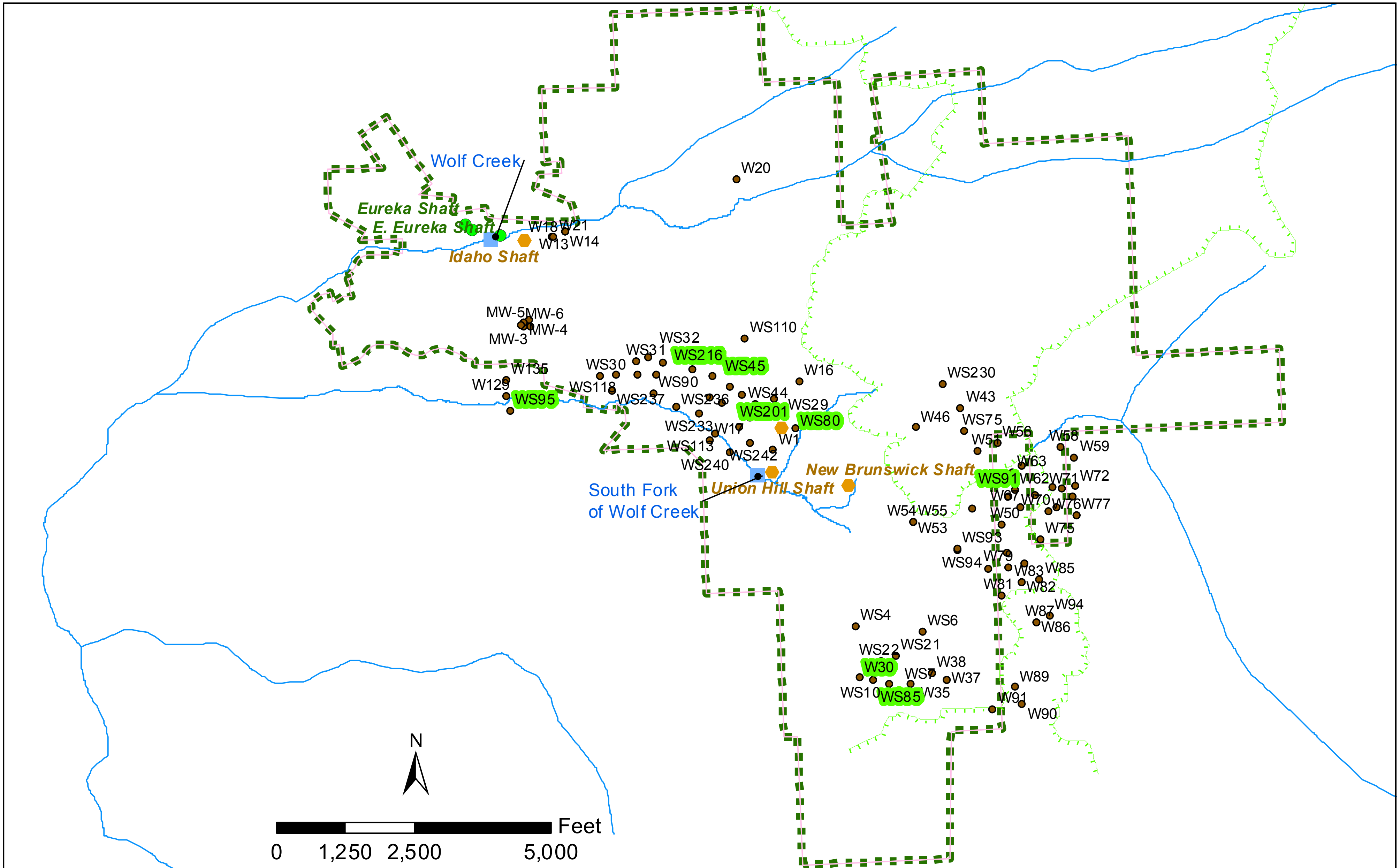
DRAWING NAME	COND
DRAWING DATE	27 FEB 2020
REVISION DATE	

ITASCA™ Denver, Inc.

Estimated Hydraulic Conductivities at Boreholes along the Depth

CLIENT: Rise Grass Valley Inc.

FIGURE NO. 2-5



Legend

- Streamflow Monitoring Location
- Mineral Rights Boundary
- NID Canals
- Creeks
- Drains
- Shafts
- Wells

Note: Highlighted wells are shown in Figure 4-8.

PROJECT NO.	4091
BY	DD
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DRAWN	DD
DRAWING NAME	Figure 2-6 Wells
DRAWING DATE	Mar. 16, 2020
REVISION DATE	

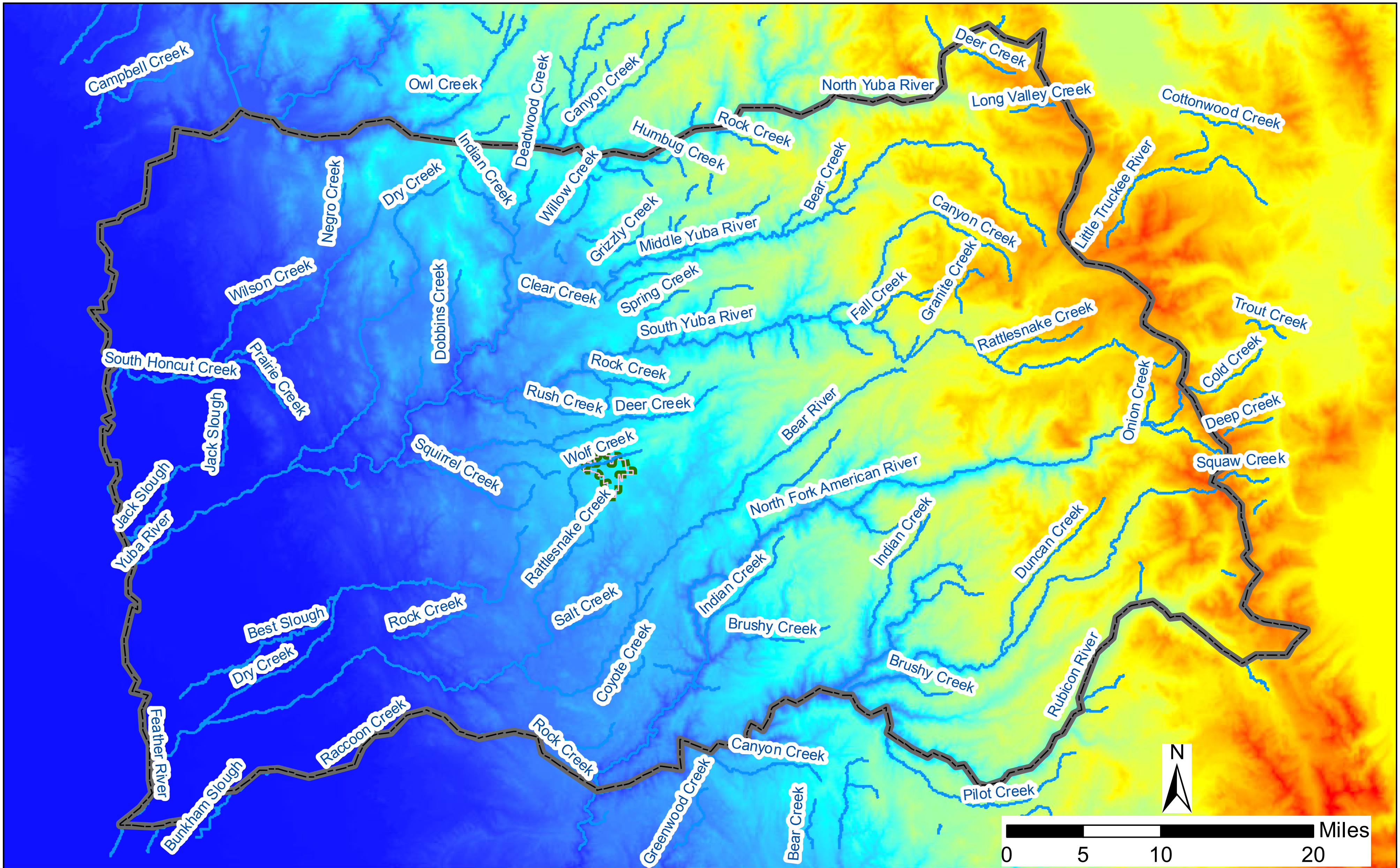
ITASCA Denver, Inc.

Locations of Domestic Wells, Streamflow Monitoring, and Historical Mine Shafts and Drains

CLIENT: Rise Grass Valley Inc.

FIGURE NO. 2-6

E:\Projects\4091_Rise_grass_valley\Work\mxd\Figures\Figure 2-6 Wells-highlight.mxd



Legend

Model Boundary

Mineral Rights Boundary

Elevation (ft amsl)

10,440

-22

PROJECT NO.	4091
BY	DD
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DRAWN	DD
DRAWING NAME	Figure 2-7 Topography
DRAWING DATE	Feb. 10, 2020
REVISION DATE	

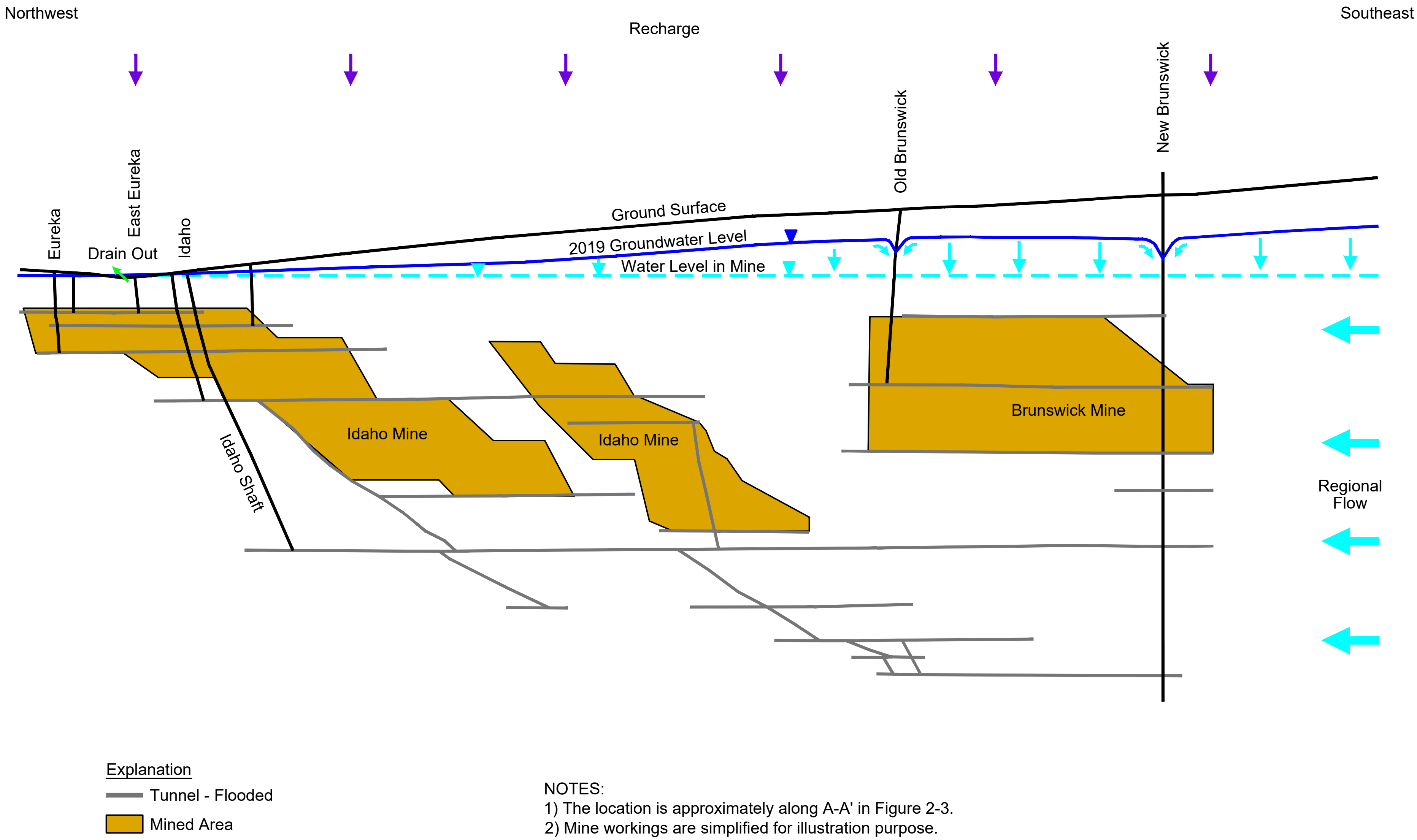
ITASCA Denver, Inc.

Topography and Boundary of Hydrologic Study Area

CLIENT: Rise Grass Valley Inc.

FIGURE NO. 2-7

E:\Projects\4091_Rise_grass_valley\Work\mxd\Figures\Figure 2-7 Topography.mxd



NOTES:
1) The location is approximately along A-A' in Figure 2-3.
2) Mine workings are simplified for illustration purpose.

Modified from Rise (2019b pers. comm.)

PROJECT NO.	4091-19
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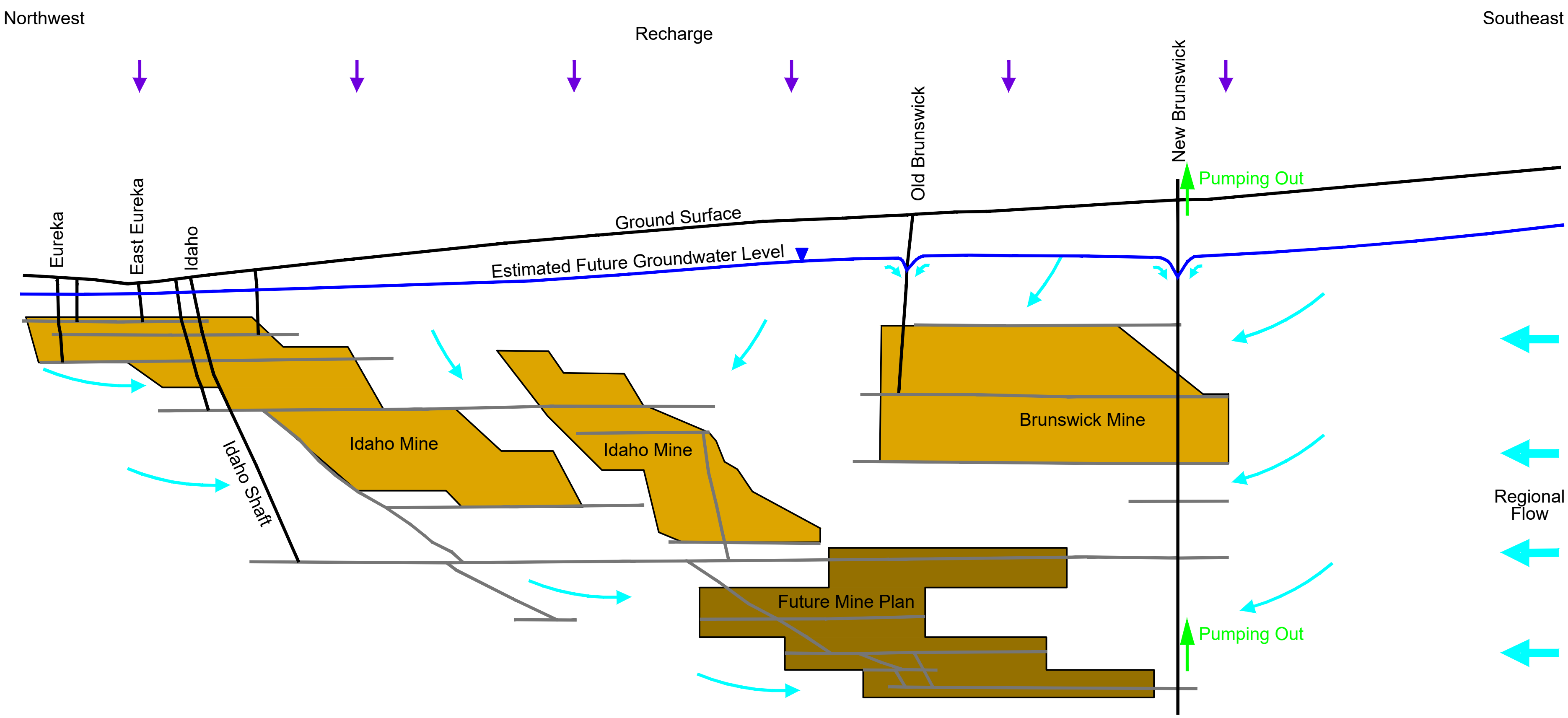
DRAWN	RJN
DRAWING NAME	CONCEPT
DRAWING DATE	27 FEB 2020
REVISION DATE	

ITASCA™ Denver, Inc.

Main Components of the Conceptual Hydrogeologic Model - Current Conditions

CLIENT: Rise Grass Valley Inc.

FIGURE NO. 3-1



Explanation

- Tunnel - Flooded
- Mined Area
- Future Mine Plan

NOTES:
1) The location is approximately along A-A' in Figure 2-3.
2) Mine workings are simplified for illustration purpose.

Modified from Rise (2019b pers. comm.)

PROJECT NO.	4091–19
BY	DD
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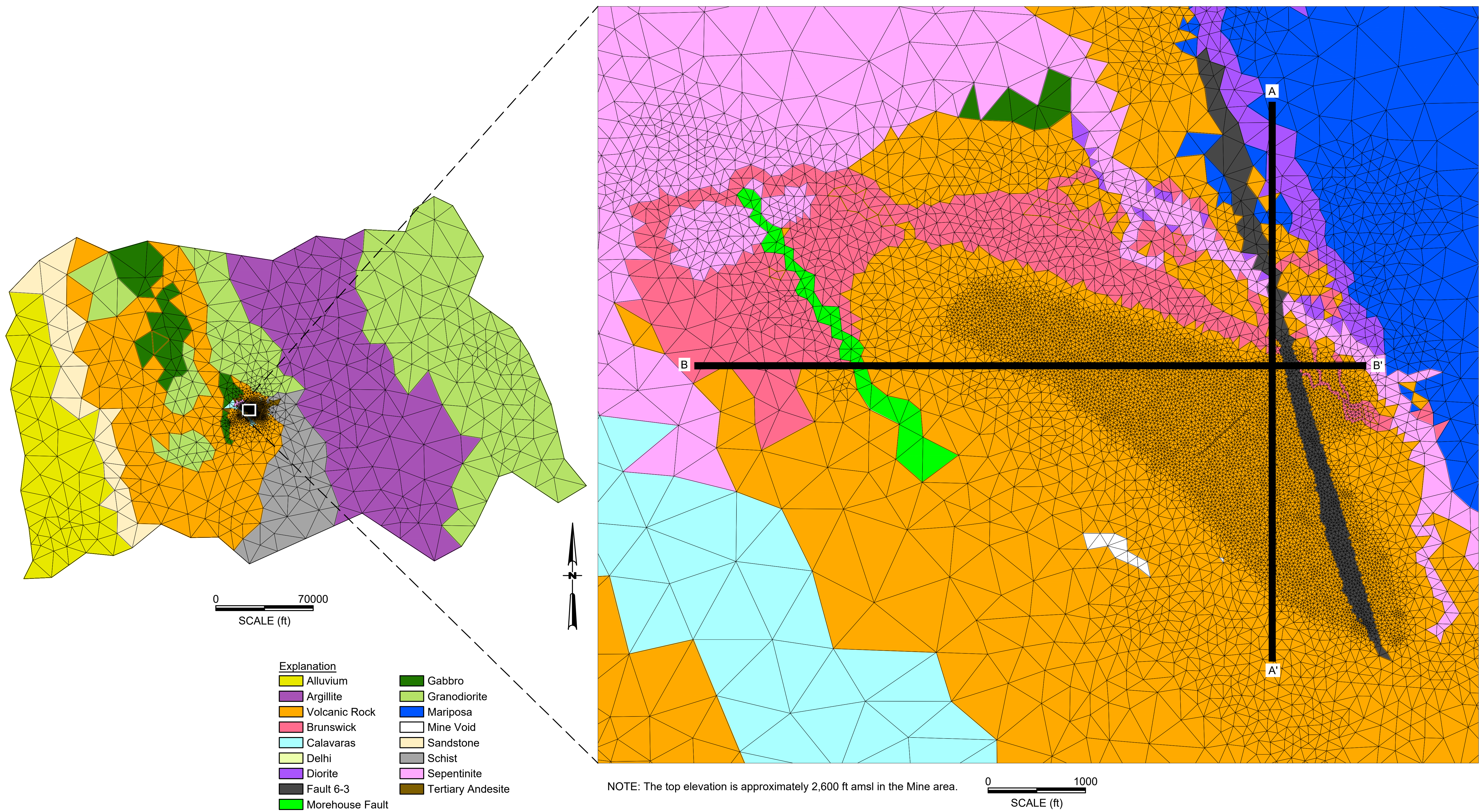
DRAWN	RJN
DRAWING NAME	CONCEPT
DRAWING DATE	27 FEB 2020
REVISION DATE	

ITASCA™ Denver, Inc.

Main Components of the Conceptual Hydrogeologic Model - Future Mining

CLIENT: Rise Grass Valley Inc.

FIGURE NO. 3-2



NOTE: The top elevation is approximately 2,600 ft amsl in the Mine area.

PROJECT NO.	4091-19
BY	DD
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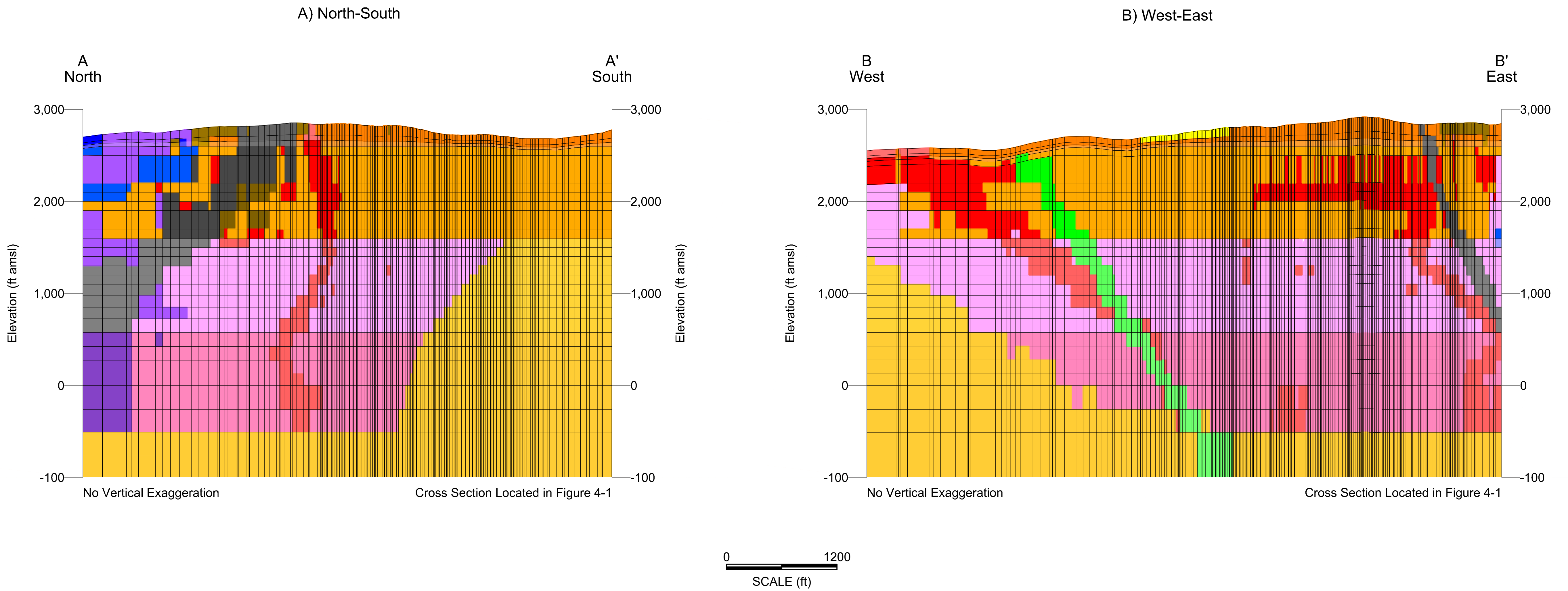
DRAWN	RJN
DRAWING NAME	MODEL
DRAWING DATE	27 FEB 2020
REVISION DATE	

ITASCA™ Denver, Inc.

Model Discretization and Simulated Geologic Units in Model Layer 4

CLIENT: Rise Grass Valley Inc.

FIGURE NO. 4-1



Explanation

Tertiary Andesite	Volcanic Rock	Calavaras	Delhi	Schist	Mariposa	Diorite	Sepentinite	Brunswick	Fault 6-3	Morehouse Fault	River Sediment
Fractured	Fractured	Fractured	Fractured	Fractured	Fractured	Fractured	Fractured	Fractured	Fractured	Transition	
Transition	Transition	Transition	Transition	Transition	Transition	Transition	Transition	Transition	Transition	Top	
Top	Top	Top	Top	Top	Top	Top	Top	Top	Top	Middle	
	Middle	Middle	Middle	Middle	Middle	Middle	Middle	Middle	Middle	Deep	
	Deep	Deep	Deep	Deep		Deep	Deep	Deep	Deep		
	Country Rock			Country Rock							

PROJECT NO.	4091-19
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DRAWN	RJN
DRAWING NAME	XSEC
DRAWING DATE	27 FEB 2020
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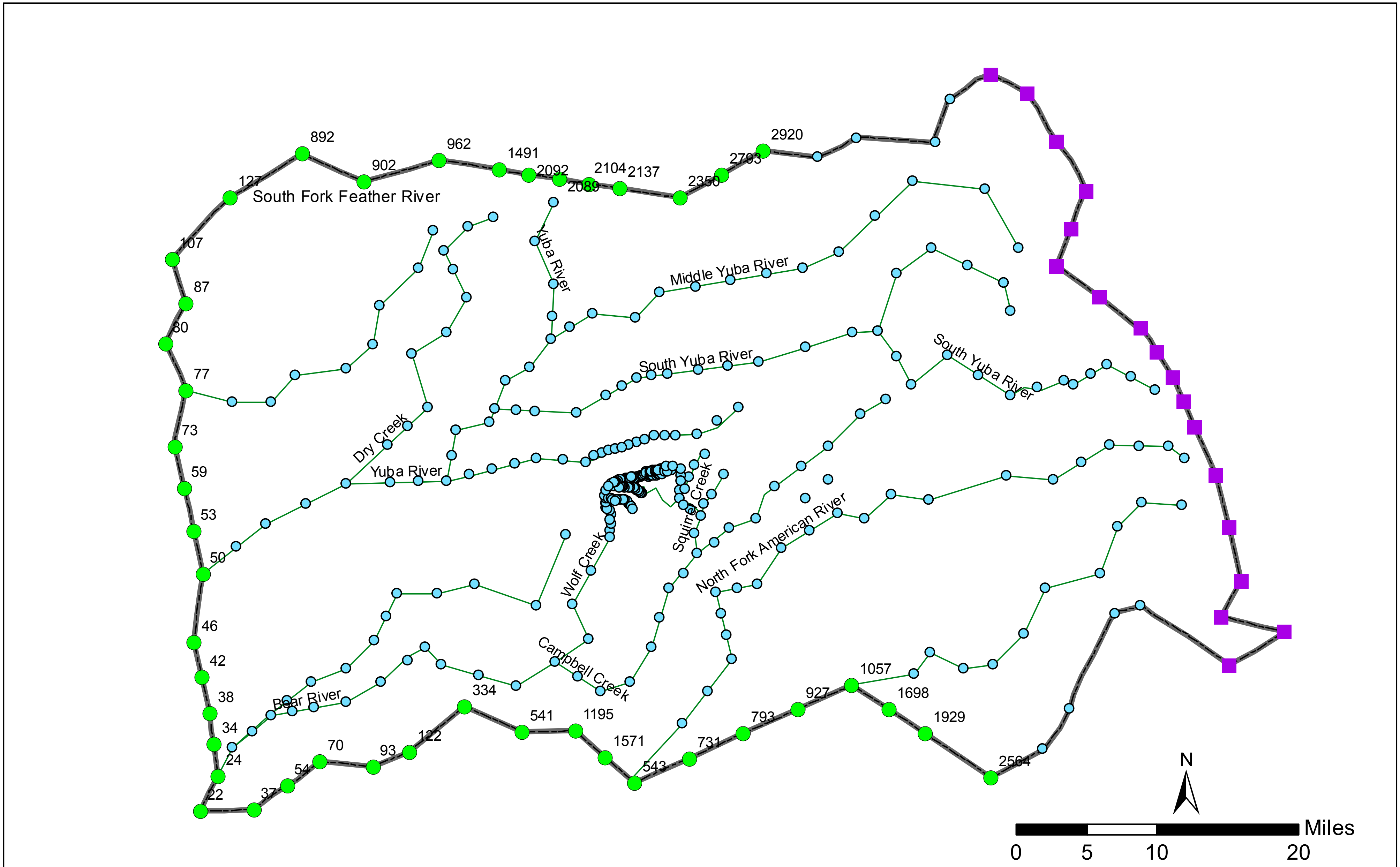
ITASCA™ Denver, Inc.

Simulated Geologic Units in Cross Section

CLIENT: Rise Grass Valley Inc.

FIGURE NO. 4-2



Legend

- No Flow
- Constant Head (ft amsl)
- Simulated Stream
- Model Boundary

PROJECT NO.	4091
BY	DD
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DRAWN	DD
DRAWING NAME	Figure 4-3 Boundary
DRAWING DATE	Feb. 21, 2020
REVISION DATE	

ITASCA Denver, Inc.

Model Boundary Conditions

CLIENT: Rise Grass Valley Inc.

FIGURE NO. 4-3

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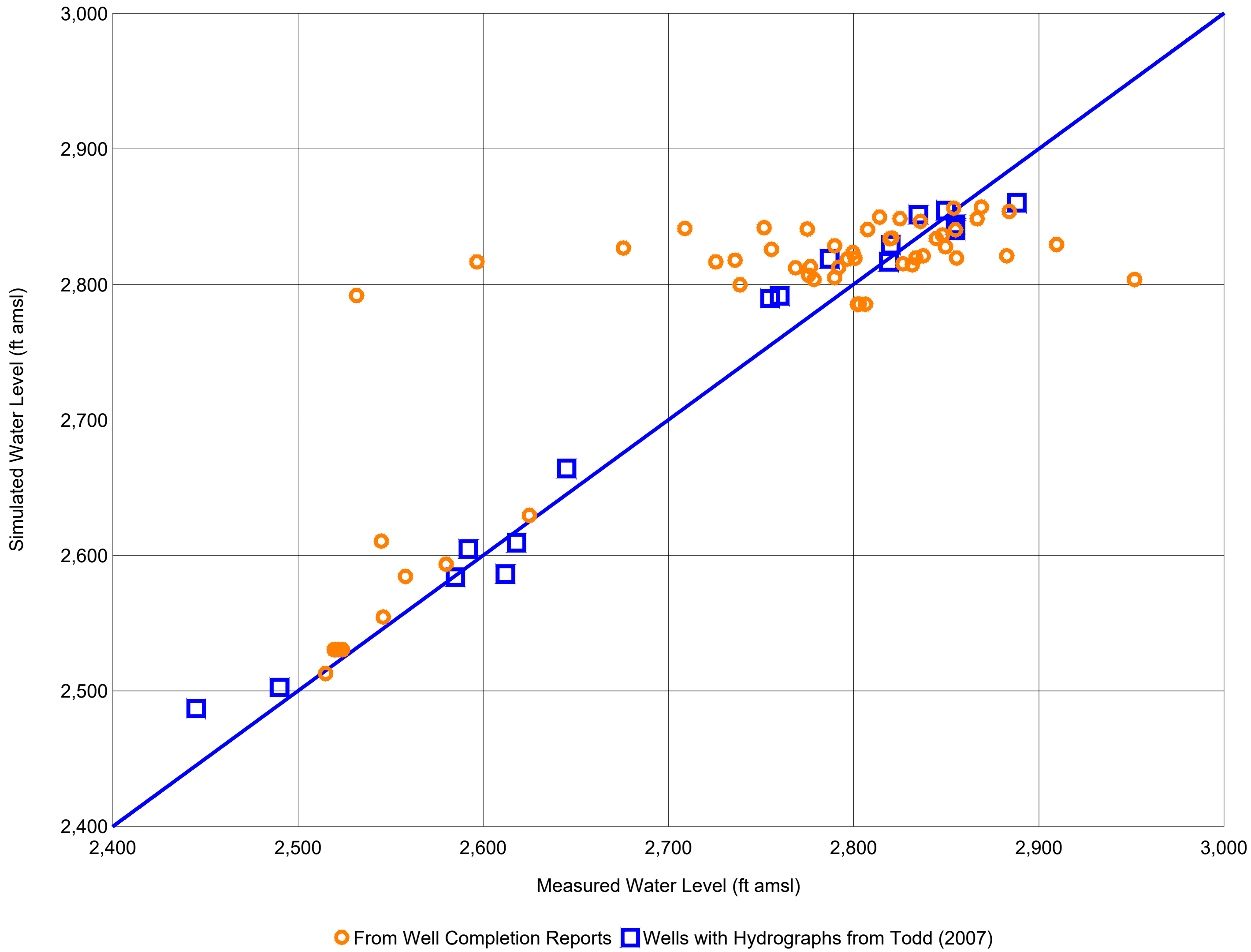

PROJECT NO.	4091–19
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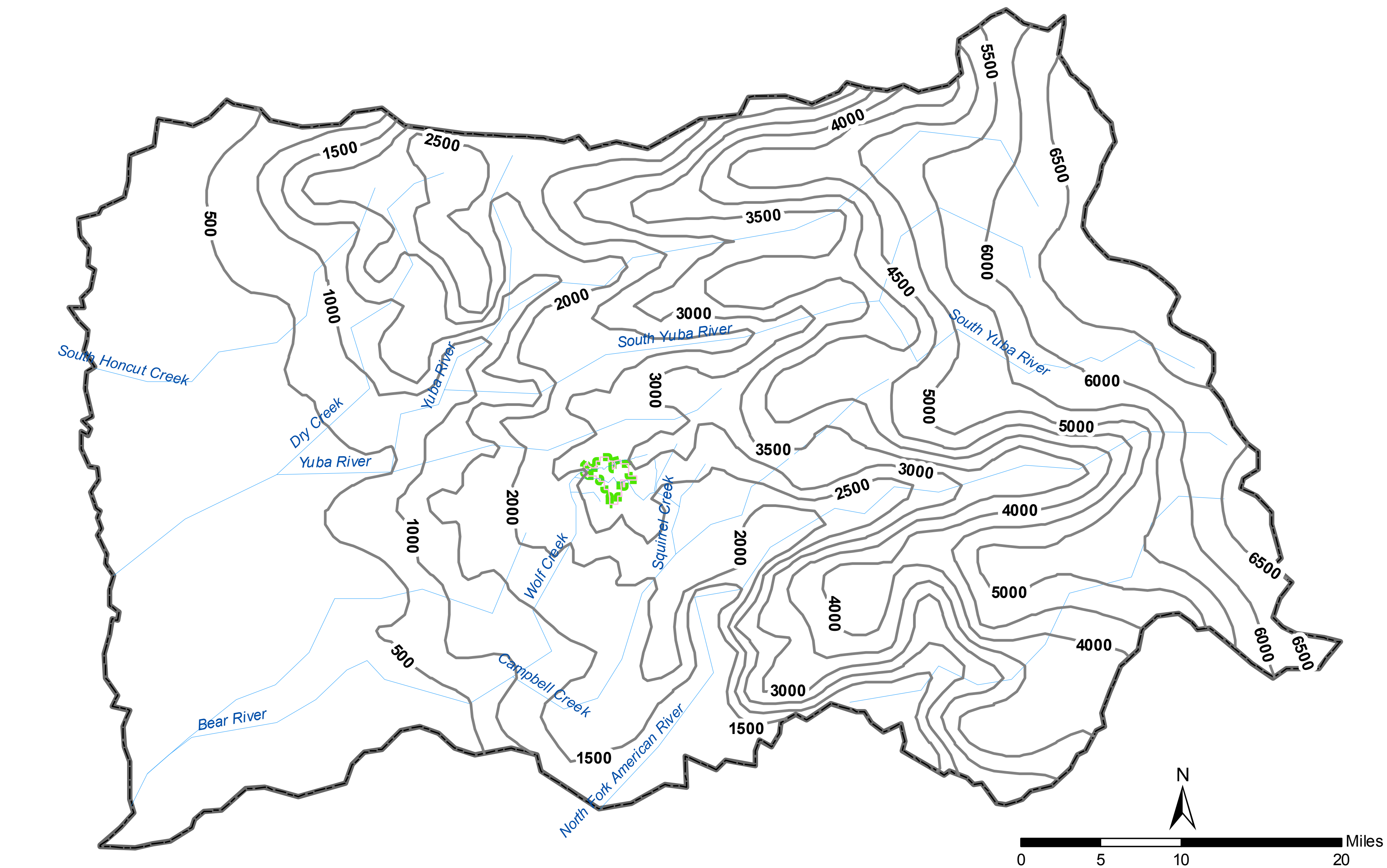
DRAWING NAME	HIST
DRAWING DATE	27 FEB 2020
REVISION DATE	

ITASCA™ Denver, Inc.

Simulated and Measured Groundwater Levels under Pre-Historical-Mining Condition

CLIENT: Rise Grass Valley Inc.

FIGURE NO. 4-4



Legend

Groundwater Contour (ft amsl)

Mineral Rights Boundary

Model Boundary

Simulated Streams

PROJECT NO.	4091
BY	DD
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DRAWN	DD
DRAWING NAME	Figure 4-5 SS Contour
DRAWING DATE	Feb. 28, 2020
REVISION DATE	

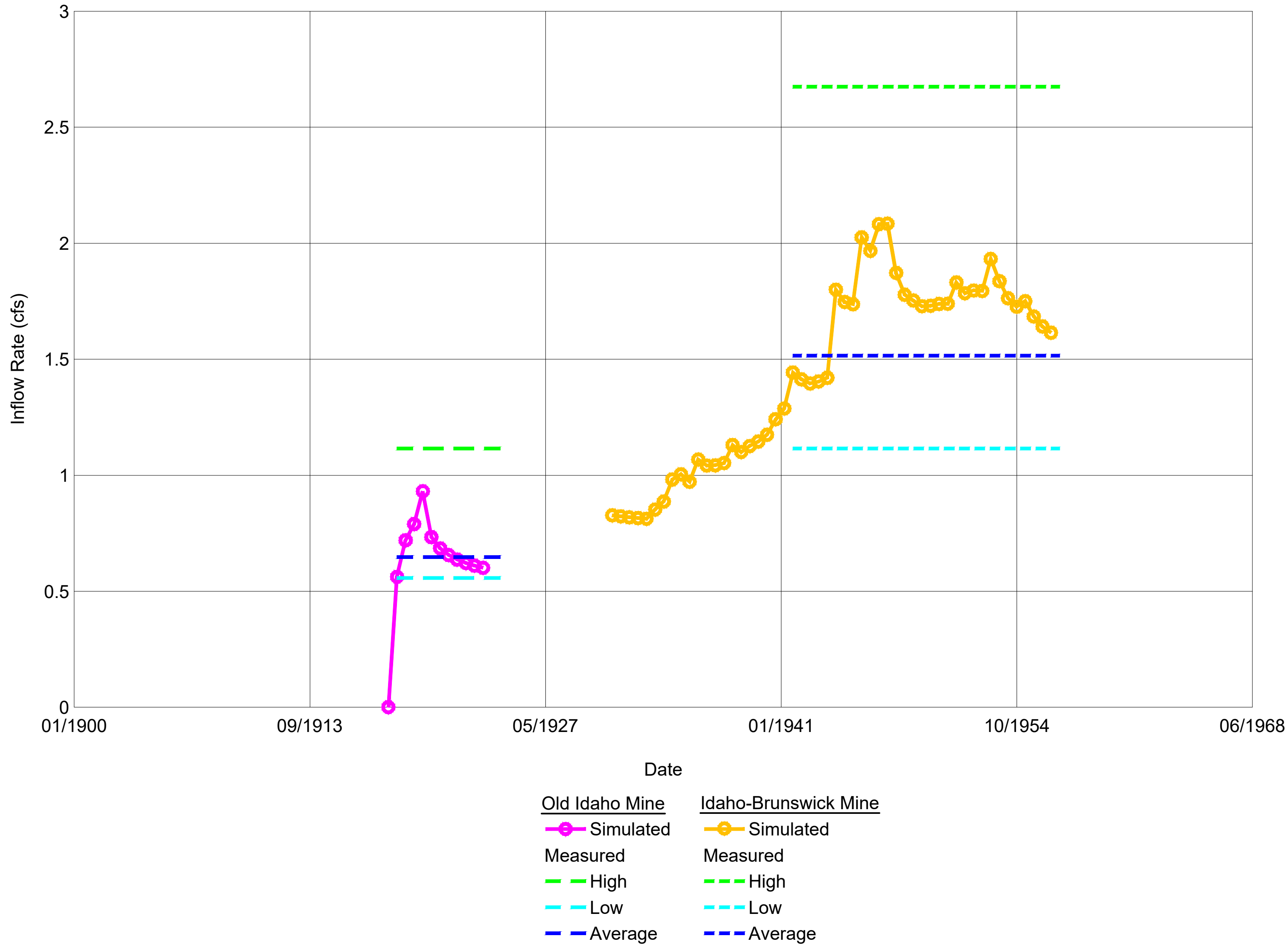
ITASCA Denver, Inc.

Simulated Groundwater Contours under Pre-Historical-Mining Condition

CLIENT: Rise Grass Valley Inc.

FIGURE NO. 4-5

E:\Projects\4091_Rise_grass_valley\Work\mxd\Figures\Figure 4-5 SS Contour.mxd



PROJECT NO.	4091–19
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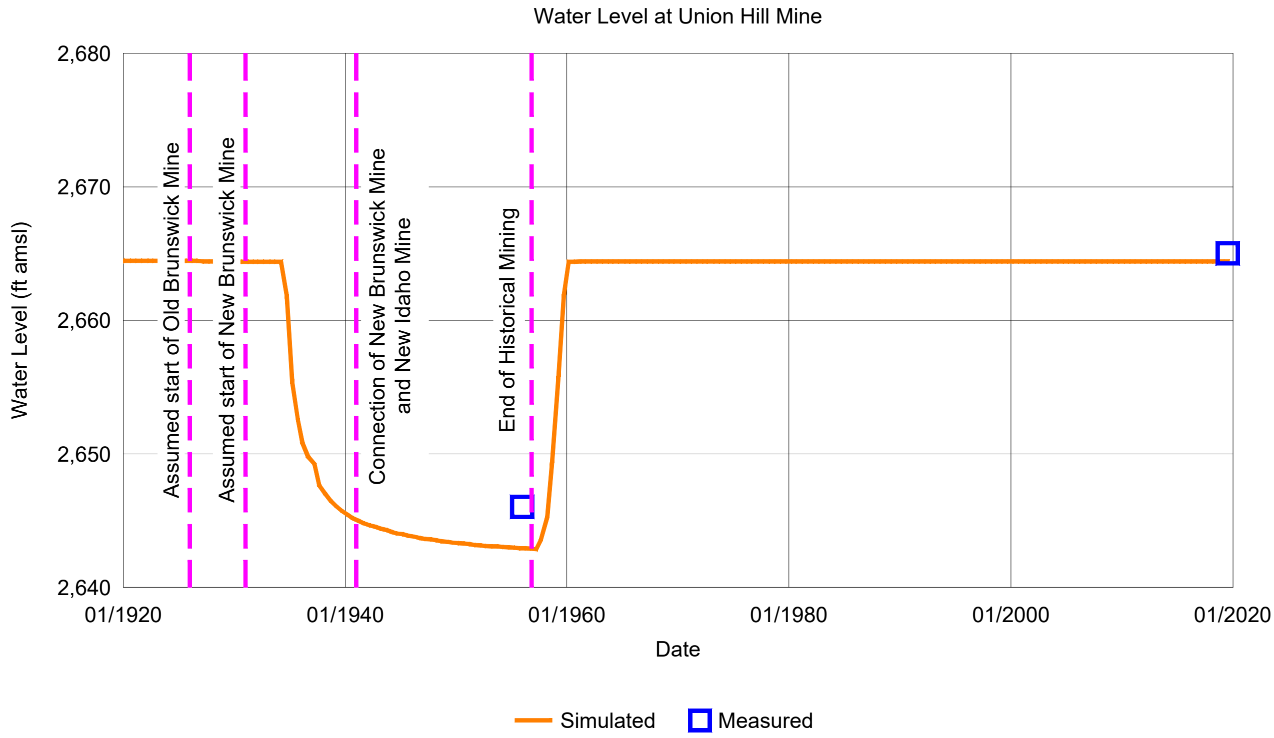
DRAWN	RJN
DRAWING NAME	FLOW
DRAWING DATE	27 FEB 2020
REVISION DATE	

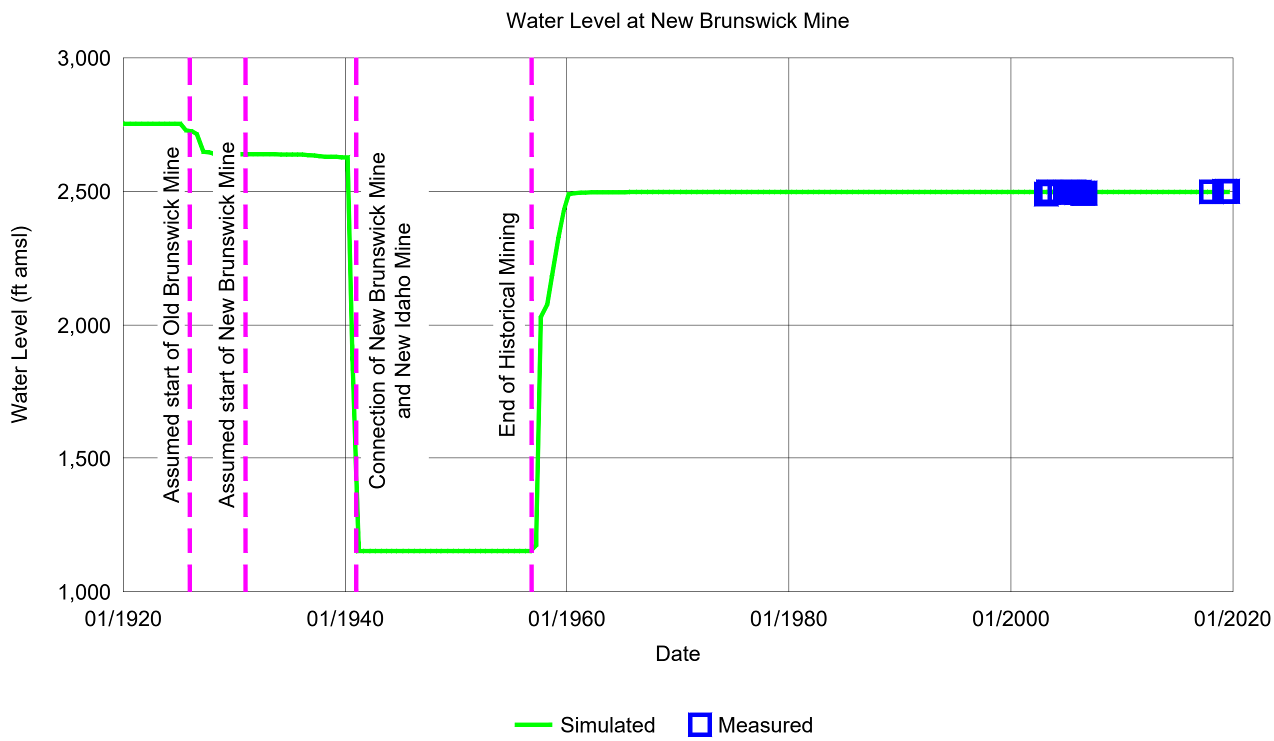
ITASCA™ Denver, Inc.

Simulated and Measured Flow Rates for the Historical Mines

CLIENT: Rise Grass Valley Inc.

FIGURE NO. 4-6





PROJECT NO.	4091-19
BY	DD
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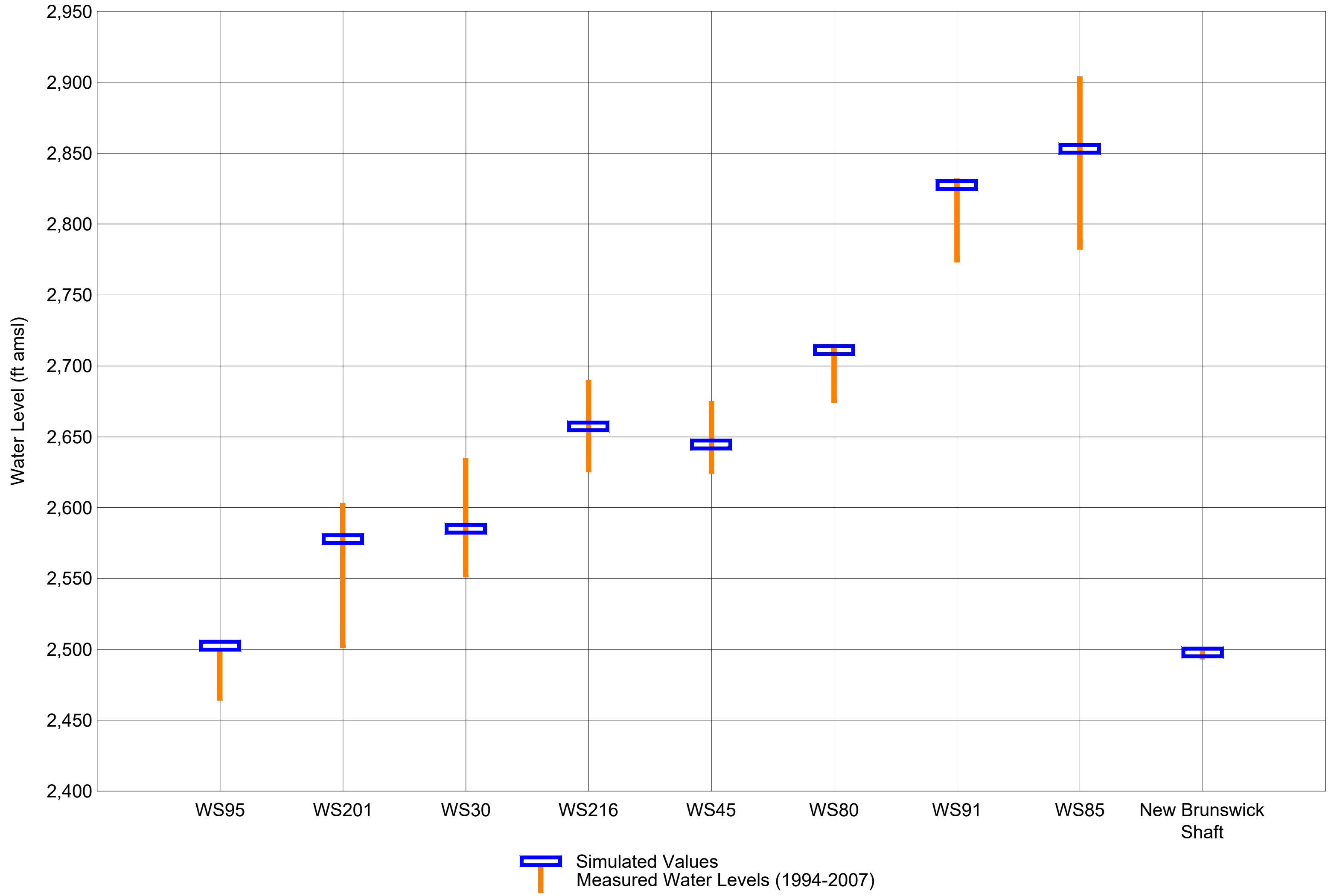
DRAWN	RJN
DRAWING NAME	UNION
DRAWING DATE	27 FEB 2020
REVISION DATE	

ITASCA™ Denver, Inc.

Simulated and Measured Water Levels at the Union Hill Mine and New Brunswick Mine

CLIENT: Rise Grass Valley Inc.

FIGURE NO. 4-7



NOTE:
1) Measured water levels in the New Brunswick Shaft are from 2003-2019.
2) Locations of wells are shown in Figure 2-6.

PROJECT NO.	4091–19
BY	DD
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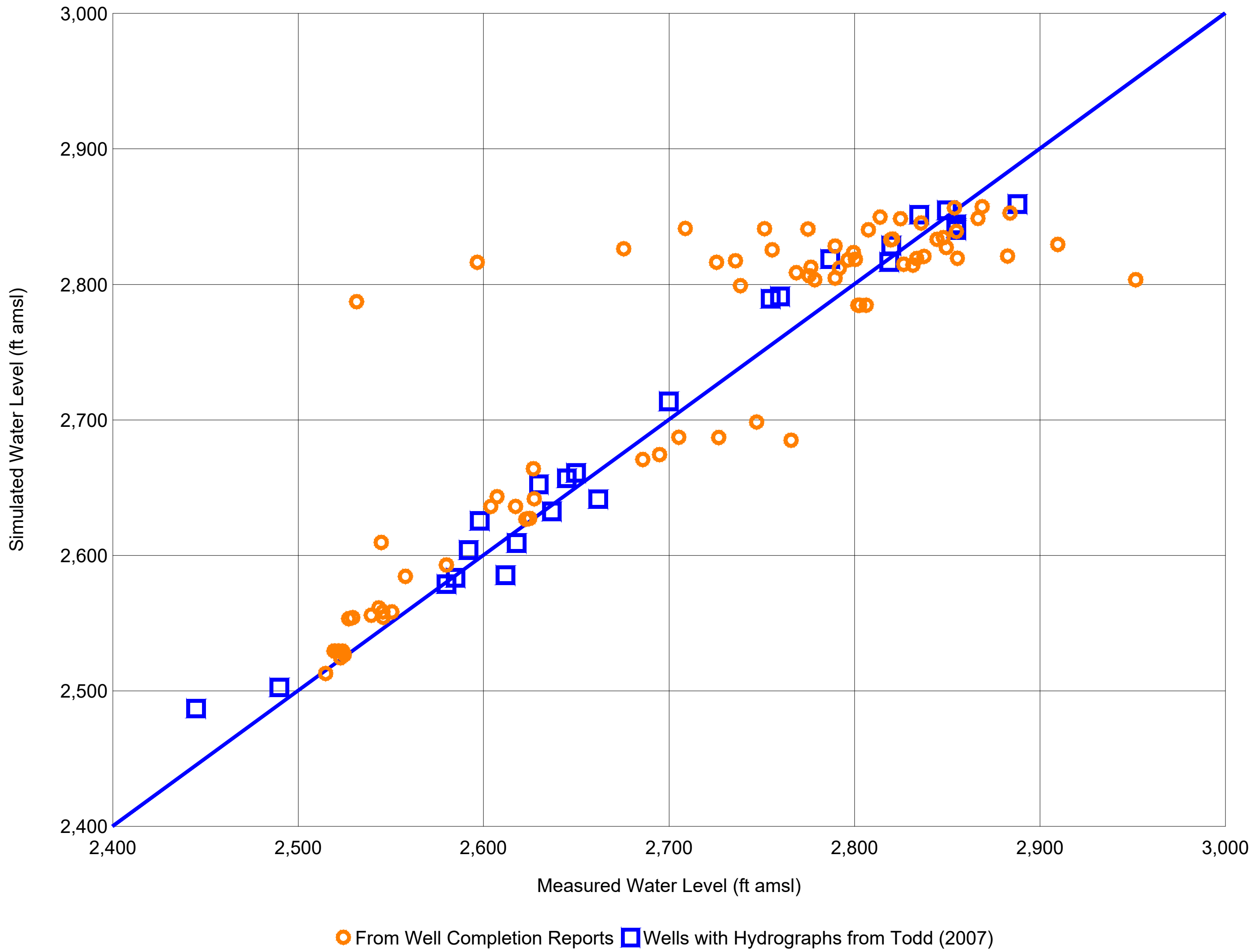
DRAWN	RJN
DRAWING NAME	DOMESTIC
DRAWING DATE	27 FEB 2020
REVISION DATE	

ITASCA™ Denver, Inc.

Water Levels at Selected Domestic Wells and Shaft in the Mine Area

CLIENT: Rise Grass Valley Inc.

FIGURE NO. 4-8



PROJECT NO.	4091–19
BY	DD
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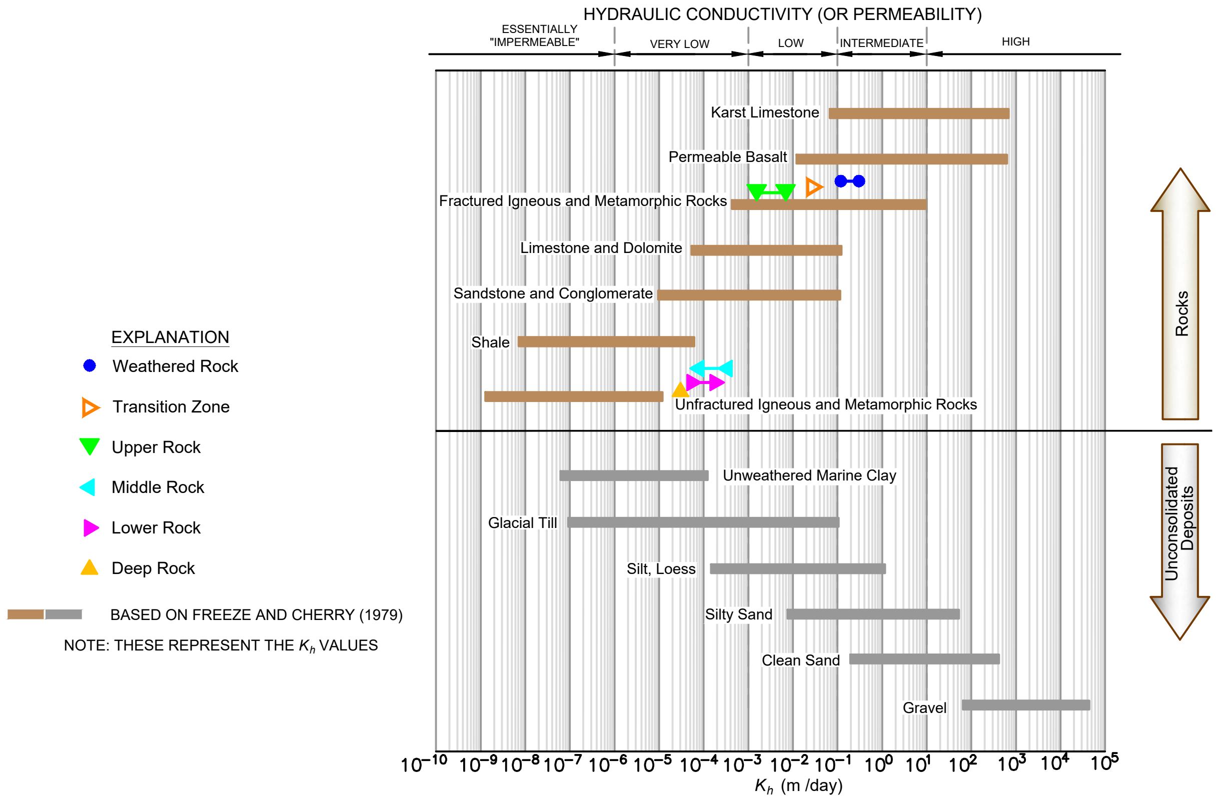
DRAWING NAME	HIST
DRAWING DATE	27 FEB 2020
REVISION DATE	

ITASCA™ Denver, Inc.

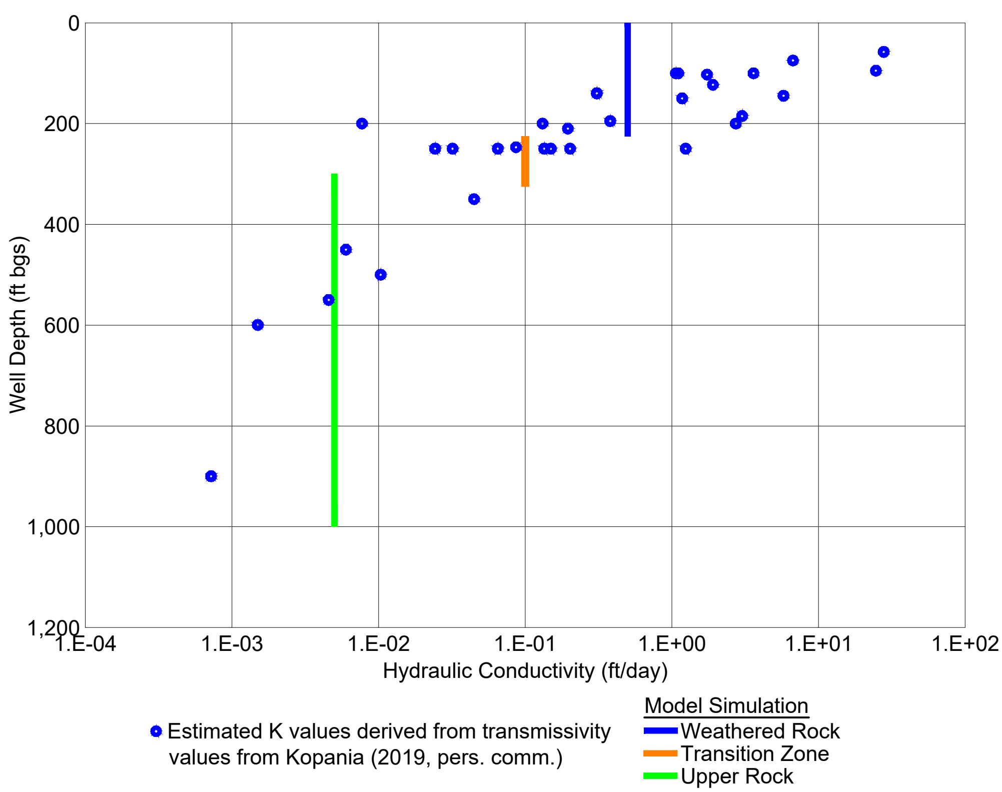
Simulated and Measured Groundwater Levels under Current Condition (as of 2019)

CLIENT: Rise Grass Valley Inc.

FIGURE NO. 4-9



Source: Freeze and Cherry (1979)



PROJECT NO.	4091-19
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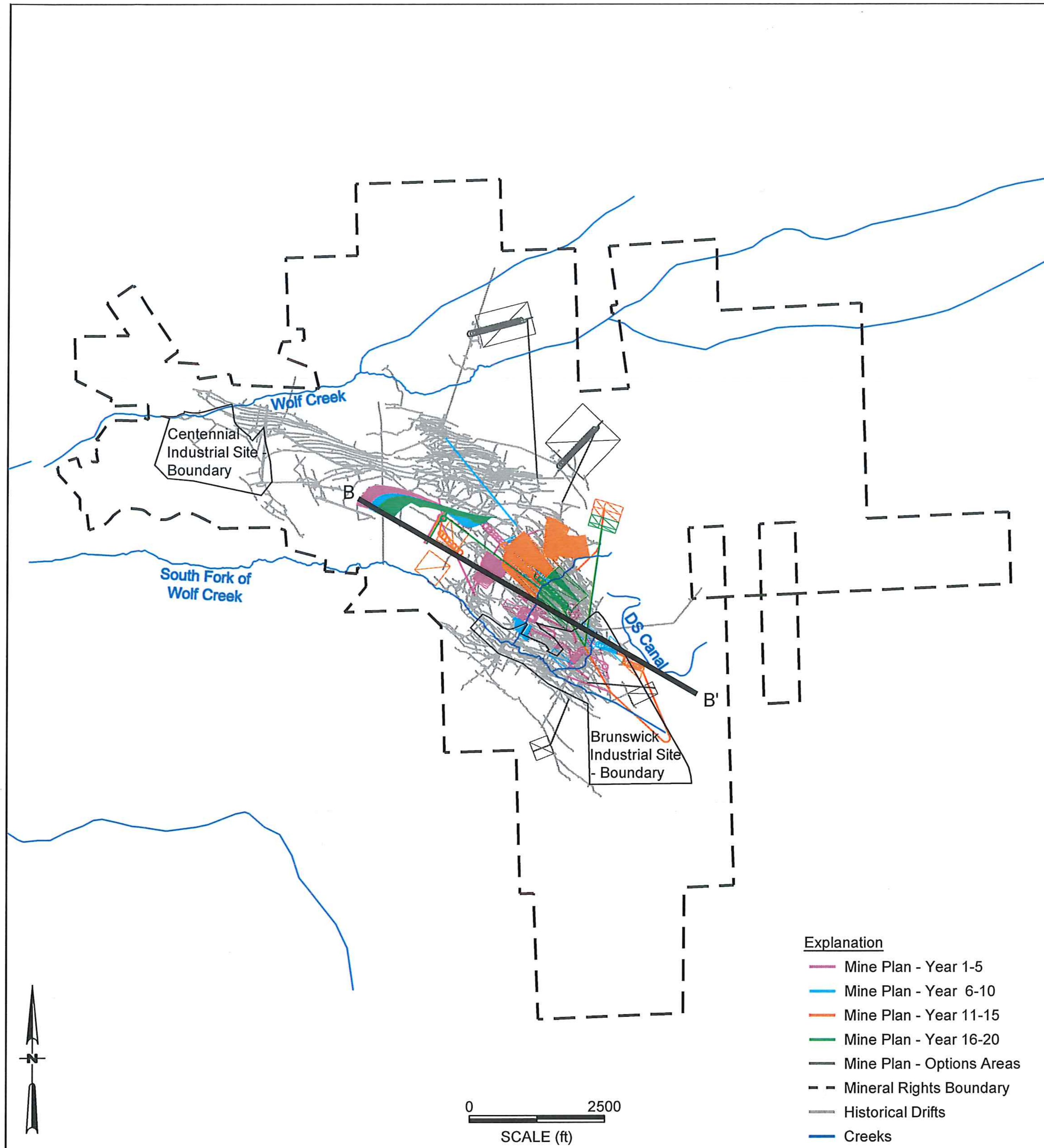
DRAWING NAME	COMP
DRAWING DATE	27 FEB 2020
REVISION DATE	

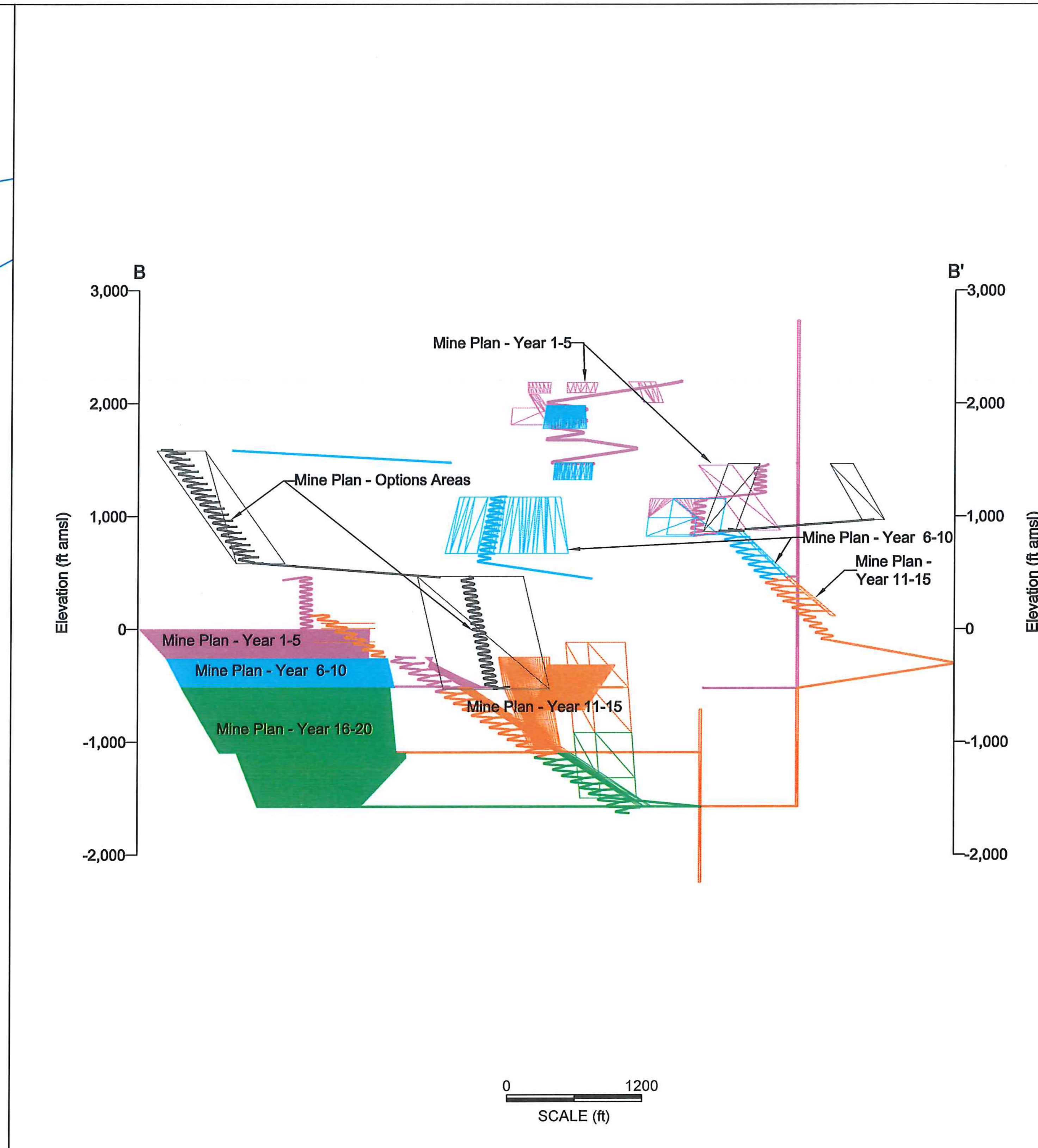
ITASCA Denver, Inc.

Comparison of Hydraulic Conductivities in Model Simulation with Estimated Hydraulic Conductivity Values

CLIENT: Rise Grass Valley Inc.

FIGURE NO. 4-10





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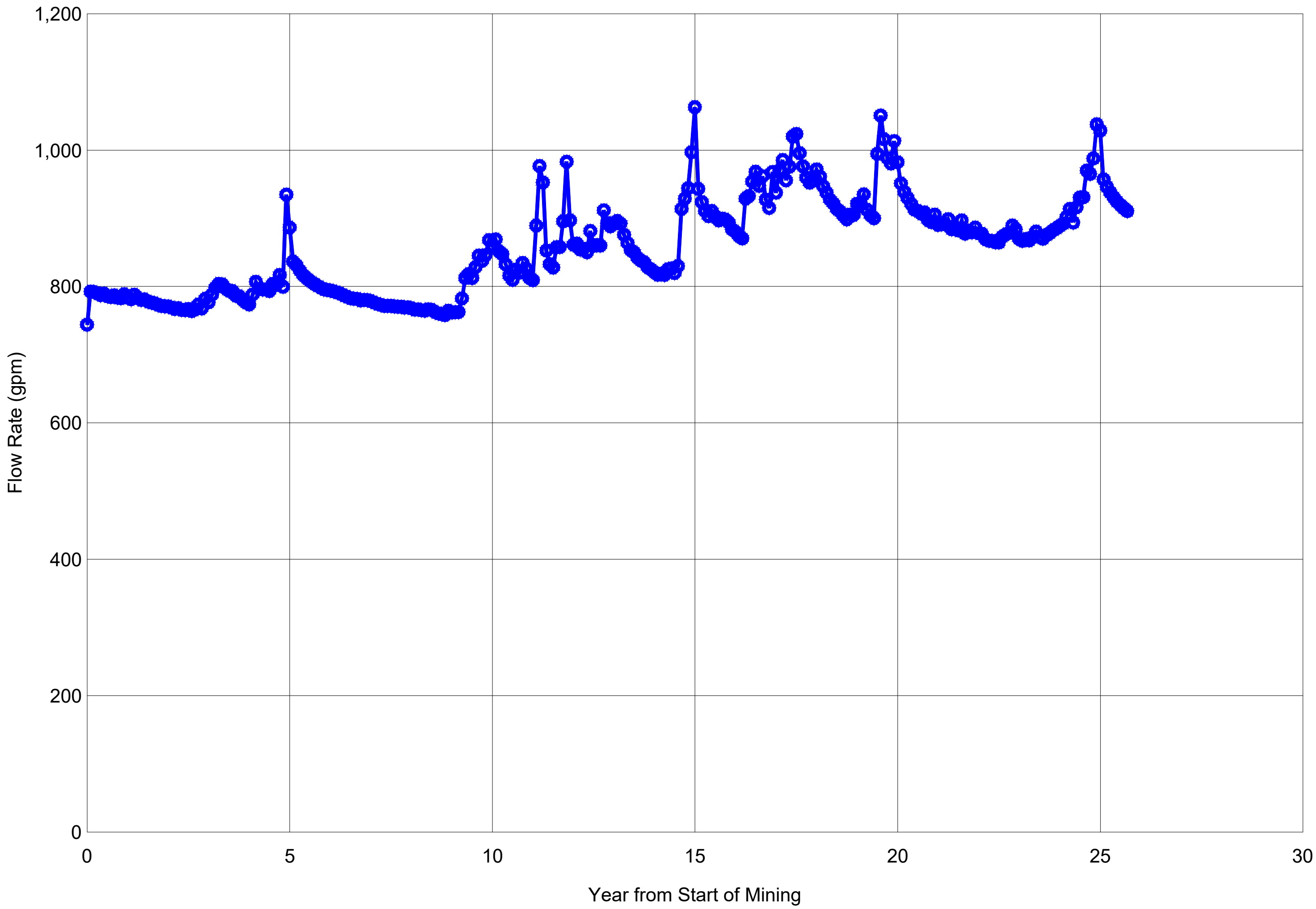
DRAWING NAME	EXTENT
DRAWING DATE	27 FEB 2020
REVISION DATE	

ITASCA™ Denver, Inc.

Plan View and Cross-Section View of the Future Mine Plan

CLIENT: Rise Grass Valley Inc.

FIGURE NO. 5-1



PROJECT NO.	4091–19
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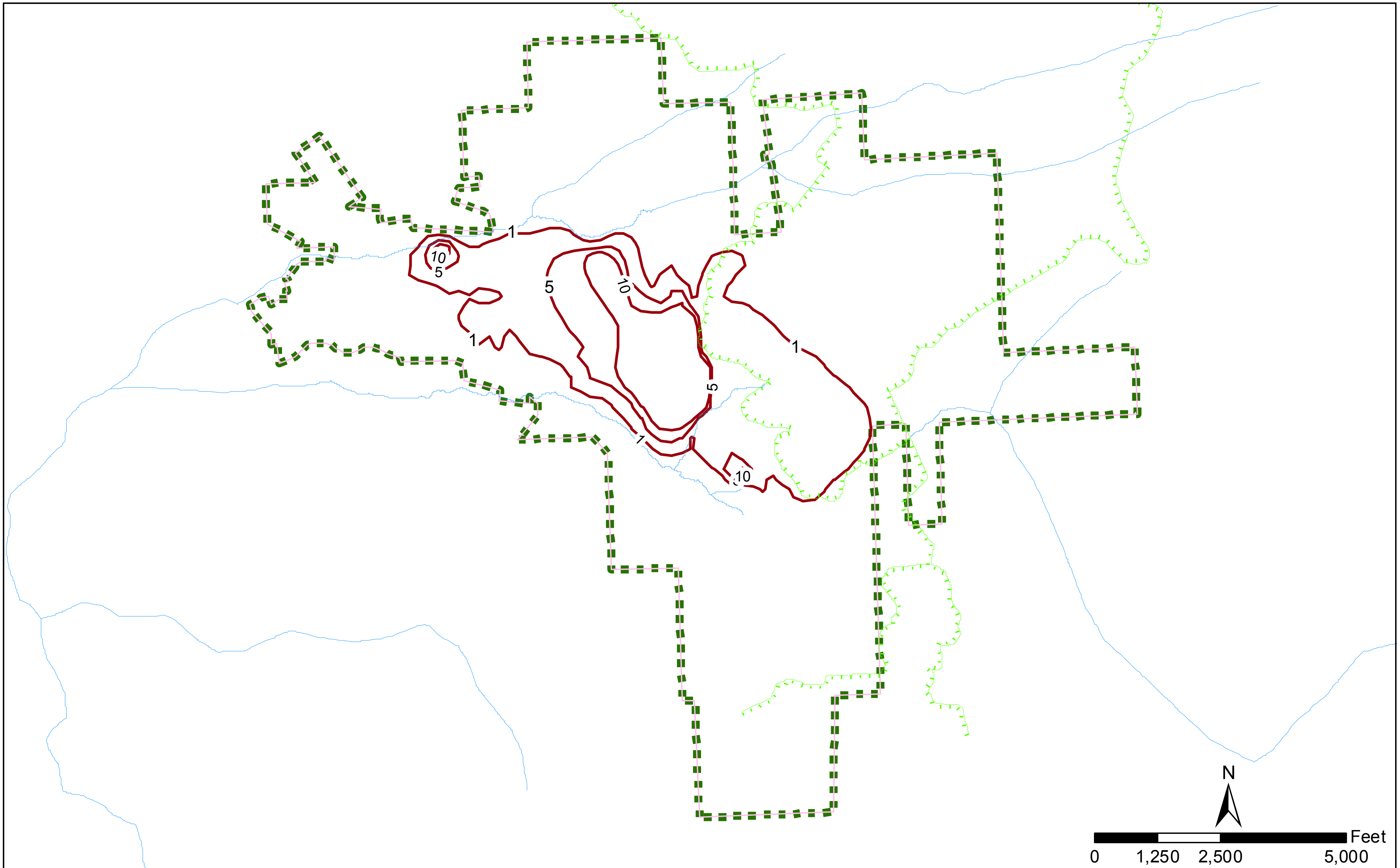
DRAWN	RJN
DRAWING NAME	INFLOW
DRAWING DATE	27 FEB 2020
REVISION DATE	

ITASCA™ Denver, Inc.

Predicted Inflow Rates to the Mine Workings during Future Mining

CLIENT: Rise Grass Valley Inc.

FIGURE NO. 5-2



Legend

- NID Canals
- Creeks
- Drawdown as of 2019 (ft)
- Mineral Rights Boundary

PROJECT NO.	4091
BY	DD
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DRAWN	DD
DRAWING NAME	Figure 5-3 2019 Impact
DRAWING DATE	Feb. 26, 2020
REVISION DATE	

ITASCA Denver, Inc.

Simulated Drawdown of Groundwater Levels under Current Condition Relative to Pre-Historical-Mining Condition

CLIENT: Rise Grass Valley Inc.

FIGURE NO. 5-3

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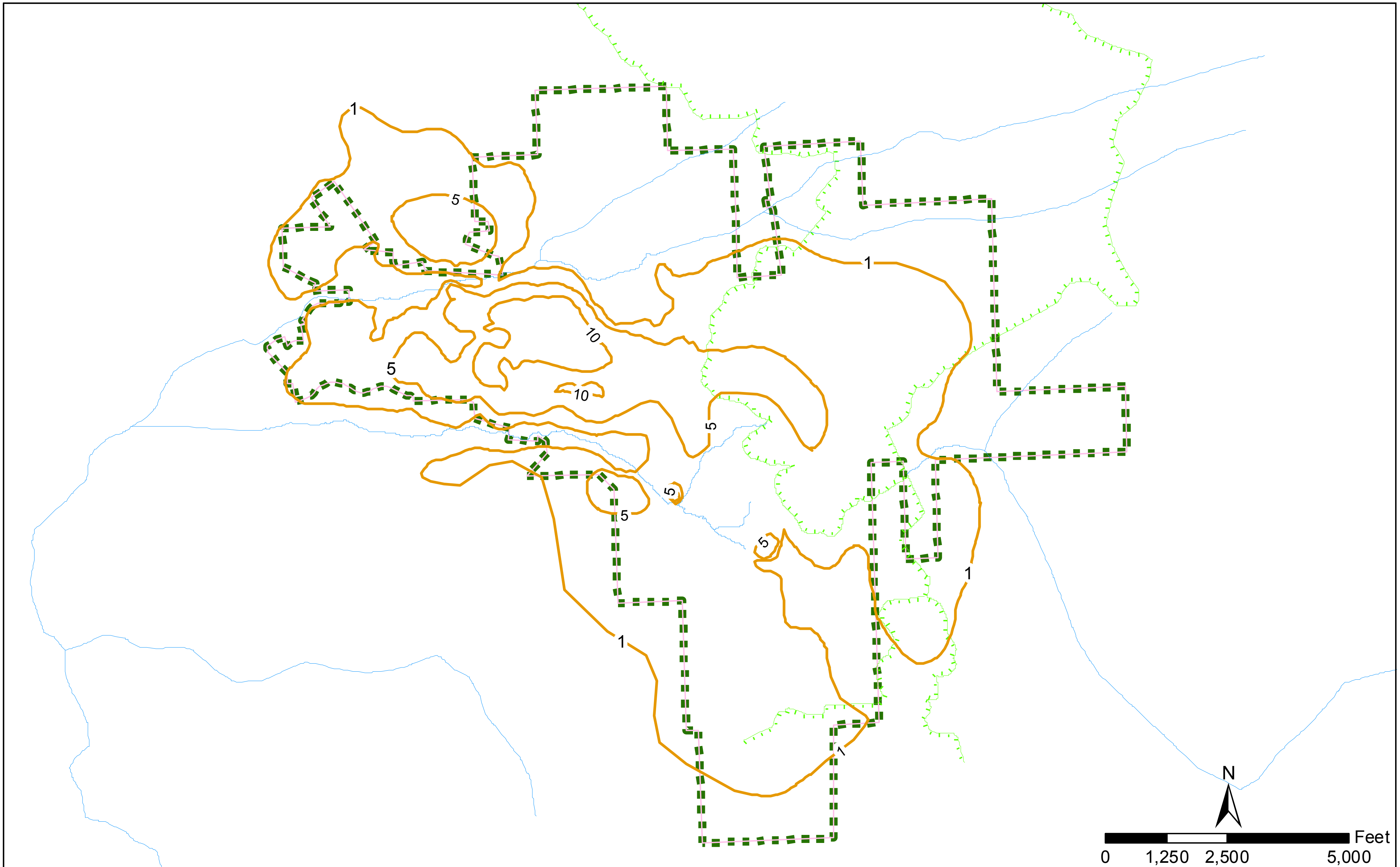

Legend

- Drawdown (ft) - End of Future Mining
- NID Canals
- Creeks
- Mineral Rights Boundary

PROJECT NO.	4091
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DRAWING NAME	Figure 5-4 EOM-2019
DRAWING DATE	Feb. 26, 2020
REVISION DATE	

ITASCA Denver, Inc.

Simulated Drawdown of Groundwater Levels
at the End of Future Mining
Relative to 2019 Water Level

CLIENT: Rise Grass Valley Inc.

FIGURE NO. 5-4

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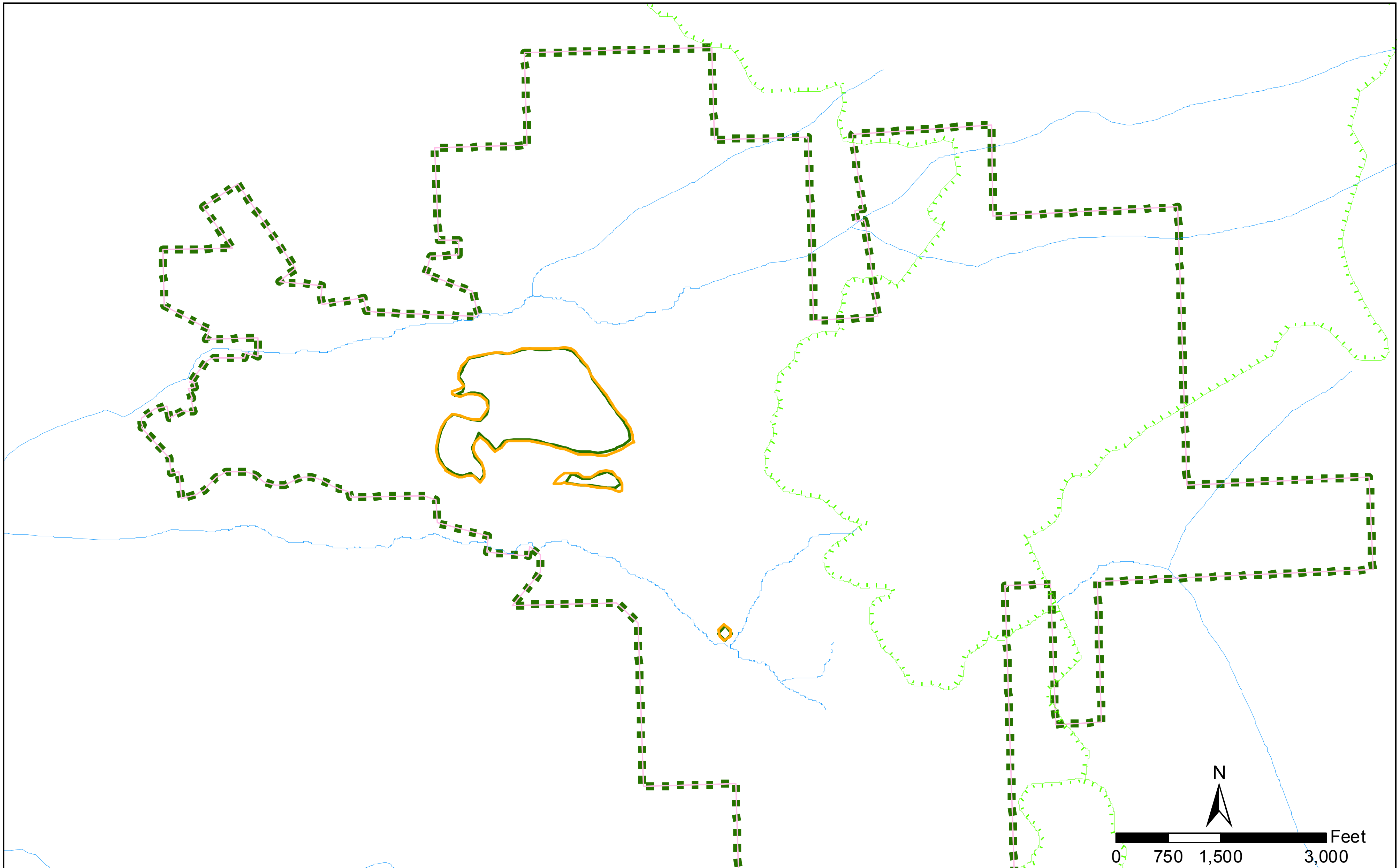

Legend

- After 10 Years of Future Mining
- End of Future Mining (25 Years)
- NID Canals
- Creeks
- Mineral Rights Boundary

PROJECT NO.	4091
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DRAWING NAME	Figure 5-5 10-ft
DRAWING DATE	Feb. 26, 2020
REVISION DATE	

ITASCA Denver, Inc.

Simulated 10-Foot Groundwater Drawdown
Contours at Different Times
Relative to 2019 Water Level

CLIENT:
Rise Grass Valley Inc.

FIGURE NO.
5-5

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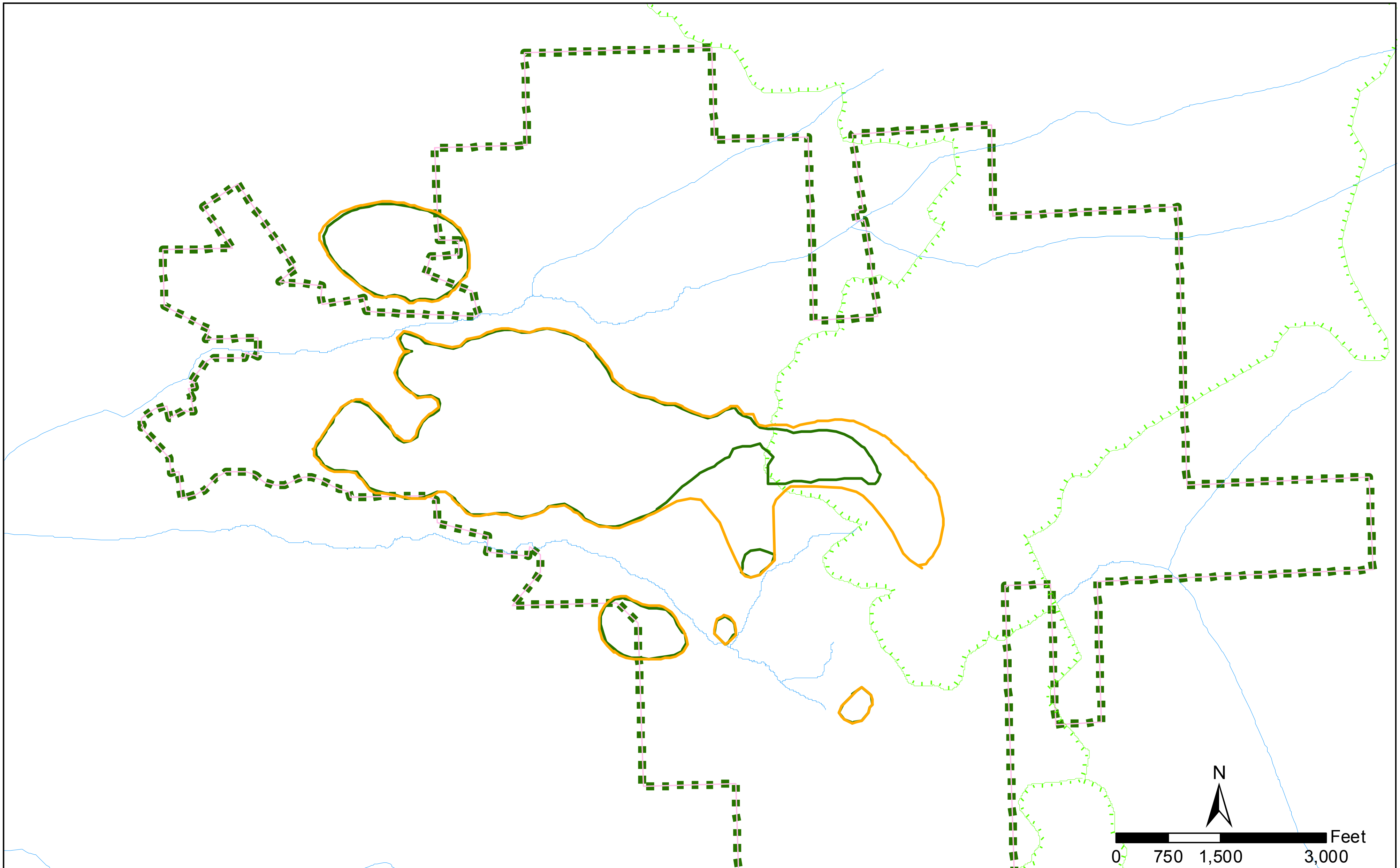

Legend

- After 10 Years of Future Mining
- End of Future Mining (25 Years)
- NID Canals
- Creeks
- Mineral Rights Boundary

PROJECT NO.	4091
BY	DD
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DRAWN	DD
DRAWING NAME	Figure 5-6 5-ft
DRAWING DATE	Feb. 26, 2020
REVISION DATE	

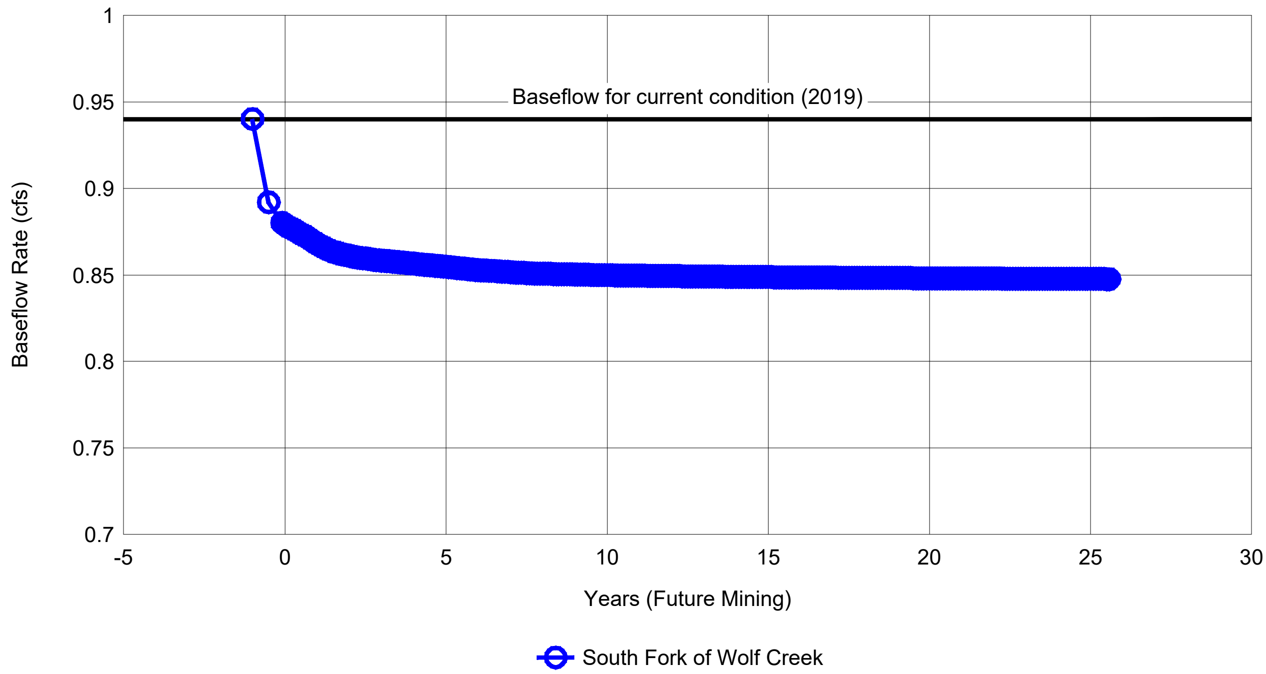
ITASCA Denver, Inc.

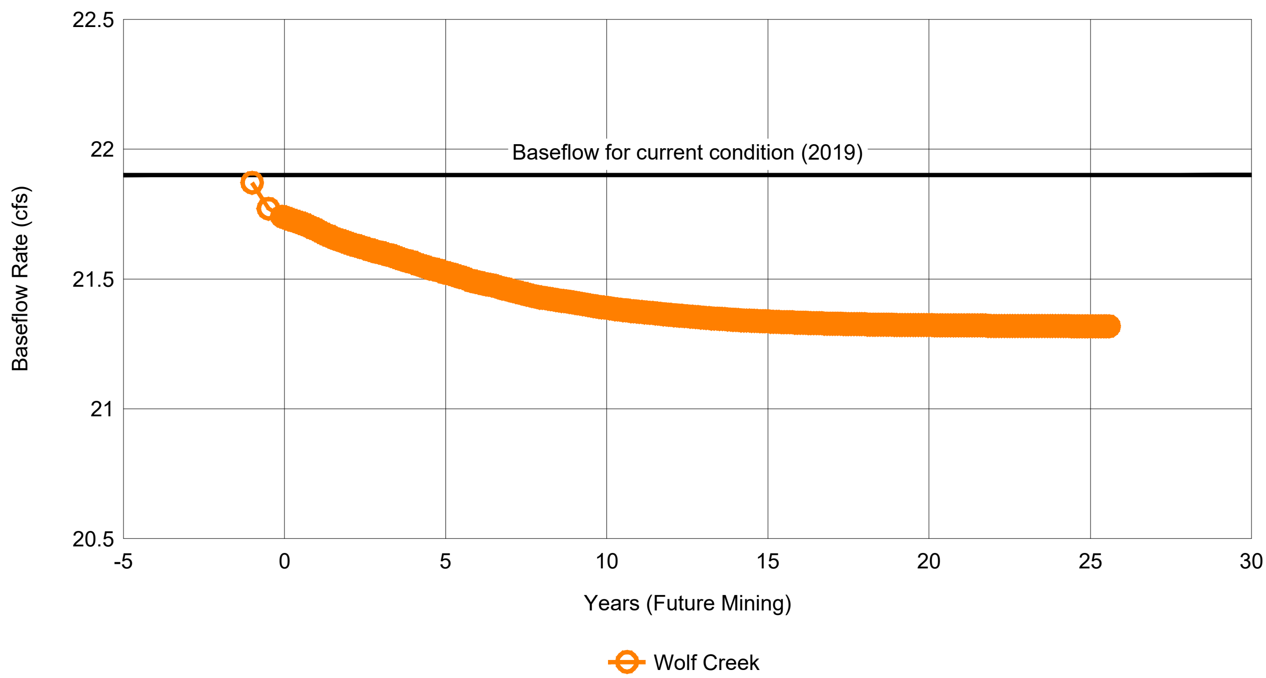
Simulated 5-Foot Groundwater Drawdown Contours at Different Times Relative to 2019 Water Level

CLIENT: Rise Grass Valley Inc.

FIGURE NO. 5-6

E:\Projects\4091_Rise_grass_valley\Work\mxd\Figures\Figure 5-6 5-ft.mxd





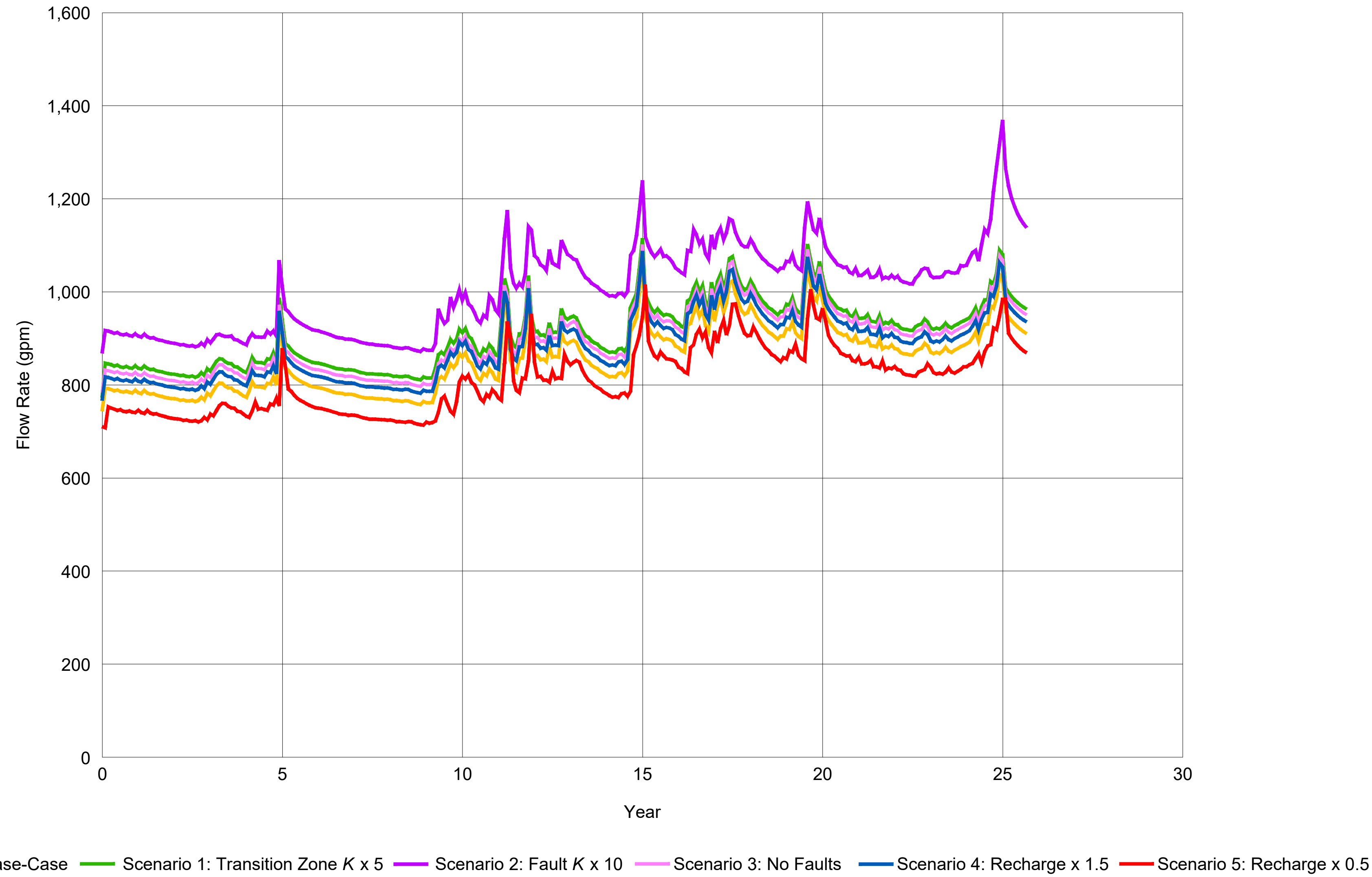
PROJECT NO.	4091-19
BY	DD
CHECKED	HL
DRAWN	RJN
DRAWING NAME	BASE
DRAWING DATE	27 FEB 2020
REVISION DATE	

ITASCA™ Denver, Inc.

Change of Baseflow Rates in the South Fork of Wolf Creek and Wolf Creek over the Life of the Mine

CLIENT: Rise Grass Valley Inc.

FIGURE NO. 5-7



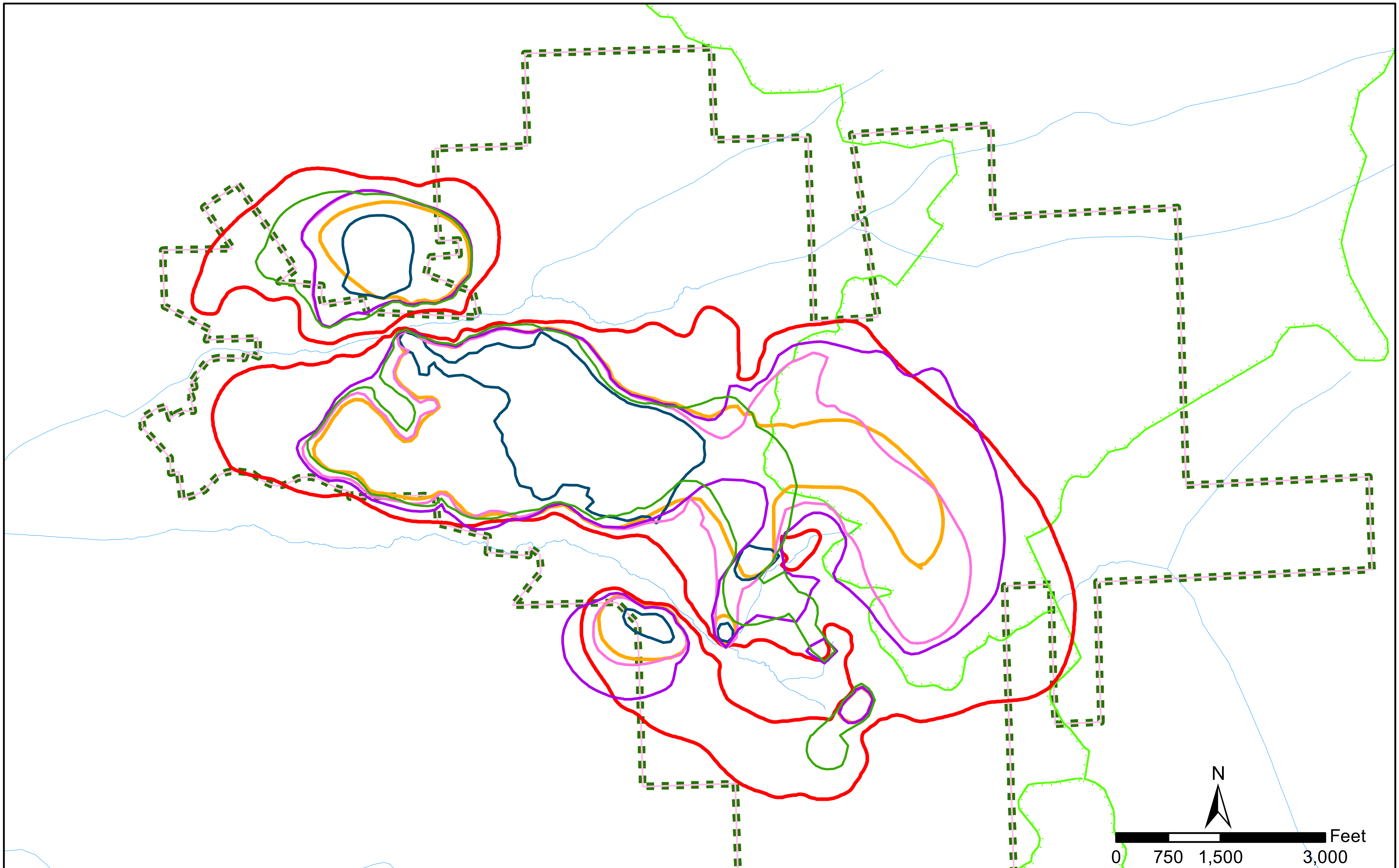
PROJECT NO.	4091–19
BY	JX
CHECKED	HL
DRAWN	RJN
DRAWING NAME	SENS
DRAWING DATE	27 FEB 2020
REVISION DATE	15 OCT 2020

ITASCA™
Denver, Inc.

Predicted Groundwater Inflows to the Mine Workings under Sensitivity Scenarios

CLIENT: Rise Grass Valley Inc.

FIGURE NO. 5-8



Legend

- Scenario 1
- Scenario 2
- Scenario 3
- Scenario 4
- Scenario 5
- Base-Case
- NID Canals
- Creeks
- Mineral Rights Boundary

PROJECT NO.	4091
BY	JX
CHECKED	HL
DRAWN	NP
DRAWING NAME	Figure 5-9 Sens
DRAWING DATE	Oct. 14, 2020
REVISION DATE	

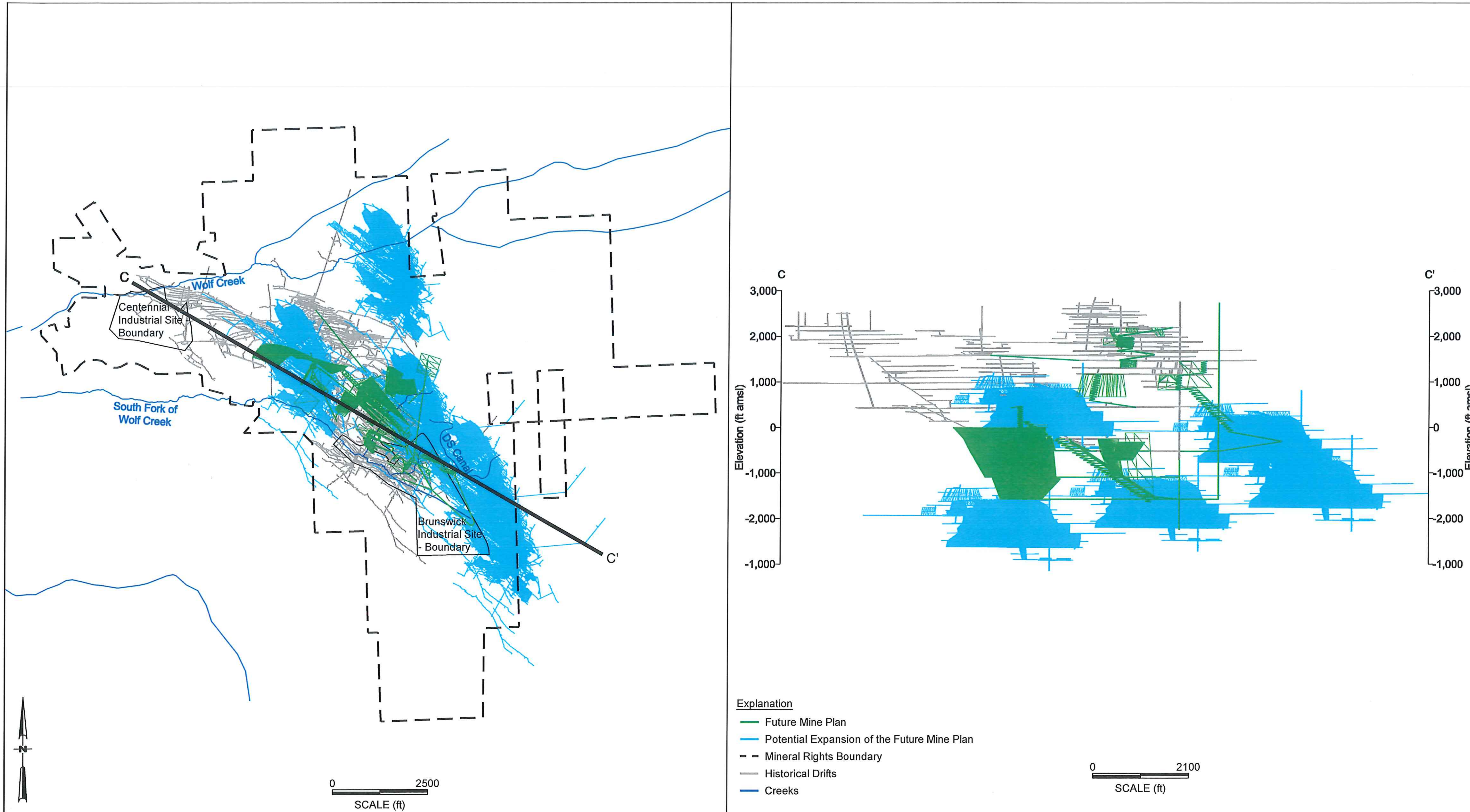
ITASCA™ Denver, Inc.

Simulated 5-Foot Groundwater Drawdown Contours for Senstivity Scenarios at the End of Mining Relative to 2019 Water Level

CLIENT: Rise Grass Valley Inc.

FIGURE NO. 5-9

G:\ARCGIS\4091_RiseGrass\MXDs\Working\Figure 5-9 Sens.mxd



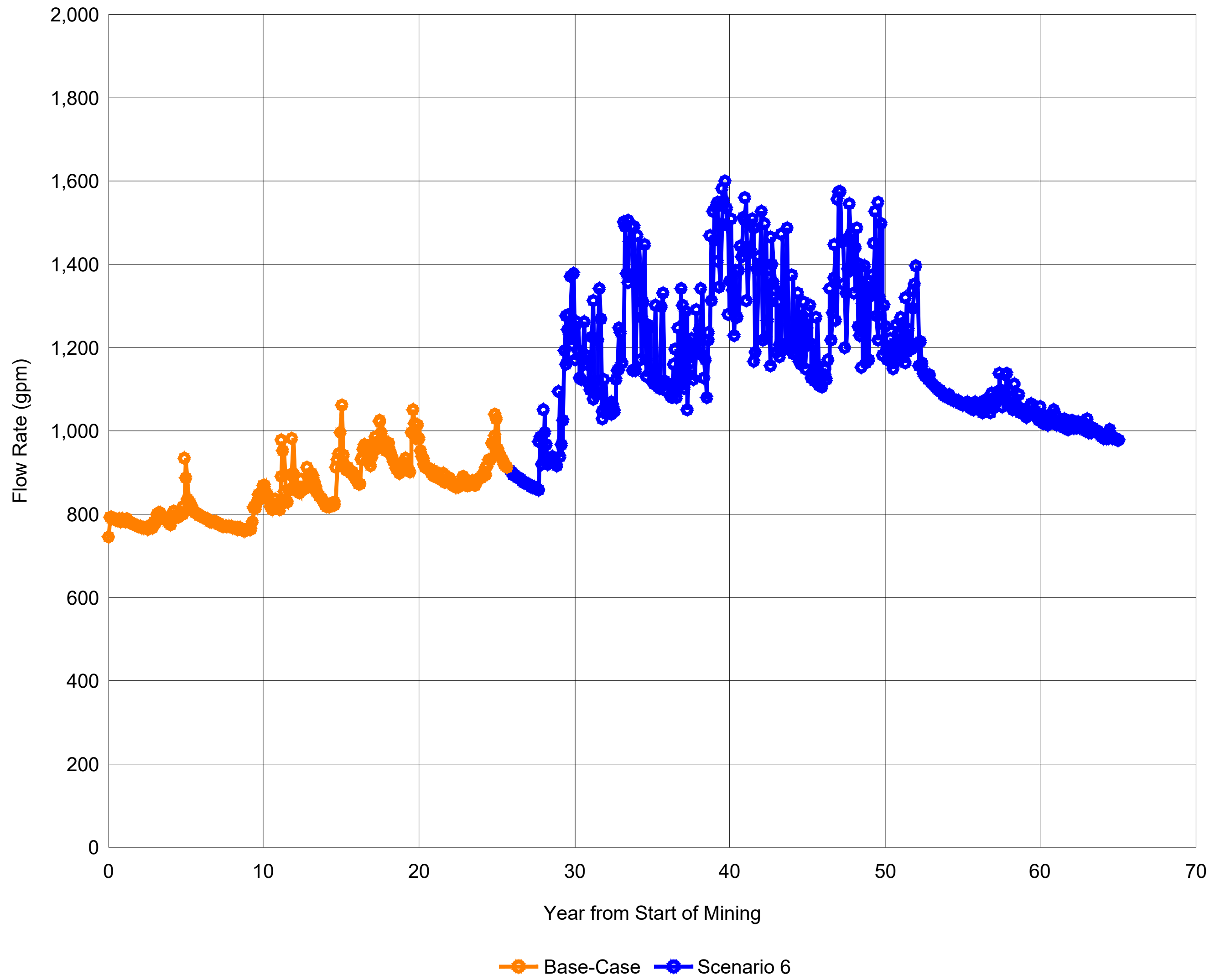
PROJECT NO.	4091-19
BY	DD
CHECKED	HL
DRAWN	RJN
DRAWING NAME	MINEPLAN
DRAWING DATE	27 FEB 2020
REVISION DATE	

ITASCA™ Denver, Inc.

Plan View and Cross-Section View of the Potential Expansion of the Future Mine Plan

CLIENT: Rise Grass Valley Inc.

FIGURE NO. 5-10



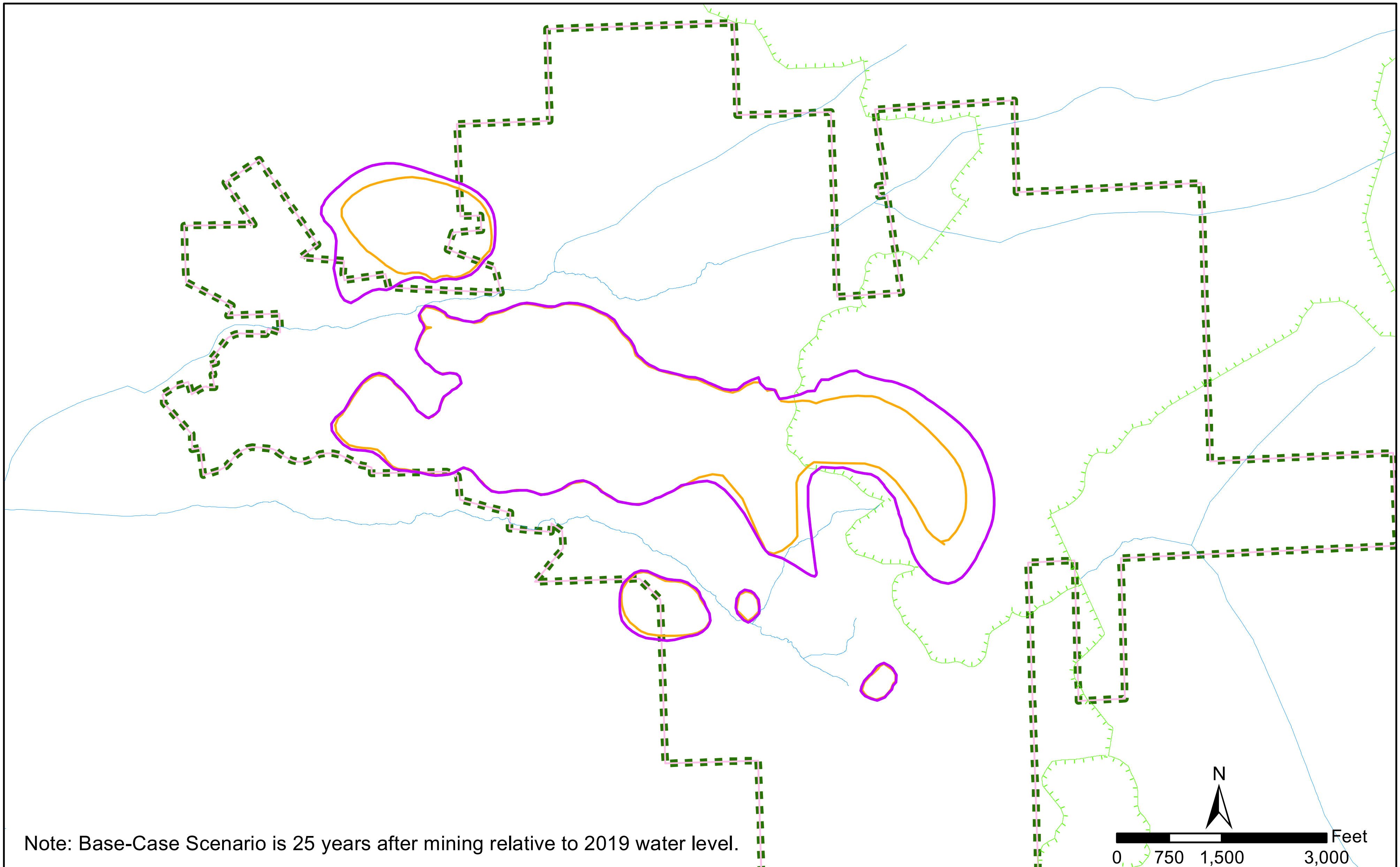
PROJECT NO.	4091–19
BY	DD
CHECKED	HL
DRAWN	RJN
DRAWING NAME	S5
DRAWING DATE	27 FEB 2020
REVISION DATE	21 OCT 2020

ITASCA™ Denver, Inc.

Predicted Groundwater Inflows to the Mine Workings of the Potential Expansion of Future Mining

CLIENT: Rise Grass Valley Inc.

FIGURE NO. 5-11



Note: Base-Case Scenario is 25 years after mining relative to 2019 water level.

Legend

- Scenario 6
- Base-Case
- NID Canals
- Creeks
- Mineral Rights Boundary

PROJECT NO.	4091
BY	JX
CHECKED	HL
DRAWN	NP
DRAWING NAME	Figure_5-12_ S5-5
DRAWING DATE	Oct. 21, 2020
REVISION DATE	

ITASCA™ Denver, Inc.

Simulated 5-Foot Groundwater Drawdown Contour at the End of the Potential Expansion of Future Mining (Year 65) Relative to 2019 Water Level

CLIENT: Rise Grass Valley Inc.

FIGURE NO. 5-12

G:\ARCGIS\4091_RiseGrass\MXDs\Working\Figure_5-12_ S5-5.mxd

TABLE 2-1

Elevations, Mine Lives, and Measured Flow Rates of the Historical Mines

<table>
<tr><th rowspan="2">Mine</th><th colspan="2">Elevation
(ft amsl)</th><th colspan="2">Mine Life
(Year)</th><th colspan="3">Flow Rate
(gpm)</th></tr>
<tr><th>Bottom</th><th>Top</th><th>Start</th><th>Close</th><th>From</th><th>To</th><th>Average</th></tr>
<tr><td>Union Hill</td><td>1,619</td><td>2,737</td><td>NA</td><td>1918</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td>Old Idaho</td><td>317</td><td>2,557</td><td>1866</td><td>1925</td><td>250</td><td>500</td><td>290</td></tr>
<tr><td>Old Brunswick</td><td>1,675</td><td>2,855</td><td>1888</td><td>1927</td><td>NA</td><td>NA</td><td>NA</td></tr>
<tr><td>New Brunswick</td><td>-709</td><td>2,452</td><td>NA</td><td>1956</td><td rowspan="2">500</td><td rowspan="2">1,200</td><td rowspan="2">680</td></tr>
<tr><td>New Idaho</td><td>-384</td><td>2,665</td><td>NA</td><td>1956</td></tr>
</table>

Note:
1. NA = not available

TABLE 2-2

Information and Average Measured Water Levels at Domestic Wells
(Page 1 of 2)

Rise Well ID	EIR 1995 Well ID	Todd 2007 Well ID[1]	Easting (ft)	Northing (ft)	Top Elevation of Well (ft amsl)	Well Depth (ft bgs)	Screen From (ft bgs)	Screen To (ft bgs)	Measured Water Level (ft amsl)	Measurement Date/Year	Used for Pre-Historical-Mining Simulation[2]
W129		WN0323	6833687.6	2205996.0	2,515.0	140.0	120.0	140.0	2,445.0	2007	√
W130	WS95	WN0095	6833754.9	2205729.1	2,510.0	100.0	60.0	100.0	2,490.0	1994-2007	√
	WS90	WN0090	6836366.8	2206037.8	2,590.0	72.0			2,585.0	1994-2007	√
	WS125	WN0125	6836407.3	2206372.2	2,670.0	120.0			2,592.0	1994-2007	√
W5	WS30	WN0030	6835379.4	2206357.5	2,644.0	230.0			2,612.0	1995-2007	√
	WS236	WN0236	6836771.2	2205795.5	2,635.0	199.0			2,618.0	1994-2007	√
	WS216	WN0216	6837070.2	2206475.2	2,770.0	199.0			2,645.0	1995-2007	√
W49	WS93	WN0093	6841882.2	2203215.6	2,801.0	400.0	42.0	62.0	2,755.0	1995-2007	√
W48	WS94	WN0094	6841891.5	2203199.1	2,801.0	400.0	95.0	115.0	2,760.0	1995-2007	√
W34	WS6	WN0006	6841253.6	2201705.4	2,877.0	250.0	0.0	140.0	2,787.0	1994-2006	√
W47	WS221	WN0221	6842139.7	2203948.8	2,818.0	90.0	50.0	90.0	2,819.0	1995-2007	√
W65	WS91	WN0091	6842916.5	2204295.0	2,866.7	500.0	160.0	180.0	2,820.0	1996-2007	√
W32	WS7	WN0007	6841020.3	2200747.7	2,948.0	350.0	110.0	130.0	2,835.0	1994-2006	√
W40	WS85	WN0085	6840637.1	2200763.5	2,945.0	175.0	40.0	175.0	2,850.0	1995-2007	√
W31	WS4	WN0004	6840027.6	2201813.2	2,932.0	295.0	80.0	150.0	2,855.0	2006-2007	√
W36	WS21	WN0021	6840752.6	2201268.8	2,916.0	325.0	90.0	150.0	2,855.0	1995-2007	√
W39	WS25	WN0025	6841421.9	2200961.7	2,899.0	350.0	50.0	70.0	2,855.0	1994-2007	√
W44	WS230	WN0036	6841616.3	2206213.9	2,966.0	175.0	135.0	175.0	2,888.0	1995-2007	√
	WS201	WN0201	6838535.8	2205950.5	2,860.0	425.0			2,720.0	1995-2007	x
	WS233	WN0233	6837178.6	2205676.3	2,640.0	90.0			2,598.0	1994-2007	x
	WS113	WN0113	6837482.4	2205319.4	2,645.0	55.0			2,637.0	1995-2007	x
	WS242	WN0242	6838104.2	2205145.9	2,695.0	155.0			2,650.0	1995-2007	x
W8	WS45	WN0045	6837427.5	2206358.9	2,769.0	300.0	200.0	300.0	2,662.0	1994-2007	x
W7	WS80	WN0080	6838933.7	2205394.6	2,797.0	100.0			2,700.0	1994-2007	x
	WS240	WN0240	6837746.0	2204970.2	2,650.0	199.0			2,630.0	1995-2007	x
W19	WS122	WN0122	6838119.4	2205610.1	2,779.0	220.0	180.0	220.0	2,863.0	1994-2007	x
W6	WS31		6836048.6	2206624.5	2,685.0	320.0			2,545.0	Aug-1981	√
W9	WS32		6836524.8	2206608.7	2,747.0	400.0			2,377.0	Oct-1987	√
W10			6834750.5	2208982.9	2,528.0	20.0			2,520.0	Nov-1991	√
W11			6834750.5	2208982.9	2,528.0	19.0			2,519.5	Nov-1991	√
W13			6834750.5	2208982.9	2,528.0	11.0	3.0	11.0	2,524.0	Jun-1996	√
W14			6834750.5	2208982.9	2,528.0	14.0	4.0	14.0	2,522.0	Jun-1996	√
W29	WS10		6840336.8	2200825.5	2,949.0	250.0	95.0	135.0	2,854.0	Sep-1985	√
W30			6840095.1	2200869.8	2,949.0	400.0	80.0	135.0	2,869.0	Jul-1985	√
W33	WS22		6840499.2	2201182.8	2,919.0	300.0	100.0	120.0	2,814.0	Jan-1985	√
W35			6841687.3	2200839.9	2,865.0	125.0	90.0	125.0	2,775.0	Sep-1985	√
W37			6841687.3	2200839.9	2,865.0	125.0	90.0	125.0	2,775.0	Sep-1985	√
W38			6841421.9	2200961.7	2,899.0	250.0			2,709.0	Nov-1983	√
W43			6841935.6	2205767.6	2,924.0	175.0	95.0	175.0	2,884.0	Mar-1980	√
W45	WS75		6842006.2	2205360.8	2,896.0	140.0	80.0	140.0	2,836.0	Dec-1989	√
W46			6841130.4	2205417.9	2,883.0	110.0	70.0	110.0	2,848.0	Jan-2011	√
W50			6842674.2	2203651.1	2,846.0	160.0	120.0	160.0	2,736.0	Aug-1989	√
W51			6842237.2	2204998.2	2,870.0	105.0	40.0	100.0	2,855.0	Aug-1998	√
W52			6842780.4	2203150.2	2,842.0	240.0	220.0	240.0	2,792.0	Sep-1999	√
W53			6841070.4	2203697.3	2,819.0	24.0			2,806.5	Nov-2006	√
W54			6841070.4	2203697.3	2,819.0	25.0	15.0	25.0	2,803.0	Nov-2006	√
W55			6841070.4	2203697.3	2,819.0	25.0			2,802.0	Nov-2006	√
W135			6833681.6	2206277.6	2,535.0	200.0	45.0	65.0	2,515.0	Mar-2003	√
W56			6842608.0	2205149.5	2,871.7	300.0			2,751.7	Jan-1986	√
W58			6843742.3	2205071.3	2,841.7	175.0	20.0	175.0	2,826.7	May-1982	√
W59			6844007.0	2204866.3	2,879.7	175.0	40.0	180.0	2,789.7	Mar-1981	√
W61			6843056.1	2204728.6	2,869.7	125.0	85.0	125.0	2,844.7	Dec-1997	√
W62			6843056.1	2204728.6	2,869.7	150.0			2,819.7	Nov-1990	√
W63			6842878.0	2204606.0	2,865.7	125.0	105.0	125.0	2,820.7	May-1996	√
W66			6842796.5	2204170.0	2,859.7	150.0	110.0	150.0	2,849.7	Apr-2003	√
W67			6843018.9	2203966.2	2,895.7	155.0	135.0	155.0	2,755.7	Jul-1988	√
W68	WS81		6843289.7	2204192.3	2,905.7	300.0	140.0	300.0	2,675.7	May-1990	√
W70			6843603.1	2204343.2	2,918.7	380.0	340.0	380.0	2,768.7	Apr-2004	√
W71			6843781.8	2204303.1	2,935.7	230.0	170.0	230.0	2,725.7	Oct-1988	√
W72			6844021.3	2204351.0	2,960.7	250.0	210.0	250.0	2,775.7	Nov-1986	√
W73			6843688.1	2203976.8	2,953.7	247.0	127.0	247.0	2,833.7	Aug-1994	√
W75			6843387.3	2203397.3	2,937.7	130.0	50.0	130.0	2,837.7	Jun-2001	√
W76			6844050.6	2203818.7	2,993.7	100.0	40.0	100.0	2,951.7	Mar-1984	√
W77			6844050.6	2203818.7	2,993.7	340.0	320.0	340.0	2,738.7	Aug-2001	√

TABLE 2-2

Information and Average Measured Water Levels at Domestic Wells
(Page 2 of 2)

Rise Well ID	EIR 1995 Well ID	Todd 2007 Well ID[1]	Easting (ft)	Northing (ft)	Top Elevation of Well (ft amsl)	Well Depth (ft bgs)	Screen From (ft bgs)	Screen To (ft bgs)	Measured Water Level (ft amsl)	Measurement Date/Year	Used for Pre-Historical-Mining Simulation[2]
W78			6842446.4	2202845.2	2,808.7	100.0	40.0	100.0	2,778.7	Sep-1981	√
W79			6842809.5	2202877.1	2,841.7	100.0	5.0	95.0	2,831.7	Dec-1990	√
W80	WS217		6843101.8	2202955.5	2,870.7	100.0			2,855.7	Aug-1990	√
W81			6842687.1	2202376.3	2,868.7	300.0	200.0	300.0	2,776.7	Sep-1990	√
W82			6843049.3	2202618.4	2,896.7	720.0			2,796.7	Sep-1996	√
W83			6843049.3	2202618.4	2,896.7	560.0	280.0	300.0	2,596.7	Aug-1996	√
W85			6843374.6	2202660.2	2,892.7	100.0			2,882.7	Dec-1990	√
W86			6843304.1	2201888.2	2,969.7	350.0	80.0	100.0	2,909.7	May-2002	√
W87			6843304.1	2201888.2	2,969.7	350.0	150.0	350.0	2,789.7	May-1995	√
W89			6842917.2	2200701.1	2,957.7	420.0	280.0	420.0	2,807.7	Sep-1995	√
W90			6843055.3	2200403.3	2,966.7	600.0			2,866.7	Aug-2000	√
W91			6842522.6	2200305.3	2,900.0	110.0	70.0	110.0	2,825.0	Dec-1986	√
W94			6843565.0	2202004.3	2,979.7	480.0			2,799.7	Dec-2005	√
W100			6843964.0	2204168.2	2,966.7	780.0	420.0	440.0	2,531.7	Aug-2005	√
W101			6843523.8	2203897.1	2,950.7	450.0	250.0	450.0	2,800.7	Feb-2006	√
	WS124		6836264.5	2206687.2	2,730.0	208.0			2,625.0	NA[3]	√
	WS243		6836071.2	2206374.7	2,640.0	131.0			2,558.0	NA	√
	WS118		6835671.2	2206380.5	2,665.0	200.0			2,580.0	1979	√
	WS237		6835594.3	2206079.7	2,620.0	200.0			2,546.0	1979	√
W1			6838534.1	2205005.8	2,747.0	420.0			2,727.0	Aug-1999	x
W16			6839015.6	2206259.9	2,826.0	140.0			2,766.0	May-1994	x
W17			6837373.5	2205180.8	2,684.0	150.0	130.0	150.0	2,604.0	May-2000	x
W18			6834516.2	2208874.4	2,530.0	560.0	140.0	160.0	2,525.0	Mar-2011	x
W20			6837861.6	2209933.7	2,648.0	100.0	60.0	100.0	2,623.0	Jun-2006	x
W21			6834546.0	2208888.9	2,530.0	15.0			2,523.0	Jun-1996	x
	WS116		6837379.7	2205958.4	2,700.0	208.0			2,617.4	1975	x
	WS114		6837592.6	2205870.6	2,710.0	208.0			2,627.4	NA	x
	WS119		6837743.5	2206166.2	2,780.0	145.0			2,695.0	1989	x
	WS44		6838216.9	2205847.2	2,810.0	225.0			2,627.0	1982	x
	WS29		6838719.2	2205632.4	2,788.0	425.0			2,705.4	1986	x
	WS235		6837967.0	2206024.5	2,805.0	200.0			2,686.0	NA	x
	WS121		6837921.3	2205424.0	2,690.0	155.0			2,607.4	1978	x
	WS110		6838024.3	2207045.2	2,830.0	208.0			2,747.4	NA	x
MW-1			6834073.0	2207317.0	2,569.9	24.0			2,545.9	2007	x
MW-2			6834101.0	2207375.0	2,569.9	19.2			2,550.7	2007	x
MW-3			6834127.0	2207265.0	2,571.6	34.4			2,543.6	2007	x
MW-4			6834003.0	2207259.0	2,572.1	50.0			2,539.6	2007	x
MW-5			6833993.0	2207319.0	2,569.1	48.4			2,529.6	2007	x
MW-6			6833950.0	2207286.0	2,569.7	55.0			2,527.4	2007	x

Notes:

1. The 26 wells labeled with "Todd 2007 Well ID" had hydrographs; the measured water levels are the stable values visually obtained from the hydrographs with the consideration of seasonal changes.

2. The wells highlighted in green are outside of the footprint of the historical mining area and were used for the simulation of the pre-historical-mining condition.
√ = Yes; × = No

3. NA = not available

TABLE 2-3

Measured Streamflow Rates and Discharge Rate from NID Canal

Stream	Coordinate		Flow Rate (cfs)		
	Easting (ft)	Northing (ft)	Apr-2019	Aug-2019	Estimated Baseflow
South Fork of Wolf Creek	6838228	2204566	6.5	1.0	1.0
Wolf Creek	6833389	2208847	51.3	74.6	<31
NID Canal	NA	NA	19.4	NA	NA

Note:
1. NA = not available

TABLE 2-4

ITASCA™ Denver, Inc.

Elevations of Drains and Mine Water Levels Estimated in 2019

Location	Elevation (ft amsl)
Eureka Drain	2,502
East Eureka Shaft Drain	2,497
East Eureka Shaft	2,501
New Brunswick Shaft[1]	2,499

Notes:
1. Water level in the historical mine.

TABLE 4-1

Elevations and Thicknesses of Model Layers in the Mine Area

Node Layer	Elevation (ft amsl)	Thickness (ft)
1	2,900	
2	2,800	100
3	2,700	100
4	2,600	100
5	2,500	100
6	2,200	300
7	2,100	100
8	2,000	100
9	1,900	100
10	1,700	200
11	1,600	100
12	1,500	100
13	1,400	100
14	1,300	100
15	1,200	100
16	1,100	100
17	975	125
18	850	125
19	725	125
20	575	150
21	425	150
22	275	150
23	125	150
24	0	125
25	-260	260
26	-515	255
27	-1,095	580
28	-1,575	480
29	-2,245	670
30	-2,445	200
31	-2,845	400
32	-3,445	600

TABLE 4-2

Calibrated Hydraulic Properties of Geologic Units

Zone	Horizontal Hydraulic Conductivity (ft/day)[1]						Storativity (ft^{-1})	Specific Yield (-)
	Weathered	Transition	Upper	Middle	Lower	Deep		
Mariposa	1	0.1	0.005	0.001	0.0008	0.0001	5.00E-06	0.005
Calavaras	0.5	0.1	0.005	0.001	0.0008	0.0001	5.00E-06	0.005
Tertiary	0.5	0.1	0.005	0.001	0.0008	0.0001	5.00E-06	0.005
Diorite	0.5	0.1	0.01	0.001	0.0008	0.0001	5.00E-06	0.005
Sepentini	1	0.1	0.02	0.001	0.0008	0.0001	5.00E-06	0.005
Delhi	0.5	0.1	0.01	0.001	0.0008	0.0001	5.00E-06	0.005
Fault 6-3	0.001	0.001	0.001	0.001	0.0008	NA	5.00E-06	0.005
Fault Morehouse	0.001	0.001	0.001	0.001	0.0008	NA	5.00E-06	0.005
Argillite	1.5	0.1	0.01	0.0005	0.0008	0.0001	5.00E-06	0.005
Volanic Rocks	0.4	0.1	0.005[2]	0.0002	0.0002	0.0001	5.00E-06	0.005
Andesite	0.5	0.1	0.01	0.001	0.0008	0.0001	5.00E-06	0.005
Granodior	2.5	0.1	0.01	0.002	0.0008	0.0001	5.00E-06	0.005
Schist	1.5	0.1	0.01	0.0005	0.0005	0.0001	5.00E-06	0.005
Sandstone	0.5	0.3	0.05	0.004	0.004	0.0001	5.00E-06	0.005
Gabbro	1	0.1	0.01	0.0005	0.0005	0.0001	5.00E-06	0.005
Brunswick	1	0.1	0.01	0.0005	0.0005	0.0001	5.00E-06	0.005
Alluvium [3]	2.5	0.5	0.25	0.005	0.005	0.001	1.00E-05	0.05
Riverbed Sediments	10	NA [4]					1.00E-05	0.05
Mine Void	8000						1.00E-05	0.5

Notes:

1. Anisotropic ratio K_h/K_v = 10, $K_X = K_y$
2. Hydraulic conductivity of Slate unit along the Morehouse Fault and Union Hill Mine was assumed as 0.0015 ft/day.
3. *K* values in the area with alluvium on the surface were assigned to decrease along depth. The weathered rock and transition zone do not apply to this unit.
4. NA = not simulated in the model

ITASCA Denver, Inc.

TABLE 5-1

Simulated Baseflow of Nearby Creeks under Sensitivity Scenarios at the End of Mining

Scenarios	Baseflow (cfs)	
	Wolf Creek	South Fork of Wolf Creek
Base-Case	21.3	0.8
Scenario 1 (Transition Zone *K* x 5)	21.8	0.9
Scenario 2 (Fault *K* x 10)	21.3	0.8
Scenario 3 (No Faults)	21.3	0.8
Scenario 4 (Recharge x 1.5)	30.8	1.2
Scenario 5 (Recharge x 0.5)	11.6	0.4
Scenario 6 (Potential Expansion of Future Mining)	21.3	0.8

APPENDIX A

Introduction of *MINEDW*

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INTRODUCTION OF *MINEDW*

MINEDW is a three-dimensional (3-D) finite-element groundwater modeling code developed specifically for mining and civil engineering applications. This white paper outlines the mathematical basis of the groundwater flow code, boundary conditions, and features, such as the ones listed below, developed specifically for simulating common mining scenarios. The information in this white paper is supplemented by the ***MINEDW*** manual, which gives in-depth information about how to construct a groundwater model using ***MINEDW***.

Itasca Denver, Inc. (Itasca) developed ***MINEDW***, a 3-D finite-element groundwater flow code. The core of the code is based on algorithms previously developed by Durbin and Berenbrock (1985) for the United States Geological Survey (USGS) code *FEMFLOW3D*. As of early 2018, ***MINEDW*** had been used successfully at more than 75 mines located throughout the world and in diverse hydrogeologic and climatic conditions. The code has been in use for approximately 30 years, and its predictions have been validated by field data collected over many years and the Sandia National Laboratory (Corbet et al. 1998). Moreover, ***MINEDW*** was reviewed by the Nevada Division of Environmental Protection (NDEP 2018; Appendix 2) and approved for regulatory use.

The ***MINEDW*** software includes special features that facilitate the 3-D simulation of dewatering operations in open-pit and underground mines. Some of these features are as follows:

- A groundwater flow problem is simulated as saturated-unsaturated groundwater flow based on Darcy's law. This allows the finite-element mesh to remain fixed with time (except for excavations) and the saturated flow domain to adjust with time in accordance with changes in the position of the water table. The fixed mesh, in contrast to a deforming mesh, facilitates the representation of the spatial hydrogeologic variability of a groundwater system by the finite-element mesh.

- ***MINEDW*** provides 3-D graphic representations of geology, model domain, pit geometry, groundwater heads, groundwater flux, recharge and evaporation zones, particle tracking, and pore pressures.
- Specified-head boundary conditions can be imposed using heads that are either invariable with time or variable with time. In the latter case, the boundary heads are specified in terms of tables representing a hydrograph of the heads.
- Specified-flux boundary conditions and internal source-sink terms are defined by a group of data sets that can be combined in different configurations for each time step.
- Variable-flux boundary conditions can be imposed to simulate time-variant boundary fluxes in response to changing boundary heads. This boundary condition allows the finite volume of the modeled flow domain to be "extended" to infinity by "attaching" the analytical solution for a semi-infinite, linear aquifer to the boundary of the flow domain.
- The interaction between the groundwater system and river networks can be realistically simulated. Streams are simulated as a river network (or networks) that consists of a main river channel and tributary channels. The model accounts for streamflow depletions or additions by simulating the exchange of water between the stream and the groundwater system.
- In addition, evapotranspiration of groundwater from vegetated areas or evaporation from bare-soil areas can be simulated. The evapotranspiration rate is assumed to be inversely proportional to the depth from the ground surface to the water-table elevation. ***MINEDW*** uses the maximum evaporation rate and the extinction depth as constraints.
- Spatial and temporal variation in precipitation across the model domain can be simulated. In areas with steep relief, ***MINEDW*** has the capability to simulate orographically controlled precipitation.
- Open-pit excavation, open-pit backfilling, and pit-lake formation can be efficiently simulated within a ***MINEDW*** model.
- ***MINEDW*** can efficiently simulate the formation of a zone of relaxation (ZOR) around a pit excavation or underground mining operation through time according to the mining schedule.
- Outputs of pore-pressure distribution can be seamlessly used in both two-dimensional (2-D) and 3-D geomechanical models using Itasca's geomechanical codes.

In addition, when predicting inflows to both open-pit and underground mines and to help design mine dewatering and depressurization systems, ***MINEDW*** overcomes limitations in model discretization inherent in finite-difference codes:

1. The discretization used in a numerical model can strongly affect the predictions of inflow and the shape of the water table near an open-pit or underground excavation. Not only must discrete features, such as faults and contacts between significantly different hydrogeologic materials, be included in the discretization, but predicting the essentially radial flow toward an excavation is more accurately performed by using small, approximately logarithmic horizontal and vertical grid spacing.
2. The seepage face—the surface of the open-pit highwall through which lateral flow occurs—is difficult to estimate using finite-difference codes (i.e., *MODFLOW*). The height of the seepage face affects both the amount of lateral inflow and the height of the water table behind the highwall. A poor estimate of the height of the seepage face can introduce significant errors to the predicted inflows and pore-pressure distribution.

The following list indicates some of the mining hydrogeology projects in which ***MINEDW*** was used for groundwater modeling of dewatering system design and impact analyses:

- Anglo American – Sishen and Kolomela Mines, South Africa;
- Aurora Mining Company – Aurora Mine, Guyana;
- Cameco Corporation – McArthur River, Cigar Lake, and Millennium Mines, Canada;
- De Beers Canada – Victor, Snap Lake, Gahcho Kué, and Fort à la Corne Mines, Canada;
- De Beers Consolidated Mines – Premier, Finsch, Venetia, Voorspoed, AK6, and Mulepe Mines, South Africa;
- Debswana – Orapa, Letlhakane, Jwaneng, and Damtshaa Mines, Botswana;
- Eurasian Resource Group – Frontier Mine, Democratic Republic of Congo;
- Goldcorp – Éléonore Mine, Canada;
- Kinross Gold Corporation – Fruta del Norte Project, Ecuador;
- Newmont Mining Corporation – Lone Tree, Twin Creeks, Gold Quarry, and Leeville Mines, U.S.A.;

- Rio Tinto – Resolution Mine, Arizona, U.S.A.; and
- Alrosa - Mir Mine, Mirny, Russia.

APPENDIX B

Review of the *MINEDW* Groundwater Flow Modeling Code

NEVADA DIVISION OF
ENVIRONMENTAL PROTECTION

STATE OF NEVADA
Department of Conservation & Natural Resources

26 November 2018

Mr. Braden Hanna
Principal Geochemist
Itasca Denver, Inc.

VIA EMAIL

Re: Review of the *MINEDW* Groundwater Flow Modeling Code

Dear Mr. Hanna:

The Nevada Division of Environmental Protection (Division) – Bureau of Mining Regulation and Reclamation (BMRR) is in receipt on 2 May 2018 of a request from Itasca Denver, Inc. (Itasca) for BMRR to review the finite-element groundwater flow modeling code *MINEDW*. For code review to progress it was necessary for project-specific groundwater modeling to be completed with *MINEDW* and submitted to the Division. Groundwater modeling files and an associated report were submitted in reference to the Lone Tree project (NEV0090058). The Lone Tree groundwater model review will be addressed under separate cover to Newmont Mining Corporation. The Lone Tree groundwater flow model project files were used to test the *MINEDW* code. Testing and approval of commercially available and non-open source codes is required per the Division's Guidance for Hydrogeologic Groundwater Flow Modeling at Mine Sites (https://ndep.nv.gov/uploads/documents/201803_CPN_Hydro_Guidance_revision01.pdf). The purpose of the testing is not to evaluate the mathematical methods or the programming structure of the code. Testing is simply designed to determine if Division personnel could reasonably use the code to evaluate sensitivity of any models submitted using *MINEDW*. Testing therefore focuses on simple aspects of the code such as reproducibility of a simple steady-state model, reasonable modification of hydraulic properties, and implementation of specialized and useful tools such as particle tracking.

The Division has determined that *MINEDW* is acceptably transparent for regulatory use, and may therefore be applied to predictive groundwater flow modeling studies to be submitted to BMRR. The review and approval of the code were greatly streamlined by the inclusion of the draft user's manual (Itasca, 2016) and the previous rigorous assessment of the code (Corbet et al., 1998). This approval does not necessarily extend to other state or Federal regulatory agencies, such as the Nevada Division of Water Resources (NDWR) or the U.S. Bureau of Land Management (BLM). Itasca is encouraged to contact each specific agency to determine appropriate guidelines.

I. Code Testing

Detailed below are several tests that were conducted using the Lone Tree groundwater model in comparison to analytic element solutions (AEM; Hunt, 2006), or other tests conducted to evaluate code transparency and usability.

1. **Steady-state simulation.** The Division used *MINEDW* to extract potentiometric surface contours from the first and second layers of the Lone Tree groundwater model (Figure 1). These potentiometric surface contours were then compared to two AEM simulations using the Tim^{ML} application (Bakker, 2010). The simulations used hydraulic parameter values extracted from the *MINEDW* model.

   The first AEM simulation created a single inhomogeneity representing the area of the Lone Tree pit (with increased hydraulic conductivity [K] values), included the same constant head boundary on the eastern side of the model domain as in the Lone Tree model (black square on figures), and included a line sink to represent the Humboldt River (northwest-southeast trending line on figures). Results of this simulation are illustrated in Figure 2. The second AEM simulation included the same features of the first, but added an additional inhomogeneity to account for K contrasts between alluvium in the vicinity of the Humboldt River and at greater distances. Results of this simulation are shown in Figure 3.

   Overall, the AEM simulations arrive at similar (but clearly simplified) results when compared to the *MINEDW* simulation. The three simulations all indicate generally lower water levels in the vicinity of the mine and the river, and the second AEM simulation produces some of the complexity in water levels observed to the east of the Lone Tree pit. The AEM simulations indicate acceptable overall reproducibility in comparison to the *MINEDW* code.

Figure 1. Head isolines extracted from the steady-state Lone Tree simulation.

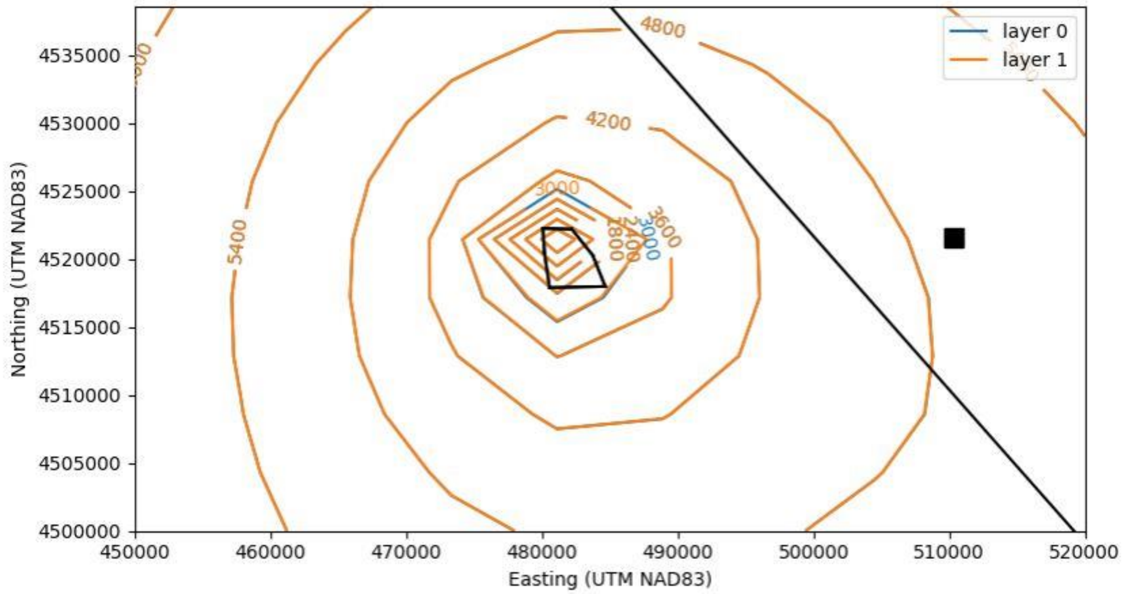

Figure 2. Predicted potentiometric surface of AEM simulation one.

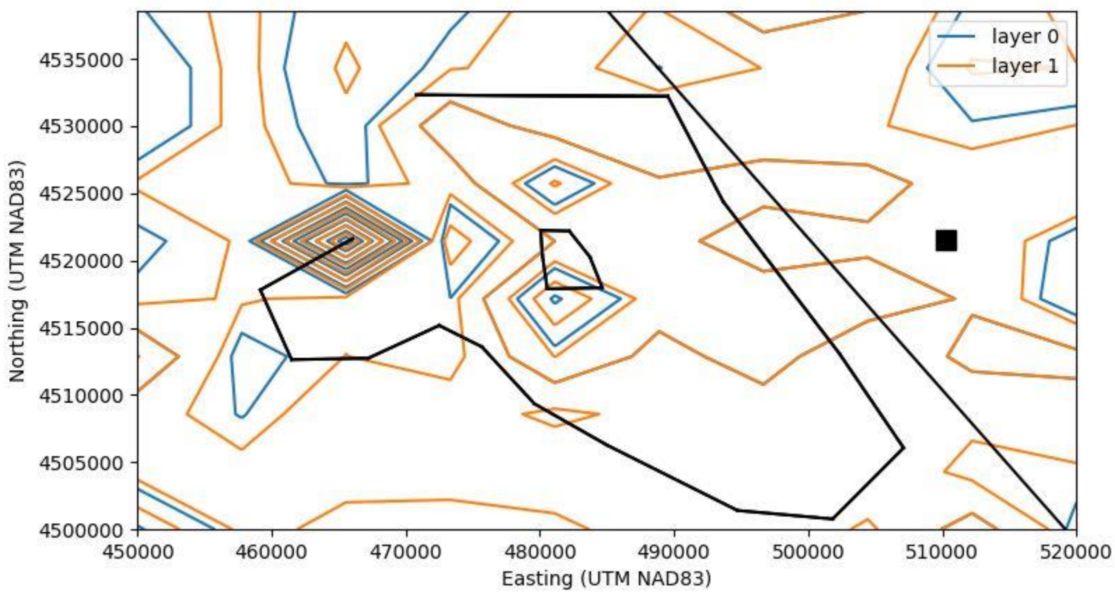

Figure 3. Predicted potentiometric surface of AEM simulation two.

2. **Modification of parameter values.** The Division commonly encounters submitted model reports with questionable or unverified parameter values (e.g., K, specific storage [S_s], specific yield [S_y]). It is therefore important for BMRR to be able to test scenarios by modifying some parameter values. For the *MINEDW* testing, the K values of the FAUL-PIT zone were modified to be 0.1 ft/day, and the Havallah (HAVA-PIT) were modified to be 10, 10, and 2 ft/day respectively for the x, y, and z dimensions. All modifications were made to the steady-state model. This allowed the Division to test the ability to modify input parameters in the code and run the

model. The model ran to completion and the Division was able to evaluate the resultant changes in the predicted steady-state potentiometric surface.

3. **Particle Tracking.** The final test completed by the Division was activation of particle tracking capabilities. This was completed in the transient model. Both forward and reverse particle tracking were completed. The results suggest that the code was able to create the particle tracks, but the visualization functions were not functioning according to the user's manual. See item II.3 below.

II. Issues Identified

Although *MINEDW* is approved for use for BMRR permitting studies, included below are several issues that may require action in the future.

1. **Mesh generator.** The Division was unable to use the mesh generator function, despite multiple attempts and checking common errors. Itasca (2016) notes that the mesh generator function is a separate program with a different graphical user interface (GUI). It is possible that this program was not installed appropriately on the computer utilized by the Division during review, or was not included on the software license key supplied by Itasca. Although this is troubling from a model design standpoint, the Division has determined that generating meshes would not be imperative for model review purposes. This problem has therefore not affected model approval.

2. **Solvers.** As noted in the 2 May 2018 correspondence from Itasca, one proprietary solver (the Algebraic Multigrid Methods for Systems [SAMG]) was not included in the software distribution provided to the Division. BMRR assumes that this would not affect the ability of BMRR to review submitted models.

3. **Particle tracking visualization.** As described above, the particle tracking capabilities appear to be functional. The Division was able to review the results of the particle tracking (as a .DAT file) using a standard text editor. These particle tracks could be visualized using a plotting routine based on the x-y-z location of the particle tracks through time. However, the functionality of the *MINEDW* GUI did not appear to be as stated in the user's manual, because no particle tracks appeared when the workflow was followed as detailed in the user's manual. This does not require additional attention at this time, but in the future correspondence may be required as to the potential causes for this discrepancy.

In conclusion, BMRR has determined that *MINEDW* may be utilized for future predictive modeling applications in support of mining regulatory permitting. Itasca should contact other agencies however to evaluate their specific needs and requirements. It is imperative that BMRR maintains the ability to review submitted *MINEDW* models. Therefore the software license key supplied by Itasca (serial number 303-001-0005-53369) must remain active to allow the software to run on BMRR computers.

Thank you for the opportunity to review the *MINEDW* groundwater flow modeling code. The listing of accepted codes (available at https://ndep.nv.gov/land/mining/regulation/guidance-policies-references-and-requirements) will be updated shortly to reflect this approval.

Finally, in the initial request for review, Itasca requested that key serial number 303-001-0005-53369 would be provided specifically for use by myself. However, I will be leaving the Division in the near future. The provided software key will be retained by the Division for future use by the Closure Branch.

Sincerely,

Connor Newman
Environmental Scientist – Hydrology and Geochemistry, Closure Branch
Bureau of Mining Regulation and Reclamation
Nevada Division of Environmental Protection

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Itasca, 2016, Draft MINEDW User Manual, version 3.0, pp. 144.

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