APPENDIX M: Hydrologic Modeling

GROUNDWATER MODELING ASSESSMENT
FOR THE BLACK BUTTE COPPER PROJECT
MEAGHER COUNTY, MONTANA

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GROUNDWATER MODELING ASSESSMENT
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1.0 INTRODUCTION

Tintina Montana (Tintina) is in the process of permitting and subsequently developing the Black Butte Copper (BBC) Project located north of White Sulphur Springs, Montana. The permitting process includes an assessment of how mining may effect water resources in the vicinity of the proposed mine. Tintina contracted with Hydrometrics, Inc. to develop a three dimensional groundwater flow model to assess potential hydrologic effects from the development of the proposed Black Butte Copper Mine. The assessment includes an evaluation of effects on groundwater and surface water in the vicinity of the project.

1.1 MODEL OBJECTIVES

Tintina in consultation with the Montana Department of Environmental Quality (MDEQ) developed the following modeling objectives:

- Estimate and evaluate groundwater inflow rates to mine workings.
- Assess changes in surrounding groundwater levels (drawdown) due to mine dewatering.
- Evaluate the potential location and magnitude of stream depletion effects.
- Assess a range of postulated time requirements for post-mining water level recovery.
- Evaluate potential mitigation alternatives (e.g., grouting).
- Evaluate mine closure options and groundwater discharge to primary watersheds.
- Based on model calibration and sensitivity analysis develop a clear explanation of the extent to which the modeling results can effectively be used to address the individual objectives, the associated data limitations and the accuracy of specific predictions.

The groundwater model provides Tintina and MDEQ with a tool to help with planning and identify areas where ongoing monitoring should be conducted to resolve concerns regarding the potential for hydrologic impacts.

1.2 PREVIOUS WORK

The geologic setting of the regional area has been mapped by Reynolds and Brandt (2005 and 2006). More detailed geologic mapping has been conducted by Tintina in the project area. The hydrogeologic setting was not extensively studied prior to the work conducted by Tintina. This is likely due to the rural nature of the area and the fact that the Newland shales in the area are typically low yield groundwater systems.

Tintina has conducted baseline water resource monitoring and numerous hydrological investigations to assess the hydrologic setting in the project area. The baseline water resource monitoring and hydrologic investigations are summarized in the Baseline Water Resources Monitoring and Hydrogeologic Investigations Report (Hydrometrics, 2015b). The hydrogeologic investigations were documented in detail for each investigation (Hydrometrics, 8/2012; 2013; 2015a).

1.3 MODEL SELECTION AND APPROACH

The model codes considered for this modeling analysis included MODFLOW-USG (control volume finite difference, with unstructured grid; Panday, et. al., 2013) and FEFLOW (finite element; DHI-WASY, 2013). These models were considered as they are both widely used in the groundwater modeling industry and allow for detailed evaluation of groundwater and surface water interaction. MODFLOW-USG applies an unstructured grid approach and is a fully saturated model; where cells that are or become dry are not actively used in the flow analysis. FEFLOW uses a mesh which can be refined horizontally, however, all layers must have an identical grid structure which can lead to excessively large number of model cells. FEFLOW typically applies a variably saturated flow solution (using Richard's Equation) in evaluating deep dewatering projects; the complexity and corresponding uncertainty that is inherent to the unsaturated flow parameters (especially in bedrock systems) within a finite element model was considered a limitation to using FEFLOW.

MODFLOW-USG was selected for this modeling assessment because the unstructured grid approach allows for detailed and efficient discretization (horizontally and vertically) in areas of groundwater and surface water interaction and mine structures where there are likely to be steep head gradients. MODFLOW-USG uses the Newton solver which provides for an accurate and efficient solution when the water table crosses multiple model layers. The three-dimensional groundwater flow model was developed using the GMS 10.0 and 10.1 software (Aquaveo, 2015) for preprocessing. PEST (Watermark Computing, 2010), a parameter estimation routine, was used to assist with steady state calibration and sensitivity analysis. PEST adjusts model parameters within established ranges to optimize the fit between model output and field observations.

The general approach to the BBC groundwater model consisted of development of a watershed-scale model to evaluate the impacts of mining on water resources. The data collected in the baseline monitoring and hydrogeologic investigations were used to develop a conceptual model, which was used as the basis to develop the three-dimensional numerical model. The numerical model was calibrated to steady state and transient observations prior to conducting predictive simulations. The modeling analysis was conducted based on the seasonal low water table, which represents baseflow conditions in the streams and it is assumed that groundwater discharge accounts for the majority of the stream flow during this period. The model was calibrated to baseflow conditions as one of the main objectives of the model is to evaluate the potential impact of dewatering on streamflow; using baseflow conditions provides a conservative analysis because inclusion of higher surface water flow components would likely attenuate depleted groundwater levels/flows due to mine dewatering. Predictive simulations were evaluated on an annual basis throughout the mine life. Mitigation alternatives were evaluated in areas that showed the largest impacts. Lastly, a sensitivity analysis was conducted to evaluate how uncertainty in the input parameters effects the model predictions. Details of the conceptual model, model build, forecasting simulations and sensitivity analysis are discussed in Sections 2.0 through 6.0 below.

This modeling approach provides a detailed evaluation of the groundwater flow system(s) in the project area and the effects that mining may have on water resources. The results of the modeling analysis should be used in conjunction with empirical data to assess potential impacts to water resources. Model limitations are discussed in detail in relation to simulation results in Sections 5.0 and 6.0 of this report.

2.0 CONCEPTUAL GROUNDWATER FLOW MODEL

2.1 REGIONAL SETTING

The Project Area lies within the Sheep Creek drainage on the southern edge of the Little Belt Mountains. Sheep Creek originates at an elevation of about 7,400 feet and discharges to the Smith River approximately 36.6 river miles to the west at an elevation of 4,380 feet. Sheep Creek flows south out of the little Belt Mountains and then shifts to the west with the little Belt Mountains rising steeply to the north and the lower foothills to the south. The project area lies on the southern side of Sheep Creek; 17.7 river miles from the head of the drainage. This conceptual model focuses on the upper two thirds of the Sheep Creek watershed, which extends from the headwaters of Sheep Creek downstream to the confluence of Black Butte Creek (Figure 2-1).

Sheep Creek has a number of named and unnamed tributaries that are shown in Figure 2-1. Little Sheep Creek, and Black Butte Creek (also referred to as Big Butte Creek or Butte Creek) are two of the larger named tributaries in the immediate project area that support perennial flow over a large portion of their length. Little Sheep Creek is located southeast of the project area and converges with an unnamed tributary (referred to here as Brush Creek) before joining Sheep Creek in Sheep Creek meadows in the lower project area. Black Butte Creek lies immediately east of the project area and joins Sheep Creek downstream approximately 7 miles to the west-northwest.

Moose Creek and Calf Creek are two prominent tributaries with perennial flow that enter Sheep Creek from the north downstream of the project site. Adams Creek is the largest of the upstream tributaries coming out of the Little Belt Mountains from the north. There are a number of smaller upstream tributaries that include Kinney, Daniels, and Jumping Creek. These smaller tributaries have less incised channels, and perennial flow is only evident on their lower reaches.

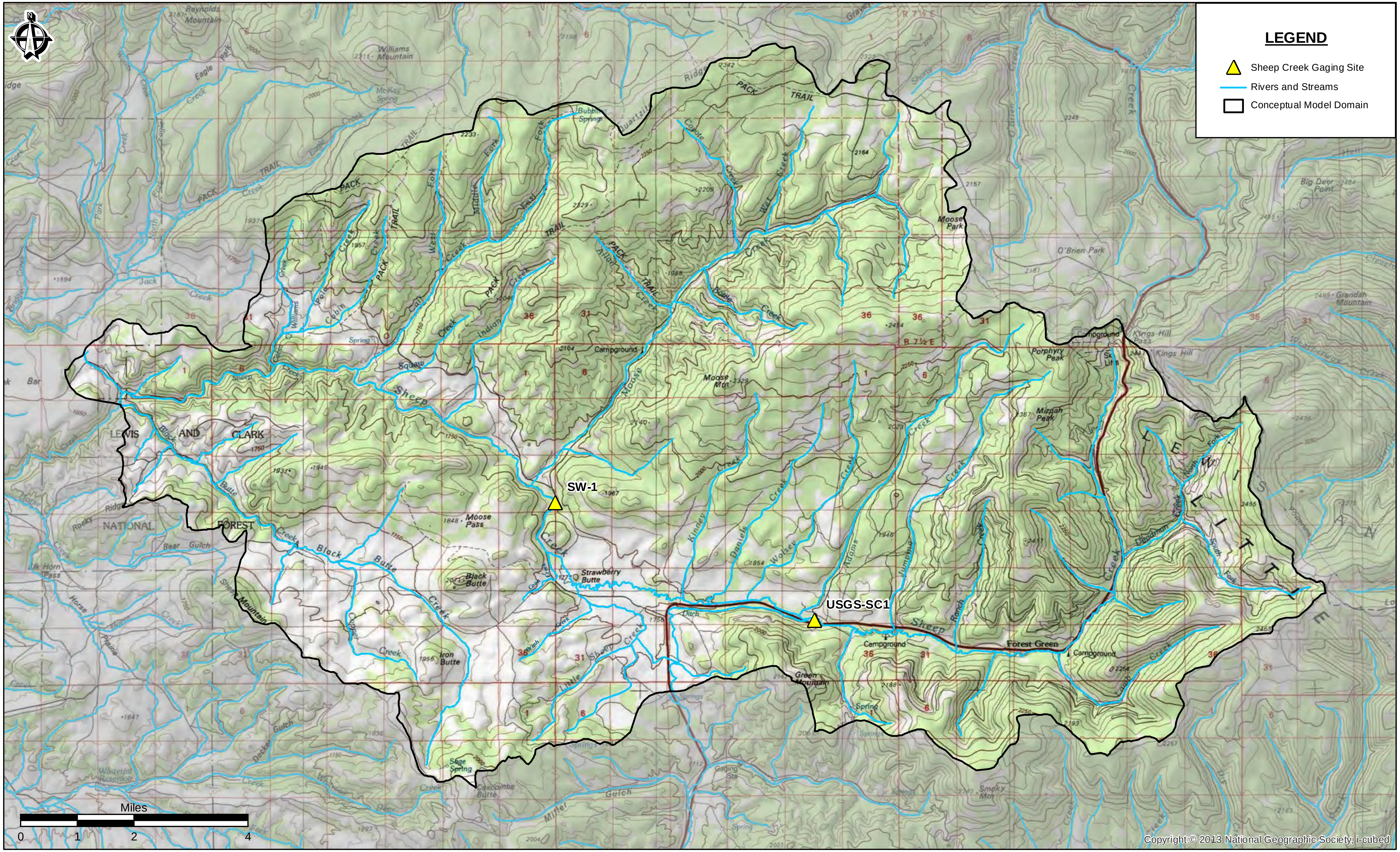

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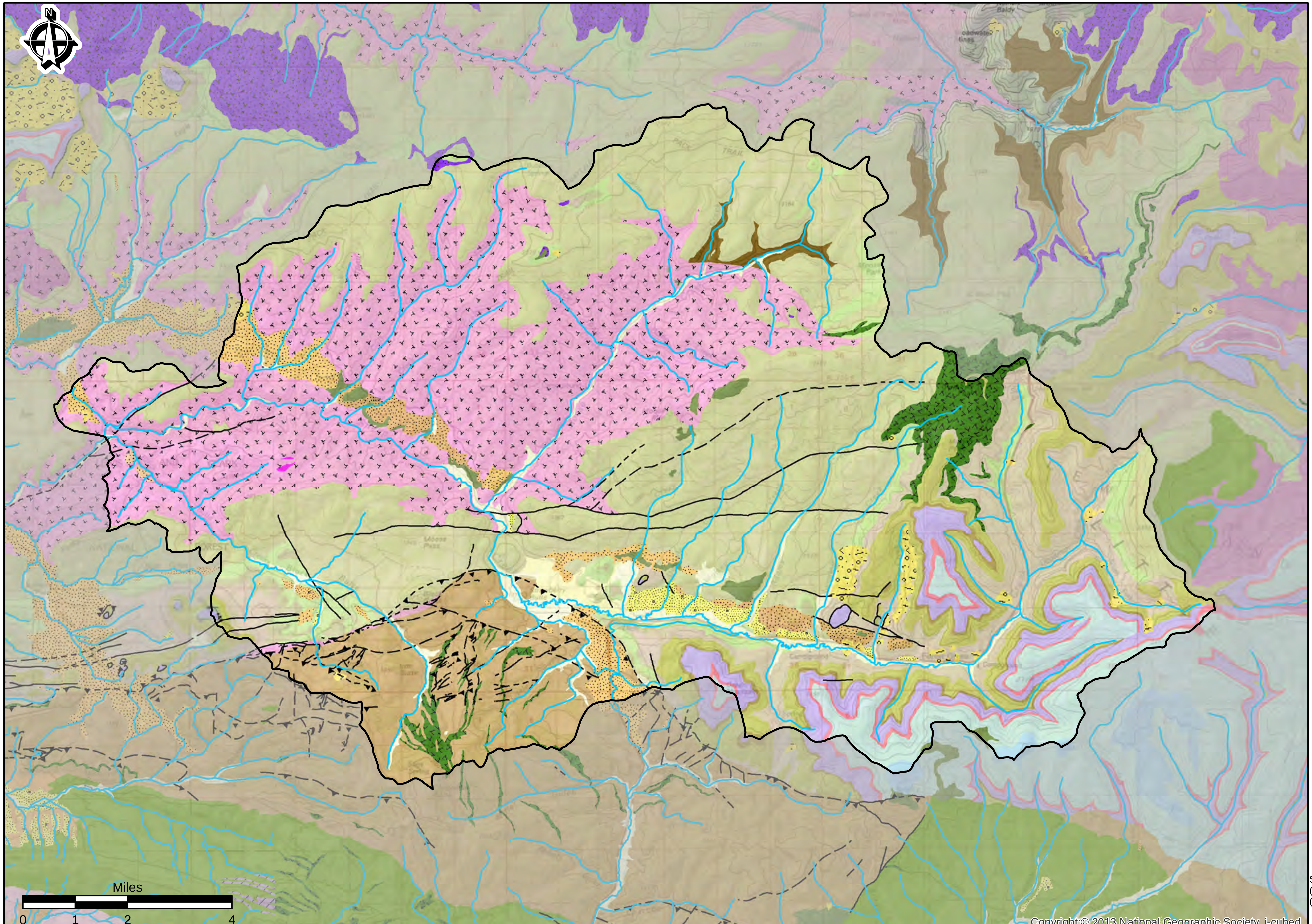
Figure 2-1
Conceptual Model Area
Black Butte Copper Project
Meagher County, Montana

2.2 GEOLOGIC SETTING

A prominent northeast trending thrust fault known as the Volcano Valley Fault (VVF) runs through the southern third of the Sheep Creek drainage (Figure 2-2). The geology to the south of the VVF consists largely of Precambrian lower Newland Formation shales, which extend to the southernmost boundary of the Sheep Creek drainage. The lower Newland Formation is often greater than 2500 feet thick in the area and consists mainly of gray dolomitic and non-dolomitic shales that dip gently to the south/southwest.

The topography rises steeply on the north side of the VVF into the Little Belt Mountains where it exposes Precambrian crystalline basement rock. On the south flanking slopes of the Little Belts the crystalline basement rock is overlain by Proterozoic Neihart quartzite and Cambrian Flathead sandstone. On the lowermost slopes where the Flathead sandstone approaches the VVF, it unconformably overlies Proterozoic Chamberlain shale and Neihart quartzite. A thin slice of lower Newland Formation is present above the Chamberlain shale where it abuts the Volcano Valley Fault in the immediate project area. A geologic map is shown in Figure 2-2 and a generalized cross section in Figure 2-3 depicting the stratigraphic relationships between these units. The geology becomes more complex in the upper watershed of Sheep Creek above Adams Creek. This area exposes a much larger sequence of Paleozoic formations along with Tertiary volcanics (Figure 2-2).

The Johnny Lee upper ore body is hosted within the lower Newland Formation and lies between the VVF and a separate northeast verging segment of the VVF thrust fault called the Black Butte Fault (BBF) to the south (Figure 2-2). There are two copper rich zones within the Johnny Lee deposit, the Upper Copper Zone (UCZ) and the Lower Copper Zone (LCZ). The UCZ is up to 90 feet thick and lies at a depth of approximately 250 to 350 feet below ground surface at an elevation between 5,165 and 5,687 feet MSL. The LCZ is up to 55 feet thick and lies at a depth of approximately 1,300 to 1,500 feet below ground surface at an elevation of 3,954 to 4,853 feet MSL. The lower copper zone is within the comparatively thin slice of lower Newland that lies on the north side (the footwall) of the VVF (Figure 2-3). The Lower Ore Zone lies just above the contact with the Chamberlain Formation and is cut to



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LEGEND

Quaternary

- Qt Terrace gravel (Holocene and Pleistocene)
- Qp Pediment gravel (Holocene? and Pleistocene)
- QTg Older gravel (Pleistocene and Pliocene)
- Qoa Old alluvium (Holocene or Pleistocene)
- Ql Landslide deposit (Holocene and Pleistocene)
- Qc Colluvium (Holocene)
- Qac Alluvium and colluvium, undivided (Holocene)
- Qa Alluvium (Holocene)

Tertiary

- MIOGs Sedimentary rocks, undivided (Miocene and Oligocene)
- OGs Sedimentary rocks older than basalt flow (Oligocene and Eocene?)
- EOqm Quartz monzonite (Eocene)
- Eobhqm Biotite hornblende quartz monzonite (Eocene)
- Eobgd Biotite hornblende dacite (Eocene)
- Oib Basalt (Oligocene)

Paleozoic

- Mm Mission Canyon Limestone (Upper and Lower Mississippian)
- Ml Lodgepole Limestone (Lower Mississippian)
- MDt Three Forks Formation (Lower Mississippian and Upper Devonian)
- Du Upper and Middle Devonian rocks, undivided
- Dj Jefferson Formation (Upper Devonian)
- DCm Maywood Formation (Upper and Middle Devonian) and locally Upper Cambrian beds
- Cpi Pilgrim Formation (Upper Cambrian)
- Cp Park Shale (Upper and Middle Cambrian)
- Cm Meagher Limestone (Middle Cambrian)
- Cf Flathead Sandstone (Middle Cambrian)
- Cw Wolsey Formation (Middle Cambrian)

Belt Supergroup

- Yg Greyson Formation (Mesoproterozoic)
- Yn Newland Formation (Mesoproterozoic)
- Yc Chamberlain Formation (Mesoproterozoic)
- Xag Augen gneiss (Paleoproterozoic)
- Xgg Granite gneiss (Paleoproterozoic)
- Xbg Biotite gneiss (Paleoproterozoic)
- Xgda Gneissic granodiorite and amphibolite, undivided (Paleoproterozoic)
- Xd Diorite (Paleoproterozoic)
- Xa Amphibolite (Paleoproterozoic)
- Xpd Pinto Diorite (Paleoproterozoic)
- Wd Metadiorite (Neoarchean)

- Fault_defined
- Fault_approximate
- Fault_inferred
- Thrust_defined
- Thrust_approximate
- Thrust_inferred

Souce: Geologic data from White Sulphur Springs Quadrangle (Reynolds and Brandt, 2006) and Canyon Ferry Dam Quadrangle (Reynolds and Brand,2005)

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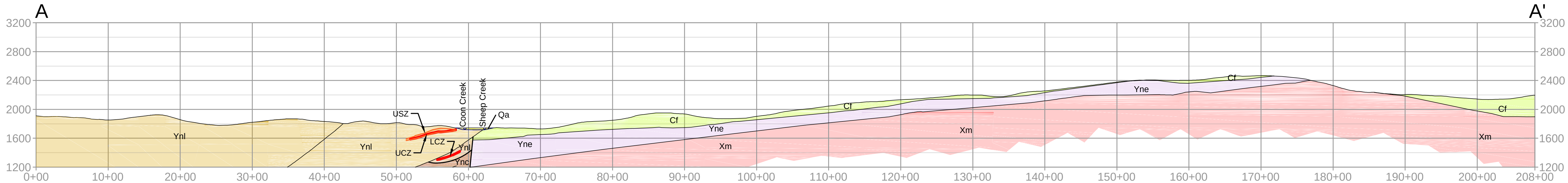
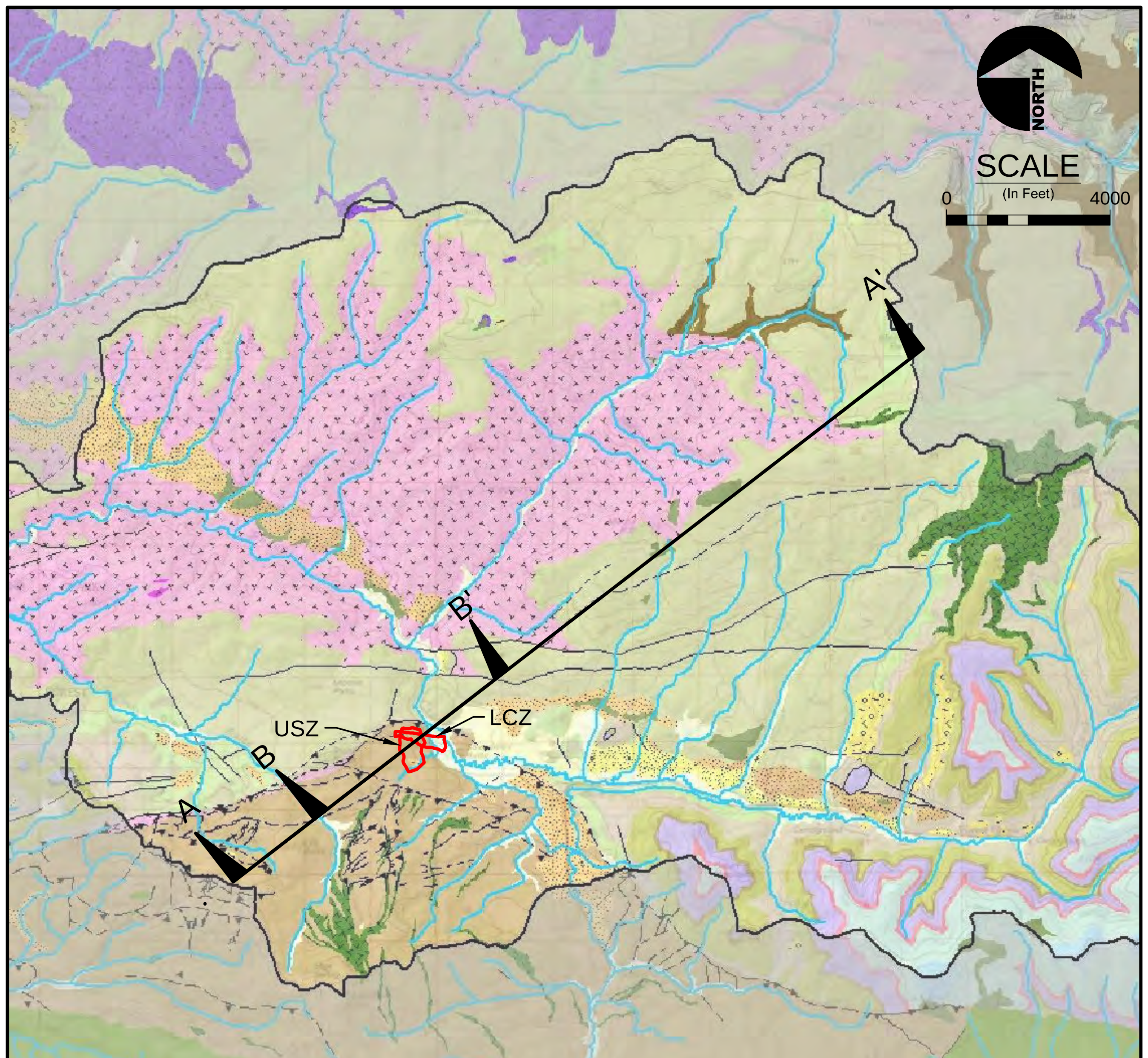
Figure 2-2

Geologic Map of Conceptual Model
Black Butte Copper Project
Meagher County, Montana

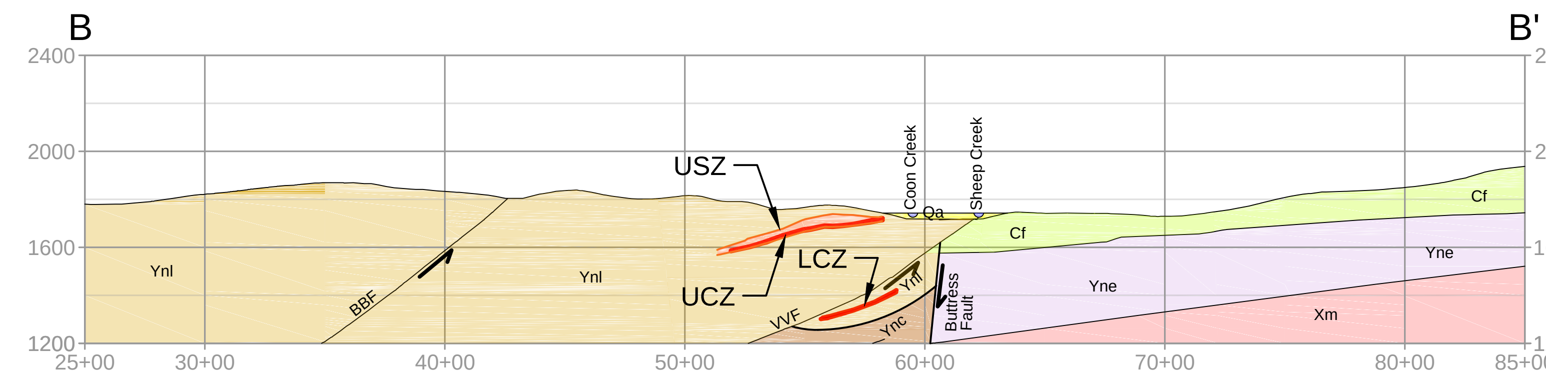


CROSS SECTION A - A'

1"=1400'



CROSS SECTION LOCATION MAP



CROSS SECTION B - B'

1"=800'

LEGEND

Qal	Quaternary Alluvial Deposits
Cf	Flathead Sandstone
Ynl	Lower Newland Shales
USZ	Upper Sulfide Zone
UCZ	Upper Copper Zone
LCZ	Lower Copper Zone
Yc	Chamberlain Shale
Yne	Neihart Quartzite
Xm	Crystalline Bedrock
VVF	Volcano Valley Fault
BBF	Black Butte Fault

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Figure 2-3
Schematic Cross Sections
Black Butte Copper Project
Meagher County, Montana

the north by the Buttress Fault, a Precambrian normal fault (Figure 2-3). The Buttress fault does not extend to the surface in the immediate project area but is truncated by the VVF.

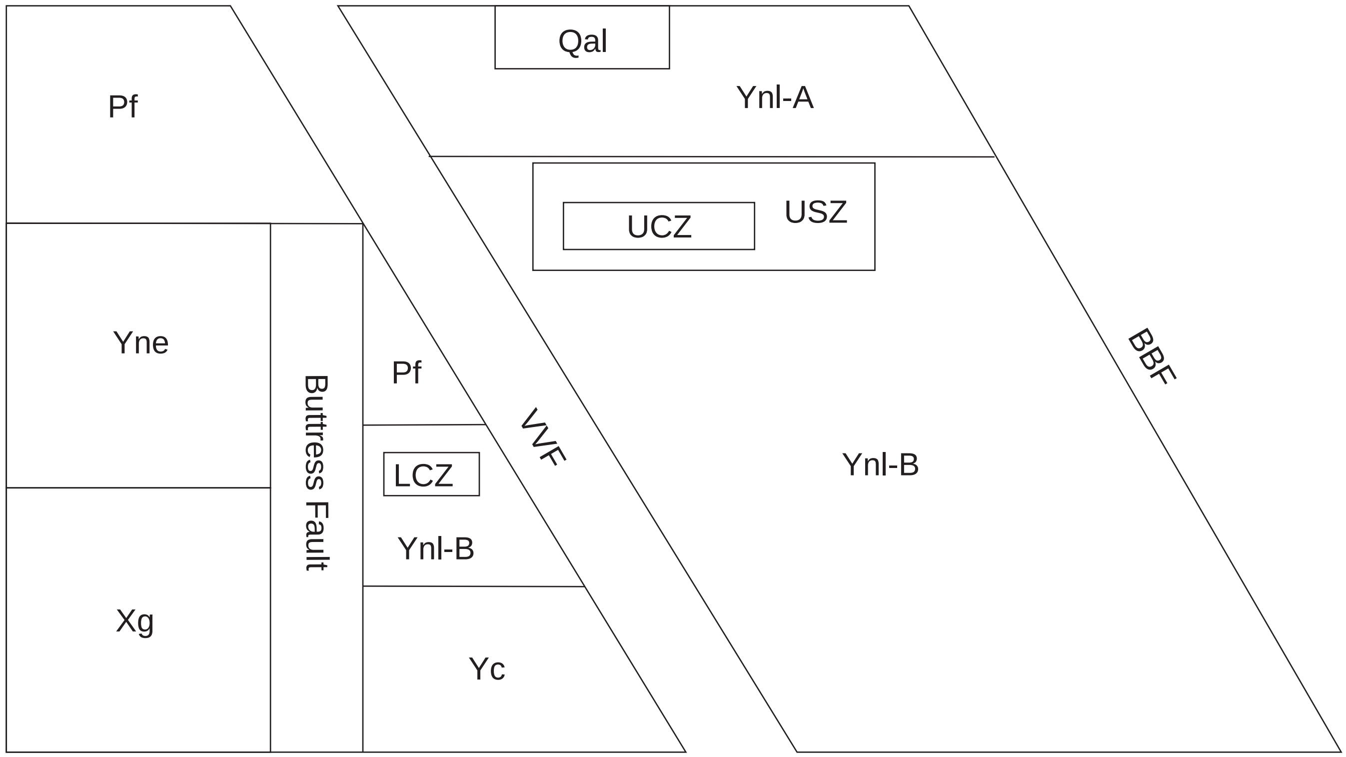
In addition to the bedrock units discussed above, there are also unconsolidated surficial deposits present within the drainage; however, these are relatively limited in extent as shown in Figure 2-2. These include alluvial deposits along the axis of the major drainages and older (Quaternary/Tertiary) basin-fill sediments that form terraces flanking these drainages in a few areas (Figure 2-2). The alluvial deposits are most prominent in the middle reach of the Sheep Creek drainage where the valley is comparatively wide. Significant portions of the upper and lower reaches of Sheep Creek cut through narrow bedrock canyons where surficial deposits are minor or absent.

2.3 HYDRO-STRATIGRAPHIC UNITS

The major hydro-stratigraphic units (HSUs) generally coincide with the principal geologic units in the area but also include fault zones. The principal HSUs are described below and are shown in the schematic diagram in Figure 2-4. Hydraulic properties of the major units within the project area have been determined through aquifer testing, which have been detailed in technical reports for the project and summarized in the Baseline Water Resources Monitoring and Hydrologic Investigations Report (Hydrometrics, 2015b – see Table 7). Hydrologic characteristics of units outside of the project area have been estimated based on literature values for similar formations.

2.3.1 HSUs Established Based on Geologic Units

<u>Quaternary Deposits</u> – This unit corresponds to the alluvial sand and gravel deposits that lie along the axes of the major drainages. Well MW-4A was completed in the alluvial aquifer in Sheep Creek Meadow to assess the hydrologic characteristics and water quality within the Sheep Creek alluvium. The well encountered comparatively coarse-grained sand and gravel to a depth of 17 feet in this area. Slug testing yielded a hydraulic conductivity (K) for the Sheep Creek alluvial aquifer of 200 feet per day. Storage properties cannot be determined from single well tests, but literature values for specific yield of mixed sand and gravel



LEGEND

Qal	Quaternary Alluvial Deposits
Pf	Flathead Sandstone
Ynl-A	Lower Newland Shales/Shallow
Ynl-B	Lower Newland Shales/Deep
USZ	Upper Sulfide Zone
UCZ	Upper Copper Zone
LCZ	Lower Copper Zone
Yc	Chamberlain Shale
Yne	Neihart Quartzite
Xg	Crystalline Bedrock
VVF	Volcano Valley Fault
BBF	Black Butte Fault

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Figure 2-4
Hydro-Stratigraphic Units
Black Butte Copper Project
Meagher County, Montana

alluvium are typically in the range of 20-35% (Fetter, 2001; Anderson and Woessner, 1992). These properties are believed to be reasonably representative of the alluvial aquifers in this area based on materials observed in steam bed cuts and surface exposures.

Newland Formation – For the purposes of this model, the lower Newland Formation is divided into shallow and deep bedrock units. The shallow and deep bedrock units in the project area correspond to the Ynl-A and Ynl-B units, which are divided by the USZ.

The Ynl-A unit typically consists of calcareous and non-calcareous shale and siltstone with discrete weathered intervals that exhibit oxidized surfaces within the upper 130 to 150 feet. The base of the Ynl-A is at the contact with the Upper Sulfide Zone (USZ). Wells that penetrate the Ynl-A have produced yields of 5 to 30 gpm within discrete zones during drilling. The hydrologic characteristics of the Ynl-A were assessed in a 48 hour pumping test at test well PW-3 and in a 31 day extended pumping at test well PW-8. Both tests yielded similar ranges of hydraulic conductivity with K values from the pumping wells ranging from 1 to 2.3 feet per day and a geometric mean of 1.5 feet per day. The PW-8 pumping test yielded a slightly higher K range based on observed drawdown at PW-3 with K values ranging from 4.3 to 5.8 ft/day. The K range in the Ynl-A are uncharacteristically high for a shale and siltstone unit; this may be a result of greater weathering of the shallow unit. Although the lower range values appear characteristic of the well yields, the higher range K values for the Ynl-A should be considered in evaluating model sensitivity with respect to Ynl-A hydraulic conductivity. Storativity results from the extended test range from 1×10^{-4} to 8×10^{-6}.

The Ynl-A is separated from the Ynl-B by the USZ, which includes the Upper Copper Zone (UCZ). The mineralized shale in the USZ and UCZ typically produces very low yields. A number of aquifer tests were conducted in the Upper Sulfide Zone to define the hydrologic characteristics of this unit and the tests include a 5-day pumping test at PW-2, a 2-day test at PW-4, and a 19-day test at PW-9. Hydraulic conductivities based on observed drawdown in the USZ wells ranged from 0.01 to 0.7 feet per day with a geometric mean of 0.08 feet per day. Well MW-3, completed in the USZ, was monitored during the PW-2 and PW-9 aquifer tests. The observed drawdown at this well yielded storage coefficients of 6 x 10^{-5} and 9 x 10^{-5}.

The deeper bedrock in the lower Newland formation (Ynl-B unit) also consists of dolomitic and nondolomitic shales and siltstones like the Ynl-A unit, however, the deeper bedrock typically produces lower yields than wells completed in the Ynl-A. The Ynl-B is more than 2,000 feet thick in the area to the south of the VVF. In general, wells penetrating into the lower Ynl-B unit produced little water. Test well PW-10 is completed in the Ynl-B unit below the upper ore zone and produced slightly less than 1 gpm after completion. Testing at this well yielded hydraulic conductivity values of 0.001 to 0.007 feet per day. No storage estimates are available for this unit.

The thin slice of the Ynl-B in the footwall to the north of the VVF is approximately 150 feet thick and hosts the lower ore zone. A slug test performed on PW-7 at a completion depth of 1300 to 1350 feet in the Lower Ore Zone yielded an estimated hydraulic conductivity of 0.1 to 0.2 feet per day, but this may overestimate the actual hydraulic conductivity since the well appeared to stabilize with only partial recovery during the test. To further assess the recovery response, water levels in this well were monitored after purging the well for water quality monitoring. Water levels in the well had not recovered 14 days after the sampling event and the calculated hydraulic conductivity based on drawdown recovery was 1.9 x 10^{-4} ft/day. The lower range value appears to be more consistent with the slow recovery response as well as literature values of hydraulic conductivity for shales with typical ranges from 10^{-4} to 10^{-7} feet/day (Domenico and Schwartz, 1990).

Flathead Sandstone

Flathead Sandstone is present to the north of the Volcano Valley Fault and is composed of fine- to medium-grained sand that is generally well cemented, but the degree of cementation can vary locally. The Flathead sandstone unit is approximately 100 feet thick where it has been encountered in exploration boreholes next to the VVF. There are no test wells within the Flathead sandstone in the project area to establish hydraulic parameters for this unit. Literature values for hydraulic conductivity of sandstone show a large potential range with reported K values for sandstone ranging from 10^{-5} to 1.5 ft/day (Domenico and Schwartz, 1990). Hydraulic conductivity in this unit is assumed to exhibit a general decrease with depth due to decreased weathering and greater overburden pressures.

Chamberlain Shale

Chamberlain shale underlies the Ynl-B and has only been encountered in exploration boreholes on the north side of the VVF where it appears to be up to 500 feet thick. There are no test wells that penetrate the Chamberlain shale to determine hydrologic characteristics of this unit. For the purposes of this conceptual model the Chamberlain shale is assumed to have properties similar to the lower Newland shales.

Neihart Quartzite

Neihart quartzite underlies the Chamberlain shale north of the VVF and is up to 800 feet thick. Quartzites are recrystallized sandstones that have low permeability and typically form confining units except where they are fractured. No quantitative data have been established on the hydrologic characteristics of this unit. This unit exhibits low permeability characteristics where it has been encountered in coreholes with the exception of localized zones of fracturing in association with the Buttress Fault. The Neihart quartzite is considered to be a low permeability unit in the conceptual model; however, the Neihart quartzite has the potential to produce high yields if highly fractured intervals are directly encountered in association with fault zones (see additional discussion for the Buttress Fault HSU). It should be noted that the mine workings under the current mine plan do not intercept the Neihart quartzite.

Crystalline Bedrock

Precambrian metamorphic crystalline bedrock forms the core of the Little Belt Mountains and is present in the area north of the VVF. Since crystalline rocks have negligible primary porosity, groundwater is only present within joints and fractures in the rock. The permeability of the joints and fractures typically decreases rapidly with depth due to the combined effect of the weight of the overlying rock and the tendency of weathering and surface disturbances to penetrate only a short distance into the bedrock. Representative hydraulic conductivity values for crystalline rock are on the order of 10^{-3} to 10^{-1} ft/day (Stauber and Bucher, 2007) with values for weathered crystalline rocks ranging up to several orders of magnitude higher. This conceptual model incorporates the general relationship between permeability and depth originally established by Snow (1968), which assumes that the permeability of crystalline basement rocks decreases by approximately three orders of magnitude in the upper 300 feet.

Tertiary Intrusives

The lower Newland Formation in the area south of the BBF has been intruded by Tertiary granodiorite. There are no test wells completed in the intrusives that can be used to quantify their hydrologic properties, however, granodiorite is a low permeability crystalline rock that for the purpose of this conceptual model is assumed to have hydrologic characteristics similar to the crystalline bedrock to the north.

2.3.2 Structurally Defined HSUs

The Johnny Lee ore body is bounded by fault zones that have the potential to significantly influence groundwater flow through this area. The BBF and VVF are reverse faults that bound the upper orebody to the north, south and west; the Brush Creek Fault is a north-south trending normal fault that bounds the upper orebody to the east (Figure 2-2). The lower ore zone is bounded to the north by the Buttress Fault and to the south by the VVF. The influence that these faults have on groundwater flow is a function of the permeability characteristics within the fault zones. In general, fault zones are considered to have two structural zones: a core where most of the movement takes place and a surrounding damage zone where brittle fracturing extends out into the surrounding rock. The fault core can have clay-rich fault gouge that is very low permeability and restricts groundwater flow across the fault plane, whereas damage zones can enhance the permeability of the rock immediately bounding the core and thus enhance flow parallel to the fault plane. The permeability of these features can be altered by mineralization that fills the fractures and reduces the permeability in the damage zone. The permeability characteristics of a given fault, therefore, depend on the presence and thickness of a gouge zone, the degree of supplementary fracturing in the damage zone and the presence of mineralization and cementation within the fractures. Exploration boreholes show fault gouge present within the cores of each of the faults, therefore, these fault zones are considered separate hydro-stratigraphic units for the purposes of this conceptual model. The presence and extent of fault gouge versus open fracture/damage zones are described for each of the fault units below.

<u>Volcano Valley Fault (VVF)</u>

As previously described the VVF is a large reverse fault that bounds the upper ore zone to the north and the lower ore zone to the south. Three separate test wells were drilled into or through the VVF (PW-5, PW-6, and PW-7) to assess hydrologic conditions associated with the fault zone. Each of these test wells encountered a thick sequence of clay-gouge within the VVF. The gouge zone was 170 to 180 feet thick at the well locations where the VVF was fully penetrated, which is equivalent to approximately 150 feet of thickness when adjusted for the 30 degree dip of the fault plane. Neither the fault zone nor the adjacent rock produced significant groundwater during drilling suggesting that there is not a well-developed damage zone in the Newland Formation bounding the gouged core of the VVF at this location. A series of flex wall permeameter tests conducted on samples of the gouge material from core holes yielded very low hydraulic conductivity results with K values ranging from 7.1×10^{-4} to 1.5×10^{-5} ft/day and an average of 2.8×10^{-5} ft/day (Hydrometrics, 2015b). No test wells penetrate the VVF below the ore zone where it contacts the deeper Chamberlain shale or Neihart quartzite and therefore it cannot be established whether there is a damage zone in these deeper units associated with the VVF.

<u>Black Butte Fault</u>

The BBF is a splay of the VVF that bounds the mineralized zone of the Lower Newland to the south. There is only one exploration core hole through the Black Butte Fault (BBF) and it encountered the BBF within an area of Tertiary intrusives. The exploration log notes that two gouge layers were encountered within the fault zone. These gouge zones were one to two feet in thickness. The core log also notes 21 feet of sub-vertical fractures within the granodiorite at the fault zone which when corrected for the angle of the borehole indicate a fault thickness of approximately 10 to 14 feet.

Buttress Fault

The Buttress fault is a near vertical normal fault zone that is bounded to the south by the lower Newland and Chamberlain shales, and to the north by Flathead sandstone, Chamberlain shale and Neihart quartzite (Figure 2-3). Exploration cores through the Buttress fault all show clay gouge within the core of the Buttress fault, however, the thickness of the gouge zone is significantly less than the VVF, generally only about 5 feet thick. Test well PW-6 was advanced through the lower Newland into the Buttress fault and into the underlying Neihart quartzite. The well encountered over 70 feet of gouge within a zone of fractured shale. Although this is not directly representative of the actual thickness of the fault zone since it is a vertical borehole penetrating a near vertical fault, it indicates the gouge in the fault is relatively continuous with depth at this location. The well did not encounter significant groundwater inflow within the fault zone or within the Newland or Neihart formations immediately bounding the fault. The well did encounter a fractured interval in the Neihart approximately 175 feet after passing through the Buttress fault that produced high yields and resulted in artesian flow conditions. This could be supplementary fracturing from the Buttress fault at a deeper interval in the Neihart, since the borehole is still in proximity to the Buttress fault at this depth. The fracturing and associated permeability encountered in the Neihart at depth at this location does not appear to extend vertically upward. There are 11 exploration boreholes that penetrate the Buttress fault and extend into the Neihart. The boreholes show variable degrees of fracturing in the Neihart associated with the Buttress Fault with some locations encountering competent rock with minor fracturing and others showing high angle fractures in the quartzite adjacent to the fault. Significant flow with artesian pressures was only noted at one of the exploration borehole sites.

For the conceptual model the Buttress fault is assumed to have a 5-foot thick low permeability gouge zone with permeability characteristics similar to the VVF gouge. The extent and effects of any vertical permeability components associated with Neihart in the Buttress fault zone cannot be fully determined and therefore will need to be assessed as part of the modeling analysis.

Brush Creek Fault

The Brush Creek Fault is a north-south trending normal fault that has been mapped within the Newland Formation to the east of the Ore Body. There is limited corehole information and no wells completed in this fault. One exploration corehole intercepted the upper portion of the Brush Creek fault where it encountered approximately 44 feet of sheared and fractured shale with a gouge zone approximately 1 foot in thickness. However, the fault was encountered at a relatively shallow location and other faults in the area show increased gouge with depth.

For this conceptual model all of the faults described above are considered to contain low permeability gouge zones that limit flow across these units. There does not appear to be a well-developed damage zone in the Newland shales. Where fault related fracturing is locally more notable is within the more brittle geologic units (i.e., quartzite and crystalline intrusives). In general, modeling a fault without a damage zone will tend to increase the potential for drawdown effects to extend across a fault. The low permeability of the fault gouge restricts the amount of groundwater flux through the fault zone, and the presence of a high K zone adjacent to this generally limits any further expansion of the cone of depression across the fault but may produce flow components along the plane of the fault.

2.4 GROUNDWATER FLOW CONDITIONS

Both a watershed scale potentiometric map and a local scale map of the project area have been developed to define the principal directions of groundwater flow within the watershed and provide a more detailed understanding of groundwater flow within the project area. The regional scale map presents a generalized interpretation of groundwater conditions since the area is very sparsely developed and water level data are only available from relatively few scattered well locations. The water level data outside of the project's monitoring well network were obtained from a search of Montana's Groundwater Information Center (GWIC) database maintained by the Montana Bureau of Mines and Geology. The search identified 20 wells with water level data reported in their well logs at the time of well completion. Thirteen of the wells are completed in bedrock and seven in alluvial systems. Well elevations were estimated from topographic maps and used with the reported water level data to establish approximate groundwater elevations. Because most of the wells are located in lower elevation areas, the elevation of perennial stream reaches were identified from topo maps and late season aerial photos and these were assumed to be correlative with groundwater elevations along the major drainages when developing potentiometric contours. The watershed scale potentiometric map is shown in Figure 2-5. The groundwater flow directions inferred from the potentiometric contours are generally coincident with the larger scale topographic trends. Potentiometric contours indicate that groundwater flow converges on the major drainages which include Sheep Creek, Moose Creek, Little Sheep Creek, and Black Butte Creek. Water level elevations range up to 7000 feet in the upper drainages of the Little Belts to the north, 6000 feet in the upper drainages to the south and are approximately 5000 feet at Sheep Creek near the downstream confluence with Black Butte Creek to the west.

A more detailed potentiometric map of the project area was developed based on Tintina's network of monitoring wells and piezometers and is shown in Figure 2-6. This map depicts the potentiometric surface in the lower Newland wells, as well as the water table elevation in the shallow alluvial system. Again, the groundwater flow directions inferred from potentiometric data are generally consistent with topographic trends. Groundwater flow in the alluvium is roughly parallel to the stream but converges on Sheep Creek on the southern end of the Sheep Creek meadows where the alluvium pinches out as Sheep Creek enters a narrow bedrock canyon. The alluvial groundwater system has a hydraulic gradient of approximately 0.008. The hydraulic gradient across the project area in the shallow bedrock wells is approximately 0.065, but flattens out in Sheep Creek Meadows suggesting there is discharge of groundwater from the shallow bedrock system to the overlying alluvial aquifer in this area.

Most paired wells show upward hydraulic gradients with the exception of MW-1A/1B and piezometer PZ-07A/07B. Water levels in MW-1A appear to represent shallow perched groundwater within the clayey gravel terrace deposits that overly the shale bedrock in this area. PZ-07A and PZ-07B also have a downward hydraulic gradient indicating that the springs feeding the headwaters of Coon Creek are also likely a perched system that is not fed

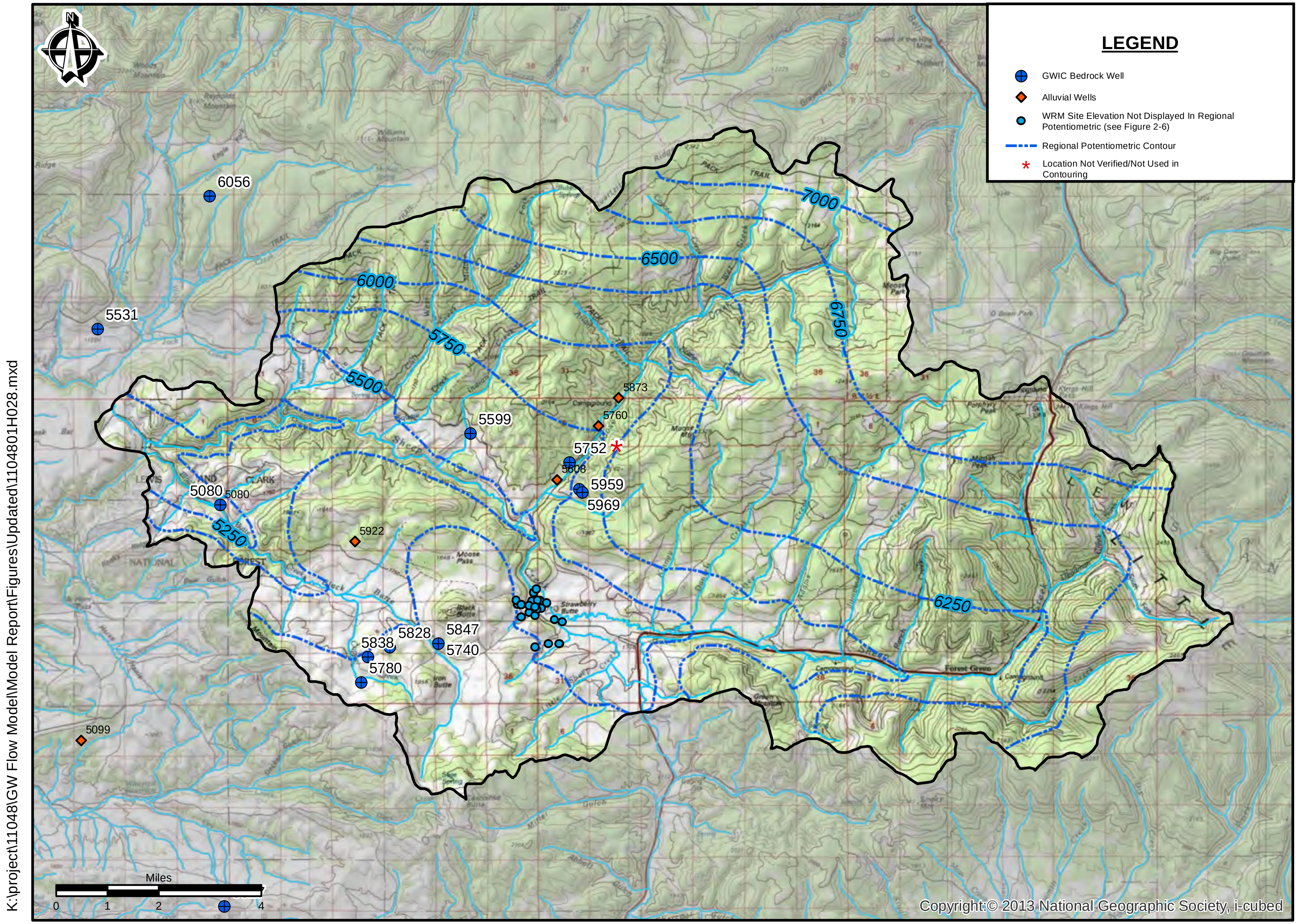

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Figure 2-5
Watershed Scale Potentiometric Map
Black Butte Copper Project
Meagher County, Montana

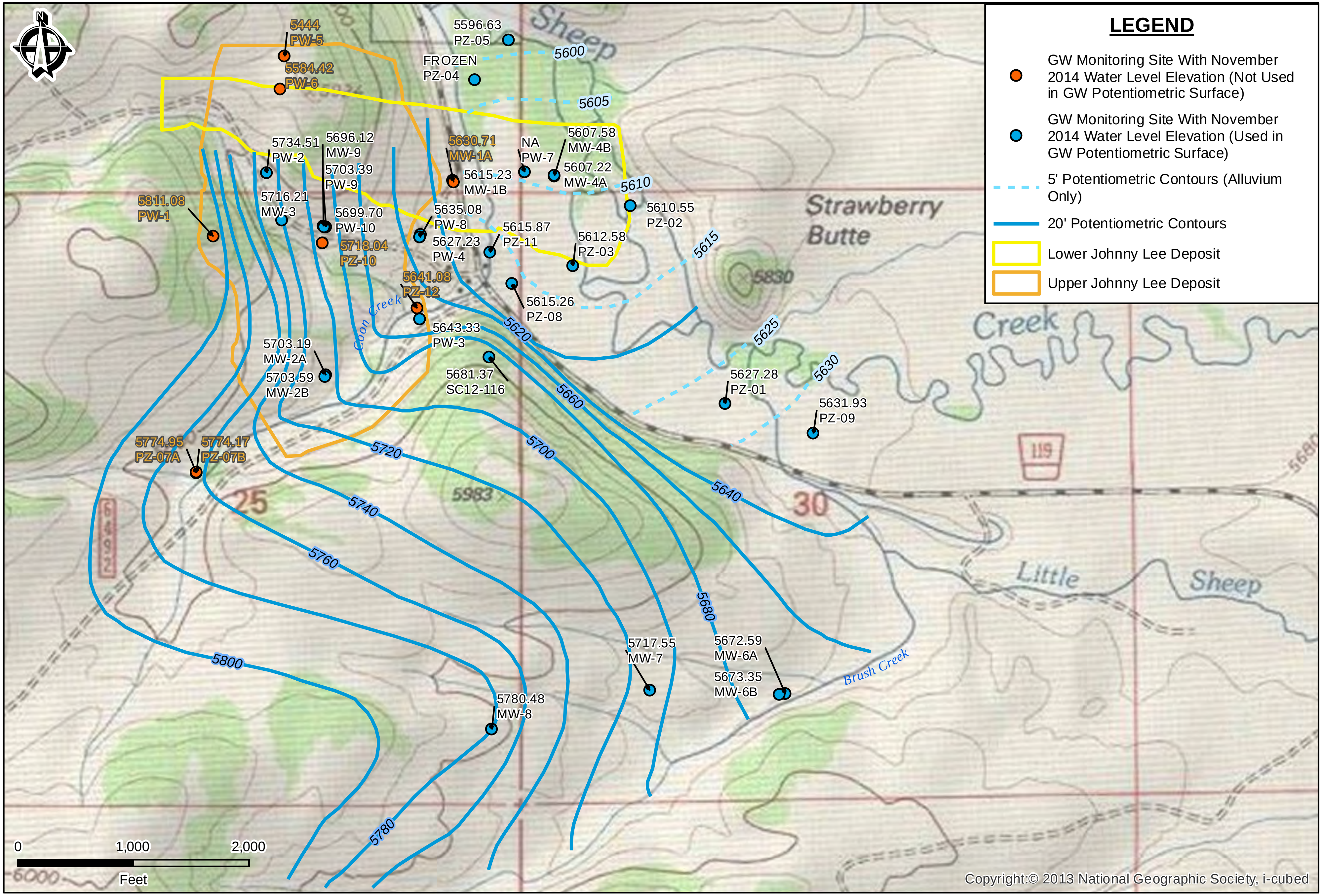

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Figure 2-6
Project Scale Potentiometric Map
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Meagher County, Montana

by the deeper bedrock aquifer in this area. In the lower elevation areas the wells show a progressive upward gradient between the deeper bedrock units and shallow units with evidence of artesian conditions at the depth of the lower ore zone as evidenced by artesian flow at PW-7. Flowing conditions have also been encountered in a separate exploration corehole in the Neihart southwest of Strawberry Butte. The Neihart dips towards the VVF and the presence of artesian conditions suggest it receives recharge from higher elevation exposures upslope and that more competent layers in the overlying Neihart and Flathead Sandstone are producing high confining pressures in this fracture system. Wells MW-9, PW-9, and PW-10 are located within 5-10 feet of each other and are completed in the Ynl-A, UCZ, and Ynl-B, respectively. These wells show a large vertical gradient from the UCZ to both the Ynl-A (7.27 feet) and the Ynl-B (3.69 feet).

Groundwater levels typically show seasonal fluctuations in the bedrock wells of 1 to 3 feet, peaking in early June and declining through the summer months (seasonal water level data are included in the baseline report; Hydrometrics, 2015b). Groundwater levels continue to decrease at a slower rate through the winter months and reach seasonal lows in February and March. The shallow alluvial system fluctuates 1 to 1.5 feet seasonally with similar seasonal trends to the bedrock system, although the seasonal spike in water levels in early June in the alluvial system occurs more rapidly than the bedrock system and tails off more rapidly. Water levels in piezometers completed in the Sheep Creek alluvium typically peak in early June and drop rapidly stabilizing at a lower level by late August or September and remaining at lower levels through April.

Water levels indicate confined or leaky confined conditions in the bedrock aquifers and unconfined conditions in the shallow alluvial system. With a few exceptions water was first encountered in the bedrock wells a substantial distance below the stabilized water level elevations in the completed wells. Low permeability shale layers appear to produce confined or semi-confined conditions in these areas. Leaky confined systems may be present in shallow bedrock wells at MW-4 and MW-6 where saturated conditions were encountered above the primary producing zones in the wells.

Groundwater flux through the Sheep Creek alluvium, the shallow bedrock system (Ynl-A) and the upper sulfide zone (USZ) can be estimated from potentiometric data and hydraulic conductivity data using a simple Darcy's Law calculation. Since this applies a simplified porous media solution to bedrock formations with variable properties it should only be considered a generalized assessment of the relative flux of groundwater in each of these units. The calculations focus on flow through the bedrock within the footprint area of the upper orebody, and flow through the downgradient alluvial system towards Sheep Creek. Input assumptions and estimated fluxes are shown in Table 2-1.

TABLE 2-1. DARCY'S LAW GROUNDWATER FLOW ESTIMATES

	Hydraulic Conductivity (ft/d)	Aquifer Width (ft)	Aquifer Thickness (ft)	Hydraulic Gradient	GW Flux (gpm)
Sheep Creek Alluvium	200	1500	16	0.008	200
Ynl-A	1.5	3400	50	0.065	90
Upper Sulfide Zone	0.01	3400	30	0.068	0.4

These estimates show the relative groundwater flux through each unit (shown graphically in Figure 2-7), which represent the relative contributions to steady state base flow in Sheep Creek from these units. Flow in the shallow bedrock system may account for up to 45% of the groundwater flow in the alluvial aquifer at this location, while flow in the Upper Sulfide Zone in the deeper Ynl-B bedrock account for less than 0.2% of that in the alluvial system. The total discharge from the alluvial aquifer in the Sheep Creek Meadows area is approximately 3% of typical steady state base flow conditions in Sheep Creek (6700 gpm) within this reach.

2.5 GROUNDWATER-SURFACE WATER INTERACTION

Exchange of groundwater and surface water is controlled by the relative elevation difference between the water table and the streams and the permeability of the streambed. With the exception of periods of peak stream levels during spring runoff, Sheep Creek is typically

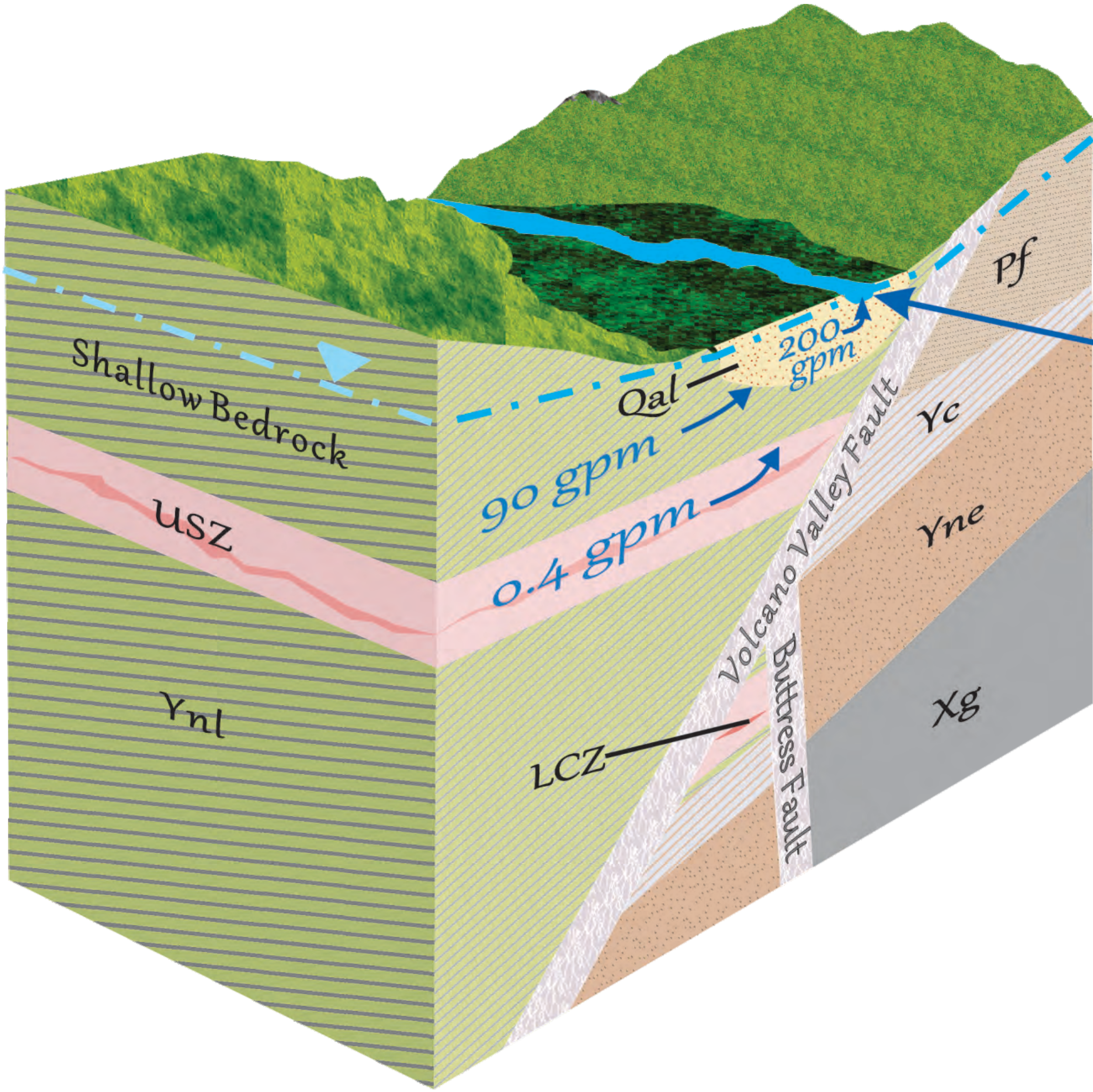

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Figure 2-7
Block Flow Diagram
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lower than groundwater levels in the alluvium and bedrock groundwater systems and acts as a sink for groundwater discharge. In contrast, some of the tributary drainages have small springs in their upper reaches that appear to represent smaller perched groundwater systems that produce small amounts of flow along portions of the drainage. This water re-infiltrates in the downstream channels and the channels only become perennial in their lower reaches where they intercept the regional water table. As an example, Coon Creek within the project area receives some groundwater recharge along its upper reach, but piezometer data show a downward hydraulic gradient downstream and the creek only appears to be in direct connection with the regional flow system once it merges into Sheep Creek meadows in the main valley.

Groundwater within the Sheep Creek alluvium is in direct connection with Sheep Creek. The alluvial gravels are recharged from the stream during high flow periods and receive groundwater recharge from adjacent and underlying bedrock systems as well as alluvial systems in tributary drainages during the remainder of the year.

There can be small amounts of inflow and outflow between the alluvial groundwater system and the creek on a given reach in response to changes in the volume and extent of the alluvium; however, there are locations on Sheep Creek where the channel enters narrow bedrock canyons and the alluvial deposits become extremely minor or absent. In these areas, the alluvial groundwater is effectively forced out into the stream. There are two locations on Sheep Creek where this occurs. The Sheep Creek alluvial deposits are pinched out where the creek enters a narrow bedrock canyon immediately downstream of the project site. As previously discussed, potentiometric data indicate groundwater flow in the project area is converging on Sheep Creek at this location and the amount of recharge to Sheep Creek from the alluvial aquifer in this area was estimated at approximately 200 gpm using a simple Darcy's Law calculation. This discharge rate still represents a relatively small increase in the total baseflow in Sheep Creek (approximately 3%). There is a second location approximately 3 miles downstream of the project area where Sheep Creek again enters a narrow bedrock canyon in which the alluvium is minor or absent and although there is no well data for that area, we presume that a similar increase in stream flow occurs at that location.

With the exception of these areas where there may be local changes in streamflow due to the bedrock impinging on the channel, there is a gradual increase in baseflow on Sheep Creek from upstream to downstream that represents progressive groundwater discharge to the stream on the order of 300 to 340 gpm per river mile (0.66 to 0.75 cfs/mile). This excludes surface inflow from the major tributaries.

2.6 WATER BALANCE

2.6.1 Groundwater Recharge

Infiltration of precipitation and snow melt are primary sources of recharge to the groundwater system. Infiltration rates of 10% to 15% of annual precipitation are commonly assumed as a reasonable approximation of groundwater recharge rates in modeling analyses of intermontane basins in western Montana (Briar and Madison, 1992). A detailed assessment of average precipitation versus observed steady state baseflow conditions in streams was used to verify and refine the applicable infiltration estimates for the Sheep Creek drainage.

Groundwater recharge can be evaluated based on the water balance of the model domain. Based on the rural setting within the conceptual model area the removal of groundwater from wells is assumed to be negligible. The conceptual model encompasses the upper half of the Sheep Creek watershed; therefore it is appropriate to assume all of the infiltration recharge to the shallow and deeper groundwater flow systems within the drainage reports back to Sheep Creek and the major tributaries within the confines of the watershed (Cherkauer, 2004). Generalized flow estimates from these drainages during steady state base flow periods (when surface runoff, interflow and irrigation are insignificant) should be approximately correlative with the percentage of annual infiltration rate within the Sheep Creek and larger tributary sub-basins (Myers, 2009).

The amount of annual precipitation and the corresponding recharge volume can vary substantially with elevation and aspect. PRISM spatial climate datasets (PRISM Climate Group, Oregon State University, http://prism.oregonstate.edu) provide estimates of the spacial distribution of precipitation over an area based on an analysis of these and other factors. Figure 2-8 shows the average annual precipitation estimates in the Sheep Creek area calculated over a 30-year period from 1981 to 2010. Annual precipitation over the entire watershed area ranged from 17.1 to 39.4 inches per year with a 30 year average of 25.1 inches per year.

To estimate recharge rates, average precipitation values were determined for watershed areas for monitoring sites on Sheep Creek (SW-1 and USCGS-SC; see Figure 2-1) and these values were multiplied by assumed infiltration rates of 10 to 15%, to establish an estimated annual volume of recharge. The annual recharge volumes were then used to derive average steady state flow rates for each of the gaging sites and these are compared to observed steady state baseflows to establish infiltration rates as a percentage of annual precipitation. The calculations are shown in Table 2-2 assuming a 10% infiltration rate, which appears to closely match observed steady state base flows and is also consistent with typical infiltration rate estimates for other intermontane basins in this region.

TABLE 2-2. COMPARISON OF INFILTRATION RECHARGE BASEFLOW ESTIMATES TO OBSERVED BASEFLOW AT STREAM GAGE SITES

Sheep Creek Gaging Stations	**USGS-SC1**	**SW1**
Watershed Area (acres)	27,676	50,162
Watershed Area (m^2)	1.12E+08	2.03E+08
Avg Annual Ppt (in)	28.3	26.4
Avg Annual Ppt (m)	0.72	0.671
Volume (acre ft)	6.53E+04	1.10E+05
Volume (m^3)	8.06E+07	1.36E+08
Assumed Infiltration rate	**10%**	**10%**
Baseflow Estimate (cfs)	9.0	15.2
Baseflow observed (cfs)	9.1	15.0

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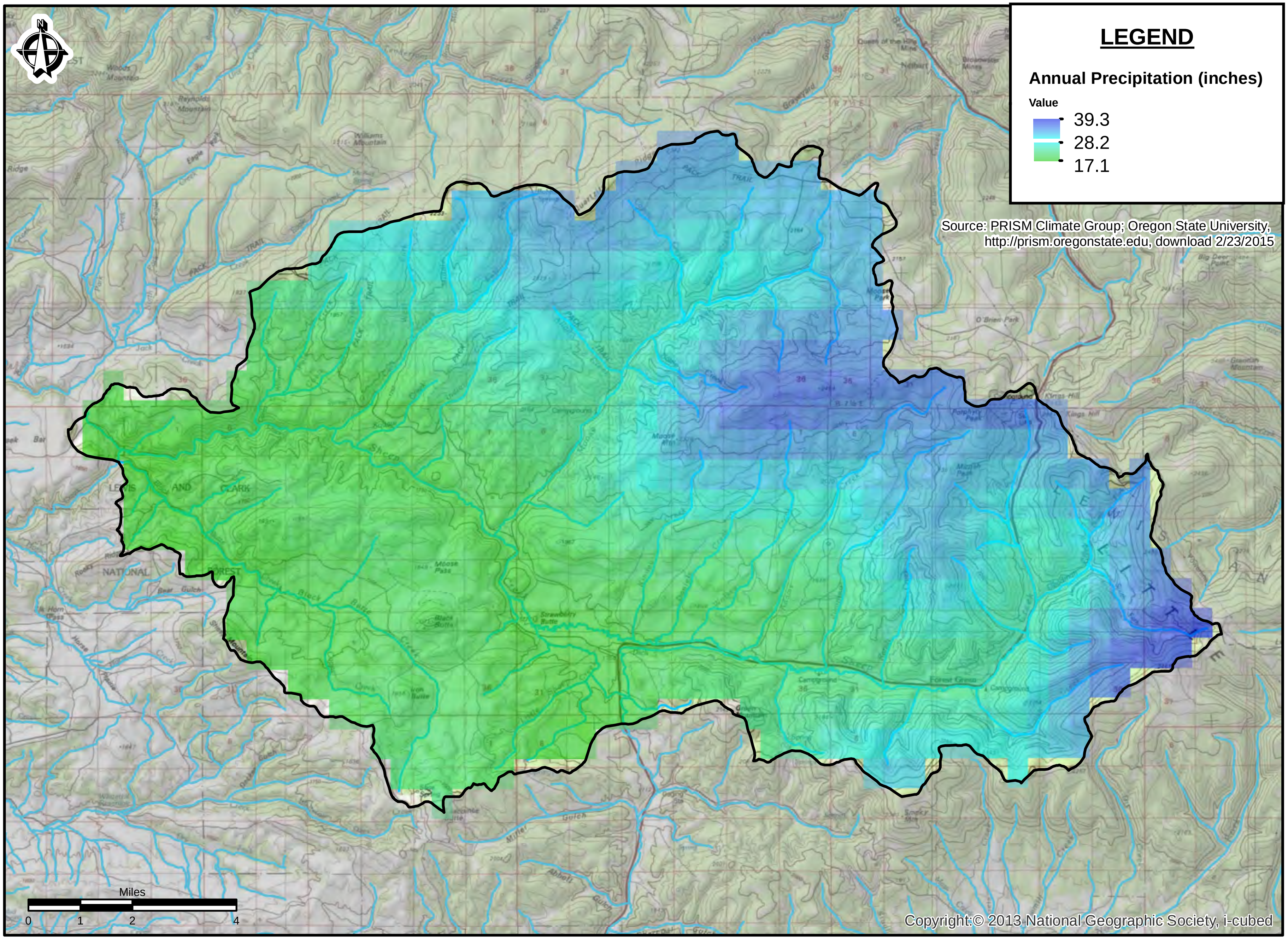

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Figure 2-8
Average Annual Precipitation
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Meagher County, Montana

Irrigation can also represent a significant source of recharge to shallow groundwater systems, particularly in alluvial aquifers if irrigation is widespread. There is some irrigated acreage adjacent to Sheep Creek in the middle reach of the watershed, however, it represents a very small fraction of the watershed area (<2%). Hydrographs show a gradual decline in streamflow in the late summer and fall that may be indicative of some return flow from irrigation, however, these returns appear to tail off in late fall and winter, and do not appear to contribute significantly to baseflow conditions in the late winter/early spring. Given the limited acreage in this watershed that is under irrigation and the timing of irrigation returns, it is unlikely to be a significant factor in simulating groundwater flow conditions during steady state base flow periods.

2.6.2 Groundwater Discharge

Groundwater flow within the shallow and deeper groundwater systems in the Sheep Creek drainage appears to coincide with general topographic trends and likely reports back to Sheep Creek within the confines of the basin. While stream flow monitoring has been conducted at baseline monitoring sites in the vicinity of the project site and there is a historical USGS gaging site on Sheep Creek below the confluence of Adams Creek (Figure 2-1), late season stream flow data is not available for many of the tributaries or for Sheep Creek at the confluence of Black Butte Creek which represents the lower boundary of the study area. Stream flow estimates for these ungauged sites were assessed using a similar method to that used to establish recharge rates as outlined below:

1. Watershed areas were measured for the principal tributaries and for Sheep Creek at the downgradient boundary of the study area.
2. PRISM data was used to establish average annual precipitation within the selected watershed areas.
3. Average precipitation was multiplied by watershed area to determine precipitation volumes for the selected watersheds and baseflow calculated assuming it is equal to 10% of watershed precipitation for all surface water bodies.

The calculated watershed areas, average annual precipitation rates, annual flow volumes and resultant baseflow estimates are summarized in Table 2-3.

TABLE 2-3. BASEFLOW ESTIMATES FOR SELECTED SHEEP CREEK WATERSHED AREAS

Watershed	Watershed Area (acres)	Average Annual Precipitation (ft)	Precip Volume (ac-ft)	Baseflow Estimate* (cfs)
Sheep CK at USGS - SC1	2.77E+04	2.36	6.54E+04	9.0
Sheep Ck at SW-1	5.02E+04	2.20	1.10E+05	15.3
Sheep Ck at confluence of Black Butte Ck	1.12E+05	2.10	2.34E+05	32.3
Moose Creek	2.32E+04	2.41	5.61E+04	7.7
Black Butte	1.47E+04	1.57	2.31E+04	3.2
Calf Creek	6.47E+03	2.30	1.49E+04	2.1
Adams Creek	4.73E+03	2.55	1.21E+04	1.7

*Calculated based on 10% of annual precipitation volume.

On September 10, 2015, flow measurements were taken on Sheep Creek at the confluence with Black Butte Creek, on Black Butte Creek at the confluence with Sheep Creek, on Moose Creek and at Sheep Creek gaging station SW-1 to compare against precipitation based flow estimates. It should be noted that flow measurements on Sheep Creek were influenced by irrigation diversions during this period. In addition, stream flow conditions are lower than normal due to lower than normal precipitation. To account for these variations a multiplier was determined to adjust flows at SW-1 to typical late winter (steady state) base flow conditions and then this multiplier was used to estimate steady state base flows at the remaining sites. The flow measurements and adjusted steady state base flow estimates are shown in Table 2-4 and compared to precipitation based flow estimates for comparison. Sheep Creek downstream results compare favorably but tributary flows on Moose Creek are slightly higher than the precipitation based estimates. This may reflect the fact that the tributary drainages have less irrigation diversions than Sheep Creek and therefore Sheep Creek adjustments may be higher than necessary to estimate late season flows in Moose

Creek. Late season adjusted flows on Black Butte Creek are slightly lower than the precipitation based estimates; however, they are within the assumed accuracy of the estimate (± 20%).

TABLE 2-4. SEPTEMBER 2015 FLOW MEASUREMENTS WITH SEASONALLY ADJUSTED BASEFLOW ESTIMATES

Site	Sept 2015 Flow (cfs)	Adjusted to Late Season Norm (cfs)	Ppt based Estimate (cfs)
Sheep Ck at SW-1	9.0	15.3	15.3
Sheep Ck at Black Butte Ck	17.7	30.0	32.2
Moose Ck at mouth	6.0	10.1	7.7
Black Butte Ck at mouth	1.5	2.6	3.2

The results on Sheep Creek compare favorably to the previous precipitation based flow estimates for steady state base flow at the downstream limits of the conceptual model. Sheep Creek and Moose Creek show greater variability which may reflect the applicability of seasonal Sheep Creek flow adjustments to these other drainages due to differences in seasonal irrigation diversions as well as seasonality of base flow characteristics.

2.7 PROPOSED MINING METHOD

The Johnny Lee deposits (UCZ and LCZ) are proposed to be mined using a cut and fill method, utilizing cemented paste backfill. The UCZ will be accessed from a surface decline; the portal of the surface decline is located to the southeast of the UCZ. It is estimated that the surface decline will encounter the water table approximately 1,700 feet into the decline. The decline provides entrance to the UCZ access ramps and the lower decline (Figure 2-9). The lower decline wraps down through the Ynl-B to access the LCZ north of the VVF. The decline will cross the VVF in two locations and provide entrance to the LCZ access ramps (Figure 2-10).

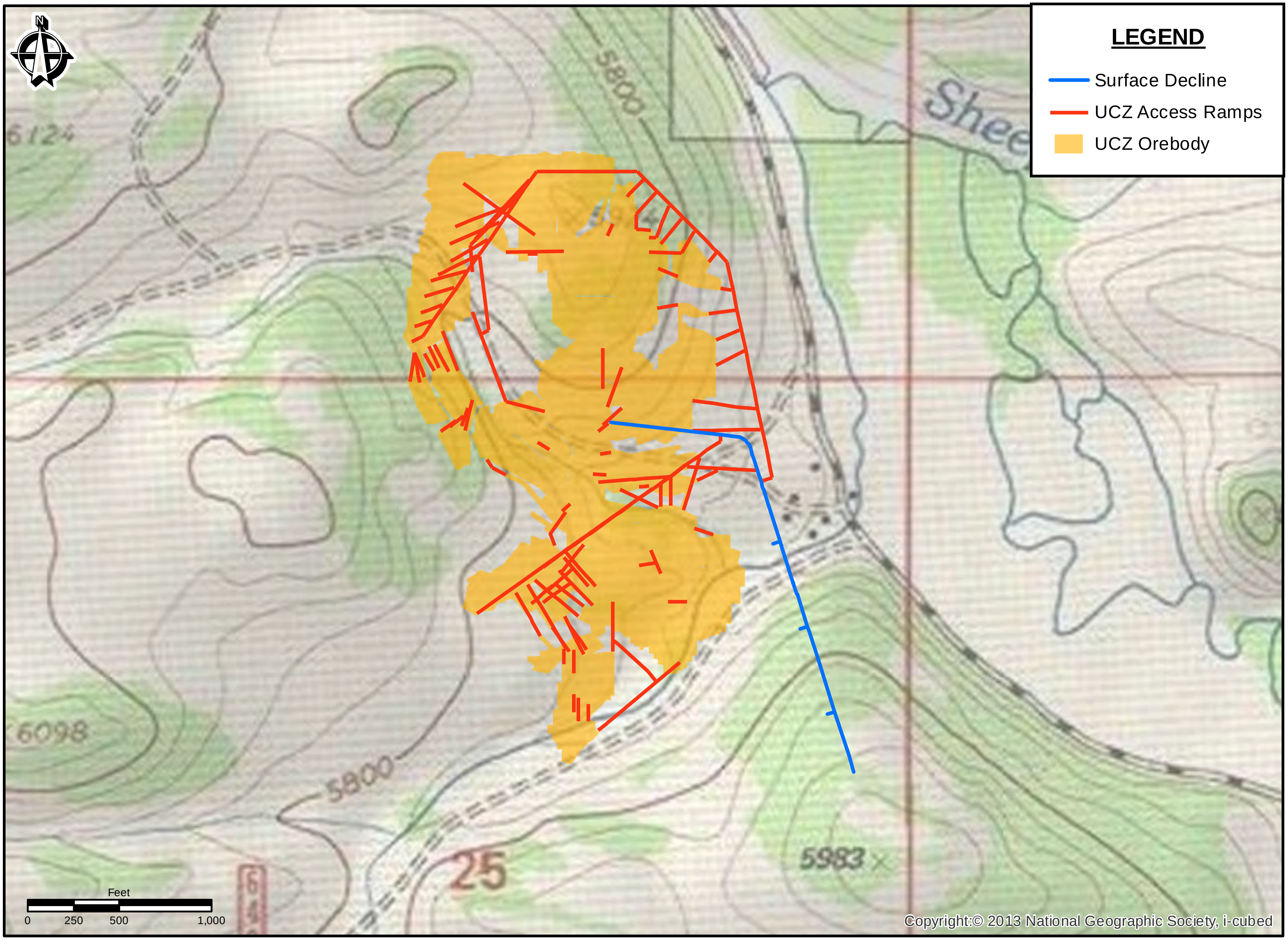

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Figure 2-9
UCZ Orebody and Access
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Meagher County, Montana

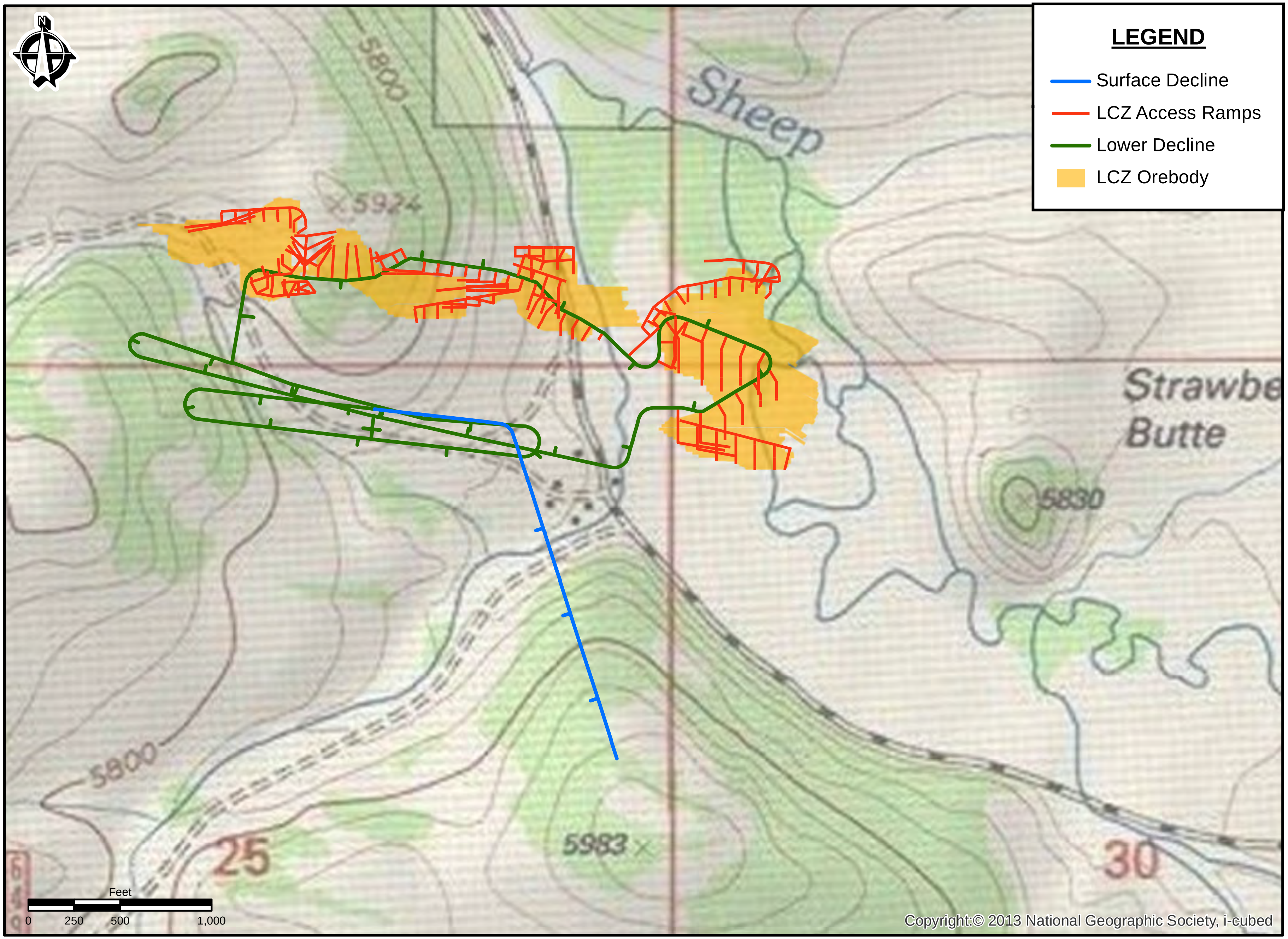

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Figure 2-10
LCZ Orebody and Access
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Meagher County, Montana

The ore will be removed from individual stopes with a maximum of 16 headings being open at one time. After a stope is fully mined, the open area will be backfilled with cemented tailing paste. Stopes will be open for approximately 60 days from the time a heading starts to the stope being fully backfilled. Permeameter tests conducted on the tailings yielded a hydraulic conductivity of 2.85 x 10^{-4} ft/day (1 x 10^{-7} cm/sec), which is approximately two orders of magnitude lower than the UCZ and similar to the hydraulic conductivity of that yielded from the short-term pumping test on the LCZ. The permeability of the paste backfill is expected to be lower than that measured for the tailings as it will contain up to 6% cement.

3.0 MODEL DESIGN

3.1 MODEL DOMAIN

The model domain encompasses the major watersheds in approximately the middle third of the Sheep Creek drainage. The model domain is bounded to the north by the upper watershed boundary of Adams Creek, Moose Creek, and Calf Creek; to the east by Adams Creek watershed boundary; to the south by the watershed boundaries of Sheep Creek, Little Sheep Creek and Black Butte Creek; and to the east by Black Butte Creek watershed and Sheep Creek watershed to the confluence with Black Butte Creek (Figure 3-1). The base of the model ranges from 4,666 - 2,128 feet MSL and extends up approximately 2,750 – 2,810 feet to an upper elevation of approximately 7,481 feet MSL. The top of the model is defined by the approximate elevation (±5-10 feet) of the groundwater table developed in the conceptual model. The model was set within GMS using metric units of meters and days and in UTM coordinate system (UTM, Zone: 12 N, NAD 83, meters). The input parameters and results were converted to imperial units in this report to allow for direct comparison to other reports.

The model domain is divided into 16 layers and discretized with an unstructured grid into 320,972 cells. The unstructured grid is more tightly discretized around key features within each layer; the grid refinement for each layer is summarized Table 3-1 and is shown for representative layers (1, 5 (UCZ), and 11 (LCZ)) in Figures 3-2 through 3-4. The grid layouts for all of the layers are included in Appendix A. To minimize the potential for numerical error, the unstructured grid refinement was limited to only allow each cell to be refined by a factor of two; ensuring that a cell is connected to no more than two cells in any given direction. The steepest head gradients will occur in the vicinity of the mine workings as the mine is dewatered, therefore, the grid refinement was extended beyond the mine working to limit the potential for numerical error in areas where steep gradient are anticipated.

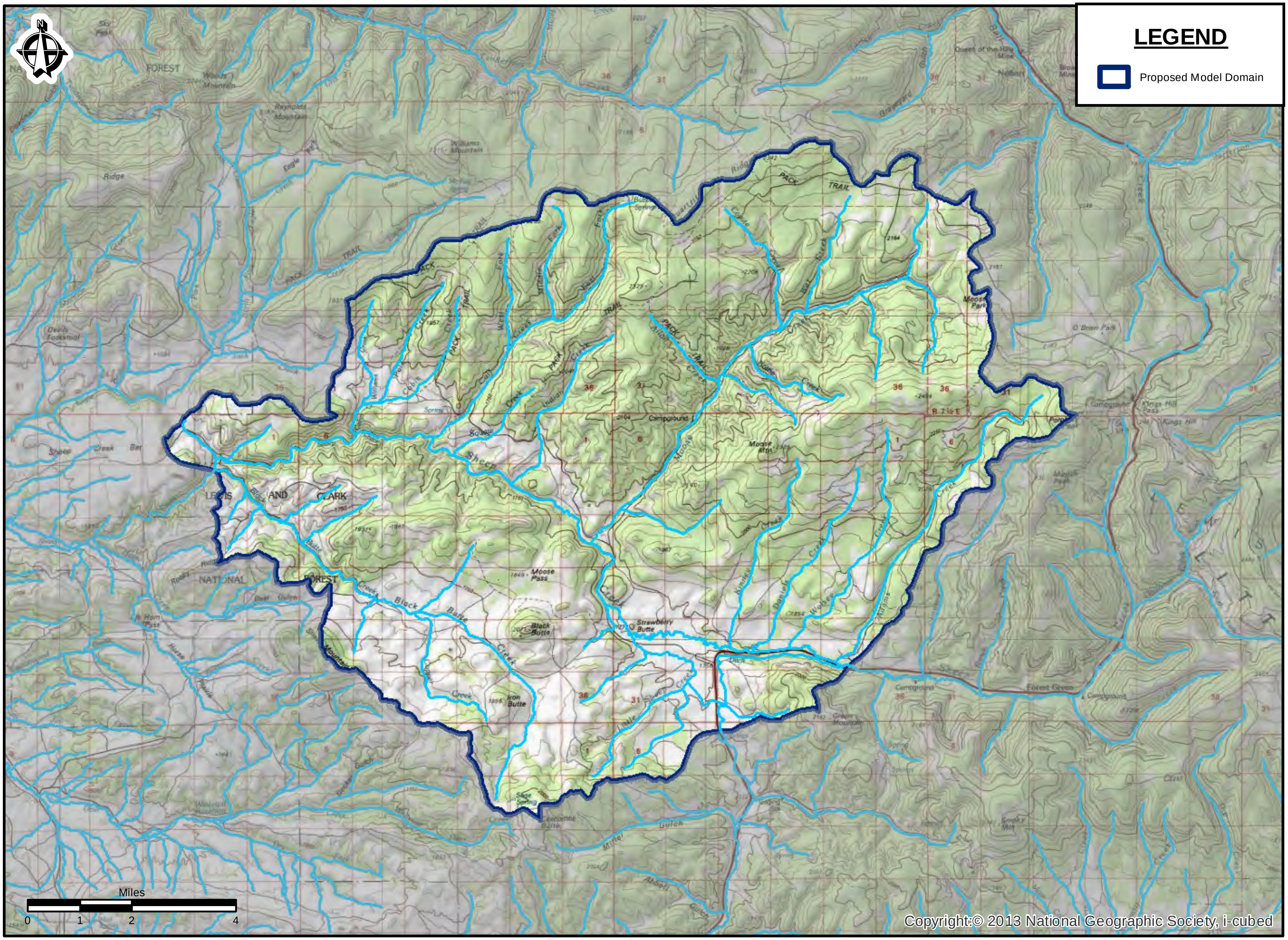

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Figure 3-1
Model Domain
Black Butte Copper Project
Meagher County, Montana

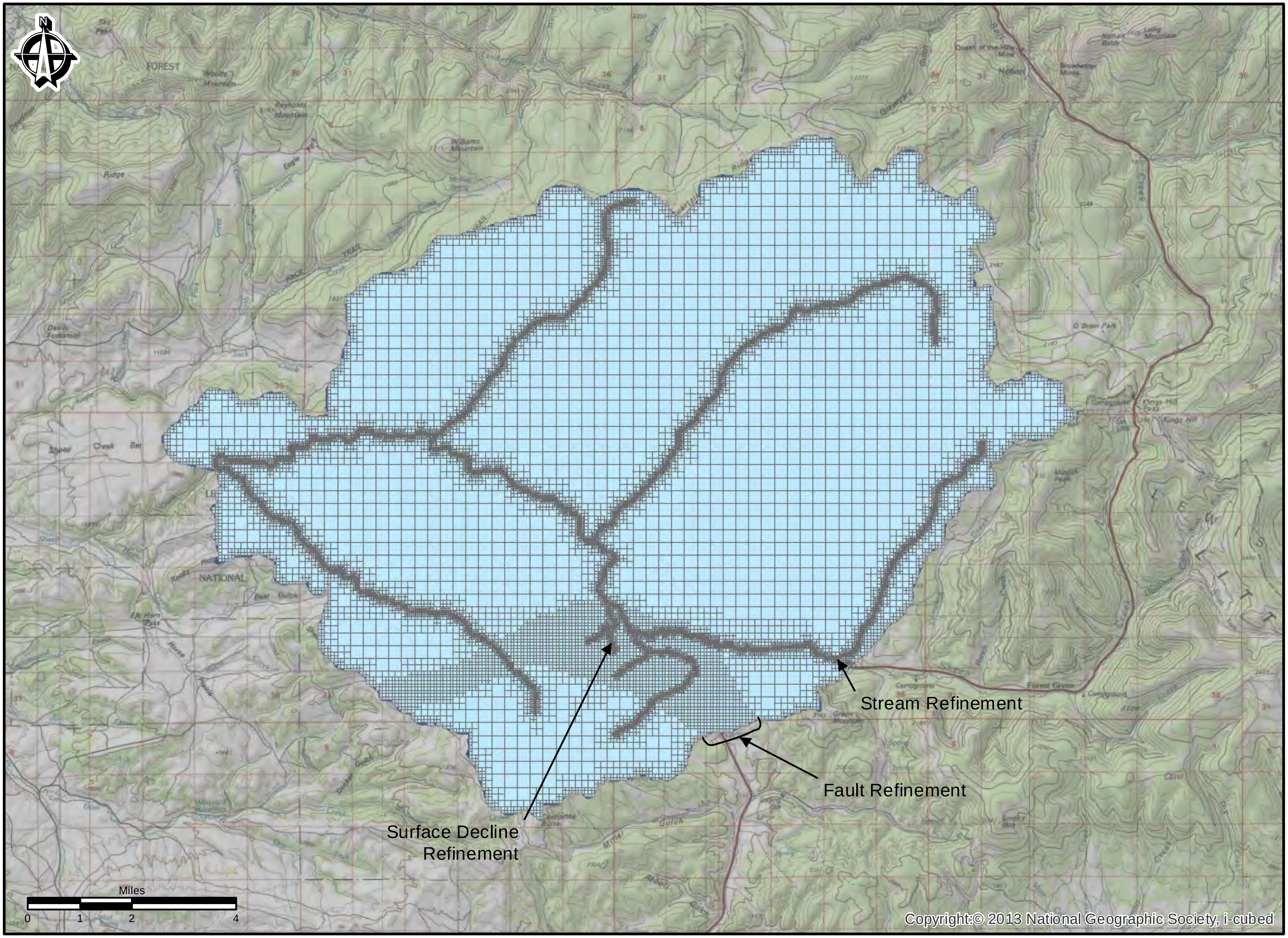

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Figure 3-2
Unstructured Grid - Layer 1
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Meagher County, Montana

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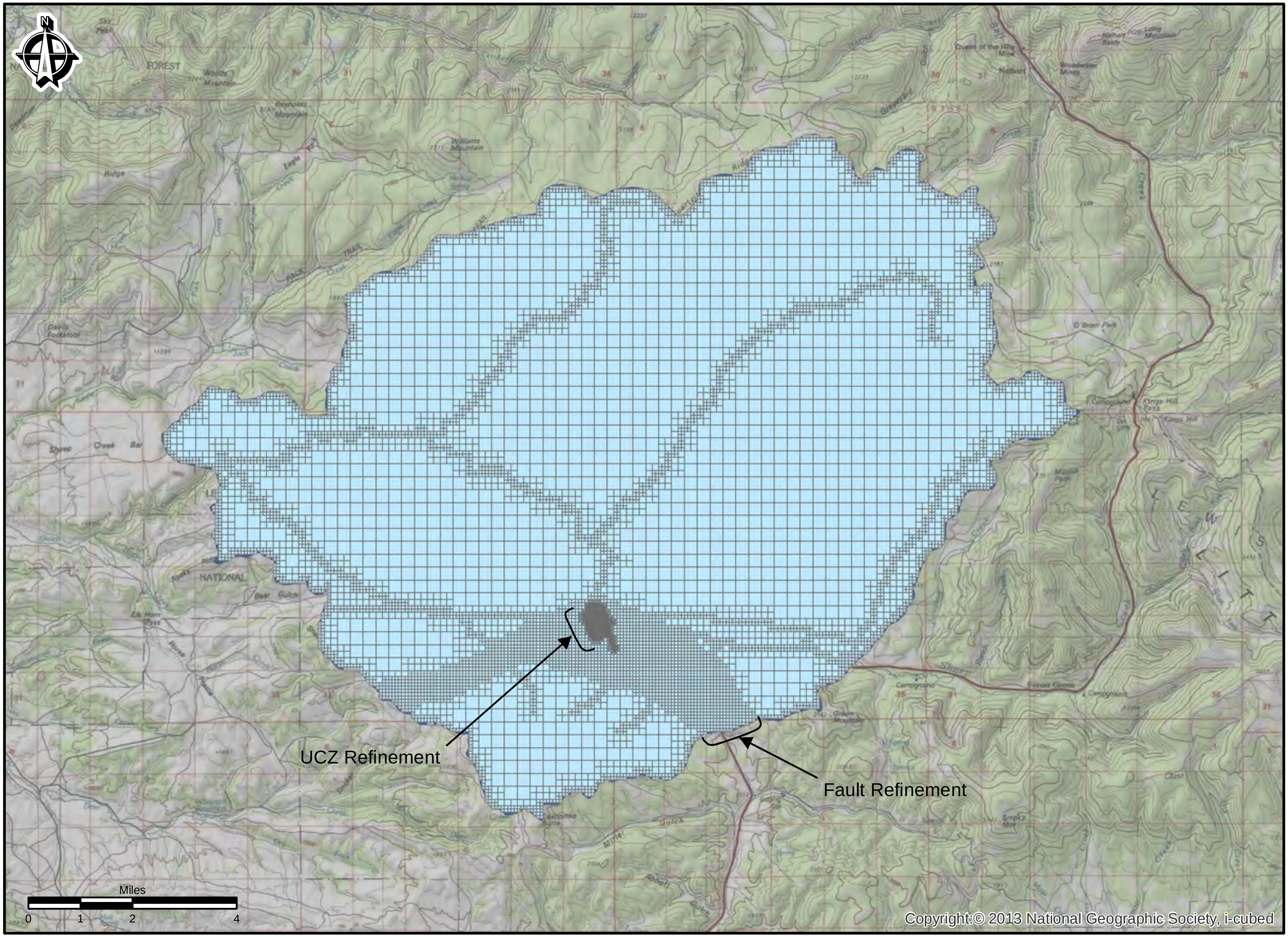

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Figure 3-3
Unstructured Grid - Layer 5
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Meagher County, Montana

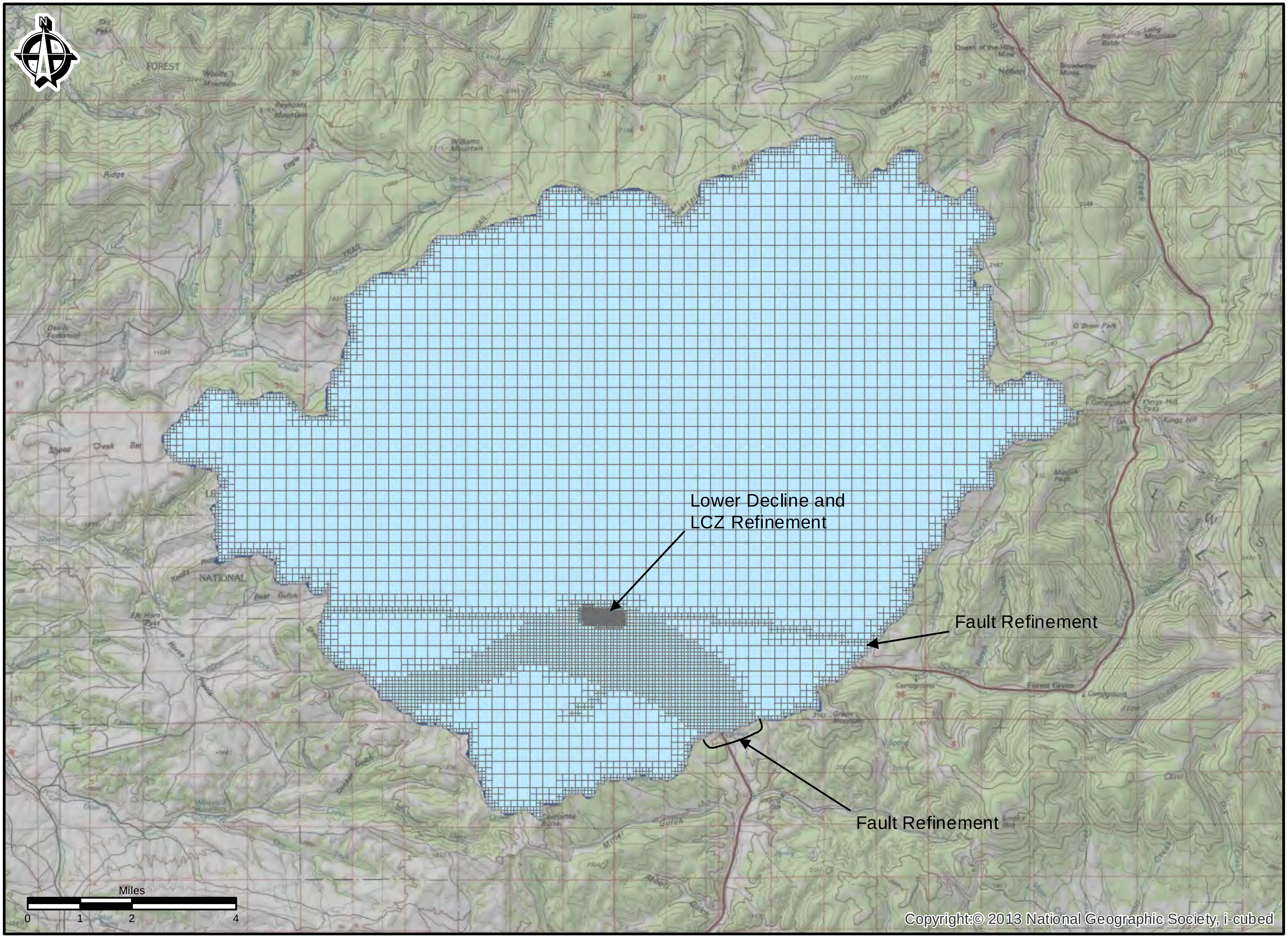

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Figure 3-4
Unstructured Grid - Layer 11
Black Butte Copper Project
Meagher County, Montana

TABLE 3-1. UNSTRUCTURED GRID REFINEMENT SUMMARY

Feature	Base Refinement (Cell Size, feet)	Layers
Streams	20	1
Faults	330	2-16
Surface Decline	20	1-5
UCZ	20	5-6
Lower Decline	20	5-11
LCZ	20	11
Model Domain	20	1-16

The layers within the model vary in thickness and are designed to provide sufficient discretization to simulate specific hydrologic relationships. Layer 1 is about 16 feet thick which represents the thickness of the alluvial systems and highly weathered shallow bedrock. Layers 2 and 3 are used to define the shallow bedrock flow conditions within the Ynl-A which is more permeable and fractured than the deeper Ynl-B bedrock. Throughout most of the model, layers 4 through 6 represent a transitions zone from the more permeable fractured bedrock conditions near the surface to the base bulk permeability of the more competent bedrock at depth. In the project area layers 4 through 6 correlate with the USZ and UCZ; layers 4 and 6 consist of the USZ overlying and underlying the UCZ in layer 5. Where necessary, the layer elevations were gradually adjusted from the regional dip to the south to match the elevations of the UCZ and USZ associated with each layer. Layers 7 through 16 represent the deeper bedrock system with layer 11 representing the LCZ in the project area. Similar to layers near the USZ/UCZ, layer elevations were gradually adjusted from the general dip to the south to match the elevations of the LCZ.

3.2 BOUNDARY CONDITIONS

The perimeter of the model consists of a no flow boundary along the watershed boundaries, with the exception of the Sheep Creek alluvial system where it enters the model domain on the eastern perimeter of the model. A constant head boundary is used to simulate groundwater flow into the model through the Sheep Creek Alluvium. The boundaries simulated in the model are shown in Figure 3-5. The constant head boundary has a defined head based on the elevation of Sheep Creek at this location. There is not a constant head at the downgradient edge of the model as there is not an alluvial system present at the confluence of Black Butte Creek and Sheep Creek to transmit water out of the model domain. It is assumed that water that enters the model domain leaves the model through the surface water bodies simulated in the model domain.

The stream package (STR-1 package; Prudic, 1989) is used to simulate groundwater/surface water interaction along the major stream drainages throughout the model domain and smaller stream drainages in the vicinity of the mine (Figure 3-5). The stream package allows for the steam stage to be calculated based on changes in head, which provides a representative depiction of groundwater/surface water interaction as stress is applied to the model. The interaction between the groundwater and surface water is controlled by the difference in head within the model and the stream stage and the conductance of the streambed. The streambed conductance is calculated based on the following equation:

$$C=(K_v/b)*(LW) \qquad \text{Eq 3-1}$$

Where:

C = Conductance of streambed (ft^2/day);

K_v = Vertical conductivity of streambed (ft/day);

b = streambed thickness (ft);

L = Stream length (calculated by GMS, ft); and

W = Width of stream (ft).

The stream boundaries were applied in the model using the map module in GMS, which requires a conductance input value based on a modified version of Eq 3-1 (C=(Kv/b)*W; GMS calculates the length of the stream along each cell the stream intersects to generate the final conductance term from Eq 3-1 and apply it to each cell in the model. The assumptions

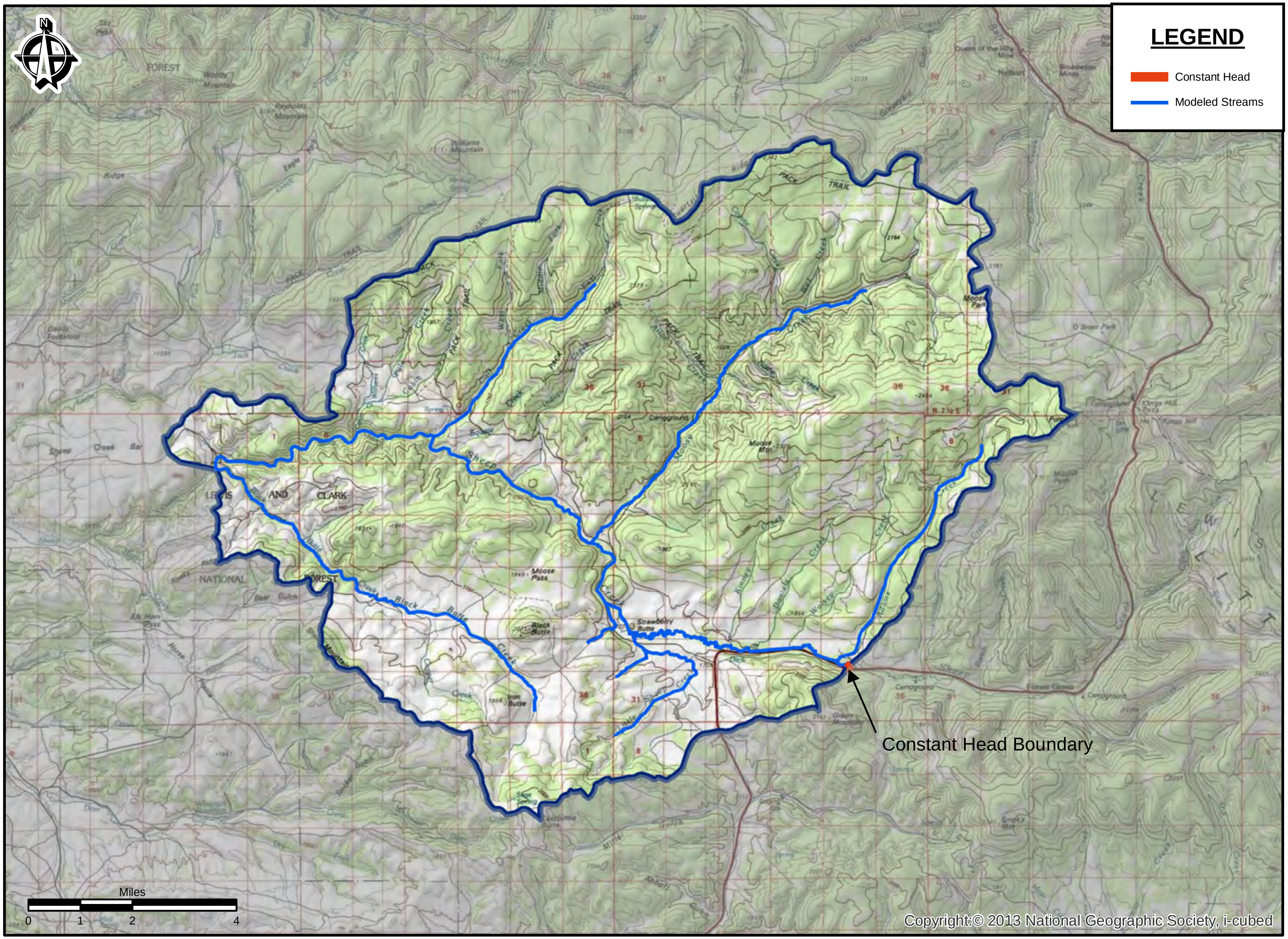

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Figure 3-5
Sources and Sinks
Black Butte Copper Project
Meagher County, Montana

K:\project\11048\GW Flow Model\Model Report\Figures\Updated\1104801H011.mxd for the initial stream conductance input into the map module of GMS are summarized in Table 3-2 and are estimates based on observed streambed sediment characteristics.

TABLE 3-2. INITIAL STREAM CONDUCTANCE CALCULATIONS

Stream Section	Streambed Description	Kv (ft/day)	Width (feet)	Thickness (feet)	Conductance[1] (ft/day)
Sheep Cr Upstream of Moose Cr	Cobble and gravel imbedded in silty sand	0.20	25.0	1	5.00
Brush Creek	Silty Sand, moderately compacted	1.10	1.5	0.5	3.30
Little Sheep Creek	Silty Sand, moderately compacted	0.50	2.5	1	1.25
Coon Creek above Meadows	Silty Sand and gravel, moderately compacted	1.00	1.5	1	1.50
Coon Creek in Meadows	Silty Sand and gravel, loosely compacted	3.00	1.5	0.5	9.00
Adams Creek	Unknown	0.50	5.0	1	2.50
Moose Creek	Cobble and gravel imbedded in silty sand	0.10	15.0	1	1.50
Sheep Cr between Moose Cr and Calf Cr	Cobble and gravel imbedded in silty sand	0.10	40.0	1	4.00
Calf Creek	Silty Sand and gravel, moderately compacted	0.50	5.0	1	2.50
Sheep Creek Below Calf Creek	Cobble and gravel imbedded in silty sand	0.10	45.0	1	4.50
Black Butte Creek	Cobble and gravel imbedded in silty sand	0.10	5.1	1	0.51

1. The conductance assigned to map module is multiplied by length of stream within a cell to assign the stream conductance for each cell.

Inflow was assigned to the upstream reach for each stream simulated in the model. A flow of 9 cfs (steady state base flow upstream of model domain) was applied to the upstream reach of Sheep Creek to simulate inflow to the stream from the upgradient portion of the Sheep Creek Watershed. The headwaters of each stream were assigned an initial flow of 0.06 to 0.1 cfs to simulate a minor contribution of surficial flow to the streams. The stream elevation (stream stage) was assigned to nodes in the map module every 200 feet in elevation drop and at locations where there were distinct changes in gradient based on the approximate topographic elevation of the stream. GMS then interpolates the stream stage between nodes to assign the stage to each cell intersected by the stream in the map module.

The stream stage was set to be constant during model calibration. Following calibration the stream stage was switched and allowed to vary as calculated by the model in the final steady state run, and in the subsequent dewatering and recovery simulations. The model calculates stream stage based on the head in the corresponding cell, gradient of the stream, and the input parameters applied to each steam reach. The input parameters used in the map module for each stream reach were adjusted slightly during model calibration and are summarized in Table 3-3.

TABLE 3-3. STREAM INPUT PARAMETER AFTER CALIBRATION

Stream Reach	Conductance (ft/day)[1]	Width (feet)	Roughness Coefficient[2]	Incoming Flow (cfs)[3]
Sheep Cr Upstream of Moose Creek	1.6-6.6	25-29	0.045	9.0
Brush Creek	3.3	1.5	0.04	0.06
Little Sheep Creek	0.3-1.6	2.5	0.04	0.06
Coon Creek	1.6-13.1	1.5	0.04	0.06
Adams Creek	2.0	5.0	0.04	0.10
Moose Creek	0.7	15	0.04	0.10
Sheep Cr between SW-1 and Calf Creek	3.0	40.0	0.04	NA
Calf Creek	2.0	4.9	0.04	0.10
Sheep Creek Below Calf Creek	3.0	45	0.04	NA
Black Butte Creek	3.3	5.1	0.04	0.06

1. The conductance assigned to map module is multiplied by length of stream within a cell to assign the stream conductance for each cell.
2. Derived from Open Channel Hydraulics, Chow, V.T., 1959.
3. Incoming flow applied to headwaters or inflow at model domain (e.g., Sheep Creek inflow at model domain).

3.3 MODEL INPUT VARIABLES

Model input variables are assigned to each cell of the model and consist of hydraulic conductivity, anisotropy (horizontal and vertical), specific storage (confined), specific yield (unconfined), and recharge. The input parameters used in the model are discussed below.

Infiltration Rate

Areal recharge rates are assumed to be directly proportional to the distribution of precipitation within the model domain. An analysis of stream steady state base flow indicates that a recharge rate equivalent to 10% of the annual precipitation would account for the steady state base flow measured in Sheep Creek near the confluence of Adams Creek and Sheep Creek and in Sheep Creek at SW-1 (Section 1.5). The areal recharge rate applied to the model was generated based on 10% of the average yearly precipitation determined from the PRISM data set (PRISM Climate Group, February 23, 2015 download). Recharge was applied to the upper most active cell in the model based on the average recharge rate in a given area (Figure 3-6). The distribution of precipitation in the model domain ranges from 17 to 39 inches per year resulting in average annual recharge rates over the model domain of 1.7 to 3.9 inches per year.

Hydraulic Conductivity (K)

Hydraulic conductivities for the formations present within the project area have been defined based on detailed testing and allow HSUs to be defined that reflect changes in material properties with depth. The hydraulic properties of the HSUs in the outlying areas are not as well established. The conceptual model relies on literature values for characteristic material properties in these areas; however, these properties can vary based on weathering and fracture characteristics of the rock. Hydraulic conductivities were initially assigned to the model based on the representative material properties established for each HSU within the model domain. The K values assigned to the HSUs were initially uniform over the lateral and vertical extent of each of the HSUs. However, in the initial model runs using these assumptions, the heads in the model rose being well above the ground surface (>1000 feet). The areal recharge rate applied to the model could not be adjusted within a reasonable range and still maintain stream flow; therefore, the conceptual model was adjusted to allow for a

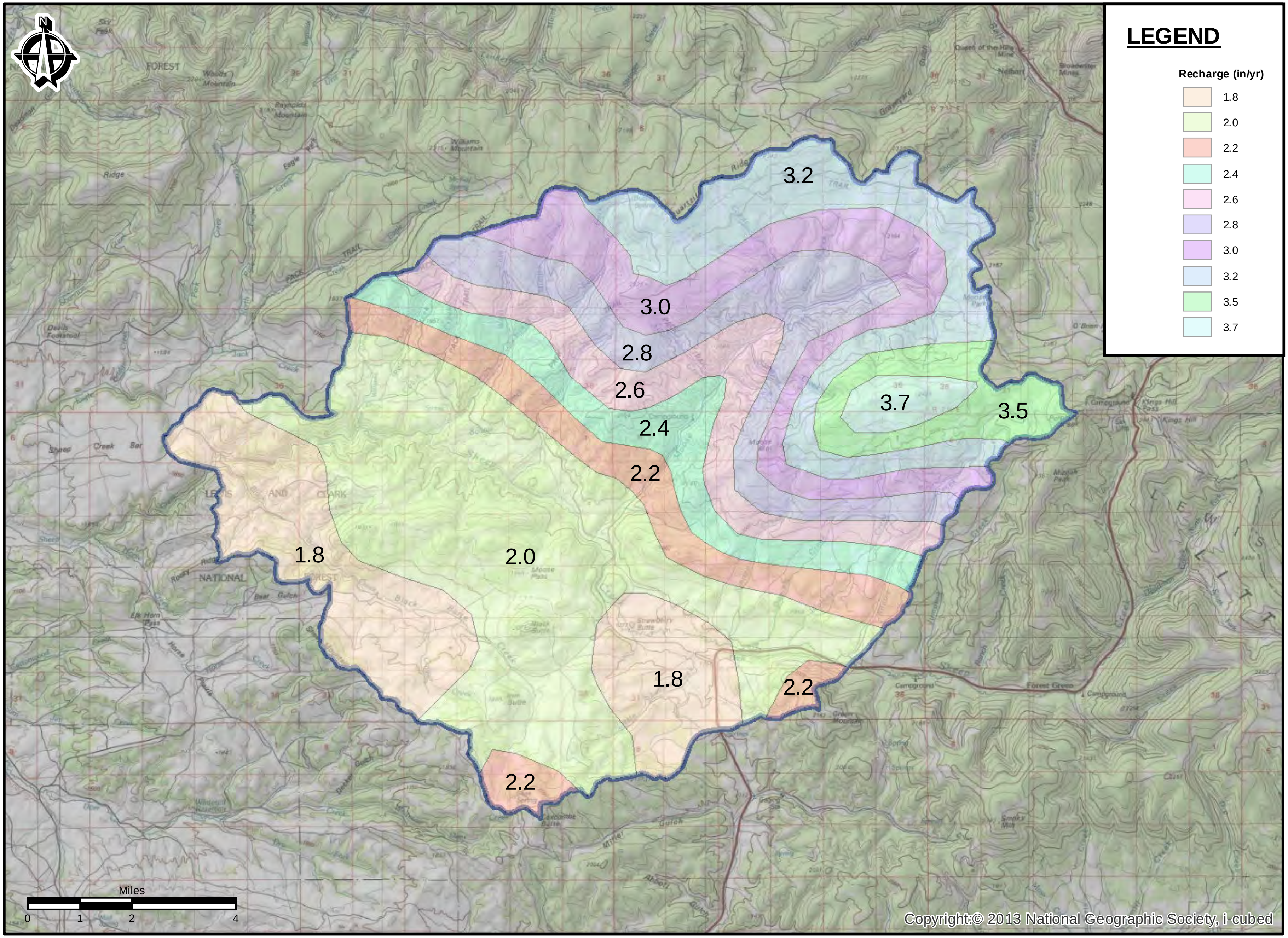

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Figure 3-6
Areal Recharge
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Meagher County, Montana

higher permeability in the shallower bedrock strata within an HSU that decreases with depth. This is typical of bedrock systems as near surface weathering and tectonic unloading enhance fracturing of the rock. With the exception of the area in the immediate vicinity of the mine, the permeability of each material property was assumed to be at the bulk permeability of the deeper bedrock at or below layer 4. The hydraulic conductivities assigned in the vicinity of the mine did not require adjustment since they were established based on data from the numerous hydrologic investigations conducted on these HSUs.

The hydraulic conductivities applied to each material property within the model based on the assumption of higher permeability shallow bedrock and decreasing permeability with depth, are shown in Table 3-4. The HSUs were discretized further during model calibration based on general trends seen in different areas of the model; areas of higher or lower head were subdivided to allow for fine tuning of the hydraulic conductivities to match the observed and projected heads within the model domain. Figures 3-7 through 3-9 show the subdivided HSUs for layers 1, 5, and 11; the distribution of HSUs for each layer is included in Appendix A. The final hydraulic conductivities assigned to the model are summarized in Table 3-4. The changes in hydraulic conductivities from the initial values are discussed further in the Model Calibration summary (Section 4.0).

Specific Storage/Specific Yield

Specific storage (S_s) describes the storage capacity of an aquifer through compression of the aquifer matrix and the fluid. Since consolidated bedrock formations have both a low compressibility and a low porosity, the quantities of water that are stored in bedrock through specific storage are extremely small. Literature values for specific storage of unweathered bedrock are typically on the order of 10^{-6} ft^{-1} or less (Streltsova, 1978; Domenico and Schwartz, 1990). Tests conducted at the site yielded specific storage (Ss) values ranging from 10^{-6} to 10^{-8} ft^{-1} (Hydrometrics, 2015b). A value of 3 x 10^{-6} ft^{-1} was assigned to all of the bedrock HSUs for the initial Ss values. Specific storage was adjusted to 3 x 10^{-7} ft^{-1} during transient calibration for HSUs; Ynl-A, Ynl-B (layer 7 only), and USZ to match the observed drawdown during the PW-8 and PW-9 aquifer test simulations (discussed further in

TABLE 3-4. INITIAL AND POST CALIBRATION MATERIAL PROPERTIES

Material Name	Hydro-Stratigraphic Unit (HSU)	Layers	Initial HK (ft/day)	Post Calibration HK (ft/day)	Vertical Anisotropy	Ss (1/ft)	Sy
Qa_ShCr	Alluvium Sheep Cr	1	200	230	10	3.28E-05	0.25
Qa_LShCr	Alluvium Little Sheep Cr	1	80	33	10	3.28E-05	0.25
Qa_CoonCr	Alluvium Coon Cr	1	130	82	10	3.28E-05	0.25
Qa_BBC	Alluvium Black Butte Cr	1	100	90	10	3.28E-05	0.25
Qa_MooseCr	Alluvium Moose Cr	1	100	35	10	3.28E-05	0.25
Pf_E1	Flathead Sandstone	1	1.64	2.76	10	3.28E-05	0.001
Pf_N1	Flathead Sandstone	1	1.64	3.86	10	3.28E-05	0.001
Pf_SE1	Flathead Sandstone	1	1.64	2.64	10	3.28E-05	0.001
Pf_SW1	Flathead Sandstone	1	1.64	2.53	10	3.28E-05	0.001
Pf_W1	Flathead Sandstone	1	1.64	0.16	10	3.28E-05	0.001
Pf_E2	Flathead Sandstone	2-3	0.328	0.180	10	3.28E-05	0.001
Pf_N2	Flathead Sandstone	2-3	0.328	1.31	10	3.28E-05	0.001
Pf_SE2	Flathead Sandstone	2-3	0.328	0.118	10	3.28E-05	0.001
Pf_SW2	Flathead Sandstone	2-3	0.328	0.373	10	3.28E-05	0.001
Pf_W2	Flathead Sandstone	2-3	0.328	0.253	10	3.28E-05	0.001
Pf_E3	Flathead Sandstone	4-7	0.00328	0.0033	10	3.28E-05	0.001
Pf_N3	Flathead Sandstone	4-7	0.00328	0.0033	10	3.28E-05	0.001
Pf_SE3	Flathead Sandstone	4-7	0.00328	0.0033	10	3.28E-05	0.001
Pf_SW3	Flathead Sandstone	4-7	0.00328	0.0033	10	3.28E-05	0.001
Pf_W3	Flathead Sandstone	4-7	0.00328	0.0033	10	3.28E-05	0.001
Pf Lower	Flathead Sandstone	7-12	0.003	0.0003	10	3.28E-05	0.001
YnlA_N1	Ynl-A	1	1	1.3123	5	3.28E-06	0.001
YnlA_N	Ynl-A	2-3	0.16	0.820	5	3.28E-06	0.001
USZ	Upper Sulfide Zone	4 & 6	0.016	0.033	5	3.28E-06	0.001
UCZ	Upper Copper Zone	5	0.016	0.164	15	3.28E-05	0.001
YnlB_N1	Ynl-B	6	0.03	0.656	5	3.28E-06	0.001
YnlB_N2	Ynl-B	7-8	0.003	0.016	10	3.28E-05	0.001
YnlB	Ynl-B	8-16	0.003	0.0003	10	3.28E-05	0.001
LCZ	Lower Copper Zone	11	2.30E-04	0.0016	20	3.28E-05	0.001
Ti/Ynl-O1	Tertieriary Instrusives	1	NA	0.033	10	3.28E-05	0.001
Ti/Ynl-O2	Tertieriary Instrusives	2-3	NA	0.010	10	3.28E-05	0.001
Ti/Ynl-O3	Tertieriary Instrusives	4-6	NA	0.0016	10	3.28E-05	0.001
YNL_S1	Lower Newland South of BBF	1	1	4.92	10	3.28E-05	0.001
YNL_S2	Lower Newland South of BBF	2-3	0.03	2.79	10	3.28E-05	0.001
YNL_S3	Lower Newland South of BBF	4-7	0.003	0.33	10	3.28E-05	0.001
BBF	BBF (Vertical K)	2-15	0.003	0.0033	100	3.28E-05	0.001
VVF	VVF (Vertical K)	2-15	0.003	0.0033	100	3.28E-05	0.001
Ync	Chamberlain Shale	13-16	0.0003	0.0003	10	3.28E-05	0.001

TABLE 3-4. INITIAL AND POST CALIBRATION MATERIAL PROPERTIES

Material Name	Hydro-Stratigraphic Unit (HSU)	Layers	Initial HK (ft/day)	Post Calibration HK (ft/day)	Vertical Anisotropy	Ss (1/ft)	Sy
Yne_E1	Neihart Quartzite	1	1.64	1.15	10	3.28E-05	0.001
Yne_W1				1.31	10	3.28E-05	0.001
Yne_E2		2-3	0.16	0.16	10	3.28E-05	0.001
Yne_W2				0.16	10	3.28E-05	0.001
Yne_E3		4-16	0.0003	0.0016	10	3.28E-05	0.001
Yne_W3				0.0016	10	3.28E-05	0.001
Yne				0.0003	10	3.28E-05	0.001
Xm_E1	Crystalline Bedrock	1	1.64	0.57	10	3.28E-05	0.001
Xm_M1				4.19	10	3.28E-05	0.001
Xm_S1				1.02	10	3.28E-05	0.001
Xm_W1				9.48	10	3.28E-05	0.001
Xm_E2		2-3	0.16	0.37	10	3.28E-05	0.001
Xm_M2				0.98	10	3.28E-05	0.001
Xm_S2				0.18	10	3.28E-05	0.001
Xm_W2				0.37	10	3.28E-05	0.001
Xm_E3		4-16	0.016	0.016	10	3.28E-05	0.001
Xm_M3				0.016	10	3.28E-05	0.001
Xm_S3				0.016	10	3.28E-05	0.001
Xm_W3				0.016	10	3.28E-05	0.001
Xm				0.016	10	3.28E-05	0.001

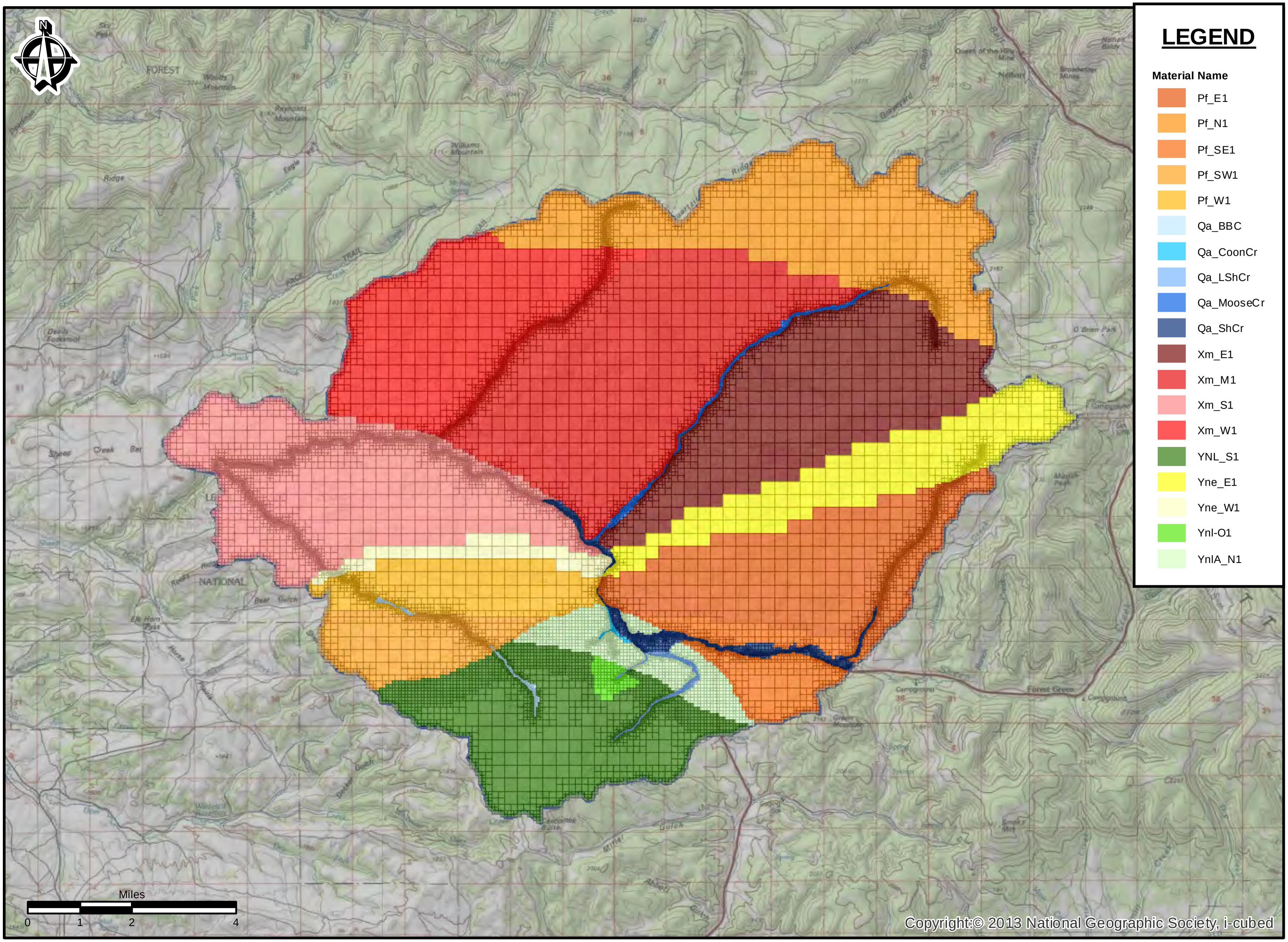

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Figure 3-7
Material Properties - Layer 1
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Meagher County, Montana

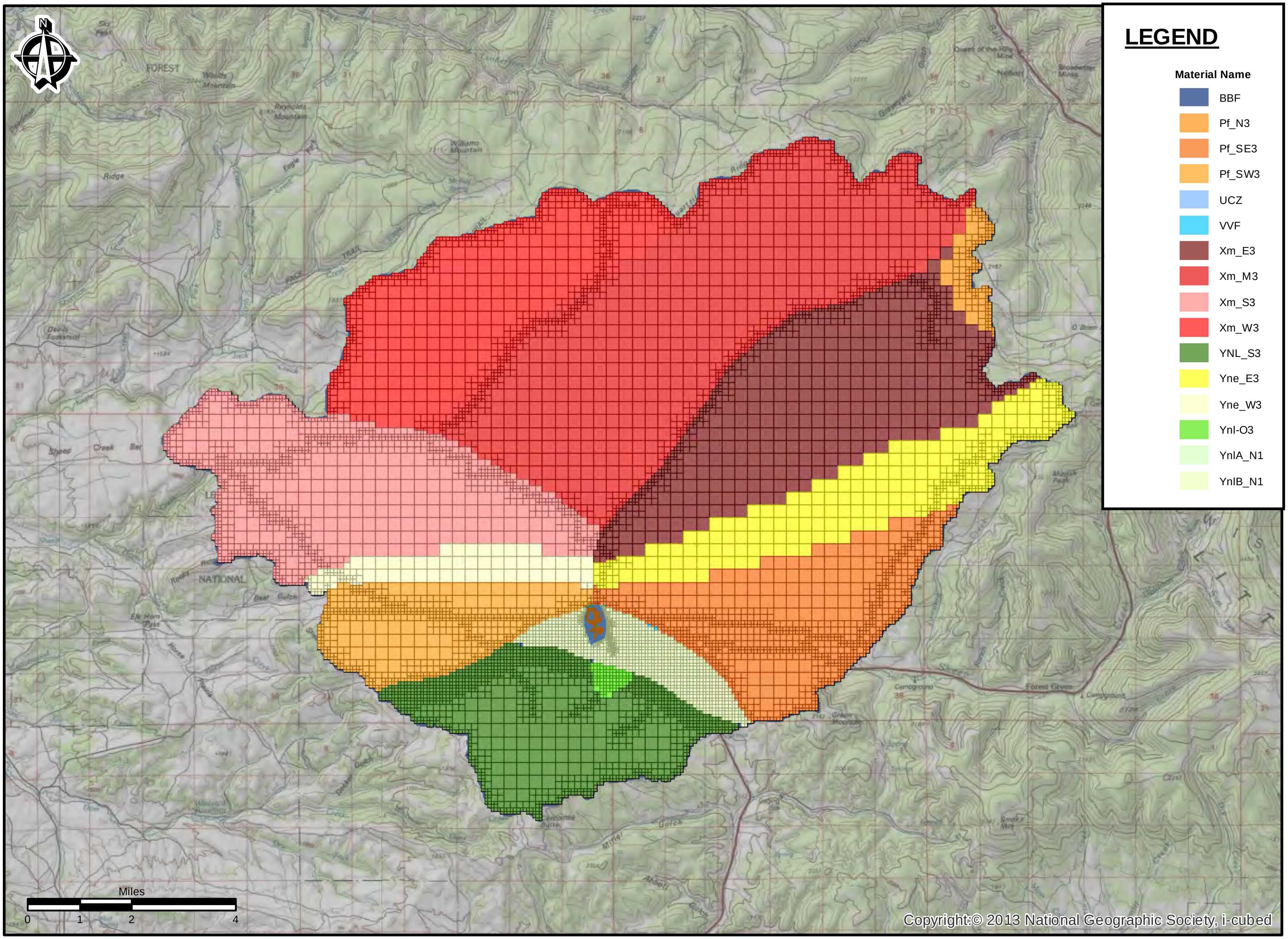

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Figure 3-8
Material Properties - Layer 5
Black Butte Copper Project
Meagher County, Montana

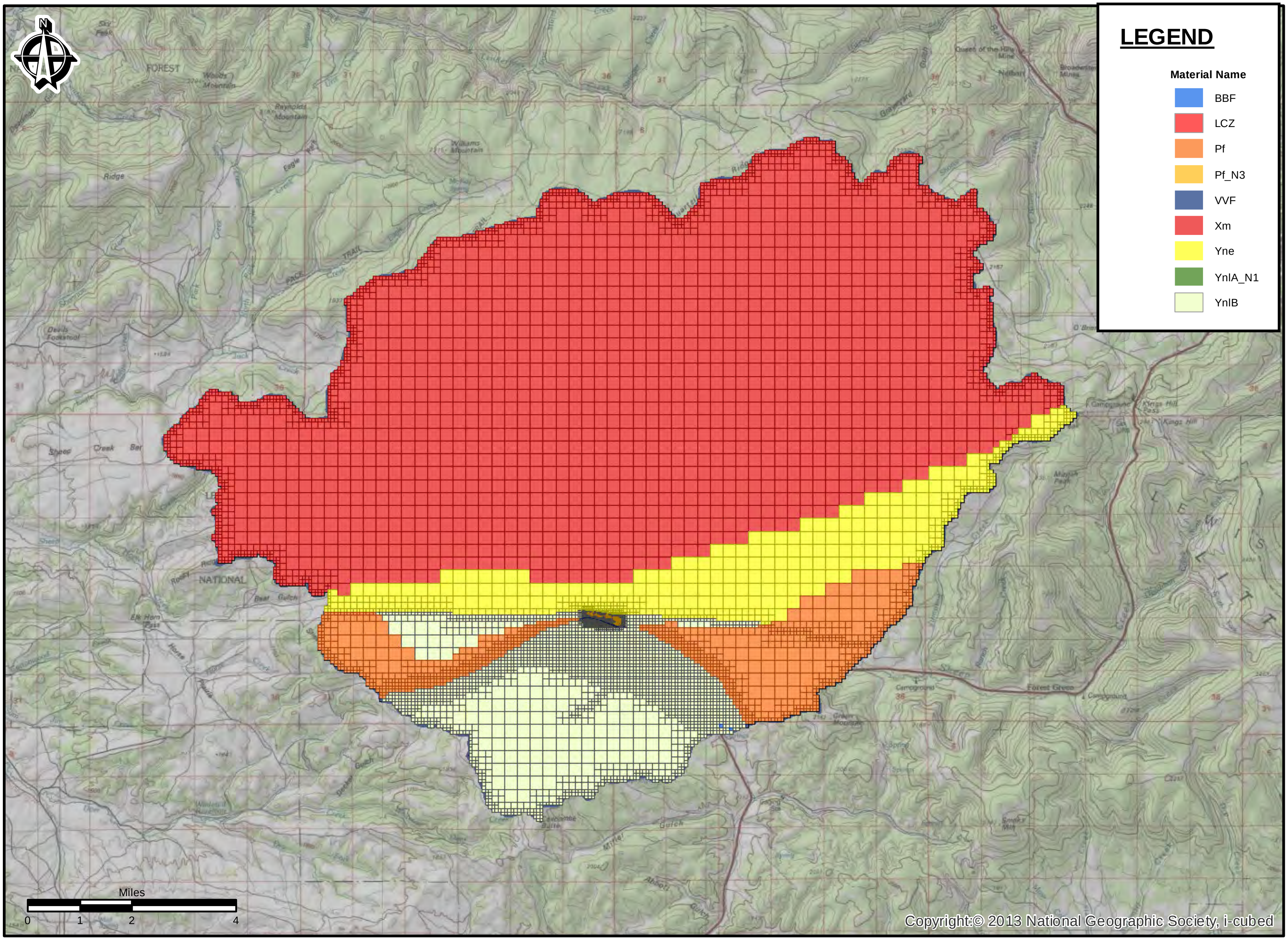

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Figure 3-9
Material Properties - Layer 11
Black Butte Copper Project
Meagher County, Montana

Section 4.0). A specific yield of 0.25 was assigned to the alluvial material represented in the model (Freeze and Cherry, 1979).

Horizontal Flow Barriers

As noted in Section 2.3.2, structurally defined HSUs (faults) in the vicinity of the Johnny Lee deposits all contain fault gouge where they have been intersected when drilling. Although damage zones are present near faults, wells completed in fault zones within the Newland Formation yield very low volumes of water and corresponding low permeability estimates from pumping tests. There is sporadic evidence of high permeability damage zones in the Neihart associated with the Buttress Fault; however, the extent and connectivity of these zones are unknown. Both low permeability gouge and high permeability damage zones tend to limit the propagation of drawdown effects across a fault zone in bedrock systems; gouge being a no flow boundary and damage zones acting as constant head boundaries. Representing the faults as low permeability boundaries is an appropriate representation of the fault systems as gouge was present in all places where the faults were intersected. Site data did not show increased permeability in the vicinity of the faults within the Newland shales and there is limited and mixed evidence for the presence of a well-developed damage zones in other units. Since the extent and connectivity of damage zones in these other units are unknown; damage zones were not simulated in the fault zones within the model; this results in a more conservative assessment of drawdown effects since representing both gouge and a high permeability damage zone would effectively simulate two barriers to drawdown.

For the purpose of this model the major faults in the model domain were modeled as horizontal flow barriers to simulate the gouge that was present in all coreholes/boreholes which penetrated faults in the project area. The Horizontal-Flow Barrier (HFB) Package can simulate narrow barriers within a courser grid system by applying intra-nodal conductivities in the finite difference approximation of the groundwater flow equation (Anderson, Woessner, and Hunt, 2015). Each HFB in the model domain is assigned a hydraulic characteristic (HC=K/b) value based on the estimated hydraulic conductivity (K; 2.8×10^{-5} ft/day) and an assumed thickness (b; 5 ft) of the barrier (HC= 5.69×10^{-6} day^{-1}).

The few coreholes that intersected faults near the water table contained less gouge content than coreholes that intersected faults at depth. It is assumed in the model that the fault gouge is not present or does not act as a regional HSU in the shallow portion of the aquifer where decreased gouge content has been noted and higher permeability shallow bedrock or alluvium is likely the controlling HSU; HFBs are simulated in layers 2 through 16. The Buttress Fault and Brush Creek Fault are simulated as vertical faults. The Buttress Fault is truncated by the VVF in the vicinity of the project area and is not simulated in layers 2 through 7 in this area. To simulate the low angle (approximately 30 degree dip) VVF and BBF, HFBs were offset based on the intersection of the fault with each layer. Figure 3-10 shows the location of the faults simulated in the model and the offset of the VVF and BBF.

The HFB package does not limit flow vertically; therefore, the offset of the low angle faults (VVF and BBF) would allow groundwater to flow vertically and by pass the HFB. To limit water from flowing vertically around the low angle faults a low vertical permeability zone was mapped on the hanging wall side of the VVF and BBF where the fault is offset between layers. The low vertical permeability zones (VVF and BBF) are shown on Figures 3-7 through 3-9, and in Appendix A. Due to the limitations of the map module in GMS, it was not possible to convert the permeabilities in all of the cells within the fault offset area when the cell size was large relative to the amount of offset in the fault. As a result there is some variability in vertical permeability within the simulated VVF and BBF fault zones.

3.4 MINING SIMULATIONS

Mine workings are simulated using the drain package. Drains are used to simulate dewatering of the surface decline, UCZ access ramps, LCZ decline, and the LCZ access ramps based on the schedule shown in Figures 3-11 and 3-12. The declines and access ramps remain active throughout the mine life (15 years). As described in Section 2.7, the proposed mining method will entail filling the completed stopes with a cement/tailings paste (paste backfill); stopes will be open a maximum of 60 days. It is not feasible nor is the model precise enough to simulate the dewatering and subsequent recovery of every mine stope for each 60-day period over the life of the mine. Therefore, mine dewatering was evaluated on an average annual basis with stopes simulated by applying drains to an open area equivalent

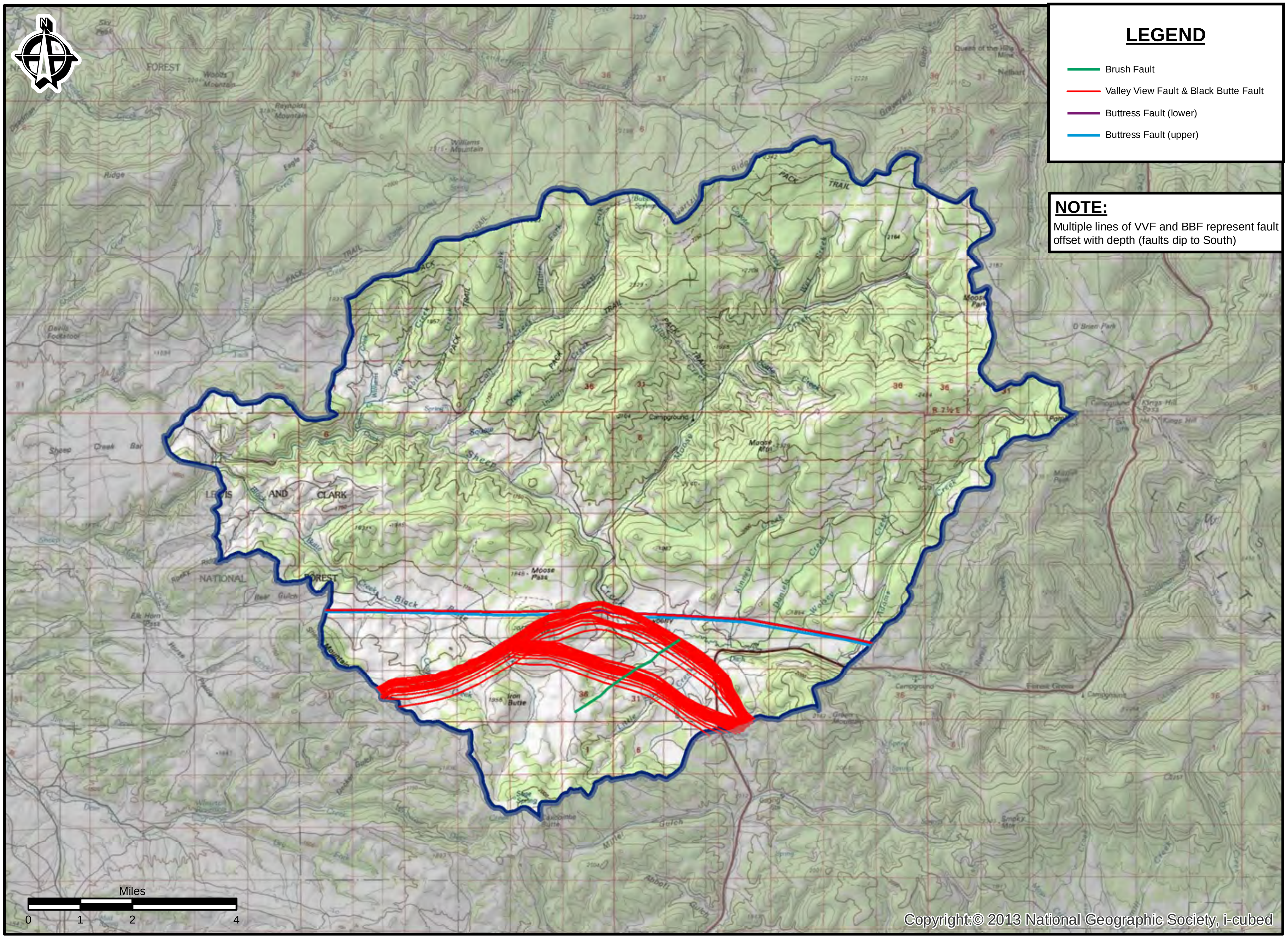

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Figure 3-10
Simulated Faults
Black Butte Copper Project
Meagher County, Montana

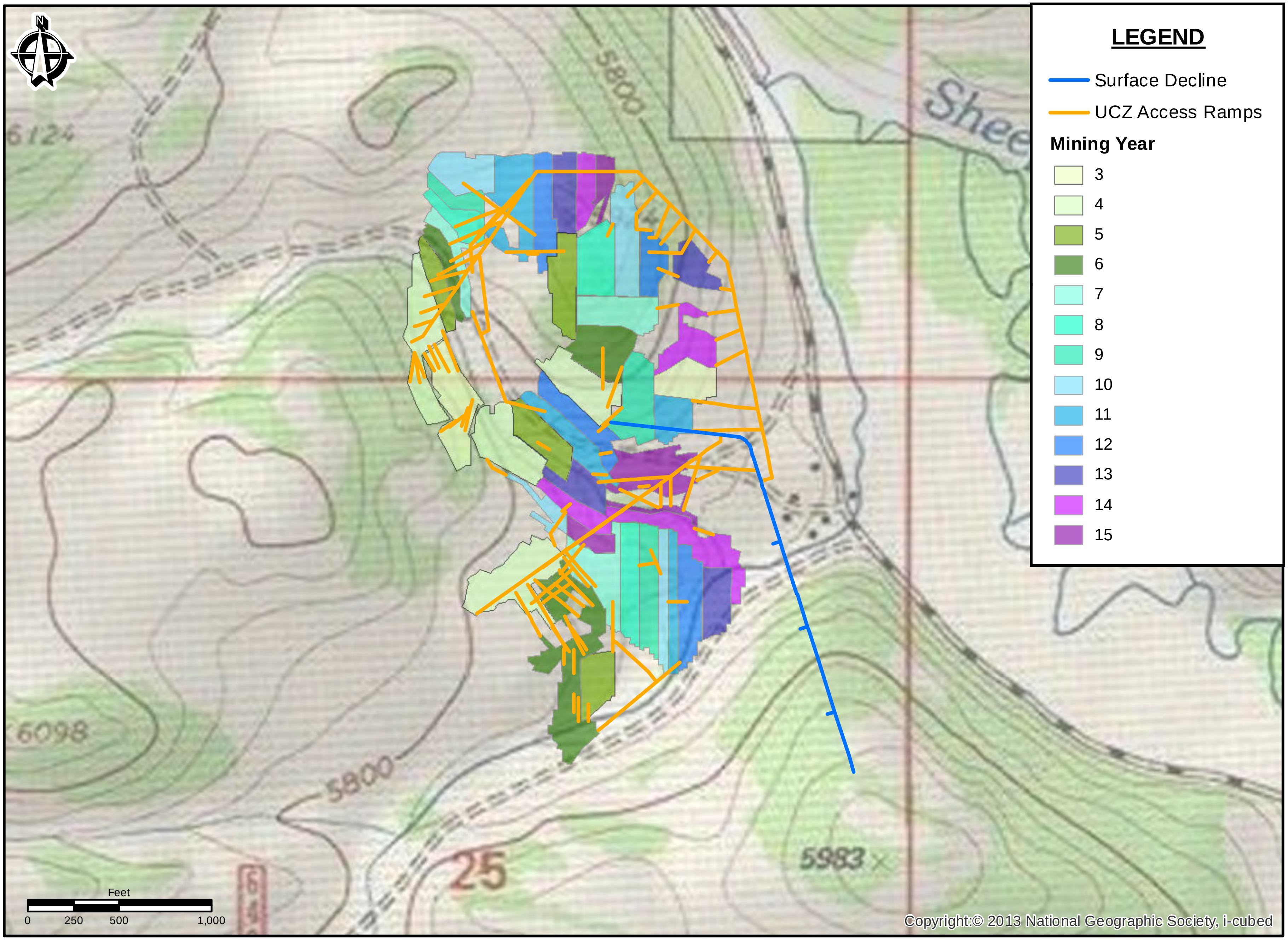

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Figure 3-11
UCZ Access and Mining Schedule
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Meagher County, Montana

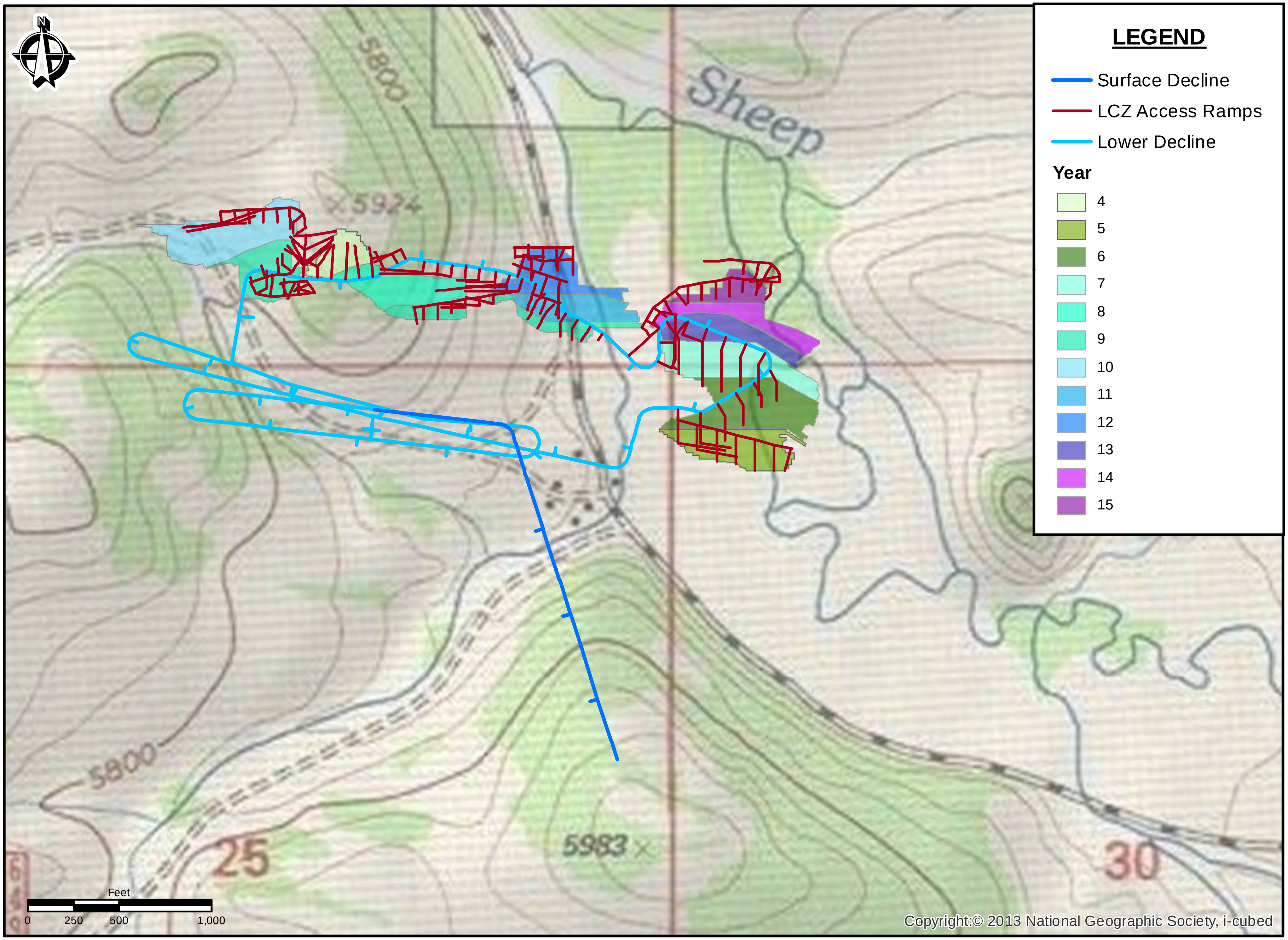

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Figure 3-12
LCZ Access and Mining Schedule
Black Butte Copper Project
Meagher County, Montana

to the maximum area open to active mining during each year of development. The stope drains were active for one year and then turned off in subsequent simulations based on the proposed rate of mine development in the UCZ and LCZs. The location of the stope drains is based on an assumed mine schedule provided by Tintina (Figure 3-11). The drain conductance for all mine workings was set at an excessively high value (33,000 ft/day multiplied by the length of drain along the cell) to ensure the drain conductance does not limit the discharge rate to the drains.

Paste backfill was simulated by changing the material properties of an area equivalent to the stopes that will be mined from each of the four quadrants of the UCZ and the LCZ as shown in Figures 3-11 and 3-12. Since material properties cannot be modified in a transient simulation, this was conducted using a method that employs what is commonly termed as "cascading models." Cascading models are generated by setting up individual transient models for each year of mining. Material properties are changed to the paste backfill properties in areas where mining was completed during the previous year and then the simulated heads for the last time step of the previous year model are set as starting heads for the next annual simulation. The hydraulic conductivity assigned to the paste backfill (K – 2.85 x 10^{-4} ft/day) is based on the permeameter testing conducted on test tailings samples. This is assumed to be a conservative permeability for the paste backfill as the cement added to the tailings will lower the permeability. The specific storage used for the paste backfill was the same as the LCZ (Ss – 0.000031/ft).

Post mining was simulated by deactivating the drains that previously were simulating dewatering of the access ramps. The drains representing the main access ramps were deactivated in the model 6 months to 1 year after mining is complete. The drains representing the smaller ramps that provide access to specific stope areas were deactivated at the beginning of the post mining simulations. The schedule for deactivating the drains representing the active mine workings during closure is described below.

- Access ramps and Lower Decline North of VVF - 6 months after mining complete;
- Lower Decline south of VVF and access ramps to the UCZ - 9 months after mining complete; and
- Surface Decline - 1 year after mining complete.

4.0 MODEL CALIBRATION

The numerical groundwater flow model was developed as described above, and the model parameters (primarily hydraulic conductivity and stream-bed conductance) were refined within established ranges from pumping test data and literature values to optimize the degree to which the model simulations match observed potentiometric data, and observed and estimated steady state base flow conditions in surface water. Calibration targets for heads were set based on 10% of the difference in head across the observed heads used to calibrate the model (Anderson and Woessner, 1992). A separate calibration target for alluvial wells was set slightly below 10% of the change in head in the alluvial wells. A ±20% target was used for the matching steady state base flow in streams, this accounts for the typical error in flow measurements (10-15%) and an assumed uncertainty in the estimated steady state base flows from the watershed analysis. The calibration targets used for the steady-state model are as follows:

- Simulated Heads
  - Alluvial Observation points – ±3.3 feet.
  - Bedrock observed heads from WRM network – 18.4 feet.
  - Mean Absolute Error - ≤ 18.4 feet.
- Match general flow direction and gradient of regional potentiometric surface.
- Groundwater Discharge to Surface Water (Steady State Base Flow) – Within 20% of calculated steady state base flow.
- Transient Calibration – Qualitative Calibration – trend and magnitude of drawdown curve from long-term pumping tests.

4.1 CALIBRATION METHOD

4.1.1 Steady State

The steady state model was calibrated to November 2014 observed water level elevations from 23 primary observations sites from the baseline water resource monitoring sites, and also to the estimated groundwater discharge to streams under steady state base flow conditions within the four sub-watersheds identified in the model. In addition to the November 2014 data, water levels were collected from five private wells in June 2015 to provide additional water level data to calibrate the model to. These wells were surveyed using a map grade GPS with an approximate horizontal accuracy of ±1 foot and vertical accuracy of ±5 feet. The domestic well observations are considered secondary observation sites and are not included in the calibration statistical analysis and were given a general target of ±40 feet based on the accuracy of the survey, the fact that water level data were collected during a different season and there is insufficient information to interpolate to seasonal low water levels, and inadequate information regarding the actual well completions and associated hydro-stratigraphy at these locations. The observed water levels and calibration targets are shown in Table 4-1.

The model was calibrated through an iterative process using manual calibration and PEST automated calibration analyses. The PEST analysis was conducted by varying the K's of the material properties for each HSU to match the observed heads. Manual calibration included varying K's and streambed conductance to match observed heads and steady state base flow in the streams. The model was initially calibrated to the regional potentiometric described in Section 2.4 (Figure 2-5). Projected observations were developed based on the regional potentiometric to facilitate the regional PEST calibration. The regional calibration was initially conducted by varying the permeability of the larger HSUs described in the conceptual model. The PEST analysis indicated that there were areas in the model that were inversely sensitive to changes in hydraulic conductivities of specific units compared to surrounding areas (e.g., heads would increase in the area between Moose Creek and Calf Creek due to decreases in K of the Xm material properties while heads between Moose Creek and Adams Creek would decrease). To provide a better calibration to the regional potentiometric surface the HSUs were discretized into sub-units and material properties were adjusted in areas where there was a distinct trend in residual heads. Streambed conductance was also adjusted slightly during the regional calibration in Moose Creek, Black Butte Creek, and the lower section of Sheep Creek to match the projected heads and to adjust the amount of groundwater discharge to the streams to meet calibration targets.

TABLE 4-1. OBSERVED WATER LEVEL ELEVATIONS AND CALIBRATION TARGETS

Observation Site	HSU	Model Layer	Observed Head (feet, MSL	Residual Calibration Target (+/-, feet)
Primary Observation Sites				
PZ-01	Qa - Sheep Creek	1	5627.23	3.3
PZ-02	Qa - Sheep Creek	1	5610.50	3.3
PZ-03	Qa - Sheep Creek	1	5612.53	3.3
PZ-05	Qa - Sheep Creek	1	5596.59	3.3
PZ-08	Qa - Sheep Creek	1	5615.22	3.3
PZ-09	Qa - Sheep Creek	1	5631.89	3.3
PZ-11	Qa - Sheep Creek	1	5615.81	3.3
MW-4A	Qa - Sheep Creek	1	5607.18	18.4
MW-1B	Ynl-A	3	5615.19	18.4
MW-2B	YNL-A	3	5703.54	18.4
MW-3	UCZ	5	5716.17	18.4
MW-4B	Ynl-A	2	5607.54	18.4
MW-6B	Ynl-A	2	5673.29	18.4
MW-7	Ynl-A	3	5717.48	18.4
MW-8	Tertiary Intrusive/Ynl-O	3	5780.44	18.4
MW-9	Ynl-A	3	5696.06	18.4
PW-2	USZ	4	5734.44	18.4
PW-3	Ynl-A	3	5643.27	18.4
PW-4	USZ	4	5627.20	18.4
PW-7	LCZ	11	5620.11	18.4
PW-8	Ynl-A	3	5635.04	18.4
PW-9	UCZ	5	5703.34	18.4
PW-10	Ynl-B	7	5699.67	18.4
Secondary Observation Sites				
DW-9	Unknown; assumed Ynl-A	3	5739.93	40
EW-02	Unknown; assumed Ynl-A	3	5746.85	40
EW-06	Unknown; assumed Ynl-A	3	5742.06	40
EW-05	Unknown; assumed Ynl-A	3	5810.49	40
EW-01	Unknown; assumed Ynl-A	3	5623.29	40

A more detailed steady state calibration (project area calibration) of the observed heads in the project area was conducted following the regional calibration. The PEST analysis provides optimized K's with respect to the observed heads in the project area, whereas the manual calibration varied the K's and streambed conductance to match observed heads and stream steady state base flow in the project area.

4.1.2 Transient Calibration

Two transient calibration simulations were conducted to match the observed drawdown from the long-term pumping tests conducted on wells PW-8 and PW-9. The pumping tests were simulated using the well package. The discharge rate assigned to the pumping wells for the two pumping test simulations is shown in Table 4-2. The specific storage and K's of units in the vicinity of the pumping and observation wells were adjusted from the steady state simulation to match the drawdown curves observed during the pumping tests. Changes to K's were applied to the steady state model prior to running the pumping test simulations to be able to evaluate the drawdown in the observation wells from steady state conditions. The parameters were adjusted in such a way to match both steady state and the transient drawdown curves.

TABLE 4-2. TRANSIENT CALIBRATION PUMPING WELL DISCHARGE RATES

Time (days)	Pumping Rate (gpm)
PW-8 Aquifer Test	
0 - 3.1	-5.5
3.1 - 5.6	-7.5
5.6 - 11.1	-9
11.1 - 14.7	-10
14.7 - 15	0
15 - 15.4	-10
15.4 - 31	-12
PW-9 Aquifer Test	
0 - 12.8	-4.8
12.8 - 19	-6.0

4.2 CALIBRATION RESULTS

4.2.1 Steady State Calibration

The final material properties assigned to the model following both transient and steady state calibration are shown in Table 3-4. The adjustments to the material properties caused minor changes to the steady state calibration. The final steady state potentiometric surface compared well to the regional and project scale potentiometric surface. A comparison of the simulated and observed regional potentiometric surface is shown in Figure 4-1 (regional). The simulated regional potentiometric surface shows that the groundwater flow converges on the major drainages. The range in head across the different watersheds in the model and general gradients are similar to the observed regional potentiometric map. There are some general discrepancies apparent in the higher elevations of the watersheds where there is the highest uncertainty in the observed potentiometric as there is no observation data in these areas.

The residual (observed – simulated heads) for each observation site are shown on Figure 4-2. Sites with green symbols indicate the residual head is within the calibration target, yellow symbols indicate the residual is 1 to 2 times greater than the calibration target and red symbols indicate the residual head is >2 times the calibration target. Negative values indicate that the observed head is lower than the simulated head at this location and positive indicate observed heads are higher than indicated by the model.

The final steady state model has 21 of the 28 observation sites within the calibration targets and 26 of the 28 observation sites within ±2 times the calibration targets. Two observation sites PW-7 and MW-7 had residuals greater than 2 times their calibration targets. The observed versus simulated heads for the observation points are shown in Figure 4-3. The graph shows that with the exception of some outliers, the observed and simulated heads are mostly distributed on either side of the 1:1 correlation line with a slight distribution bias below the line in the upper elevations.

The residual head at eight of the nine alluvial observation points were within their calibration target (±3.3 feet). The simulated water level at observation point PZ-08 was slightly higher

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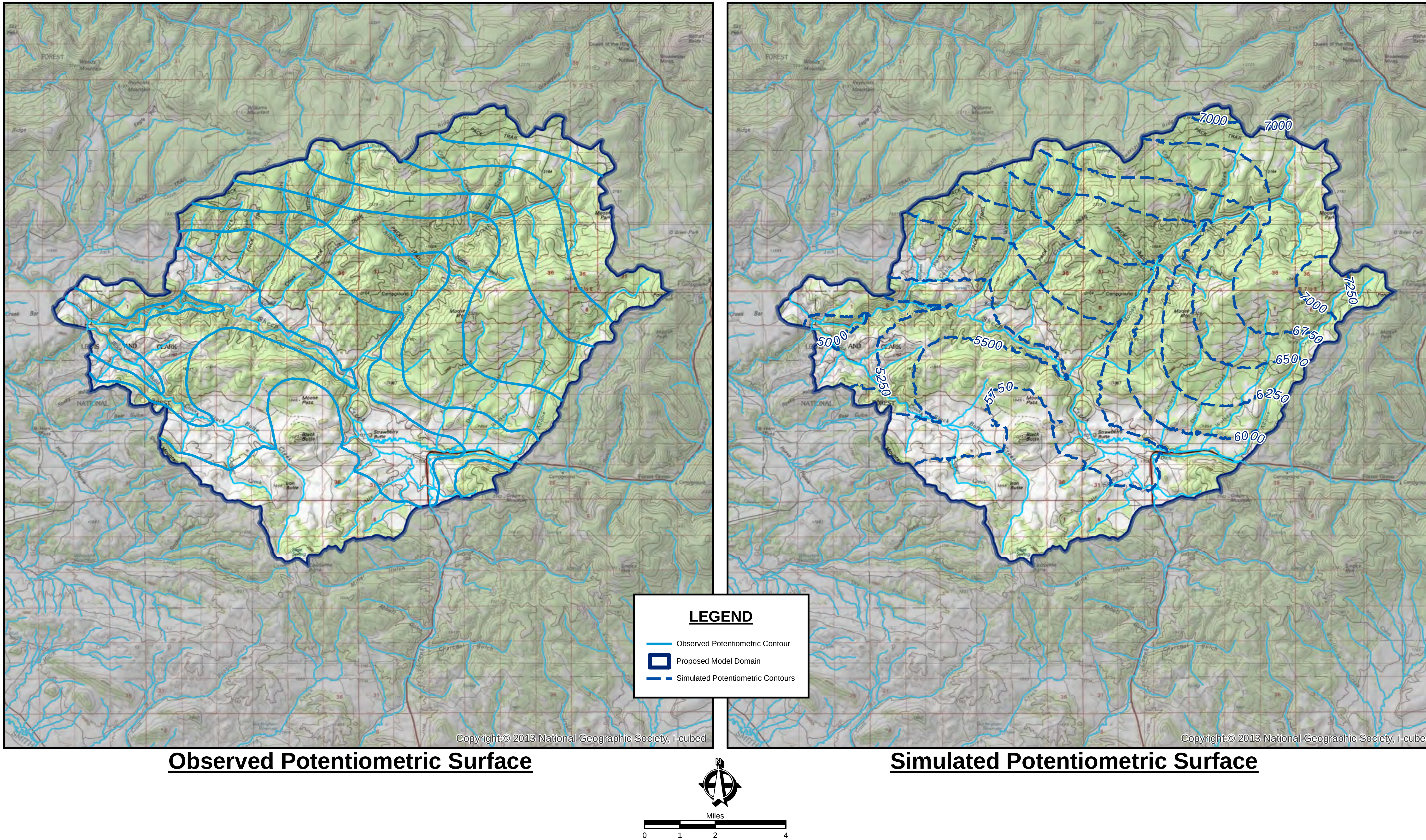

Observed Potentiometric Surface

Simulated Potentiometric Surface

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Figure 4-1
Observed & Simulated Regional Potentiometric Surface
Black Butte Copper Project
Meagher County, Montana

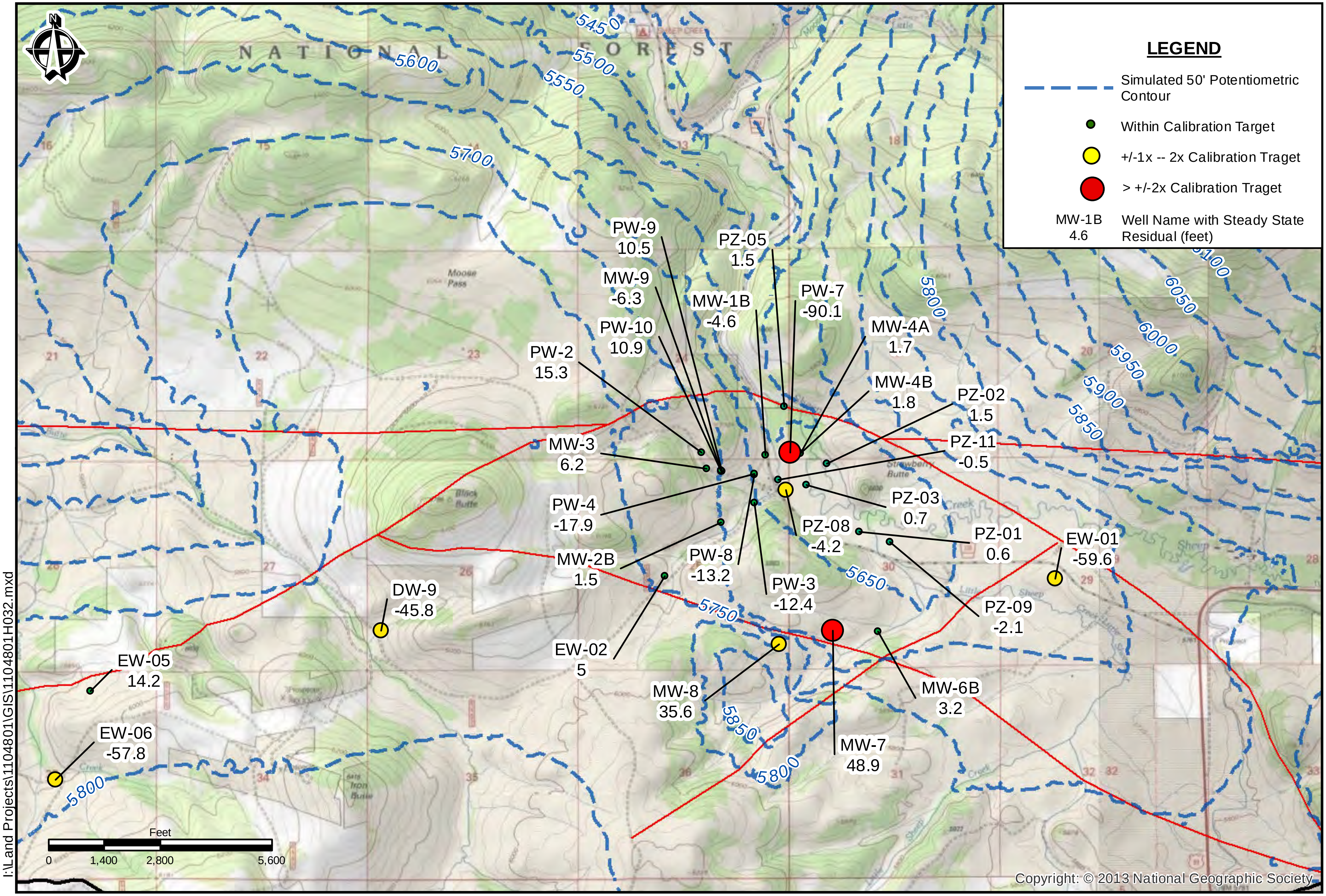

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Figure 4-2
Steady State Residuals
Black Butte Copper Project
Meagher County

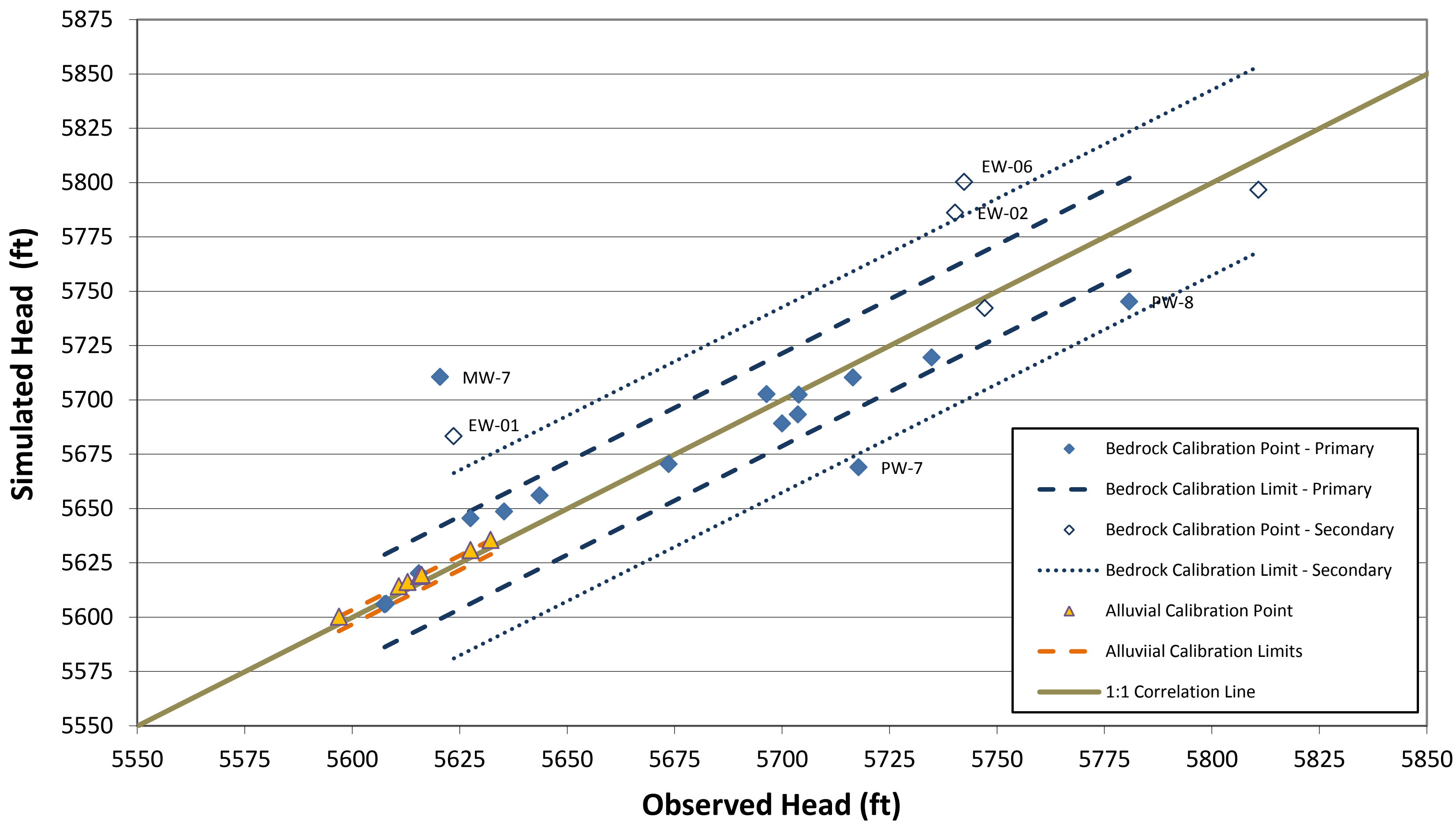

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Figure 4-3
Observed Versus Simulated Head
Black Butte Copper Project
Meagher County, Montana

than the November 2014 water level. This observation point is located near the edge of the alluvium in the area and near a change in stream gradient as Coon Creek enters the flat lying alluvial system in the meadow. These transition zones are difficult to fully simulate in watershed scale models, which can contribute to larger residuals in these areas.

The graph in Figure 4-3 indicates that the model is over predicting the heads in the LCZ (PW-7). Additional manual calibration of hydraulic conductivity of the LCZ was conducted to see to what extent the excess heads are a function of the estimated K values used in the model for this unit. The manual calibration showed that increases in K of the LCZ resulted in higher head in the LCZ, and decreases in K resulted in only slightly lower heads. Varying the permeability of the LCZ, therefore, did not appear to lower the head sufficiently to bring the LCZ into calibration. Given the low permeability of the LCZ, there is another potential explanation for the calibration disparity. Aquifer test results at PW-7 (Hydrometrics, 2015a) suggest it would take less than 1 gpm of leakage from the LCZ to reduce the simulated head in the LCZ to the observed head. This was verified in the subsequent simulations of mine development which establish that very low flow rates are required for dewatering the LCZ (discussed in Section 5.0 of this report). Although the head in the LCZ is over predicted, the associated flow with respect to the residual is very low. It is not possible to identify a specific source of leakage of this magnitude (less than 1 gpm). Since the head calibration difference represents less than 10% of the total head over the LCZ, the head deviation should not significantly influence the model results. During the calibration runs the LCZ K values in the model were doubled from the optimized PEST values which were originally near the lower permeability range derived from aquifer tests. These higher permeabilities result in a larger residual at PW-7, but were retained in the subsequent predictive simulations to provide more conservative estimates of potential mine inflows.

A second area where the simulations varied from calibration targets is at observation points MW-7 and MW-8, which showed low simulated heads compared to observed values. The complex geology (the intersection of the Black Butte Fault, Brush Creek Fault, and the presence of extensive Tertiary intrusives) in the vicinity of observation points MW-7 and MW-8 appears to complicate hydrogeologic conditions in this area and is likely a primary factor in the calibration disparity. Another contributing factor may be the hydrologic connection between the bedrock system at MW-7 and MW-8 with Brush Creek. The entire perennial reach of Brush Creek is simulated in the model as though it is in direct connection with the bedrock groundwater system at MW-7 and MW-8, although there is evidence that groundwater contributions to the upper reach may actually come from a separate perched system rather than from the bedrock in the vicinity of MW-7 and MW-8 (detailed discussion is provided in the Hydrometrics, 2013, Underground LAD Assessment). Because of the complexity of the geologic conditions in this localized area and associated uncertainty, Brush Creek's upper reach was left in the model as a conservative approach to evaluating potential effects from mine dewatering on surface water resources near the mine workings.

Additional manual calibration was conducted to see whether further adjustments in material properties would increase the heads and improve the model calibration in the vicinity of MW-7 and MW-8. The simulated heads at MW-8 were increased slightly with decreases in permeability of the Ynl-S1 and -S2 and small changes in the Tertiary intrusive permeability; however, this also produced an increase in the water level elevation in the upgradient area contributing to high water level residuals at observation sites EW-06 and DW-9. It also produced localized mounding in the area between the Black Butte Fault and the Brush Creek Fault which because of their proximity act as barriers to flow. The complex geology at the conjunction of these faults combined with the influence of low permeability intrusives within this area cannot be fully resolved in the model at this scale. The decreases in the Ynl-S1 and -S2 K values during calibration slightly improved calibration at MW-8 and MW-7 and were carried forward in the model.

The residual head at site EW-01 may be from groundwater in this area being influenced by a gravel pit just to the east of the observation site. The gravel pit extends into the alluvial water table and has groundwater outflow of several CFS. The gravel pit outfall was not included in the model since it is a localized feature which is in proximity to Little Sheep Creek and Sheep Creek, which exert strong influences on water table elevations in this area. It was assumed that the discharge effects from the pit would be compensated for by increased discharge to the adjacent stream packages representing Little Sheep Creek and/or Sheep

Creek. The omission of the gravel pit from the model, however, would still result in a localized disparity in groundwater levels in the pit area.

Statistical analyses of the residual heads at the primary observations points were performed to further evaluate the steady state model calibration. A mean absolute error (MAE) of 16.92 was calculated from the primary observation points; this is within the calibration target (≤18.4 feet). Although the root mean squared error (RMSE) was not identified as a target for calibration, it is provided as a comparison to the MAE. RMSE can be affected by outlier residuals and is typically higher than the MAE (Anderson, Woessner, and Hunt, 2015). The RMSE (28.20) of the primary observation residuals is larger than the MAE which indicates there are outlier residuals in the dataset. The MAE is used as the primary statistical target as it is not biased by positive and negative residuals and more robust to the effects of outlier residuals.

Another conventional calibration metric is the comparison of surface water discharges in the model to average steady state base flow conditions in the streams. The model was calibrated to steady state base flow for the major drainages in the model domain (Sheep Creek at SW-1, Moose Creek, Black Butte Creek, and Sheep Creek at the model domain). Estimated steady state base flows for each of these drainage areas are shown in Table 2-3. The model does not include the upper third of the Sheep Creek watershed, which contributes 9 cfs to the steady state base flow of Sheep Creek at SW-1 and the model domain. The steady state model simulated the groundwater discharge to surface water (base flow) during late season conditions (steady state) within the model domain, therefore, the target steady state base flows for Sheep Creek at SW-1 and Sheep Creek at the downstream boundary of the Model Domain were calculated by subtracting 9 cfs from the estimated discharge listed in Table 2-3. A comparison of the steady state base flow targets for the model domain and simulated steady state base flow is shown in Table 4-3. All of the simulated steady state base flows were below ±10% of the base flow contribution from the model domain. There is some uncertainty in the estimated steady state stream base flow at Black Butte Creek; the precipitation/watershed analysis resulted in an estimated base flow of 3.2 cfs (Table 2-4), however, unlike Sheep Creek, Tintina did not have direct access to Black Butte Creek until

September 2015 to collect flow measurements and verify the accuracy of this estimate. A late season (steady state) flow of 2.6 cfs was estimated for Black Butte Creek based on the observed flows in September 2015 (Table 2-4). The simulated steady state base flow is similar to the adjusted late season estimate from the observed flows (7.7% difference).

TABLE 4-3. COMPARISON OF SIMULATED AND OBSERVED STEADY STATE BASE FLOWS

Site	Steady State Base Flow Contribution from Model Domain (CFS)	Simulated Steady State Base Flow (CFS)	Percent Difference
Sheep Creek -SW-1	6.2	5.8	6.5%
Moose Creek	7.7	8.1	-4.8%
Black Butte Creek	2.6 - 3.3	2.4	7.7% - 24.6%
Sheep Creek-Model Domain	23.2	24.0	-3.3%

4.2.2 Transient Calibration

The transient calibration to the PW-8 pumping test was evaluated by comparing observed and simulated drawdown at wells PW-8, PW-4, PW-3, and MW-1B (Figure 4-4). The drawdown simulated at PW-8 (pumping well) matches the general drawdown trend observed during the pumping test; however, the magnitude of drawdown is much less. This is expected since the drawdown simulated by the model represents the average drawdown within the area of the cell containing the pumping well, rather than drawdown within the pumping well itself. Simulated water levels in the model are more representative of monitoring points in outlying areas which is consistent with the model results. Simulated drawdown curves are a good match to the first 15 days of the observed drawdown response at observation wells PW-4 and MW-1B. There was a large 3-day precipitation event after this period that caused the observed drawdown to flatten out or start to recover for the remainder of the test. The large precipitation event is likely the cause of the observed recovering above the initial water level prior to pumping (negative drawdown). Since the model did not

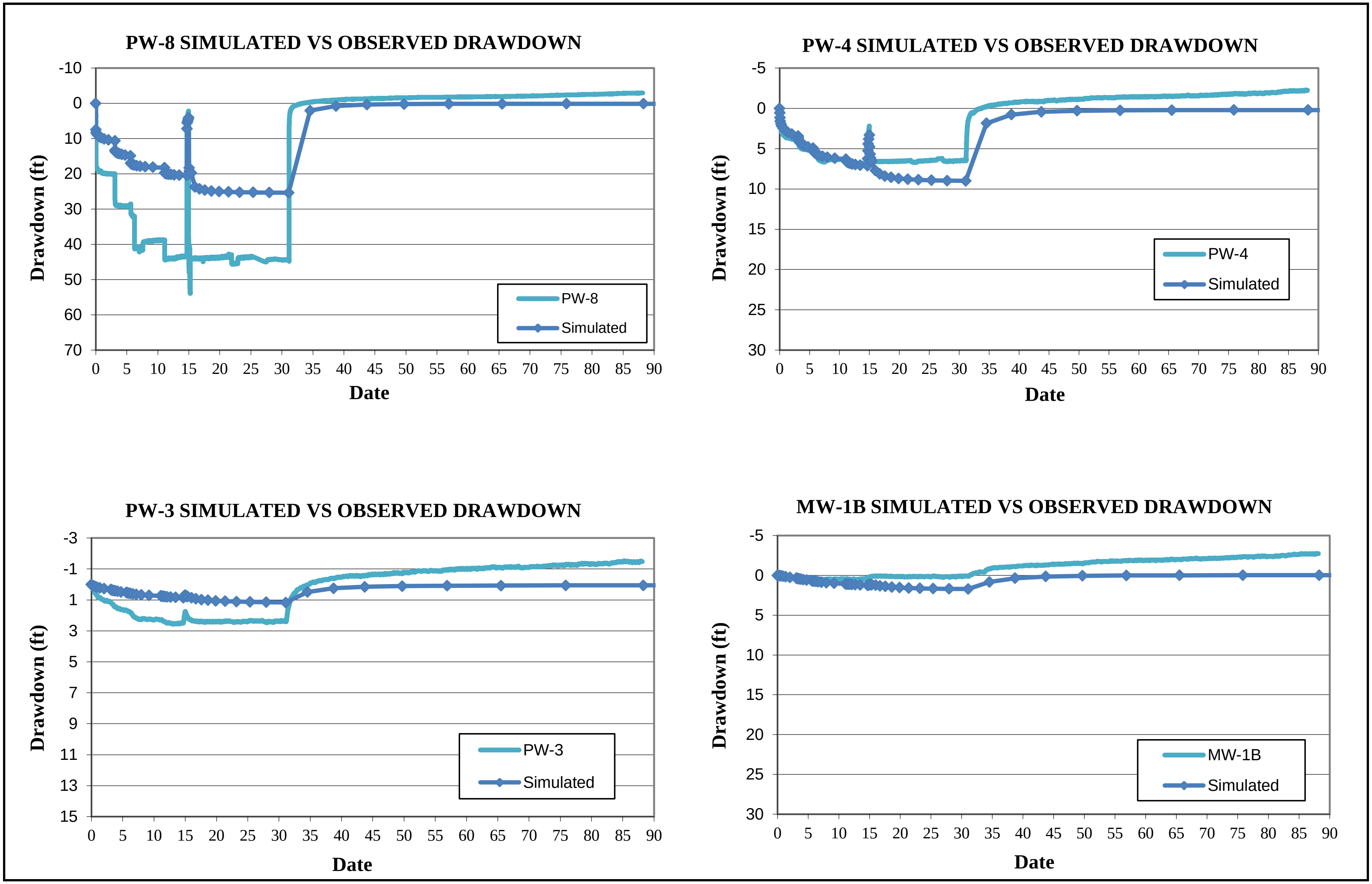

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Figure 4-4
Transient Calibration - PW-9 Drawdown
Black Butte Copper Project
Meagher County, Montana

include additional recharge in the transient simulation the effect from the precipitation event after day 15 are not reflected in the modeling results. The simulated recovery is approximately the same magnitude at the end of the pumping period when adjusted for the difference in recharge effects due to the storm event.

The simulated drawdown at well PW-3 is approximately half of what was observed during the PW-8 pumping test. This disparity appears to be related to a small overestimate in the simulation of the effects from nearby Coon Creek, Well PW-3 is located on the opposite side of Coon Creek from the pumping well. There was no observed drawdown during the PW-8 pumping test in piezometers completed in the shallow aquifer adjacent to Coon Creek, nor was there any decrease in flow measured in Coon Creek during the aquifer test. The simulated PW-8 pumping test shows a small increase in stream leakage (2 gpm) during the aquifer test. Although this is a small amount with respect to the overall flow within Coon Creek, it is approximately 17% of the discharge at the pumping well. The additional water added to the model between PW-3 and the pumping well is sufficient to account for the lower simulated drawdown at PW-3. Inclusion of Coon Creek in the model at this location, may therefore slightly overestimate the potential for interactions to occur from dewatering near the mine site. The empirical data from the pumping test and discrepancy in the observed and simulated drawdown at PW-3 should be considered when evaluating the actual significance of predicted impacts to Coon Creek on the reach upstream of the Sheep Creek alluvium.

The simulation of the PW-9 pumping test in the USZ produced lightly less drawdown than observed, as is expected in the pumping well, and provided a good match to the general trends observed at the pumping well (Figure 4-5). Simulated drawdown at MW-3, completed in the same layer (5) of the model, also matched the drawdown curve observed during the pumping test. The simulated drawdown at both PW-9 and MW-3 did not fully recover by the end of the simulation.

Observation sites MW-9, completed in layer 4 (Ynl-A), and PW-10, completed in layer 7 (Ynl-B), did not match the relatively quick initial drawdown response observed at these wells during the pumping test and had slightly less drawdown at the end of pumping. A possible

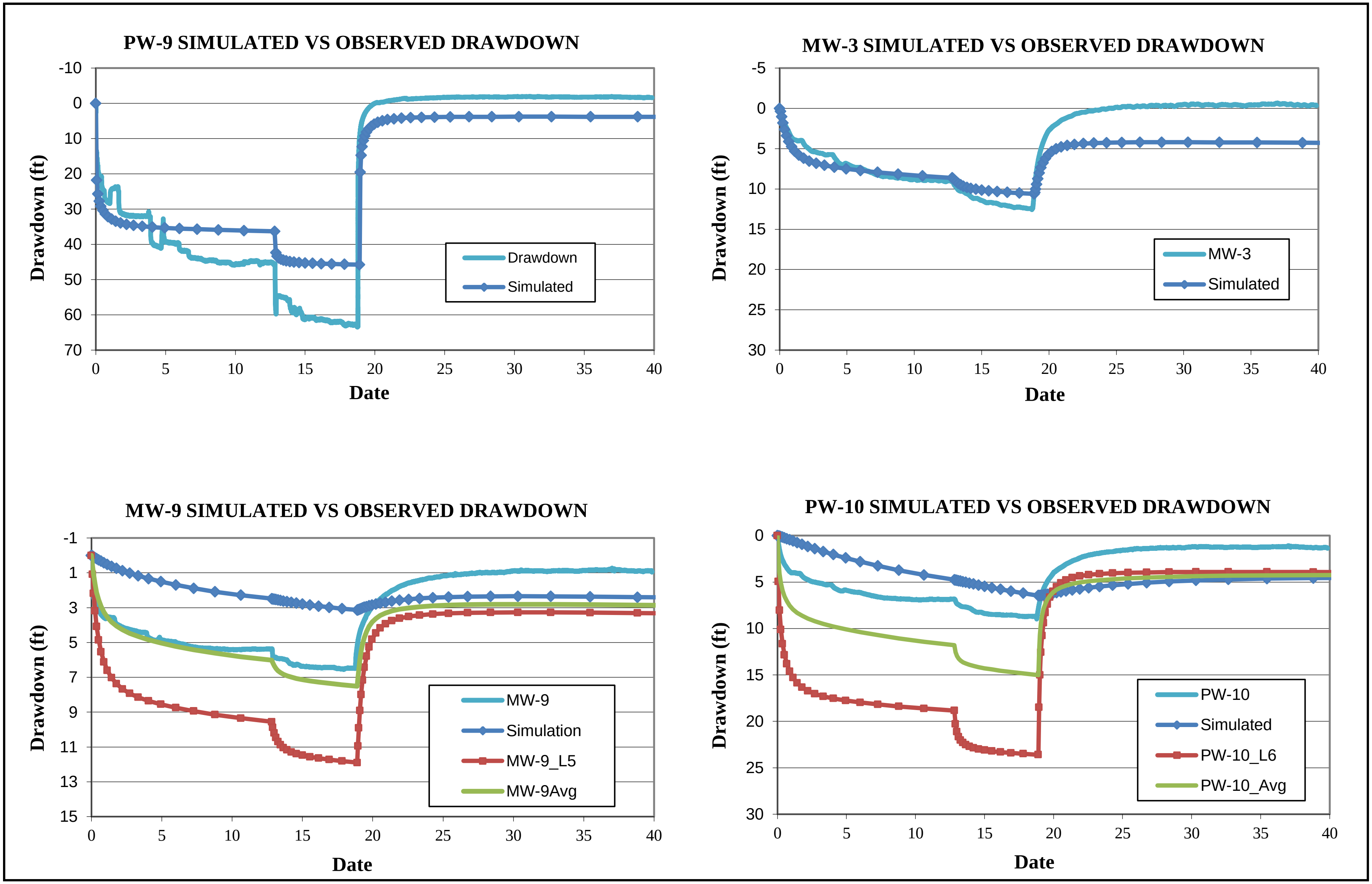

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Figure 4-5
Transient Calibration - PW-9 Drawdown
Black Butte Copper Project
Meagher County, Montana

explanation for the discrepancy relates to the completion of MW-9 and PW-10. The well screen in MW-9 is completed across the Ynl-A near its contact with the USZ. However, the borehole was over drilled and sand was used for backfill in the lower portion of the borehole; which essentially screened the well across the Ynl-A and USZ (Hydrometrics, 2015a). The completion at well PW-10 has a large sand pack interval which extends slightly up into the base of the USZ and Ynl-B. When a well is completed across two distinct HSUs the water level in the well is a representation of the combined water level of the two HSUs. The effect on water levels is more pronounced when stresses are applied to one of the HSUs. To evaluate the potential influences on water level drawdown resulting from well completions that cross different HSUs, the simulated drawdown in layers 4 (at MW-9 location) and 6 (at PW-10 location) were displayed on the drawdown graph along with an average of the drawdown from each layer at wells MW-9 and PW-10, respectively. The average drawdown from layers 4 and 5 at MW-9 is a good match to the observed drawdown, which indicates the model is well calibrated to the vertical connectivity between the Ynl-A, USZ, and UCZ. The average drawdown from layers 6 and 7 at PW-10 match the general trend in the observed drawdown, but the simulated average drawdown is almost double the observed drawdown. The difference may reflect the fact the well completion at PW-10 only partially penetrates into the USZ. Similar to PW-9 and MW-3, the simulated drawdown did not recover fully by the end of the simulation at both MW-9 and PW-10.

In summary the model met head calibration criteria throughout most the model domain. In areas where calibration disparities were found, additional calibration was performed to minimize the head residuals; however, in some instance the disparities were related to localized transitions in geology or stream boundary conditions that could not be fully resolved in a regional scale simulation. These calibration disparities appear too localized and should not significantly influence the predictive results of the model but should be considered when examining effects in these limited areas. The model met stream calibration criteria and the model was also able to reproduce the trend and magnitude of drawdown from long-term pumping tests in transient simulations with simulated drawdown effects that are both greater and less than measured values indicating a consistent bias is not introduced in the model.

5.0 MINING SIMULATIONS

The calibrated model was used to estimate mine inflows and evaluate effects on water resources throughout the life of the mine and post mining. The mine simulations were developed as described in Section 3.4. The model simulations were evaluated during different phases in the mine development as summarized below:

- Phase I – Surface Decline Development: construction of surface decline – Year 1.
- Phase II – Access Development and Mining: construction of Access Ramps and Lower Decline plus first full year of mining – Years 2 to 4.
- Phase III – Mining: simulates mine dewatering using cut and fill mining throughout life of mine – Years 5 – 15.
- Phase IV – Post-Mining: includes 1 year of closure and 100 years of post-closure water level recovery.

5.1 GROUNDWATER INFLOW AND WATER LEVEL DRAWDOWN

5.1.1 Mine Inflow and Disposal

The start of the project (Phase I) was simulated by using the modeled steady-state pre-mining water table as a starting condition, and simulating the surface decline in a one year transient simulation using drain cells to dewater the decline. The subsequent Phase II simulation included simulating the remaining access ramps and lower decline in years 2 through 4 and Phase III simulated active mining and paste backfill in years 4 through 15. The surface decline was simulated from the initial point where it intercepts the water table to the location where it turns to the west and accesses the UCZ during the first project year (Figure 5-1). The remainder of the surface decline is completed in Phase II of the project; this phase also includes development of the lower decline and all of the UCZ and LCZ access ramps.

The simulation results showing projected groundwater inflows to the underground workings are shown in Table 5-1. Estimated average inflows to the surface decline during Phase I are

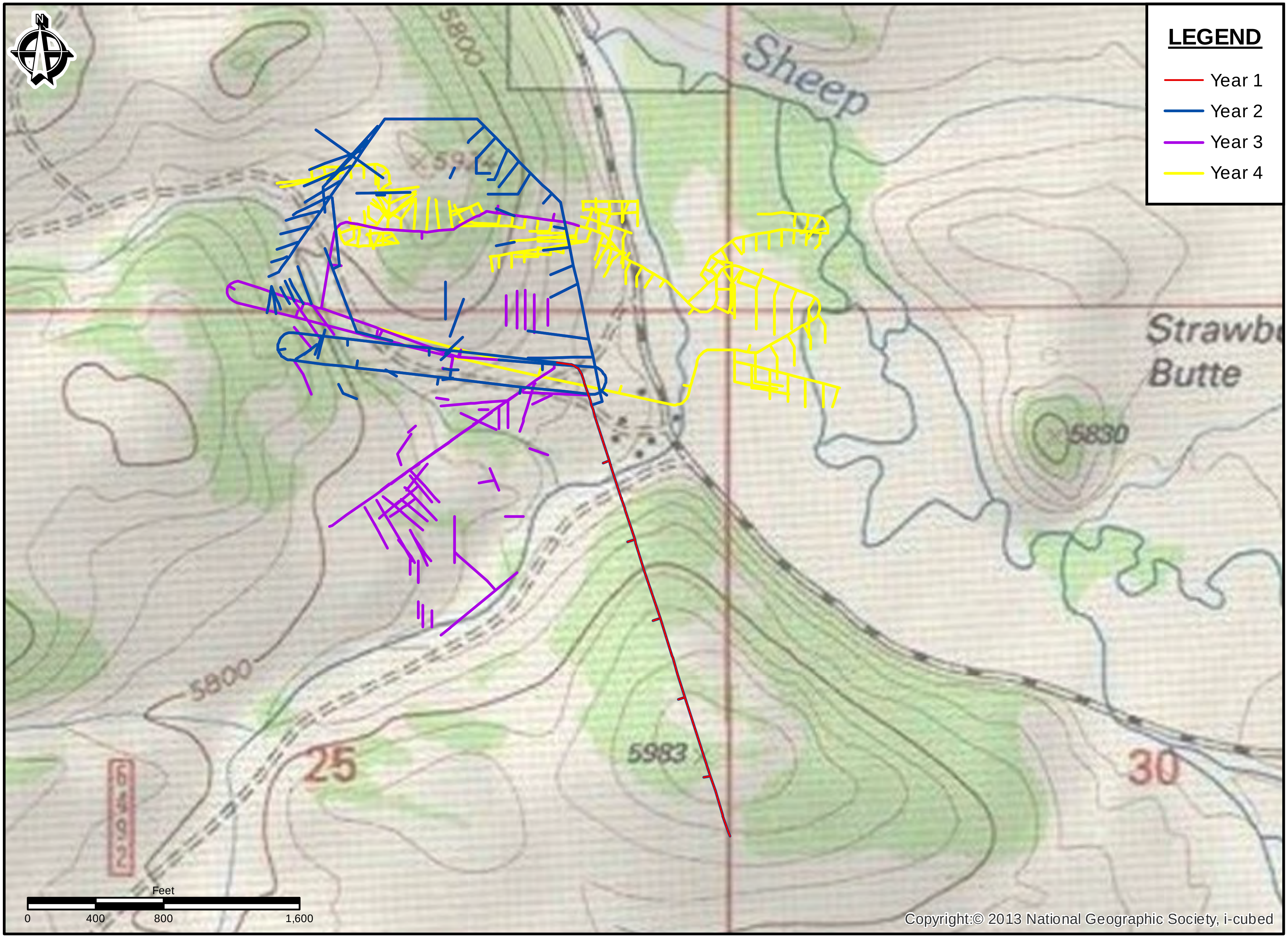

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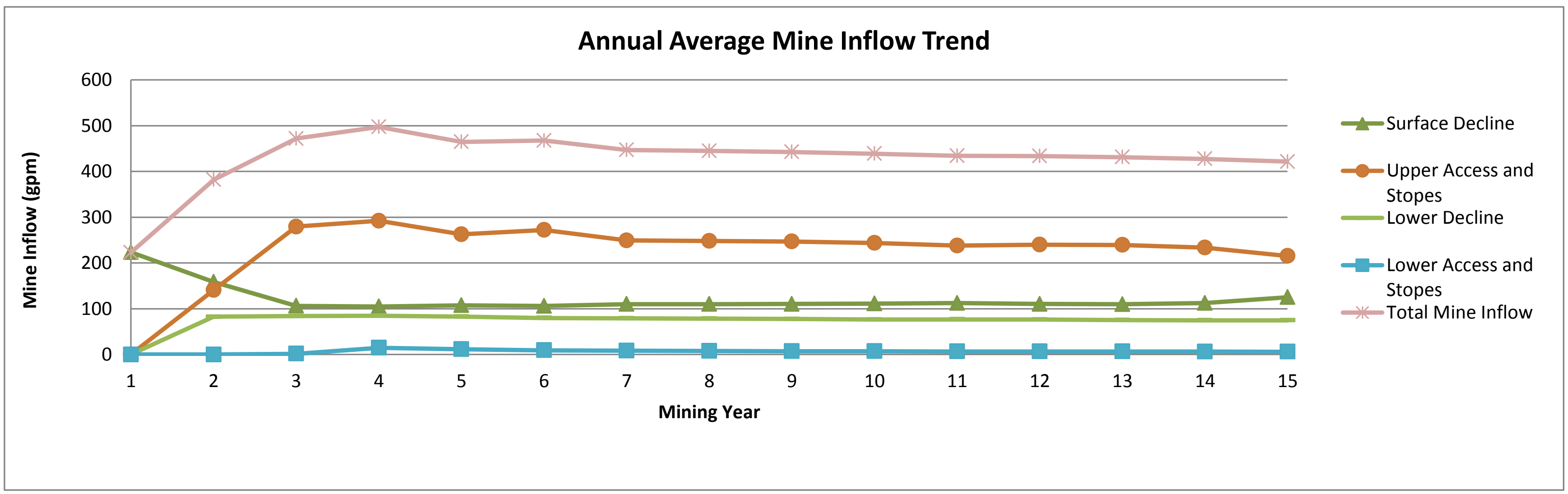
Figure 5-1
Decline and Access Ramp Schedule
Black Butte Copper Project
Meagher County, Montana

Table 5-1. Simulated Annual Average Inflow to Mine Workings

Mining Progress	Surface Decline	Declines and Access Ramps			Mine										
Project Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Mine Structure	**Inflow (gpm)**														
Surface Decline Total	**223**	**159**	**106**	**105**	**108**	**106**	**110**	**110**	**110**	**111**	**113**	**111**	**110**	**113**	**125**
Surface Decline (YNL-A)	203	146	97	96	98	97	101	101	101	102	103	101	101	104	116
Surface Decline (UCZ)	20	12	9	9	9	9	9	9	9	9	9	9	9	9	9
Upper Access and Stopes Total	**0**	**141**	**279**	**292**	**262**	**272**	**249**	**248**	**247**	**244**	**238**	**240**	**239**	**233**	**215**
UZ Access/Stopes (USZ/UCZ)	0	129	268	282	251	261	238	237	236	233	227	229	228	222	204
UZ Access (YNL-B)	0	12	12	10	11	11	11	11	11	11	11	11	11	11	11
Lower Decline Total	**0**	**83**	**84**	**85**	**83**	**80**	**79**	**78**	**78**	**77**	**77**	**76**	**75**	**75**	**75**
Lower Decline (YNL-B)	0	83	84	85	83	80	79	78	78	77	77	76	75	75	75
Lower Access and Stopes Total	**0**	**0**	**2**	**15**	**12**	**9**	**8**	**8**	**7**	**7**	**7**	**7**	**7**	**6**	**6**
LZ Access/Stopes (LCZ)	0	0	0	5	4	3	2	2	2	2	2	2	2	2	1
LZ Access (YNL-B)	0	0	2	10	7	6	6	6	5	5	5	5	5	5	5
Total Mine Inflow	**223**	**382**	**472**	**497**	**465**	**467**	**447**	**445**	**442**	**439**	**434**	**433**	**431**	**427**	**421**



approximately 220 gpm with over 90% of the simulated inflow coming from the Ynl-A (Table 5-1). The simulated inflows increase in year 2 through 4 (Stage II), with a maximum inflow during year 4 of approximately 500 gpm. Approximately 80% of the predicted mine inflow comes from the surface decline and UCZ (Upper Access and Stopes), which is expected since the highest permeabilities are in the shallower HSUs. Inflow to the active workings decrease as the water levels drop in response to dewatering and as lower permeability cemented paste encompasses more of the mine area. The simulated inflow to the lower portion of the workings peaks in year 4 at 15 gpm and reduces to 6 gpm by year 15. These low inflow rates reflect the low permeability of the LCZ. The permeability of the LCZ was evaluated in a sensitivity analysis of the LCZ hydraulic conductivity on mine inflows (Section 6.0). During the last year of mining the total inflow to the mine workings is approximately 420 gpm; over 50% of the inflow comes from the UCZ access and stopes (215 gpm).

Water that is not used in the milling or mining process will be treated and discharged back to the groundwater system through an underground infiltration gallery (the location is shown in Figure 5-2). During Phase I, all of the water from underground dewatering will be discharged to the infiltration gallery. During Phases II and III, a portion of the water pumped from the mine will be consumed in ore milling, tailings paste, and other actives. During year 2, 97 acre-ft of water from underground dewatering will be stored in the process water pond for mill start-up in year 3 (this is equivalent to an average flow rate of 60 gpm). As noted above, active mining starts in year three with full scale mining in year four. Based on the project water balance (Knight Piesold, 2015), the project will consume approximately 210 gpm when the mill is running at full capacity.

For the purpose of estimating the excess volumes of water to be re-infiltrated in the model simulations the rate of water going to storage in year 2 was assumed to be equal to the consumptive use at full mining (210 gpm). It was also assumed that the consumptive use in year 3 of the model would be 210 gpm for operational demands. These assumptions are highly conservative as the assumed storage requirement in year 2 exceeds the volume

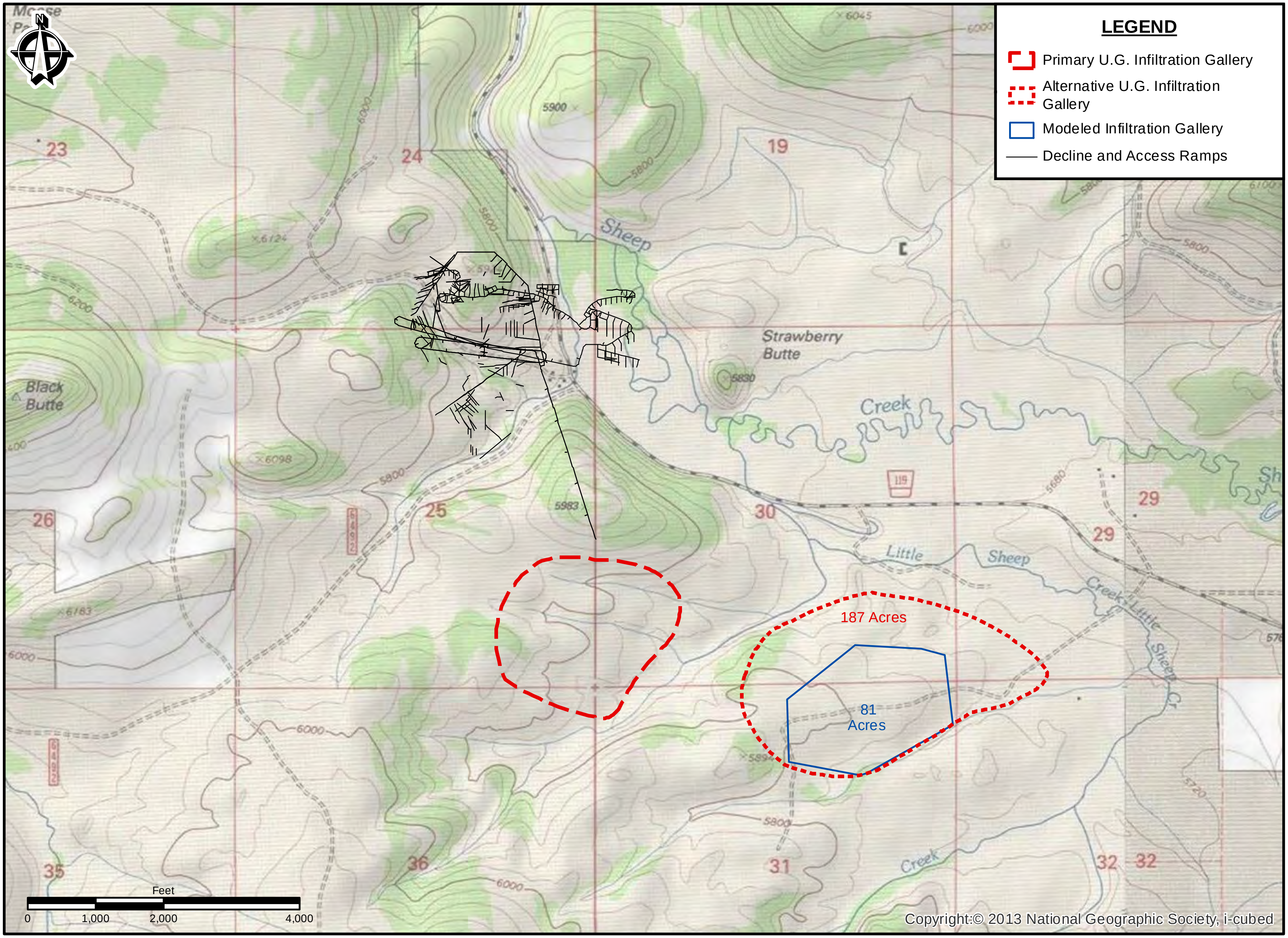


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Figure 5-2
Simulated Underground Infiltration Areas
Black Butte Copper Project
Meagher County, Montana

necessary for mill startup and the consumptive use during year 3 is not expected to meet demands as the mine will not produce sufficient ore to run the mill at full capacity. It should be noted that all depletions in surface water will be mitigated as described in Section 5.4.

During the initial mining simulations the discharge to the primary infiltration gallery resulted in excessive mounding, therefore, the model uses the alternative infiltration gallery location to dispose of the unused treated water (Figure 5-2). Disposal of water to the infiltration gallery was modelled using the recharge package, and applying a recharge rate equal to the excess water (211 to 290 gpm) divided by the infiltration area (81 acres). The recharge rate applied to the infiltration gallery is summarized in Table 5-2. Note that the area used in the model is much less than the area designated for the secondary infiltration gallery to simulate a conservative approach if only a portion of the infiltration gallery is put in use.

TABLE 5-2. APPLIED RECHARGE RATE TO INFILTRATION GALLERY

Year	Excess Water from Dewatering (gpm)	Equivalent Recharge Rate Applied to Inf. Area (in/yr)[1]
1	231	55
2	179	43
3	262	63
4	287	69
5	254	61
6	258	62
7	238	57
8	236	56
9	234	56
10	231	55
11	225	54
12	225	54
13	223	53
14	219	52
15	213	51

1. Excess water is applied over 80 acres.

5.1.2 Water Level Drawdown

The extent of the simulated drawdown during development of the surface decline (Phase I) within the general project area is shown in Figure 5-3 for layer 1 (shallow bedrock and alluvium), layer 3 (Ynl-A), layer 5 (UCZ), and layer 11 (LCZ). The 10 foot drawdown contour in Layer 1 at the end of Phase I extends 500 to 3,000 feet laterally out from the decline footprint within the shallow bedrock groundwater system. The 10 foot drawdown contour only extends into a small portion of the Sheep Creek alluvial groundwater system along the margin of Sheep Creek Meadows between the upland bedrock area and Coon Creek. Coon Creek, which runs along the margin of the alluvium, appears to limit the extent of the drawdown in the alluvial groundwater system as indicated by the 5 foot contour in the alluvial system (not shown at this scale) extending only about 100 feet beyond the 10 foot contour. There is approximately 1 foot of drawdown in the alluvium beneath Sheep Creek, which shows there is the potential to impact Sheep Creek (see Section 5.2 for discussion of impacts to streams). Drawdown in layers 3 and 5, within the Ynl-A, is similar to layer 1 but extends a little further to the east below the alluvial system east of the UCZ. There is no drawdown in layer 11 in the deeper portions of the model during this initial phase. The slightly greater drawdown to the east in layers 3 and 5 than in Layer 1 is related to the higher permeability and corresponding higher groundwater flow rate in the alluvial system, which dampens any drawdown effects.

The greatest drawdown in the upper portion of the model (layers 1 - 6) occurs in year 4 and corresponds to the initial mining stage when the highest inflow to the mine workings is predicted (Table 5-1). Simulated drawdown for year 4 is shown on Figure 5-4. The 10 foot drawdown contour extends into the Black Butte Creek watershed to the southwest and north of the VVF and Buttress fault. The extent of the 10 foot drawdown in the alluvial system remains adjacent to Coon Creek. Similar to year 1, the drawdown extends further to the east drawdown in layers 3 and 5. The maximum drawdown depth is approximately 290 feet in layer 1 and approximately 500 feet in layer 5.

The extent of drawdown in layer 11 is much smaller than in the upper layers in year 4, with the maximum extent of the 10 foot contour approximately 2,700 feet from the LCZ. The maximum drawdown in layer 11 is approximately 1,600 feet inside the LCZ. The drawdown

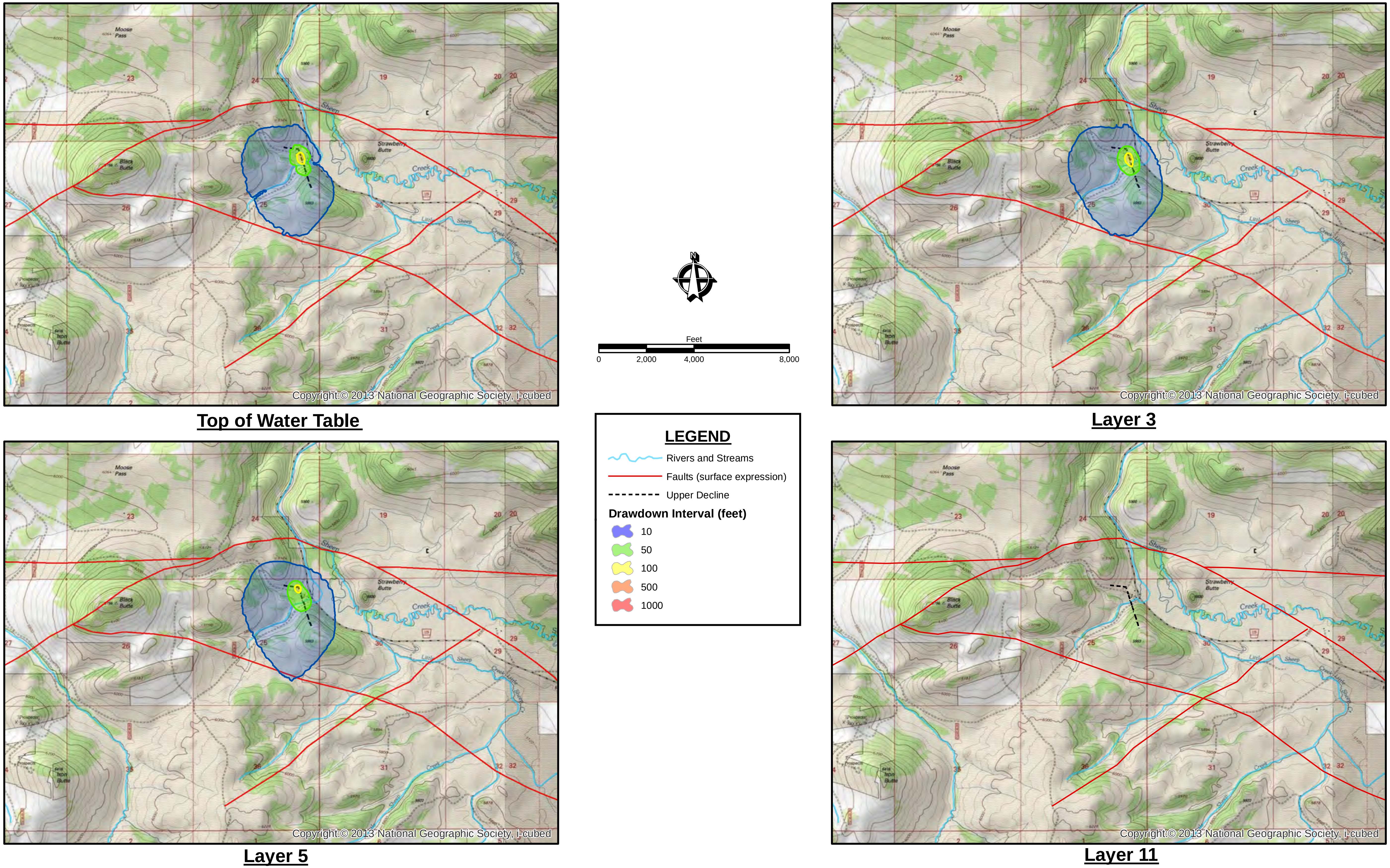

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Figure 5-3
Simulated Drawdown - Year 1
Black Butte Copper Project
Meagher County, Montana

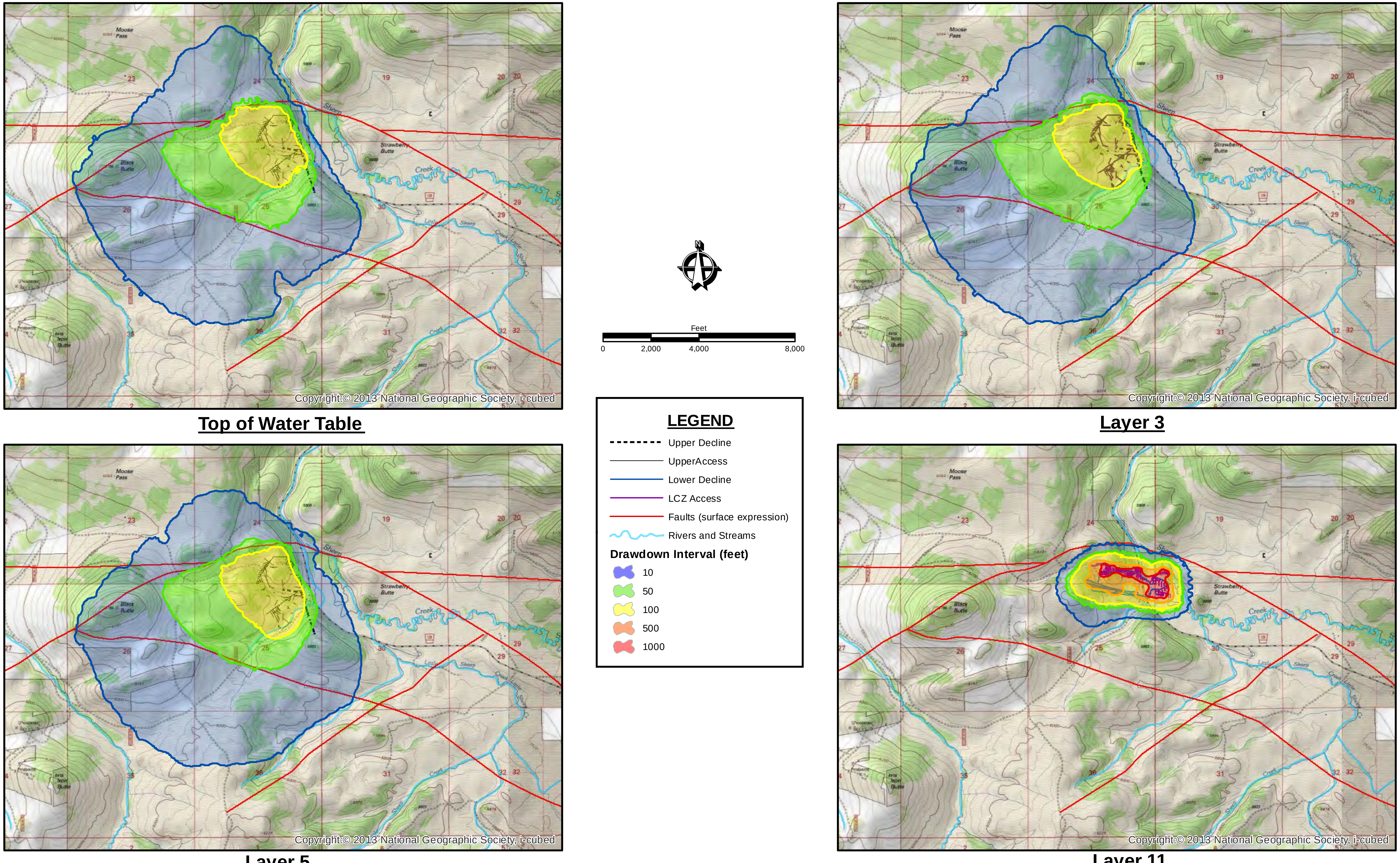

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Figure 5-4
Simulated Drawdown - Year 4
Black Butte Copper Project
Meagher County, Montana

cone is very steep outside of areas of active dewatering in layer 11 reflecting the low permeability of this unit.

The extent of drawdown decreases as more of the ore is extracted and stopes are filled with cement paste (Figure 5-5); by the end of mining the extent of the cone of depression in the shallow bedrock system recedes approximately 900 feet in the southwest portion of the depression and 1,200 feet in the northern portion. The 100 foot contour extends beyond the mine workings to the east in year 4, but by the end of mining it recedes back to the mine workings. Drawdown (10 foot contour) in the LCZ extends approximately 1 mile to the south and approximately ½ mile to the north from the LCZ workings.

5.2 CHANGES IN STREAM FLOW

Drawdown caused by dewatering (especially in the upper HSUs) captures water that would otherwise ultimately report to surface water which effectively decreases the base flow in downgradient surface water resources. The effects of mine dewatering on streamflow were evaluated based on the same watershed areas the model was calibrated to, these include the following:

- Sheep Creek – Upgradient of SW-1;
- Moose Creek;
- Black Butte Creek; and
- Sheep Creek – at Model Domain.

With the exception of Coon Creek, smaller individual streams were not evaluated as the model input parameters are not defined well enough at this scale to verify the model's predictive accuracy at these streams. The model is constructed to provide a conservative analysis of the effects on the area adjacent to the mine as it includes the headwaters of Brush Creek and Coon Creek. Hydrologic investigations conducted in the vicinity of both Brush Creek and Coon Creek suggest the deep bedrock aquifers are not in connection with either of these streams near their headwaters (Hydrometrics, 2013 and Hydrometrics, 2015a). The

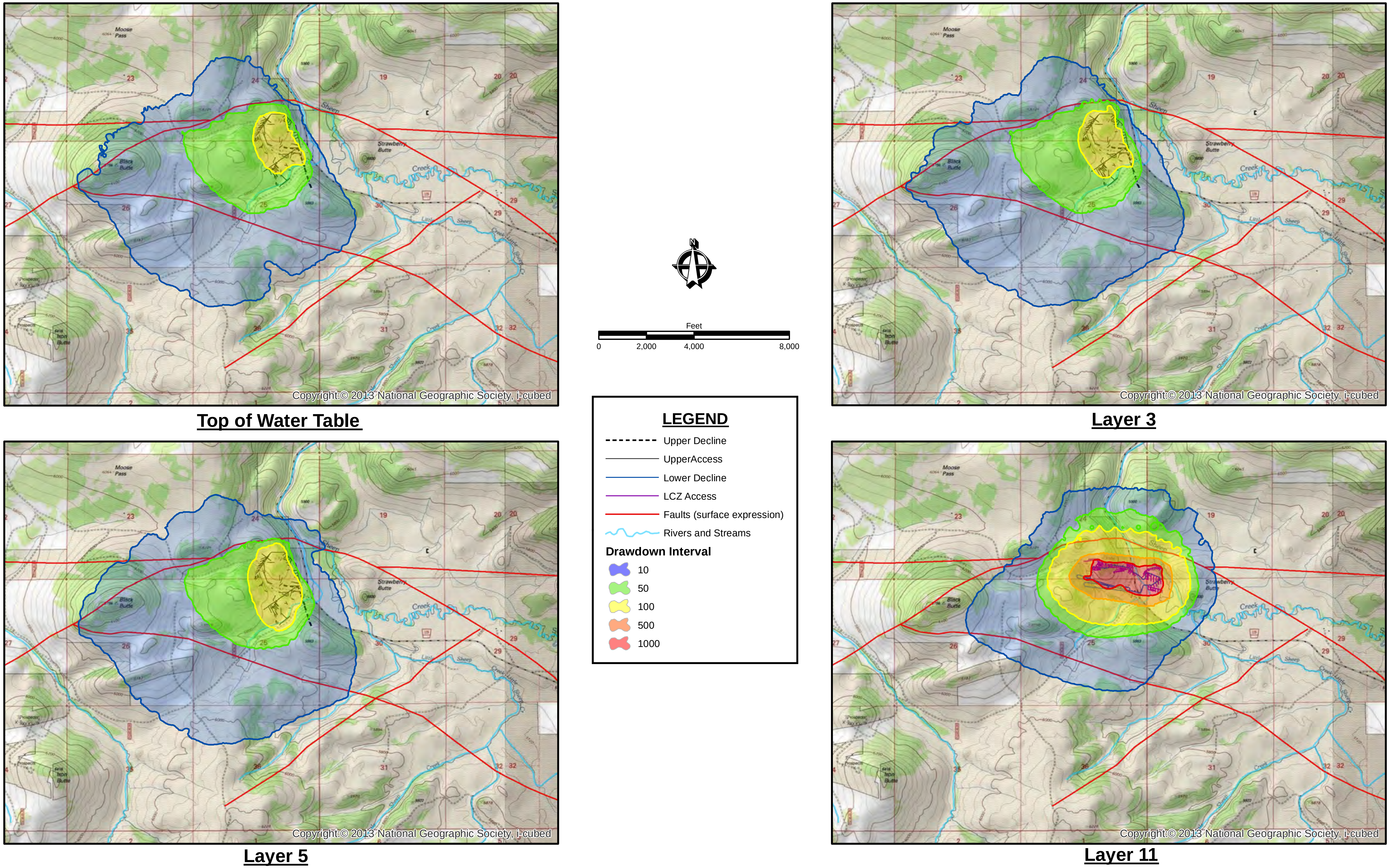

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Figure 5-5
Simulated Drawdown - Year 15
Black Butte Copper Project
Meagher County, Montana

actual potential for impacts to these reaches will depend on the extent to which they are supported by groundwater flow from the regional bedrock aquifer.

Table 5-3 shows the simulated steady state base flow for streams in the primary watershed areas addressed by the model throughout the mine life. Simulated changes to steady state base flow conditions in individual watersheds are discussed below.

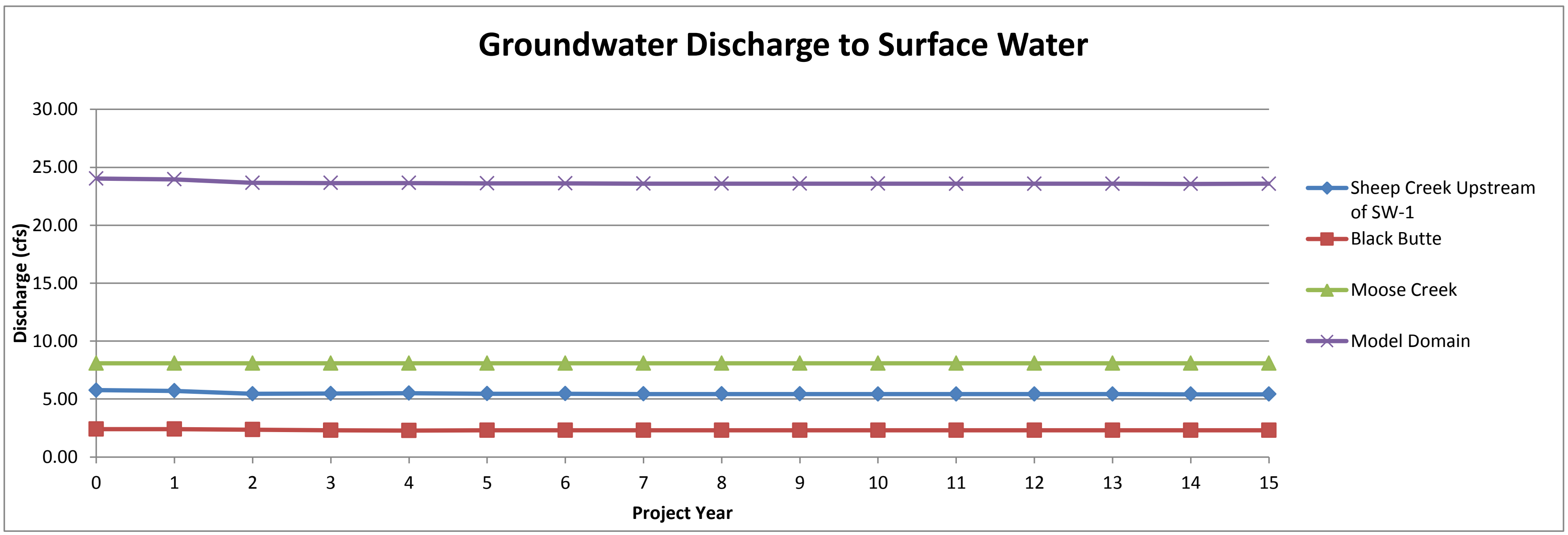
Moose Creek – The Moose Creek watershed has an estimated steady state base flow of 7.7 cfs. The steady state simulation had a base flow of 8.1 cfs in the Moose Creek watershed. The dewatering simulations indicate that there will be no measureable change in streamflow in Moose Creek from mine dewatering.

Black Butte Creek – The estimated steady state base flow at the mouth of Black Butte Creek ranges between 2.6 and 3.2 cfs. The model simulations show a decrease of approximately 0.1 cfs in Black Butte Creek. Depletion starts to occur in year 2 and reaches its peak in year 4. The simulated depletion in Black Butte Creek is approximately 3% to 4% of the steady state baseflow in the stream. The simulated depletions in Black Butte Creek are a result of capturing groundwater near the groundwater divide between Sheep Creek and Black Butte Creek, which would typically discharge to Black Butte Creek.

Coon Creek – Although there is evidence that the headwaters of Coon Creek are not connected to the deeper bedrock system and the transient calibration shows the model over predicts the influence drawdown has on Coon Creek, the depletion from mine dewatering in the upper reach of Coon Creek were evaluated due to its proximity to mine workings. The simulated effects to steady state base flow in the creek were evaluated in both the upper reach above the Sheep Creek alluvium and the reach within the Sheep Creek alluvium. The mine dewatering simulations show a reduction in 11 gpm in the upper reach of Coon Creek from steady state and a reduction in 53 gpm in the lower reach. The total reduction in Coon Creek is estimated to be approximately 70% of the steady state base flow observed the stream (0.2 at confluence with Sheep Creek).

Table 5-3. Simulated Groundwater Discharge to Surface Water

Mining Progress		Pre-Mining/ Steady State	Surface Decline	Declines and Access Ramps			Mine										
Project Year		**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Basin	**Target**	Simulated Groundwater Discharge to Surface Water (cfs)															
Sheep Creek Upstream of SW-1	**6.2**	5.76	5.70	5.44	5.47	5.49	5.46	5.45	5.44	5.43	5.43	5.42	5.42	5.42	5.41	5.41	5.41
Black Butte	**2.6-3.2**	2.40	2.40	2.35	2.31	2.29	2.29	2.29	2.29	2.29	2.30	2.30	2.30	2.30	2.30	2.30	2.30
Moose Creek	**7.7**	8.08	8.08	8.08	8.08	8.08	8.08	8.08	8.08	8.08	8.08	8.08	8.08	8.08	8.08	8.08	8.08
Model Domain	**23.2**	24.02	23.96	23.66	23.64	23.64	23.61	23.60	23.59	23.59	23.59	23.58	23.58	23.58	23.57	23.57	23.57

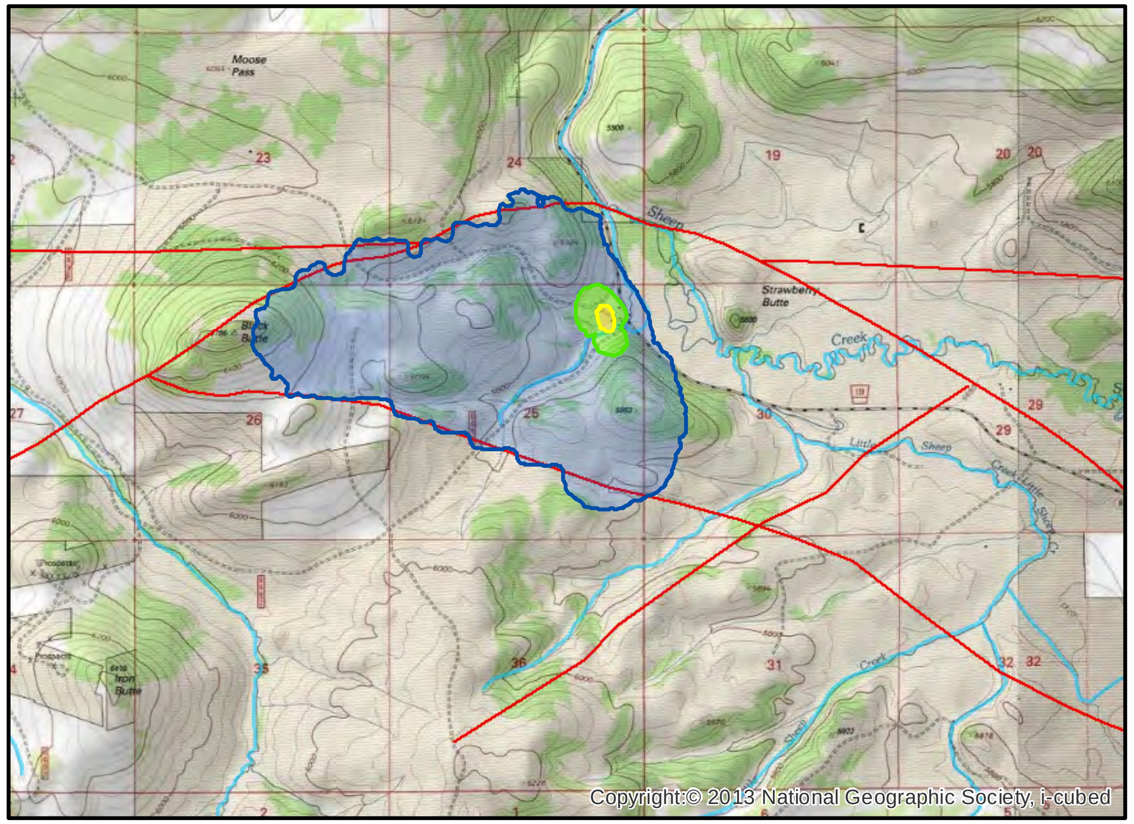


Sheep Creek – The Sheep Creek watershed upstream of SW-1 has the highest potential to incur dewatering effects as it is the closest to the project of any of the streams. Sheep Creek has an estimated steady state base flow of 6.2 cfs that is contributed from the portion of the watershed that is within the model domain. The total base flow for Sheep Creek over this reach is estimated at 15.3 cfs when the base flow from the upgradient portion of the watershed (9 cfs) is added to the base flow within the model domain (Table 2-3). Model simulations at the end of mining show a decrease in groundwater flow to Sheep Creek from the model domain of 0.35 cfs (157 gpm). The simulated depletion is approximately 2% of the total flow in Sheep Creek at this location.

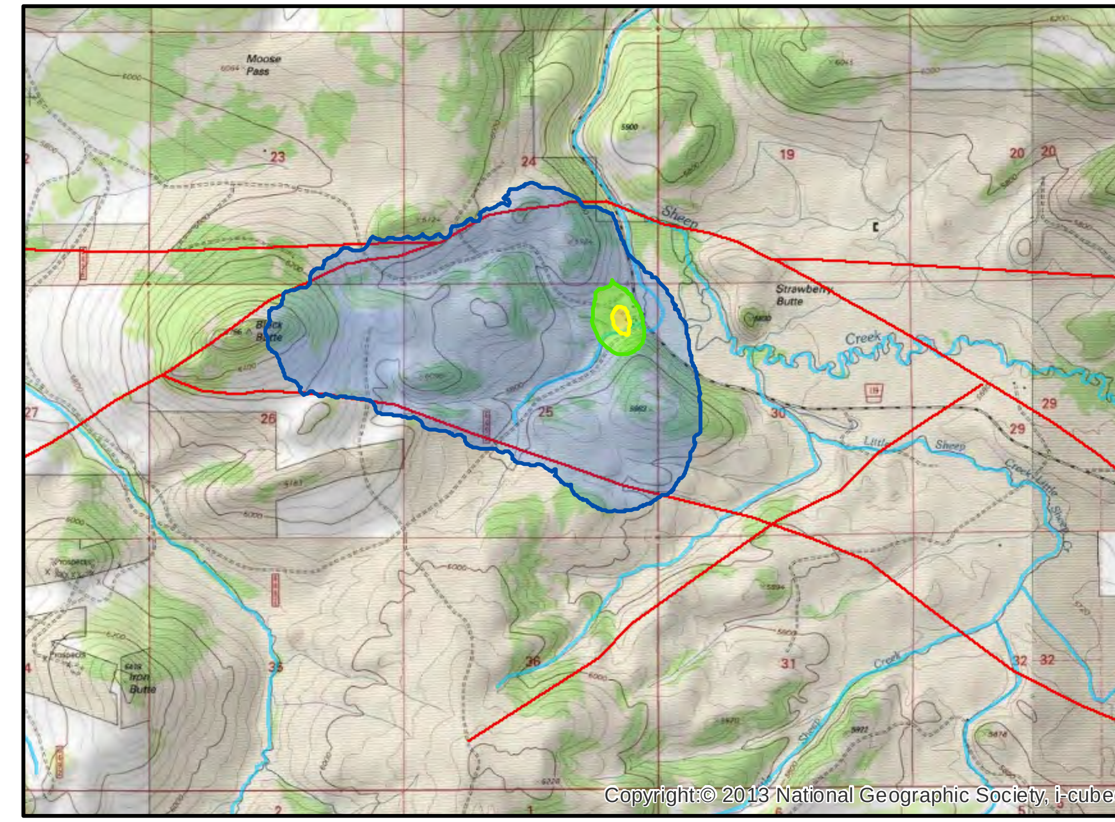
Steady state base flow in the portion of Sheep Creek within the model domain is estimated at 23.2 cfs. The model simulates a base flow of 24.0 cfs at this location under steady state conditions. At the end of mining the simulated base flow at Sheep Creek is 23.57 cfs, resulting in a depletion of 0.45 cfs (202 gpm). The total steady state base flow for Sheep Creek including the reach of the stream above the model domain is 32.2 cfs, therefore, the simulated depletion is approximately 1.4% of the total stream flow at the downgradient model boundary. This total depletion to Sheep Creek (202 gpm) is near the estimated consumptive use of the project (210 gpm), indicating that all of the water that is discharged to the underground infiltration gallery offsets any surface water depletion from mine dewatering above the consumptive use rate.

5.3 POST MINING RECOVERY

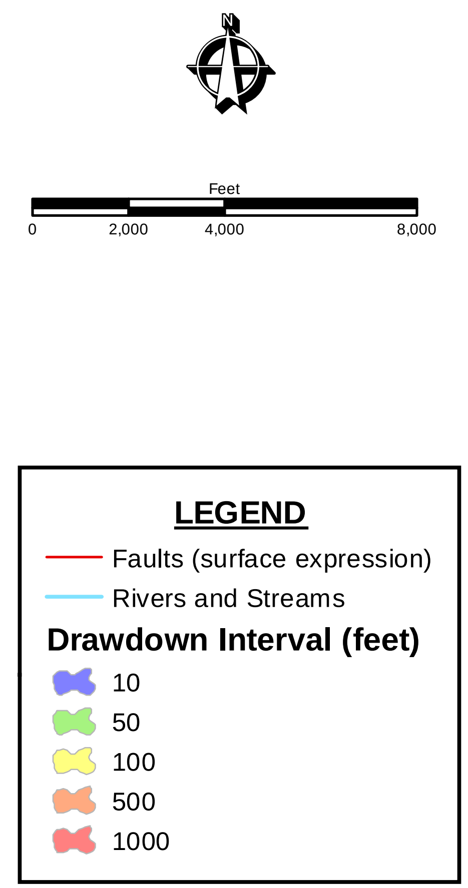
The post mining simulation includes one year for closure as described in Section 3.4. Water levels in the vicinity of the mine and at the outer extents of the drawdown cone start to recover at the beginning of post closure as dewatering in smaller access ramps to specific stope areas is ceased. Figure 5-6 shows the drawdown at the end of closure. The greatest recession of the drawdown cone is seen in layers 1 and 3 (Ynl-A). The recovery is slightly slower in layer 5 (USZ). One year into post mining there is over 1100 feet of drawdown in layer 11 (LCZ).

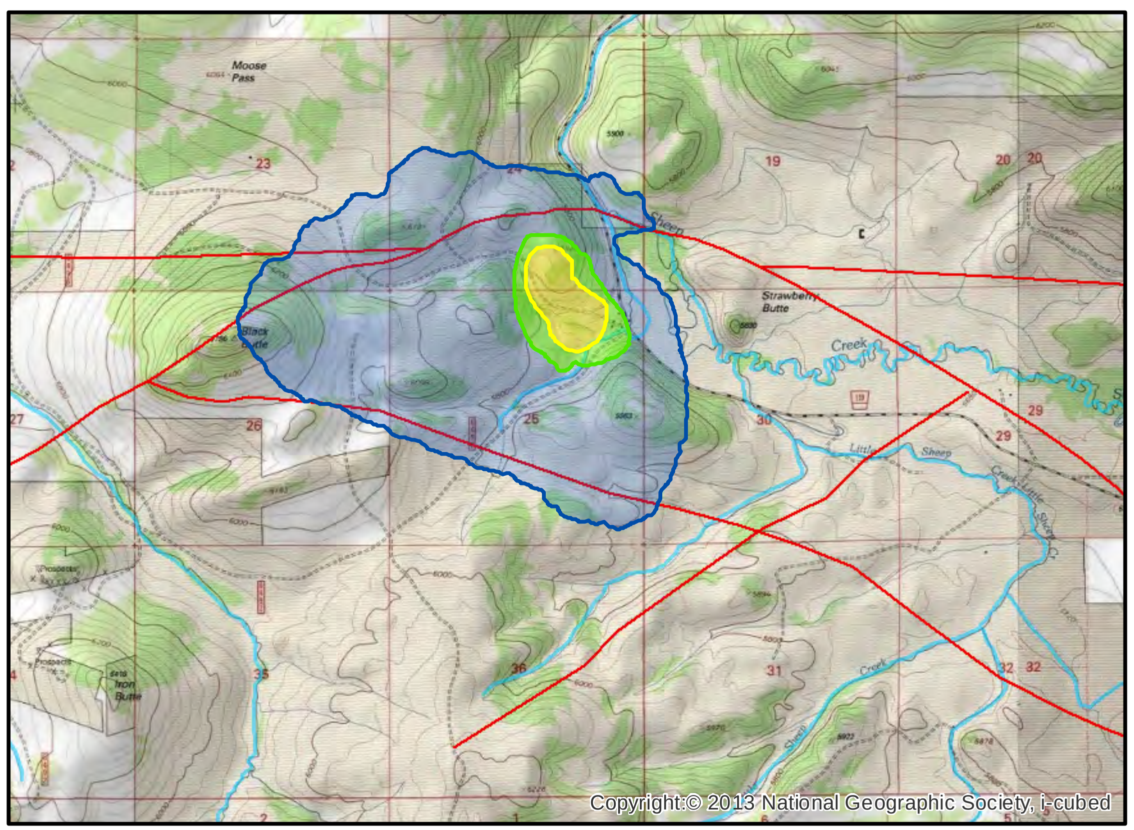


Top of Water Table



Layer 3





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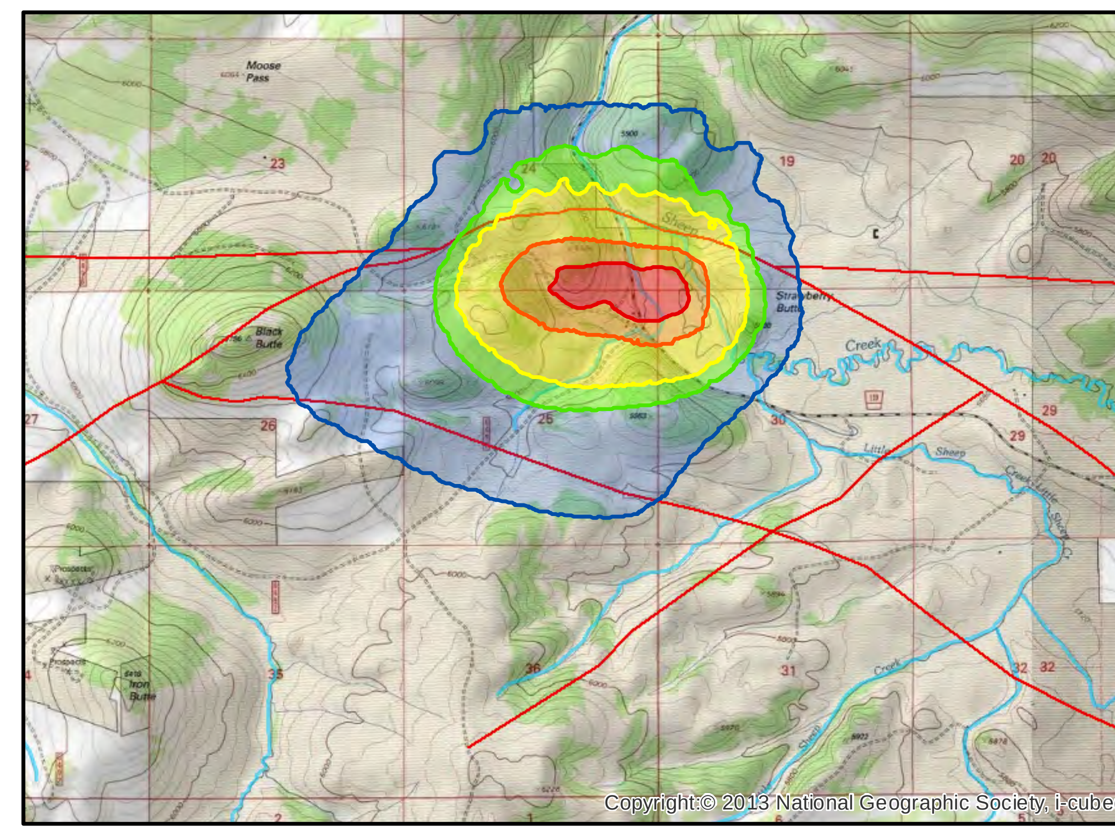

Layer 11

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Figure 5-6
Simulated Drawdown - End of Closure
Black Butte Copper Project
Meagher County, Montana

Figure 5-7 shows the recovery over time for wells completed in the Ynl-A, USZ/UCZ, Ynl-B, and LCZ. Water levels recover rapidly in the Ynl-A, with water levels recovering to within 1 to 2 feet of the pre-mining simulation after 3 to 4 years into post-mining. Similar results were seen in wells completed in the USZ and UCZ. Slow recovery rates are predicted in the Ynl-B (PW-10) due to the low permeability of this unit with water levels within 7 feet of pre-mining conditions 100 years into post-mining. The slowest recovery is simulated in PW-7, completed in the LCZ; with drawdown of 200 feet after 30 years and 19 feet after 100 years of recovery.

The effects on stream flow at the model domain were approximately 0.4 cfs at the end of mine closure (Table 5-4). Streamflow depletion was within pre-mining streamflows at the model domain 1 year after closure (2 years after end of mining). The post-mining simulation shows that Sheep Creek above SW-1 has the potential to have slightly reduced flow (0.1 cfs) 15 years after the end of mining. The stream flow at SW-1 is within the pre-mining steady state base flow 20 years after cessation of mining.

Figure 5-8 shows the simulated pre-mining water table and fully recovered water table 100 years after mining is completed for the model domain. The water table of the project area 10 years after mining and 100 years after mining are shown on Figure 5-9. The purpose of this simulation is to assess whether mine workings produce any permanent alterations in groundwater flow conditions that would potentially reroute recharge to sub-watersheds in the model domain area. The project area water table 10 years into post mining shows only minor changes is the water table compared to the simulated pre-mining water table (Figure 4.2). There are no discernable changes in groundwater flow patterns on a local or regional basis when the recovered water table is compared with the pre-mining water table.

5.4 MITIGATION

An important task in assessing impacts from mine dewatering is evaluation of mitigation alternatives. Tintina is in the process of applying for a groundwater right through DNRC for the water beneficially used in the project. Since the BBC project is located in the Upper

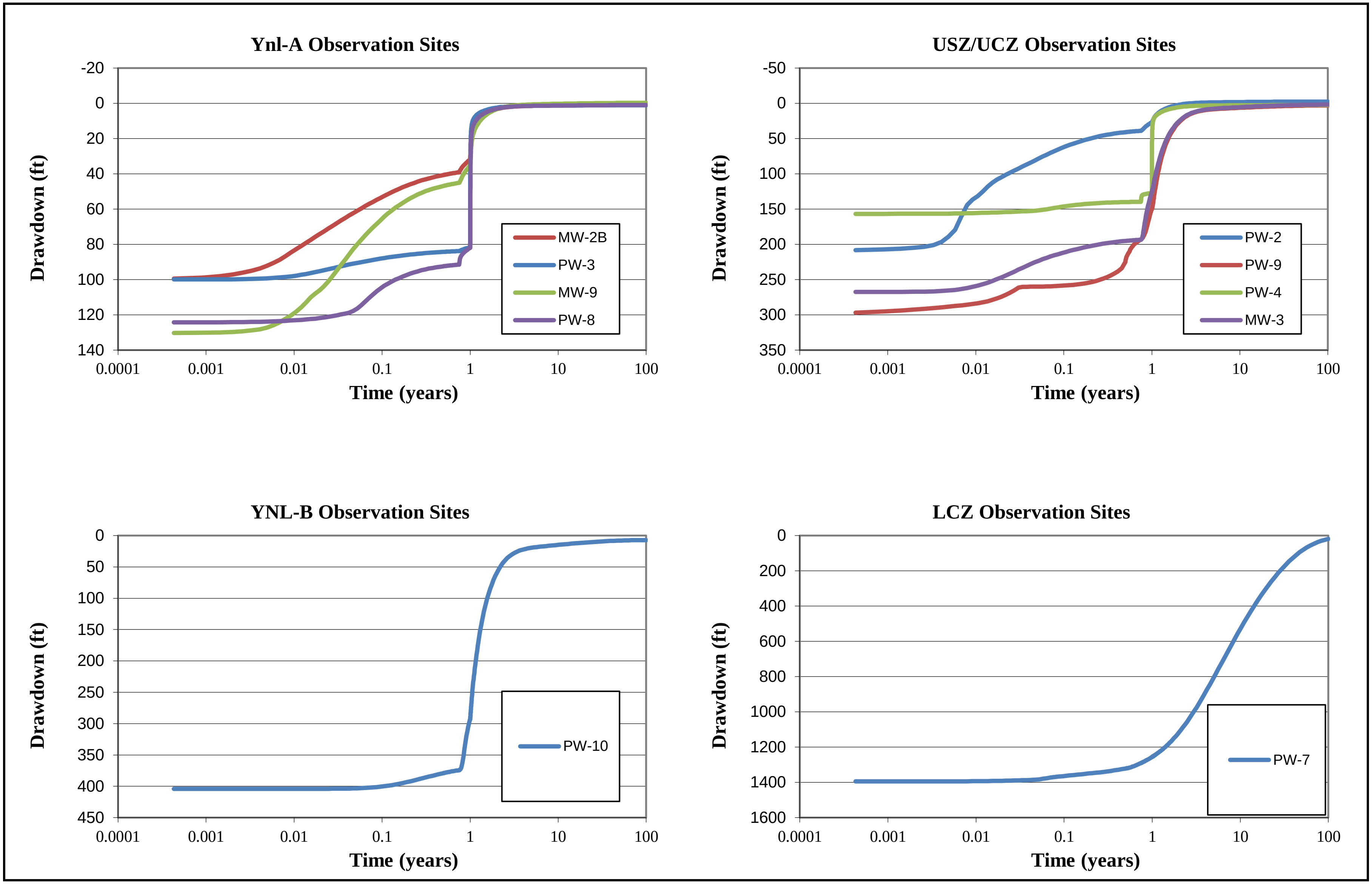

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Figure 5-7
Water Level Recovery - Post Mining
Black Butte Copper Project
Meagher County, Montana

Table 5-4. Post Mining Simulated Base Flow

Mining Progress	Pre-Mining/ Steady State	Closure			Post Mining								
Post-Mining Years	**0**	**0.5**	**0.75**	**1.0**	**2**	**3**	**4**	**5**	**10**	**15**	**20**	**50**	**100**
Basin	**Simulated Groundwater Discharge to Surface Water (cfs)**												
Sheep Creek Upstream of SW-1	**5.8**	5.7	5.7	5.6	5.7	5.7	5.7	5.7	5.7	5.7	5.8	5.8	5.8
Black Butte	**2.4**	2.3	2.3	2.3	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
Moose Creek	**8.1**	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
Model Domain	**24.0**	23.8	23.9	23.8	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0

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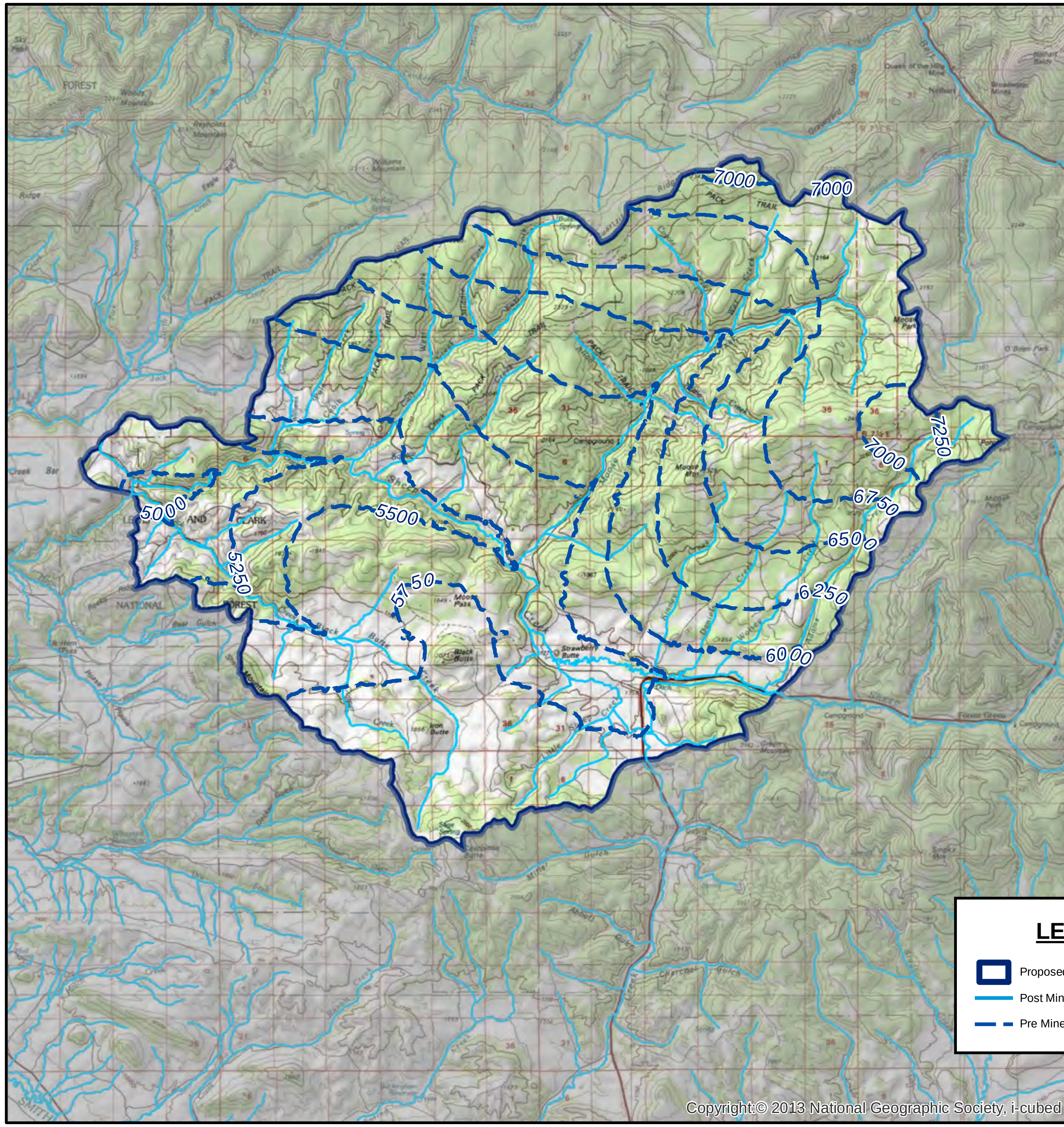
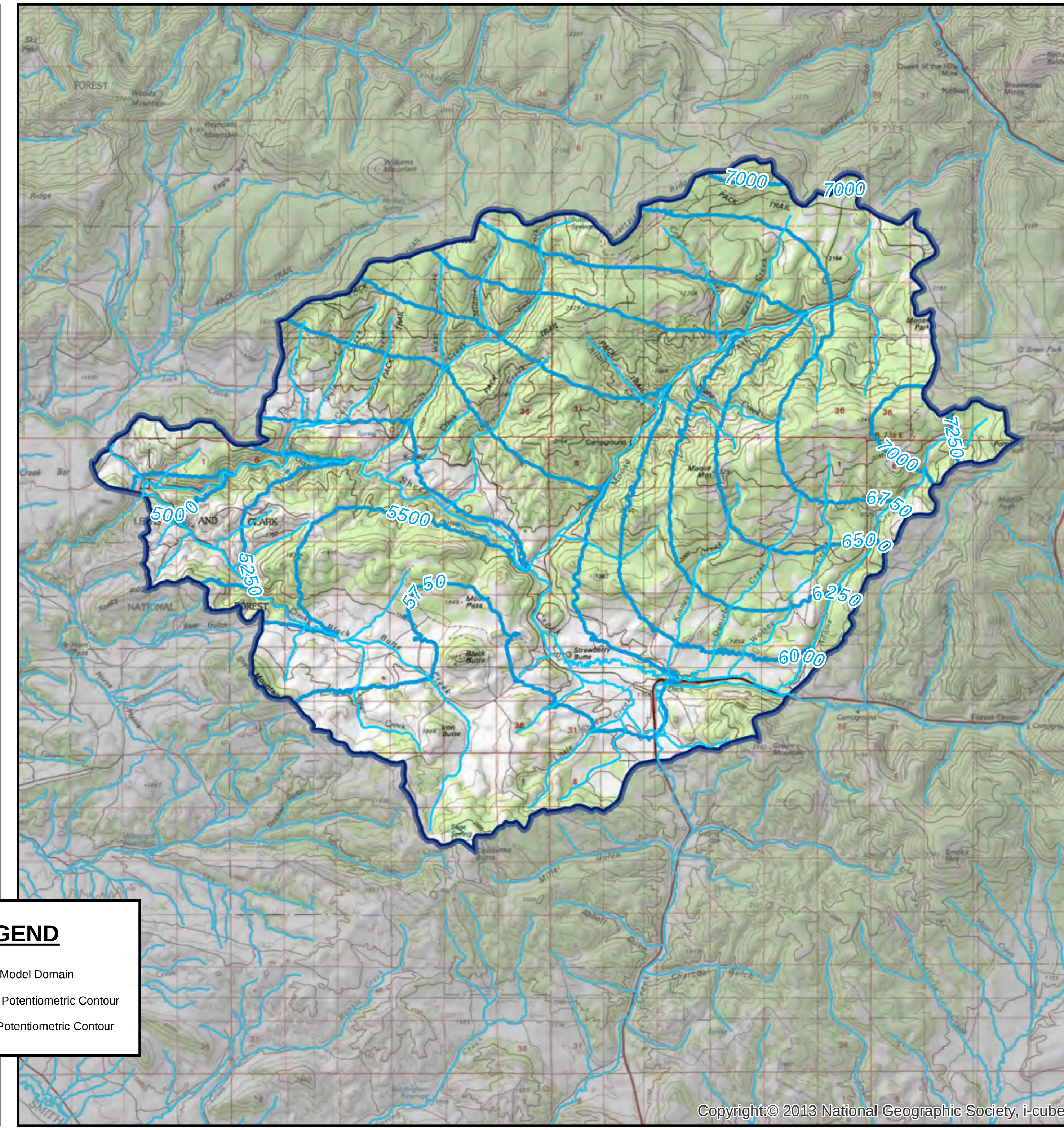


Simulated Pre Mine Potentiometric Surface



Simulated Post Mine Potentiometric Surface

LEGEND

- Proposed Model Domain
- Post Mine Potentiometric Contour
- Pre Mine Potentiometric Contour

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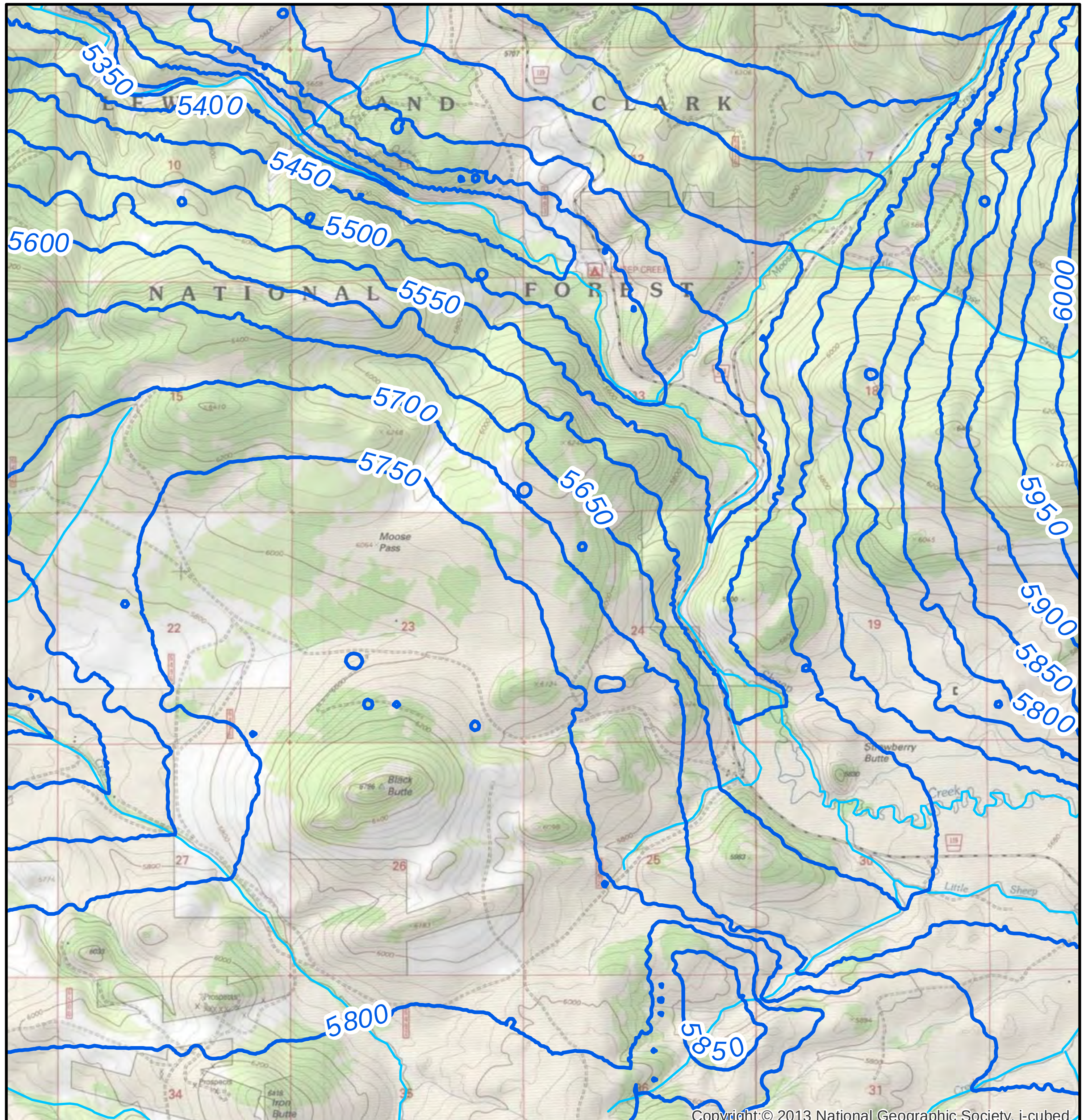
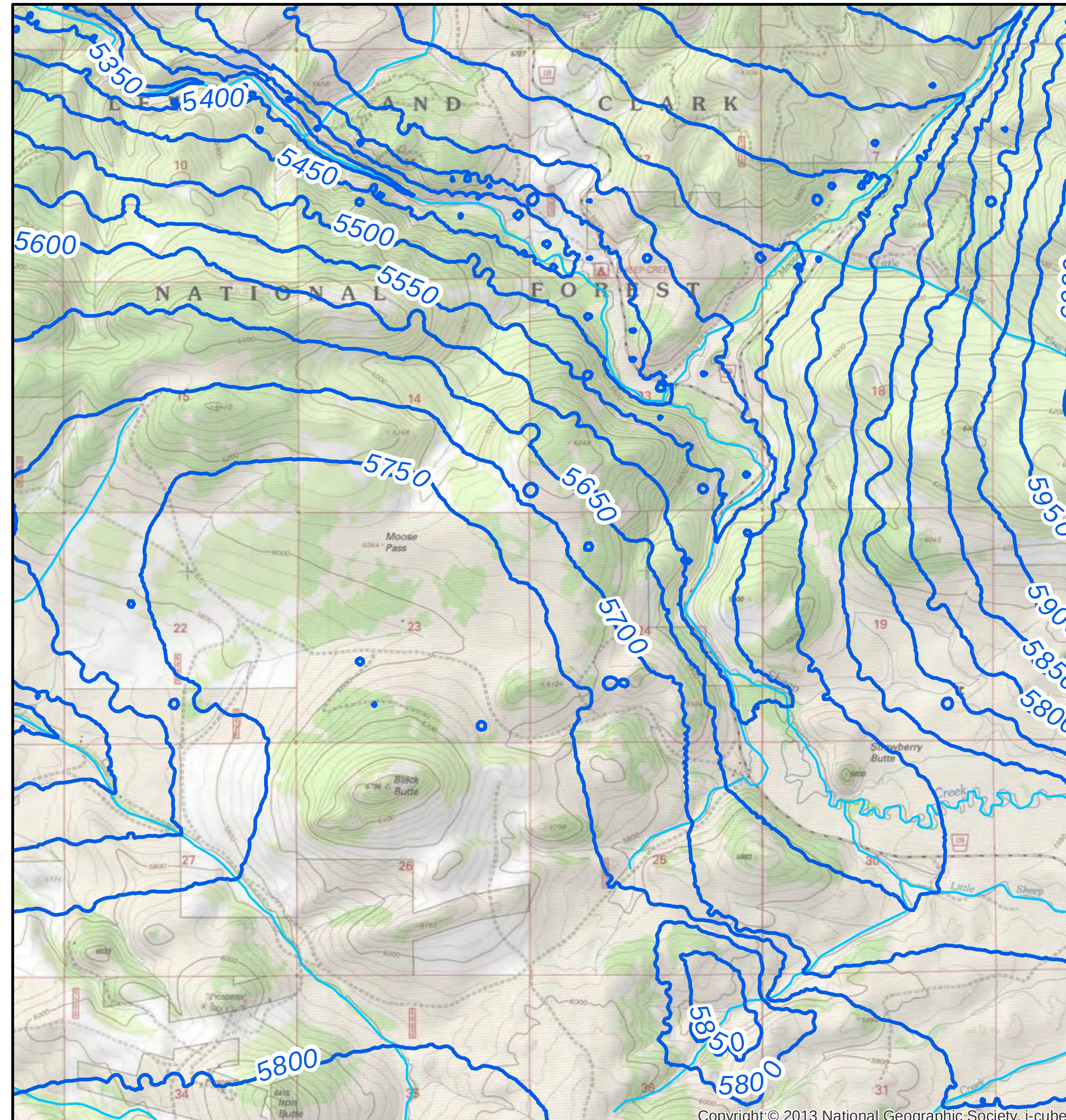
Figure 5-8
Pre & Post Mining Regional Water Table
Black Butte Copper Project
Meagher County, Montana



10 Year Post Mining Potentiometric Surface



100 Year Post Mining Potentiometric Surface

LEGEND

- Post Mining Potentiometric Contour
- Rivers and Streams

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Figure 5-9
Post Mining Project Area Water Table
Black Butte Copper Project
Meagher County, Montana

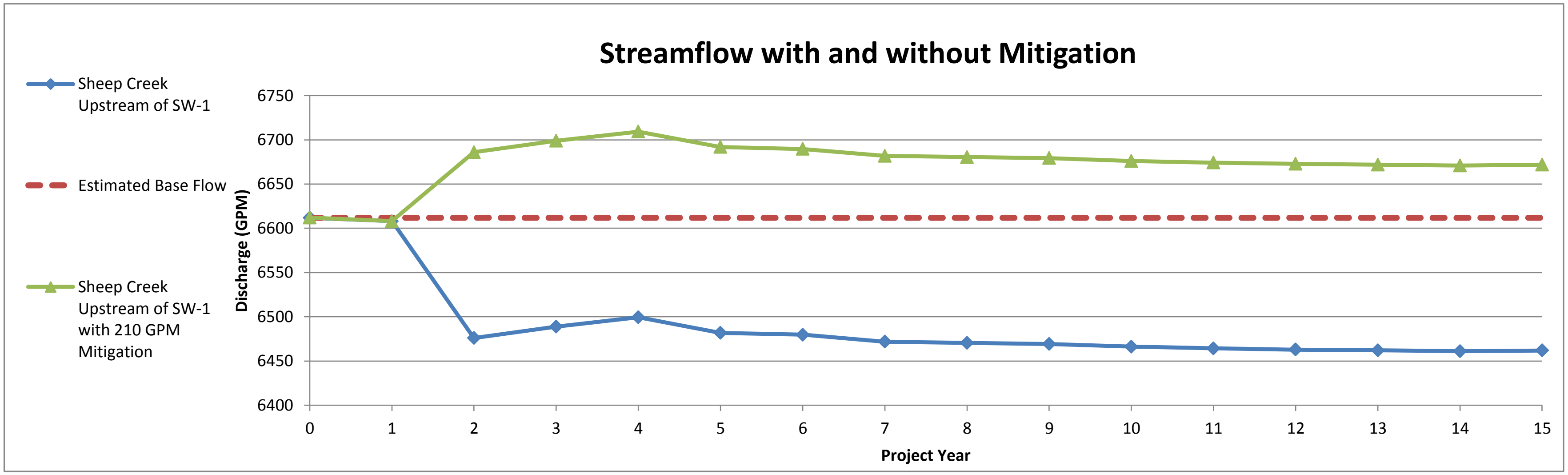
Missouri River Basin, which is closed to additional surface water appropriations, any groundwater right that has the potential to deplete surface water must mitigate for the impacts. Although the details of the mitigation plan have not been finalized, the intent is to acquire sufficient water rights to offset the amount of depletion to surface waters in place and time. The quantity of water required to offset depletion effects is assumed to be equal to the consumptive use of the project (210 gpm). Table 5-5 shows the steady state base flow in Sheep Creek in the watershed upstream of SW-1 throughout the mine life, and the resultant steady state base flow with water rights mitigation. The steady state base flow in Sheep Creek is approximately 6,600 gpm (15 cfs) at SW-1; the simulated steady state base flow throughout the mine life ranges from 6,464 to 6,598 gpm. If the water right mitigation requirement of 210 gpm is applied to the simulated stream flow throughout mining, the steady state base flow in Sheep Creek increases above the pre-mining base flow. Water rights mitigation would need to continue after dewatering is discontinued at the end of mining operations until the shallow water table has fully recovered.

An additional model simulation was conducted to assess the potential effectiveness of grouting the surface decline to minimize inflows and reduce potential impacts from mining. Grouting of declines is a proven method in reducing flows and is most effective if it is executed as the decline is driven. The decline can be grouted or shotcrete applied after the decline is driven; however, these methods are typically less effective. In this simulation, it is assumed that grouting is conducted as the decline is advanced and the permeability of the bedrock is reduced by two orders of magnitude up to a minimum permeability of 2.8×10^{-4} ft/day (10^{-7} cm/sec). Grouting was simulated in the model by decreasing the conductance of the drain using the following assumptions:

- Effective grouting would decrease bedrock permeability by two orders of magnitude up to a minimum permeability of 2.8×10^{-4} ft/day (10^{-7} cm/sec);
- Grouting would extend 3.3 feet into the bedrock at the effective permeability; and
- Width of the decline is 18 feet.

Table 5-5. Surface Water flow with Water Rights Mitigation

Mining Progress	Pre-Mining/ Steady State	Declines and Accesss		Declines/Access Ramps/Mining		Mining										
Project Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Basin	Simulated Groundwater Discharge to Surface Water (gpm)															
Sheep Creek Upstream of SW-1	**6612**	6608	6476	6489	6499	6482	6480	6472	6470	6469	6466	6464	6463	6462	6461	6462
Sheep Creek Upstream of SW-1 with 210 GPM Mitigation	**6612**	6608	6686	6699	6709	6692	6690	6682	6680	6679	6676	6674	6673	6672	6671	6672



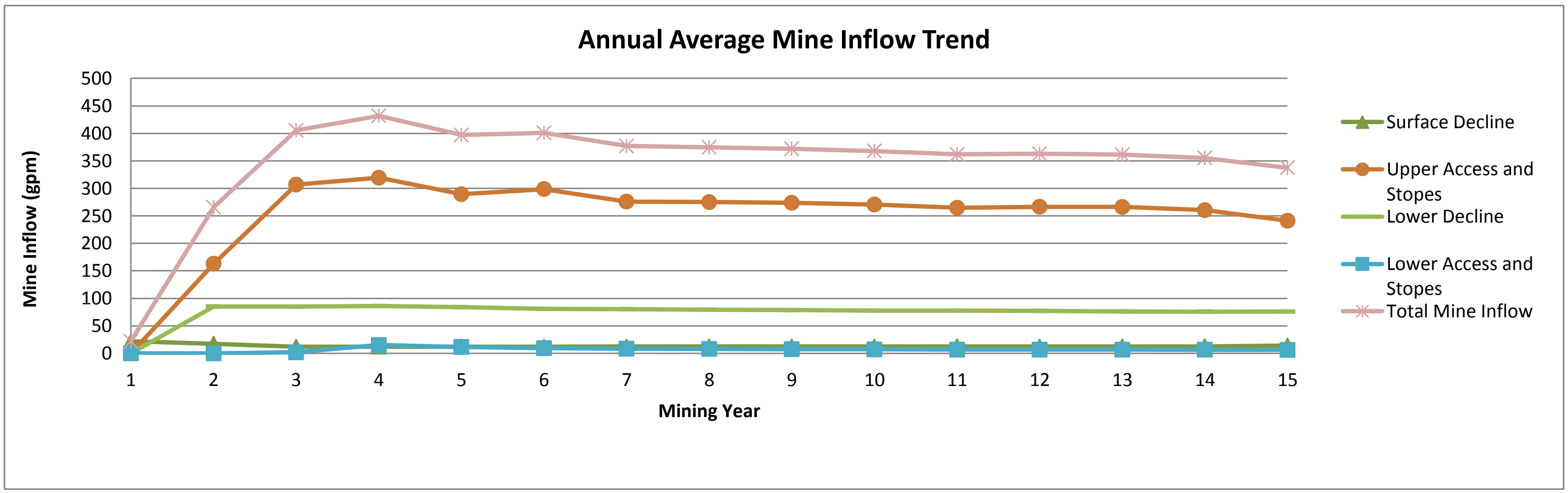
The conductance was calculated using an approach similar to the way the model assesses a stream bed conductance (see Eq 1) for each material property the decline intersects Ynl-A1, Ynl-A2, USZ, and Ynl-B1. GMS calculates the length of the drain in a cell and multiplies the modified conductance term by the length to determine the conductance to apply to each cell. The decline mitigation model shows that grouting could greatly reduce the inflow to the Surface Decline by an order of magnitude during Phase I (220 gpm w/o mitigation, 22 gpm with mitigation). Table 5-6 shows the overall changes to inflow to the mine workings over the life of the mine with grouting of the surface decline. Inflows are reduced sharply in the first two years, but changes become less pronounced as the mine workings are developed since the reduction of inflows to the surface decline results in higher heads in the groundwater system adjacent to the workings. Nevertheless, after the first two years of mining, the grouting of the decline results in a net reduction in mine inflows ranging from 66 to 84 gpm which is equivalent to a reduction of 15% to 25%.

The reduced inflows due to grouting of the decline would decrease the initial drawdown effects from construction of the decline to less than 10 feet in the upper bedrock units (Figure 5-10). Once additional mining structures are developed in Phase II the drawdown cone in the bedrock quickly mimics the drawdown without mitigation; however, the drawdown in the adjacent alluvium near Coon Creek is less throughout the mine life. The greatest reduction is seen in the area between the upper portion of the decline (southeast of Coon Creek) and Sheep Creek. Both the ten and five foot contour hug the western edge of the alluvial system when grouting is simulated in the model. The drawdown beneath Sheep Creek remains approximately 1 foot, indicating there is still the potential to impact Sheep Creek.

Although grouting, as simulated by the model, effectively reduces the rate of groundwater inflow to the mine working, there is no reduction in effects to steady state base flow in the larger surface watersheds. This is to be expected as the mine inflow rates still exceed the consumptive use of the project, therefore, depletion to streamflow will remain near the consumptive use rate. Similar to the drawdown effects, the mitigation simulation shows that grouting of the decline has the potential to reduce the depletion on Coon Creek by only 4 gpm at the end of mining.

Table 5-6. Simulated Average Annual Mine Inflow with Mitigation

Mining Progress	Surface Decline	Declines and Access Ramps			Mine										
Project Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Mine Structure	**Inflow (gpm)**														
Surface Decline Total	**22**	**17**	**12**	**12**	**12**	**12**	**12**	**13**	**13**	**13**	**13**	**13**	**12**	**13**	**14**
Surface Decline (YNL-A)	20	15	10	10	10	10	10	10	10	10	11	10	10	11	12
Surface Decline (UCZ)	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Upper Access and Stopes Total	**0**	**163**	**307**	**319**	**289**	**299**	**276**	**275**	**274**	**270**	**265**	**267**	**266**	**260**	**241**
UZ Access/Stopes (USZ/UCZ)	0	151	295	309	278	288	265	264	262	259	253	255	255	249	230
UZ Access (YNL-B)	0	12	12	11	11	11	11	11	11	11	11	11	11	11	11
Lower Decline Total	**0**	**85**	**85**	**86**	**84**	**81**	**80**	**79**	**79**	**78**	**78**	**77**	**76**	**76**	**76**
Lower Decline (YNL-B)	0	85	85	86	84	81	80	79	79	78	78	77	76	76	76
Lower Access and Stopes Total	**0**	**0**	**2**	**15**	**12**	**9**	**8**	**8**	**7**	**7**	**7**	**7**	**7**	**6**	**6**
LZ Access/Stopes (LCZ)	0	0	0	5	4	3	2	2	2	2	2	2	2	2	1
LZ Access (YNL-B)	0	0	2	10	7	6	6	6	5	5	5	5	5	5	5
Total Mine Inflow	**22**	**266**	**405**	**432**	**397**	**401**	**377**	**375**	**372**	**368**	**362**	**363**	**362**	**355**	**337**



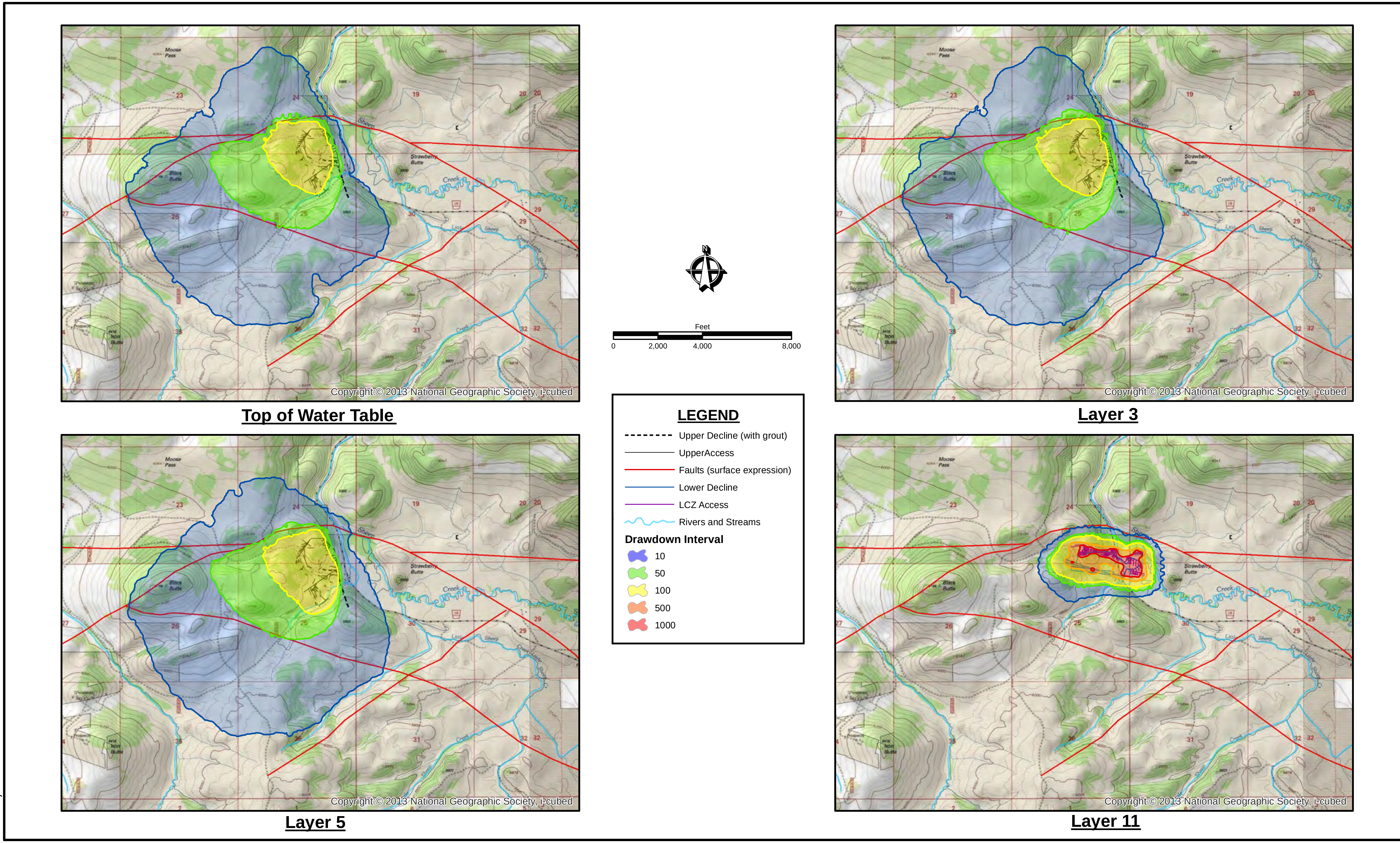


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Figure 5-10
Simulated Drawdown - Grout Mitigation - Year 4
Black Butte Copper Project
Meagher County, Montana

6.0 MODEL SENSITIVITY

A sensitivity analysis was conducted to assess the effects to the model from input parameter uncertainty. Sensitivity analyses can be conducted by systematically adjusting model parameters within plausible ranges and noting the resulting change in simulated head or flow (manual analysis). A more sophisticated sensitivity analyses can be conducted when PEST is used to automate model calibration. Sensitivity analyses were conducted using both manual and PEST to evaluate the uncertainty in both the steady state calibration and in the predictive simulations.

6.1 STEADY STATE SENSITIVITY

The sensitivity of the steady state model was evaluated qualitatively throughout the calibration process. The steady state model was most sensitive with respect to changes in head with adjustments to materials in the upper layers of the model. The primary observation points were not sensitive to the HSUs outside of the project areas (Pf, Ync, Yne, and Xm); however, the regional calibration was sensitive to the properties of these HSUs. During the regional calibration, it was noted that increases in K of the outlying units resulted in a general decrease in water levels. Stream conductance was adjusted during both regional and project area calibration. Small adjustments in stream conductance were helpful in bringing heads within calibration targets at observation points in the vicinity of streams. Adjustment of stream conductance did not have a large effect on stream flows in the larger watershed. This is to be expected as the streamflow in each watershed is a function of the amount of recharge applied to a watershed.

More detailed sensitivity metrics are provided through the PEST software suite that was used to automate steady state calibration. The basis for the PEST derived sensitivity analysis is the Jacobian matrix used within the Gauss-Marquardt-Levenberg method of parameter estimation; which assumes simulated values of targets vary as a continuous function with changes in parameters used in the calibration (Anderson, Woessner, and Hunt, 2015). The Jacobian matrix is comprised of m rows (one for each observation), and the n elements of each row are the derivatives of one particular observation with respect to each of the n parameters.

PEST calculates two types of sensitivity measures. The first is known as the composite parameter sensitivity of each parameter which is basically the product of the Jacobian matrix and the observation weights divided by the number of observations. The second measure is known as the relative composite sensitivity and is calculated as the product of the composite sensitivity and the magnitude of the value of the parameter. It is important to note that the PEST evaluation used log-transformation to each parameter that was evaluated in the analysis to facilitate shorter simulation times. Composite sensitivities are influenced by the use of log-transformations causing the sensitivities applied to each parameter to be small in magnitude. The magnitude of the composite sensitivity is not a reflection of the sensitivity in and of itself. A comparison of the relative parameter sensitivity to the other parameters used in the analysis shows how sensitive each parameter is.

The sensitivity analysis from the PEST calibration based on the project area heads is summarized in Table 6-1, with data ranked and sorted based on the composite sensitivity. The steady state heads in the project area (Table 4-1) were most sensitive to material properties with composite sensitivities within an order of magnitude of the highest values. In general these include materials associated with HSUs in the project area that are in the upper layers of the model. As noted in Section 4.1, the steady state heads are not sensitive to the hydraulic conductivity of the LCZ. The PEST sensitivity was used to identify material properties that were less sensitive to the project area calibration. These material properties and additional model parameters were evaluated in the sensitivity analyses of predictive simulations. Each predictive sensitivity analysis included a steady state simulation, the results of which are discussed below.

TABLE 6-1. RANKING OF MODEL SENSITIVITY TO MATERIAL PROPERTIES IN SPECIFIC UNITS BASED ON PEST ANALYSIS

Ranking	Material Property	PEST Optimized Hydraulic Conductivity (ft/day)	Composite Sensitivity	Relative Composite Sensitivity
1	YnlA_N	0.481	8.91E-02	1.3E-02
2	Ynl-O1	0.061	8.69E-02	1.6E-03
3	Ynl_S2	8.28	3.71E-02	9.4E-02
4	Qa_ShCr	208	3.24E-02	2.1E+00
5	YnlB_N1	0.73	3.04E-02	6.7E-03
6	YnlA_N1	6.10	2.69E-02	5.0E-02
7	UCZ	0.13	2.39E-02	9.6E-04
8	Qa_CoonCr	216	1.99E-02	1.3E+00
9	Ynl_S1	15.5	1.84E-02	8.7E-02
10	Ync	0.0003	1.46E-02	1.3E-06
11	YnlB_N2	0.019	1.38E-02	8.0E-05
12	USZ	0.038	1.38E-02	1.6E-04
13	Qa_LShCr	48	1.08E-02	1.6E-01
14	Ynl-O2	0.0047	8.96E-03	1.3E-05
15	Qa_BBC	56	4.09E-03	7.0E-02
16	Pf	0.0009	3.27E-03	8.8E-07
17	Ynl_S3	0.0548	3.27E-03	5.5E-05
18	YnlB	0.0016	3.27E-03	1.6E-06
19	Yne	0.0003	3.07E-03	2.7E-07
20	Pf_SW3	0.0016	2.45E-03	1.2E-06
21	Xm_S3	0.0070	2.45E-03	5.2E-06
22	Xm	0.0083	2.45E-03	6.2E-06
23	Pf_SE3	0.0049	2.17E-03	3.3E-06
24	Yne_E3	0.0016	2.17E-03	1.1E-06
25	Yne_W3	0.0012	2.17E-03	8.0E-07
26	Pf_W3	0.0030	2.17E-03	2.0E-06
27	Pf_E3	0.0030	2.17E-03	2.0E-06
28	LCZ	0.0008	2.17E-03	5.3E-07
29	Qa_MooseCr	34	2.17E-03	2.3E-02
30	Ynl-O3	0.0001	2.17E-03	4.5E-08

The sensitivity of the model was further evaluated by evaluating parameter sensitivity using manual techniques on parameters listed in Table 6-2. The manual analysis included an evaluation of the sensitivity of parameters to the observed head at project area observation points and to predictive simulations (discussed below, Section 6.2). The manual analysis of parameter sensitivity to observed heads is summarized in Table 6-3. The heads in the alluvium were slightly sensitive to changes in streambed conductance with higher conductance resulting in lower heads and higher heads with lower conductance. Alluvial observation sites were not notably sensitive to any of the other parameters in the sensitivity analysis.

TABLE 6-2. SUMMARY OF PARAMETER ADJUSTMENT FOR MANUAL SENSITIVITY ANALYSIS

Parameter	Adjustment High	Adjustment Low
Bulk*	$x10^{1}$	$x10^{-1}$
Faults	$x10^{1}$	NA
LCZ	$x10^{1}$	NA
Qa	x2	x0.75
Storage	$x10^{1}$	$x10^{-1}$
STR	x2	x0.5
YNL-B	x2	x0.5

*Materials: Yne, Ync, Pf, Xm

Simulated heads in the bedrock HSUs (project area and outlying observations) were sensitive to both increases and decreases in hydraulic conductivities of outlying material (Pf, Ync, Yne, Xm). Most of the observed heads decreased with increases in the outlying material K's and increased with decreases in K's. The head at MW-8 is sensitive to increases in the hydraulic characteristic of the horizontal flow barriers that represent the fault; with the observed head decreasing further with increased permeability in the fault. The simulated

Table 6-3. Summary of Manual Sensitivity Analysis to Observed Heads

Name	Steady State Residuals	Outlying Material High		Outlying Material Low		YNL-B High		YNL-B Low		LCZ High		Qa High		Qa Low		Faults High		Stream Conductance High		Stream Conductance Low	
		Res.	Diff.	Res.	Diff.	Res.	Diff.	Res.	Diff.	Res.	Diff.	Res.	Diff.	Res.	Diff.	Res.	Diff.	Res.	Diff.	Res.	Diff.
		Alluvium Sites																			
MW-4A	1.7	2.7	1.0	2.3	0.6	2.2	0.5	2.6	0.9	2.4	0.7	2.5	0.8	2.4	0.7	2.4	0.7	3.2	1.5	1.1	-0.5
PZ-01	0.6	1.3	0.8	1.1	0.5	1.0	0.4	1.3	0.8	1.2	0.6	0.5	-0.1	1.4	0.8	1.2	0.6	2.6	2.0	-1.0	-1.6
PZ-02	1.5	2.5	0.9	2.1	0.6	2.0	0.5	2.3	0.8	2.2	0.7	2.0	0.4	2.3	0.8	2.2	0.7	3.1	1.6	0.6	-1.0
PZ-03	0.7	1.6	1.0	1.2	0.5	1.1	0.4	1.5	0.9	1.4	0.7	1.9	1.2	1.1	0.4	1.3	0.7	1.9	1.3	0.2	-0.5
PZ-05	1.5	2.5	0.9	2.2	0.7	2.1	0.6	2.3	0.7	2.2	0.7	1.3	-0.3	2.5	1.0	2.2	0.7	3.4	1.8	0.5	-1.1
PZ-08	-4.2	-3.3	0.9	-3.9	0.3	-3.7	0.5	-3.7	0.5	-3.7	0.5	-3.1	1.1	-3.9	0.4	-3.7	0.5	-3.6	0.6	-4.0	0.2
PZ-09	-2.1	-1.4	0.7	-1.5	0.6	-1.6	0.5	-1.3	0.8	-1.4	0.7	-2.0	0.1	-1.2	0.9	-1.5	0.6	-0.1	2.1	-3.6	-1.5
PZ-11	-0.5	0.8	1.3	-0.5	0.0	0.0	0.5	0.0	0.5	0.0	0.5	1.8	2.3	-0.6	-0.1	0.0	0.5	0.0	0.5	-0.2	0.3
		Project Area Bedrock Sites																			
MW-1B	-4.6	-0.8	3.8	-7.2	-2.6	-2.7	1.9	-5.4	-0.8	-4.0	0.6	-3.6	1.0	-4.1	0.5	-4.0	0.6	-3.7	0.9	-4.7	-0.1
MW-2B	1.5	14.3	12.8	-6.8	-8.3	3.2	1.8	3.5	2.0	2.9	1.4	3.7	2.3	2.5	1.0	2.3	0.8	2.5	1.0	2.3	0.8
MW-3	6.2	27.4	21.1	-11.9	-18.1	9.1	2.9	7.0	0.8	7.3	1.1	8.3	2.1	7.0	0.8	7.2	1.0	7.6	1.3	6.1	-0.1
MW-4B	1.8	2.9	1.1	2.4	0.6	2.3	0.4	2.7	0.9	2.6	0.7	2.7	0.8	2.5	0.7	2.5	0.7	3.3	1.5	1.3	-0.5
MW-6B	3.2	4.6	1.4	3.0	-0.2	4.6	1.4	3.9	0.7	4.1	0.9	4.5	1.2	4.0	0.8	3.3	0.1	4.8	1.6	2.7	-0.5
MW-7	48.9	50.6	1.7	46.9	-2.0	50.4	1.5	49.8	0.9	49.8	0.9	50.2	1.4	49.7	0.8	48.3	-0.6	50.6	1.8	48.1	-0.8
MW-8	35.6	58.7	23.1	-15.5	-51.1	39.4	3.8	35.2	-0.4	36.7	1.1	37.8	2.2	36.4	0.8	70.6	34.9	37.9	2.3	34.4	-1.2
MW-9	-6.3	11.8	18.0	-21.3	-15.0	-4.6	1.7	-4.9	1.3	-5.2	1.1	-4.3	2.0	-5.5	0.7	-5.4	0.9	-5.1	1.2	-6.3	0.0
PW-2	15.3	41.0	25.7	-6.8	-22.0	17.4	2.1	16.5	1.3	16.4	1.1	17.3	2.0	16.1	0.8	16.4	1.1	16.7	1.4	15.0	-0.3
PW-3	-12.4	-7.5	5.0	-15.2	-2.8	-10.9	1.5	-11.9	0.6	-11.6	0.9	-10.6	1.9	-11.9	0.5	-11.9	0.6	-11.6	0.8	-12.0	0.5
PW-4	-17.9	-11.5	6.5	-22.6	-4.6	-15.7	2.2	-18.6	-0.7	-17.2	0.8	-16.4	1.5	-17.5	0.5	-17.3	0.6	-17.0	0.9	-17.8	0.1
PW-7	-90.1	-8.5	81.6	-190.5	-100.3	-88.7	1.4	-89.9	0.3	-90.1	0.0	-88.5	1.6	-89.6	0.6	-88.4	1.7	-87.3	2.9	-93.5	-3.3
PW-8	-13.2	-6.5	6.7	-18.1	-4.8	-11.3	1.9	-13.3	-0.1	-12.5	0.8	-11.7	1.6	-12.8	0.5	-12.6	0.6	-12.4	0.9	-13.0	0.2
PW-9	10.5	27.2	16.7	-3.3	-13.7	13.2	2.7	10.9	0.4	11.5	1.0	12.4	1.9	11.2	0.7	11.3	0.8	11.6	1.2	10.5	0.0
PW-10	10.9	28.0	17.1	-3.2	-14.0	13.6	2.8	11.1	0.3	11.9	1.0	12.7	1.9	11.6	0.7	11.7	0.8	12.1	1.2	10.8	-0.1
		Outlying Observation Sites																			
DW-9	-45.8	-23.0	22.8	-64.7	-18.8	-41.4	4.4	-47.1	-1.2	-44.8	1.0	-41.9	3.9	-45.7	0.2	-43.3	2.6	-42.8	3.0	-48.5	-2.7
EW-02	5.0	24.5	19.5	-14.4	-19.4	8.2	3.2	8.0	3.0	6.6	1.6	7.9	2.9	6.2	1.2	5.3	0.3	7.1	2.1	4.5	-0.5
EW-06	-57.8	-17.8	40.1	-116.9	-59.1	-54.0	3.8	-58.8	-0.9	-56.8	1.0	-55.1	2.8	-57.4	0.5	-53.9	3.9	-55.0	2.9	-60.3	-2.5
EW-05	14.2	50.5	36.3	-44.0	-58.2	18.0	3.8	13.3	-0.9	15.2	1.0	17.0	2.8	14.6	0.5	18.2	4.0	17.1	2.9	11.7	-2.5
EW-01	-59.6	-59.1	0.5	-58.7	0.9	-60.4	-0.8	-57.0	2.7	-58.3	1.4	-54.9	4.8	-59.4	0.3	-57.8	1.8	-54.1	5.5	-64.4	-4.8

Note: Adjustment of storage not included in analysis of sensitivity to observed heads as storage is not a factor in steady state head calculations steady state heads were not notably sensitive to changes in the K's of Ynl-B, LCZ, or alluvium (Qa).

6.2 PREDICTIVE SIMULATION SENSITIVITY

Parameter sensitivity to predictive simulations of mine inflow was evaluated for parameters listed in Table 6-2. The predictive simulation sensitivity analysis included running each parameter adjustment from steady state through year 5 of mining. The sensitivity of the peak mine inflow (year 4) to each parameter(s) is shown in Table 6-4. The table shows that simulated mine inflows are most sensitive to increased K's in Ynl-B and to increases in storage. Simulated mine inflows are slightly sensitive to decreases in outlying material K's, decreases in Ynl-B K's, and decreases in storage. Changes in other parameters did not result in notable changes in mine inflow.

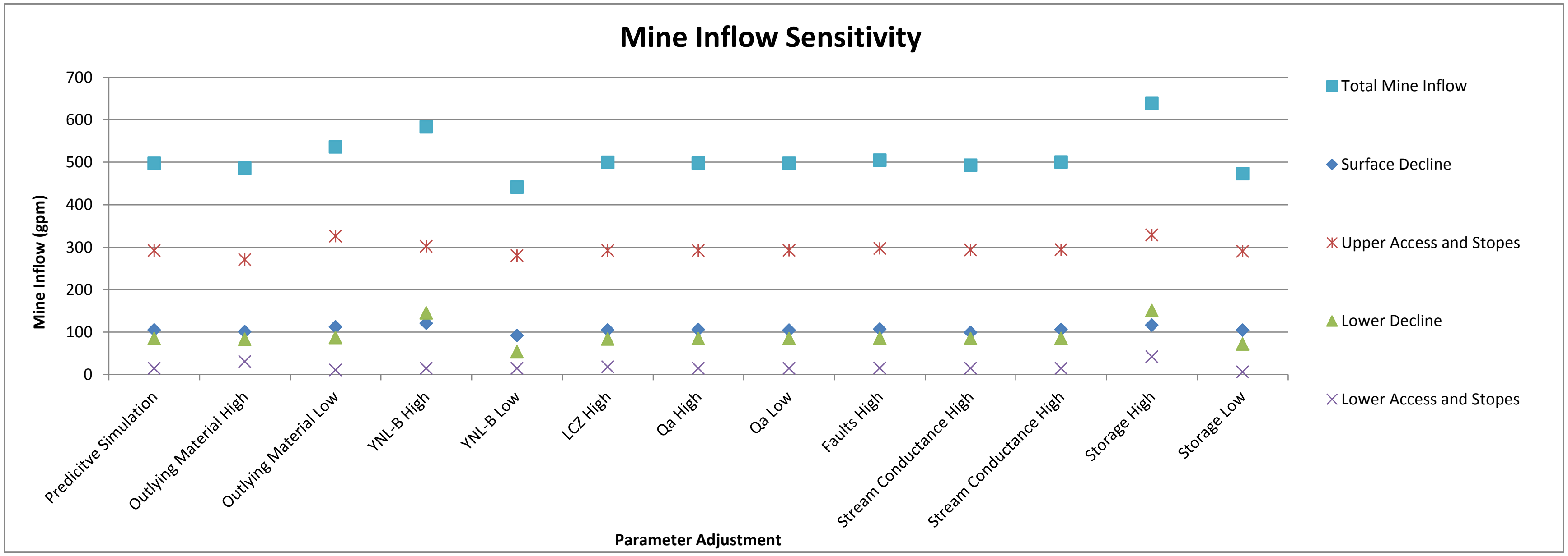
The largest change in simulated mine inflows during sensitivity analyses was from increases in storage coefficients. The majority of the increased flow resulted when storage was increased in the upper units, however, these units have the least uncertainty. The changes to predicted mine inflows from increasing storage coefficients in units with greater uncertainty (not adjusted in transient calibration) is approximately 30-90 gpm (which represents an increase of 10% to 15% of the total predicted inflow). It should be noted that storage coefficients in the upper units (Ynl-A, USZ, UCZ, and upper portion of Ynl-B) were decreased from the initial storage coefficient by approximately 1 order of magnitude during transient calibration to match the drawdown curves from pumping test observations. The storage for material properties of the lower unit was left at the higher end of the range in storage typical of bedrock HSUs.

Mine inflow was also sensitive to increases in K of materials associated with the Ynl-B HSU. The sensitivity analysis included all material groups associated with Ynl-B, some of which were sensitive to head (see Table 6-1). The material groups that were not sensitive to head were in the lower layer of the model. The only mine structure that is within the lower Ynl-B material is the lower decline. The increase in mine inflow to this structure from varying K values in the Ynl-B is approximately 60 gpm.

Table 6-4. Summary of Mine Inflow Sensitivity

Mine Structure	Predicitve Simulation	Outlying Material High	Outlying Material Low	YNL-B High	YNL-B Low	LCZ High	Qa High	Qa Low	Faults High	Stream Conductance High	Stream Conductance High	Storage High	Storage Low
	Flow (gpm)												
Surface Decline	105	101	112	121	92	105	106	105	107	99	106	117	105
Upper Access and Stopes	292	271	326	302	280	292	292	292	297	294	294	329	290
Lower Decline	85	83	87	145	53	84	85	85	86	85	85	151	72
Lower Access and Stopes	15	31	11	15	15	18	15	15	15	15	15	42	7
Total Mine Inflow	497	486	536	583	441	500	498	497	505	493	500	638	473

Note: Mine inflow is from year 4 of mining, which was the highest inflow in the predictive simulation



The sensitivity analysis shows that the steady state model is sensitive to material properties that are associated with the shallower HSUs in the project area. Representative ranges for these values are relatively well defined through onsite testing. There is greater uncertainty regarding the material properties of the units at depth and in outlying areas but the model results generally showed less sensitivity to these parameters. The predictive simulations were most sensitive to uncertainties in storage coefficients and material characteristics associated with the Ynl-B; both of these parameters/parameter groups were adjusted during model calibration in the shallower portion of the model.

7.0 DISCUSSION

This modeling analysis was conducted to provide Tintina with a tool to assist with design and planning for the BBC Project and to assess the potential for impacts to groundwater and surface water from dewatering throughout the mine life and post-mining. The model was developed based on the conceptual model presented in Section 2.0. All modeling analyses have an inherent degree of uncertainty. The hydrogeology has been well characterized in the shallow HSUs in the project area and therefore the model has a smaller degree of uncertainty associated with them. There is greater uncertainty in the properties of the lower HSUs (e.g., LCZ) and a substantial uncertainty associated with the properties of the outlying HSUs. Although there has been numerous data collected on the VVF through core drilling and hydrologic testing and some data collected on other faults in the area, faults areas can be highly complex making them difficult to fully define in any characterization. Lastly, there is some uncertainty on the connection between headwater drainages and the deeper groundwater system.

The model uses conservative assumption (e.g., higher storage in HSUs were data was not available) in assessing impacts to water resources to account for some of the uncertainty in the conceptual model. The model was developed with the headwaters of both Coon Creek and Brush Creek simulated in the model; however, hydrological investigations indicate the headwaters of these two drainages are not in connection to the deeper groundwater system. This approach was used in the model to provide a more conservative assessment of effects on surface water; however, the lack of connection shown in the hydrological investigations in the vicinity of Coon Creek and Brush Creek should be considered in addition to the model results.

The model uses equivalent porous media (EPM) assumptions as the most reasonable method to characterize the hydrogeological system. However, the regional bedrock in the model domain is a fracture controlled system. Using the EPM approach presumes that each cell in the model represents a combination of fractures and rock matrix. Where fractures are sparse the hydraulic conductivity is very low, and where fracturing is more prevalent the hydraulic conductivity is higher. However, an EPM is not capable of fully modeling disconnected fracture systems as the assumption in an EPM is that all cells have some degree of connectivity. The effects of using an EPM model to simulate fracture flow results in varying degrees of uncertainty in the results. The model was capable of reproducing the connectivity between HSUs as observed in the long-term pumping test. However, the connectivity at greater extents is unknown resulting in greater uncertainty.

The results of the modeling assessment (summarized below) should consider the uncertainties in the model in the use of the results for making regulatory decisions or their use in mine planning and operations.

Simulated mine inflows range from 220 to 500 gpm with the lowest inflows being at the completion of the surface decline at the end of year 1. The highest simulated inflows are in year 4 at the end of construction of all access ramps and declines and start of full scale mining. The calibrated model indicates the inflow rates decrease in subsequent years as more cemented paste is backfilled into the mined out stopes. Sensitivity analyses show that the estimated flow could increase between 10-15% if there is higher storage capacity or elevated K's in the lower layers than what was modeled in the steady state model.

The model simulations show that the effects on surrounding groundwater levels (drawdown) are relatively localized, with most of the drawdown within the project area. The largest magnitude of drawdown is seen in the LCZ with drawdown exceeding 1500 feet; however, the drawdown cone is very steep in the lower zone and does not extend into the upper layers. A similar trend is seen in comparing the magnitude of drawdown in the UCZ (max drawdown ~ 500 feet) and the upper most layer of the model (max drawdown ~290 feet). Similar to the mine inflow estimates, the largest extent of drawdown is seen in year 4, with the drawdown extents receding as stopes are backfilled with cement paste and mine inflows are reduced.

The simulated drawdown in the groundwater alluvial system is approximately 10 feet near the western edge of the alluvium where Coon Creek flows to the north. Coon Creek appears to limit the drawdown in this area as the drawdown is reduced below 5 feet just east of Coon Creek. Drawdown in the groundwater alluvial system beneath Sheep Creek is approximately 1 foot.

The model simulations indicate that surface water depletion from mine dewatering are primarily in Sheep Creek upstream of SW-1 with a maximum depletion of 0.35 cfs, which is approximately 2% of the steady state base flow in Sheep Creek at this location. Streamflow reductions in Sheep Creek at its confluence of Black Butte Creek (model domain) were simulated to be approximately 0.45 cfs or 1.4% of steady state base flow at this location. The stream depletion at the model domain is a combination of the depletions in Sheep Creek above SW-1 and a minor simulated depletion in Black Butte Creek of 0.1 cfs (approximately 3-4% of the flow in Black Butte Creek). The simulated depletion in Black Butte Creek is a result of capturing groundwater near the groundwater divide between Sheep Creek and Black Butte Creek, which would typically discharge to Black Butte Creek.

The largest relative impacts to streamflow are seen in Coon Creek, which is part of the SW-1 watershed and runs over the southern edge of the UCZ and above the surface decline. The model simulates a 70% reduction in steady state base flow at the end of mining; the majority of the reduction is in the lower reach of Coon Creek where it is in connection with the alluvial system. Coon Creek is a small tributary stream to Sheep Creek, which is often fully diverted during the irrigation season and is frozen during the winter months. Tintina has an agreement with the water right holder for Coon Creek to utilize their water right if necessary. Based on these factors the reduction in flow to Coon Creek itself will not have a substantive effect on water resources in the area. The primary effect on downstream water resources is addressed in the evaluation of the SW-1 watershed and at the model domain.

Post mining simulations indicate that the effects from dewatering will decrease slightly in the groundwater system and surface water resources through the first year of closure. Effects on water resources decrease quickly after the first year. The shallow water table is within 1-2 feet of pre-mining levels within 3 to 4 years of closure and the reduction in stream flows are limited to the SW-1 watershed ($\leq$0.1 cfs). There are no measureable effects to steady state stream base flow 20 years after mining has stopped.

The modeling analysis includes an evaluation of effectiveness of grouting the surface decline as a mitigation alternative to reduce mine inflow and corresponding effects on nearby streams. The grouting mitigation simulations show a large decrease in mine inflows to the surface decline; with the first year having a 10 fold reduction. However, once additional mine workings are developed the flow draining to the mine workings is only reduced by 15% to 25% (66 to 84 gpm) from the simulation without grouting. This reduction has no effect on the simulated depletion to the streams as the mine dewatering rate is still larger than the consumptive use rate of 210 gpm.

The BBC project is located in the Upper Missouri River Basin, which is closed to new surface water appropriations. Tintina is in the process of developing an application for a groundwater right for water put to beneficial use in the mill, tailings paste plant and other water needs, of which 210 gpm is consumptive. A mitigation plan is being developed with the assumption that all of the consumptive use will result in depletion in surface water, which is similar to what the model shows. The mitigation plan will provide water to the surface water system at the consumptive use rate (210 gpm) to offset any depletion in the streams. This is shown by adding the water right mitigation rate of 210 gpm to the simulated steady state base flow in the streams during mining resulting in the net flow in the streams being equal or greater than the steady state base flows prior to mining.

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APPENDIX A

MODEL GRID AND MATERIAL PROPERTIES

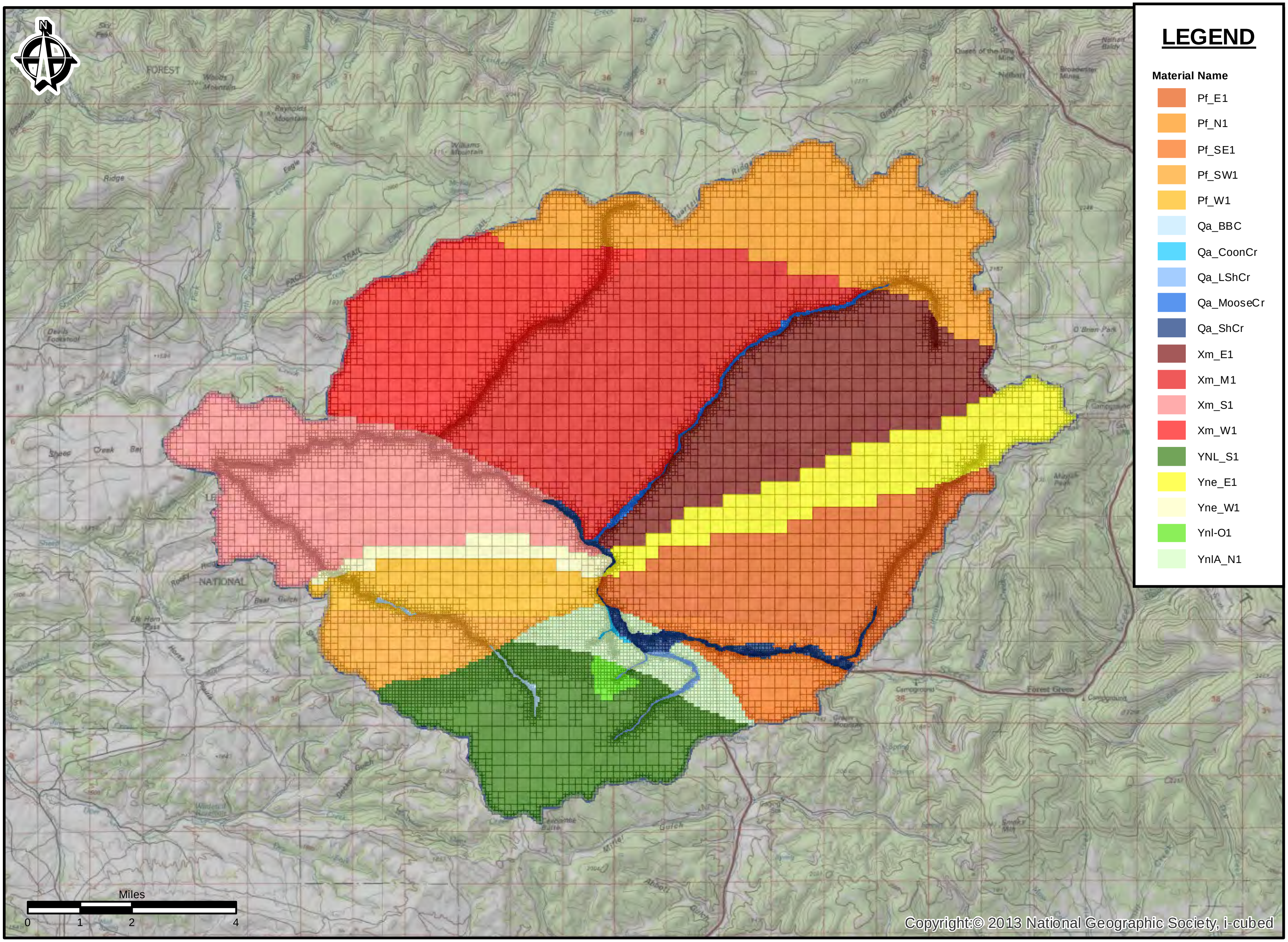

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Figure A-1
Material Properties - Layer 1
Black Butte Copper Project
Meagher County, Montana

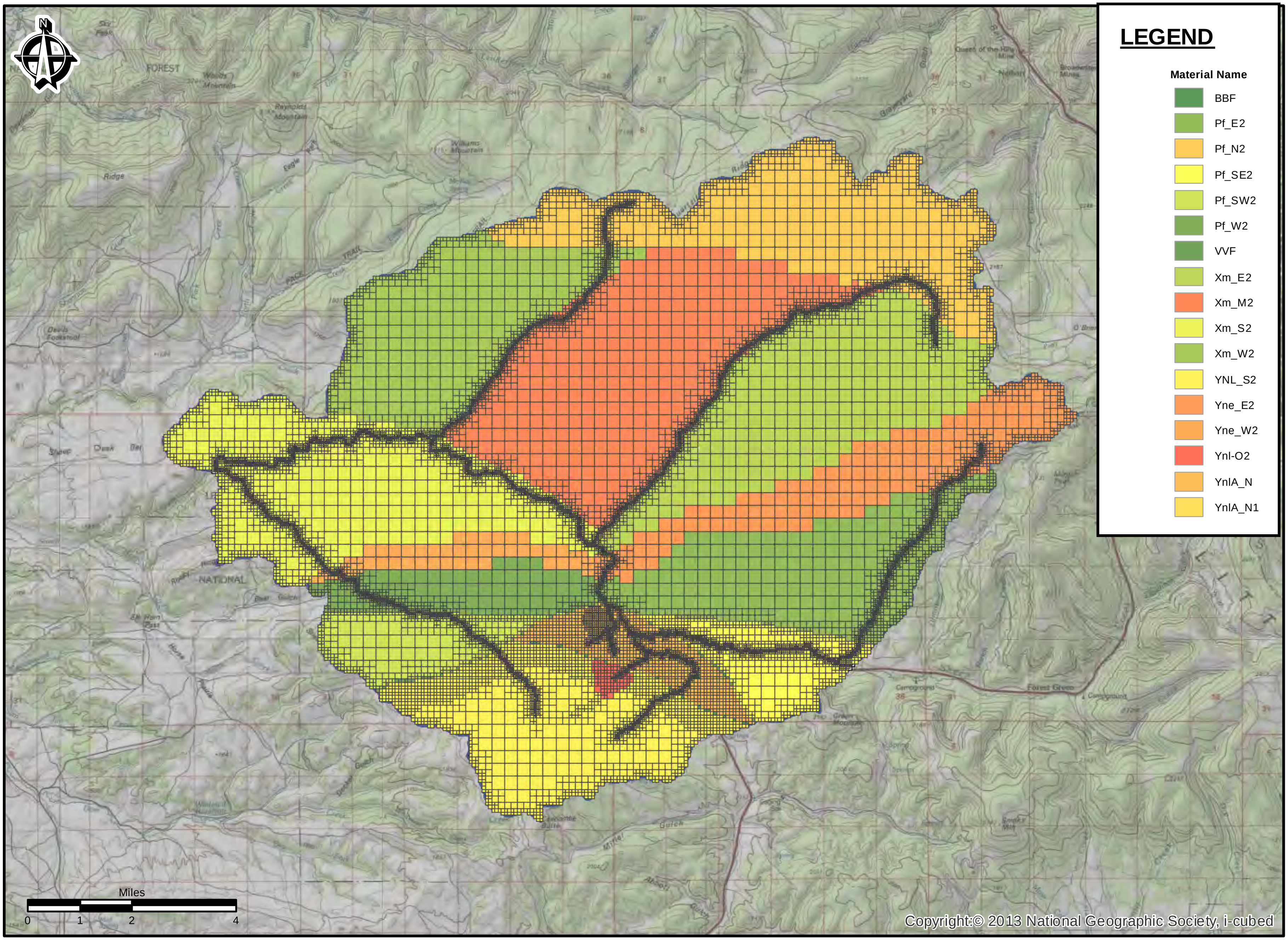

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Figure A-2
Material Properties - Layer 2
Black Butte Copper Project
Meagher County, Montana

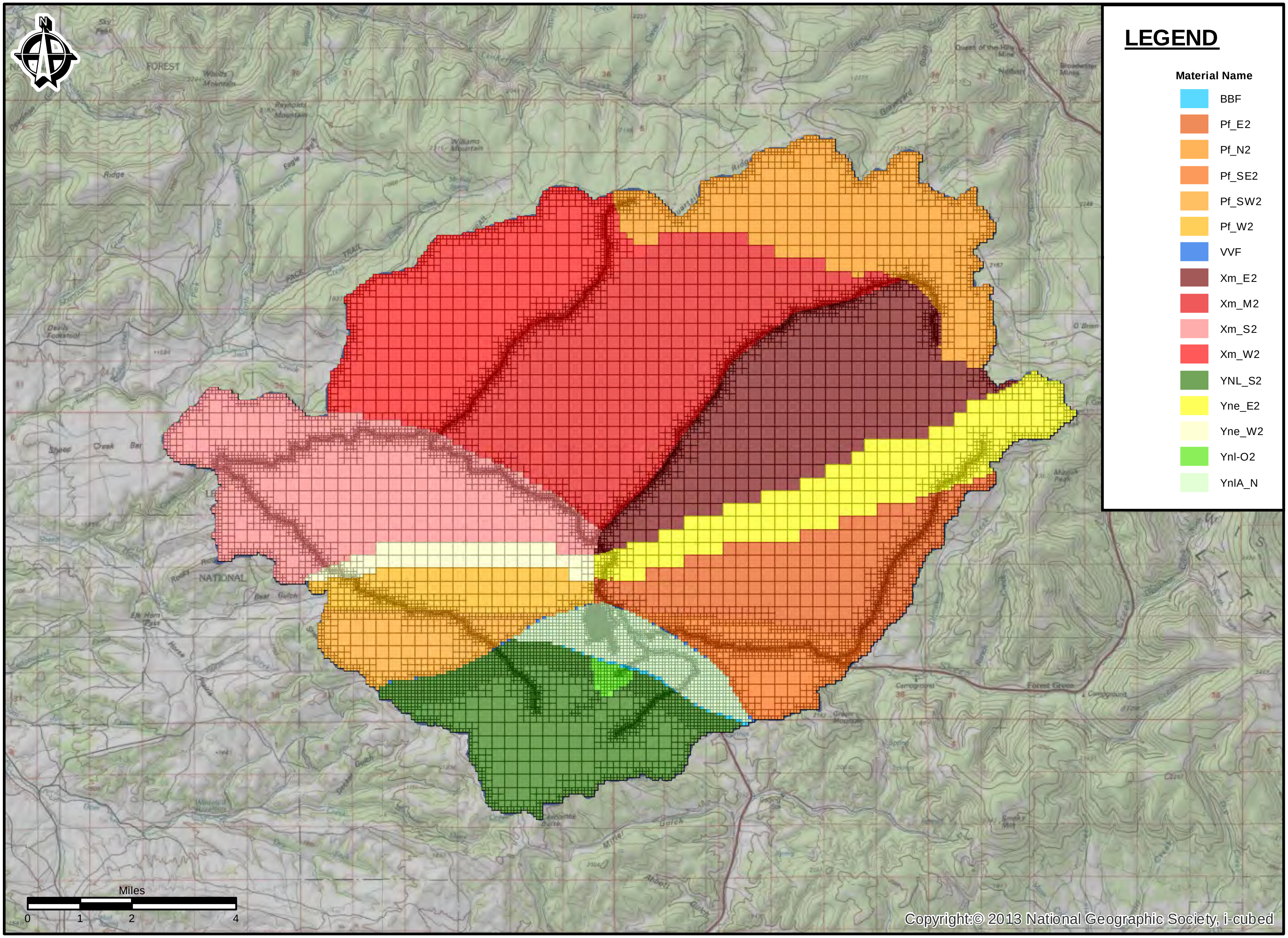

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Figure A-3
Material Properties - Layer 3
Black Butte Copper Project
Meagher County, Montana

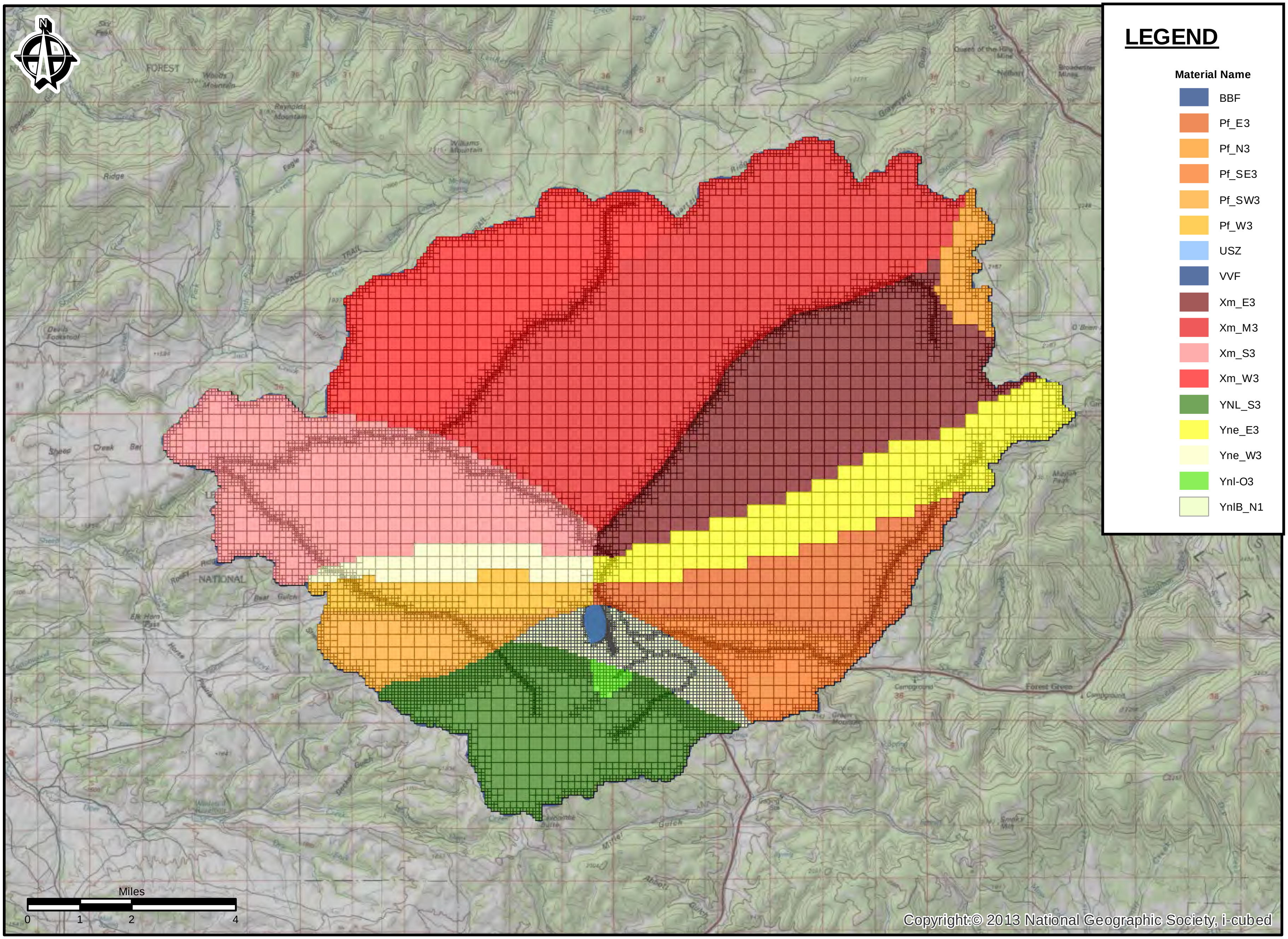

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Figure A-4
Material Properties - Layer 4
Black Butte Copper Project
Meagher County, Montana

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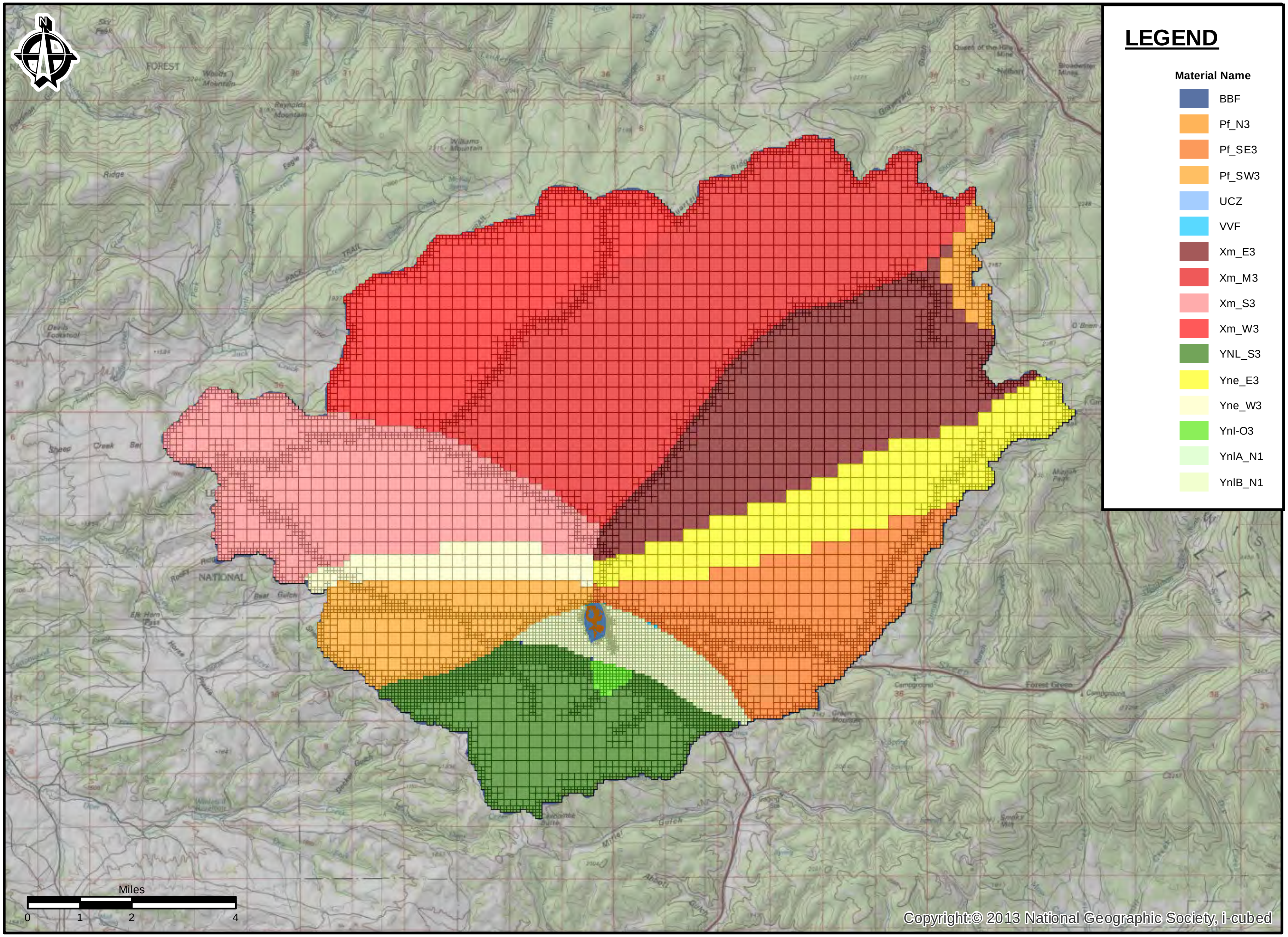

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Figure A-5
Material Properties - Layer 5
Black Butte Copper Project
Meagher County, Montana

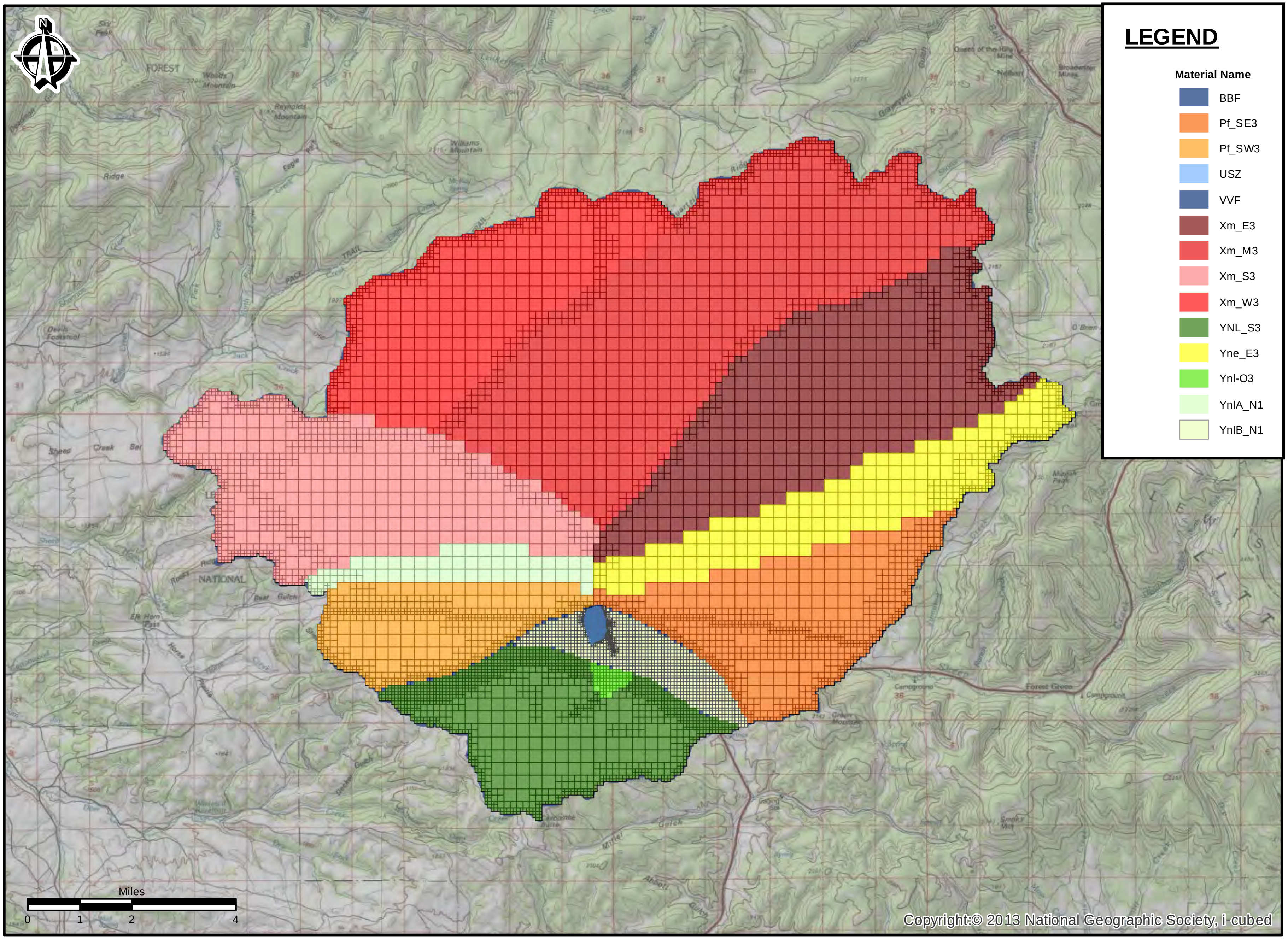

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Figure A-6
Material Properties - Layer 6
Black Butte Copper Project
Meagher County, Montana

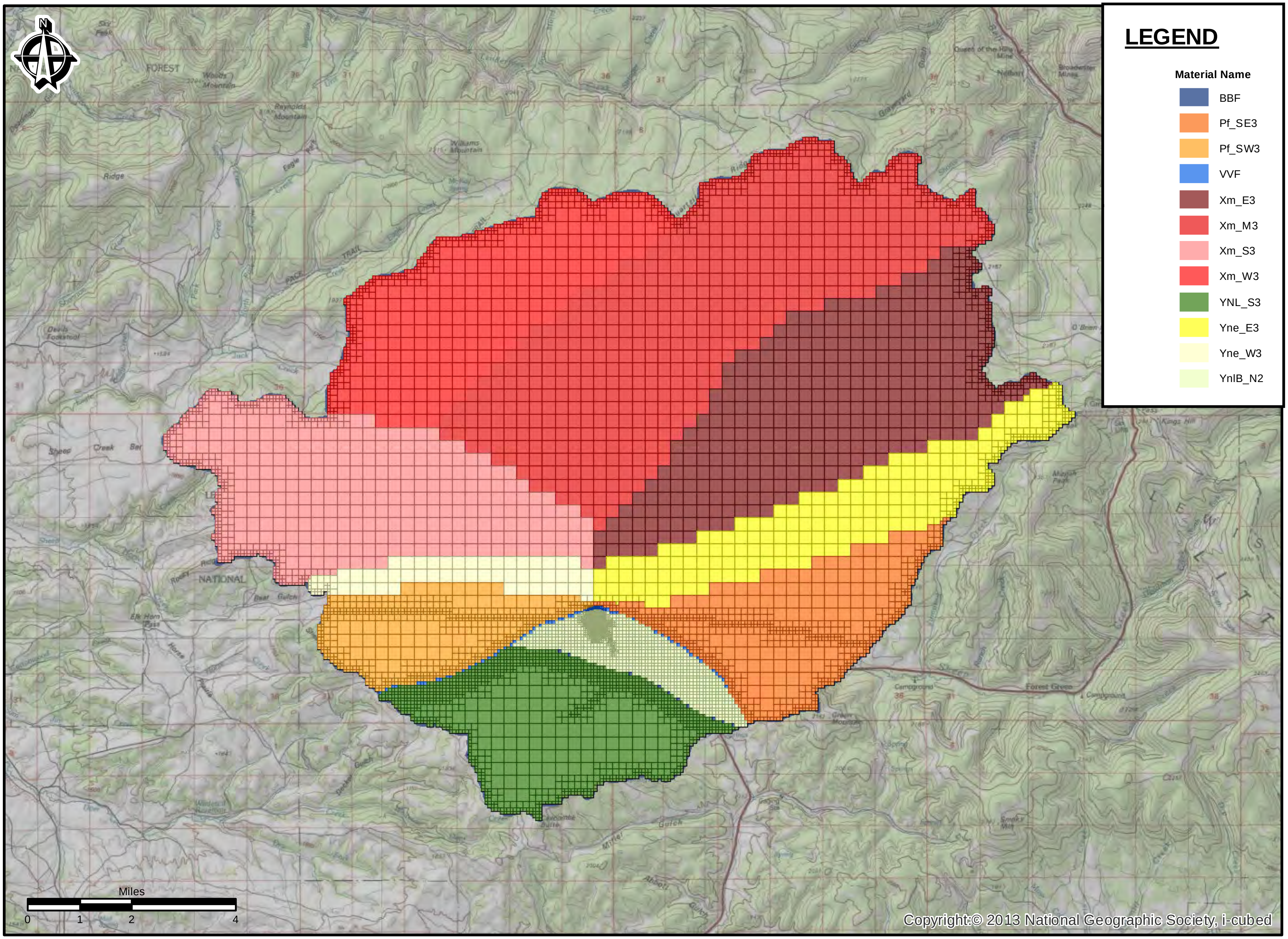

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Figure A-7
Material Properties - Layer 7
Black Butte Copper Project
Meagher County, Montana

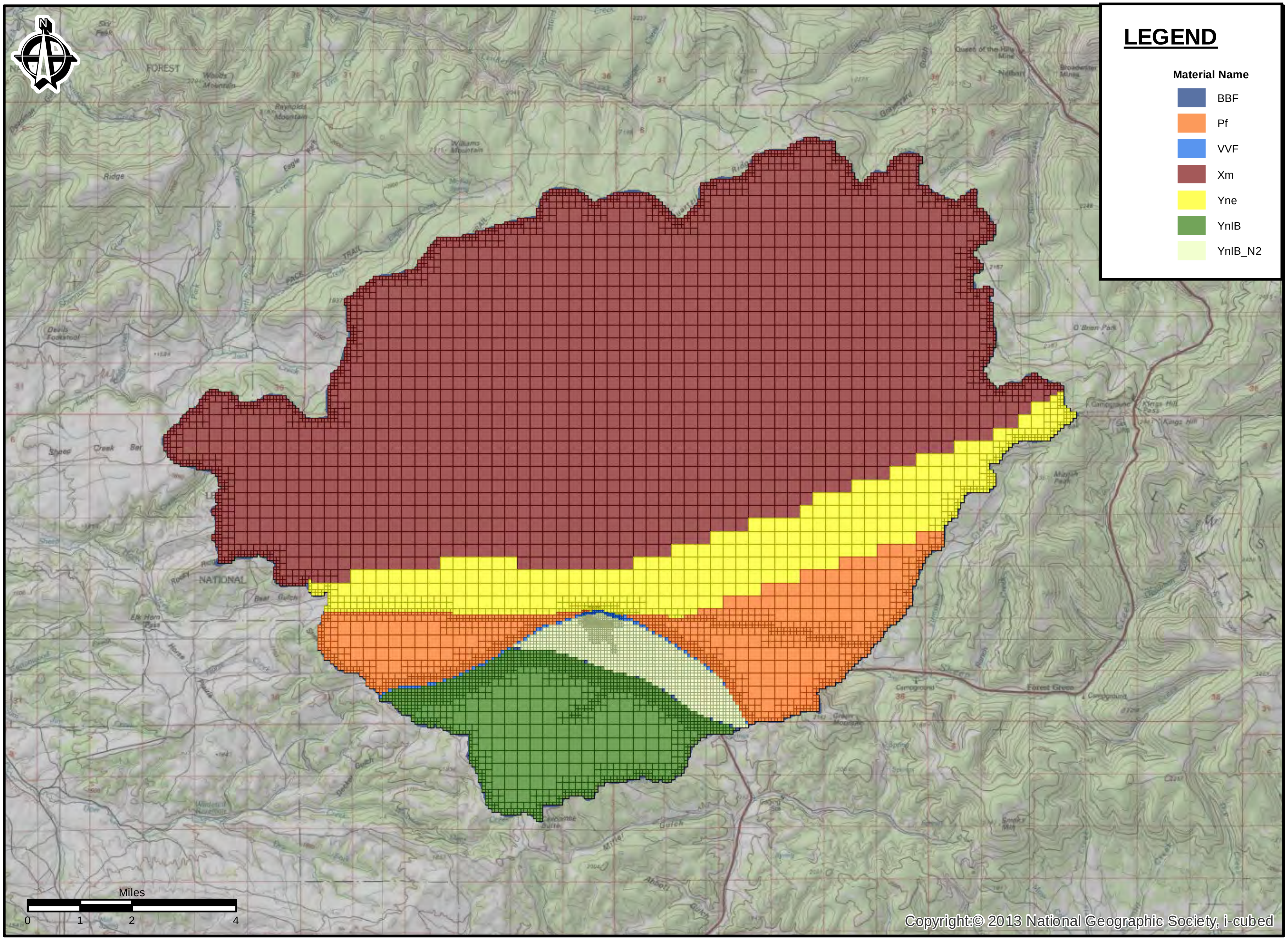

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Figure A-8
Material Properties - Layer 8
Black Butte Copper Project
Meagher County, Montana

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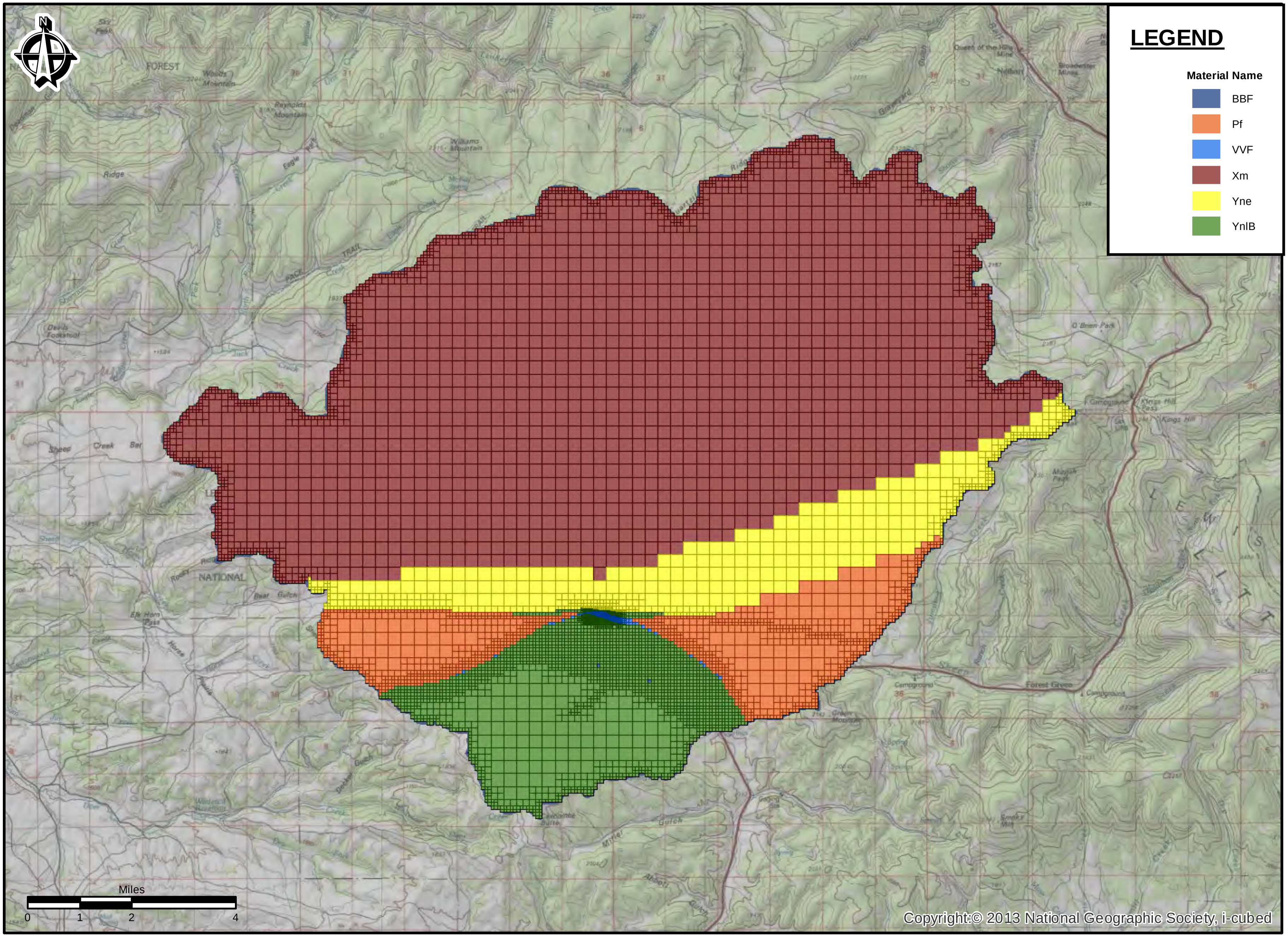

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Figure A-9
Material Properties - Layer 9
Black Butte Copper Project
Meagher County, Montana

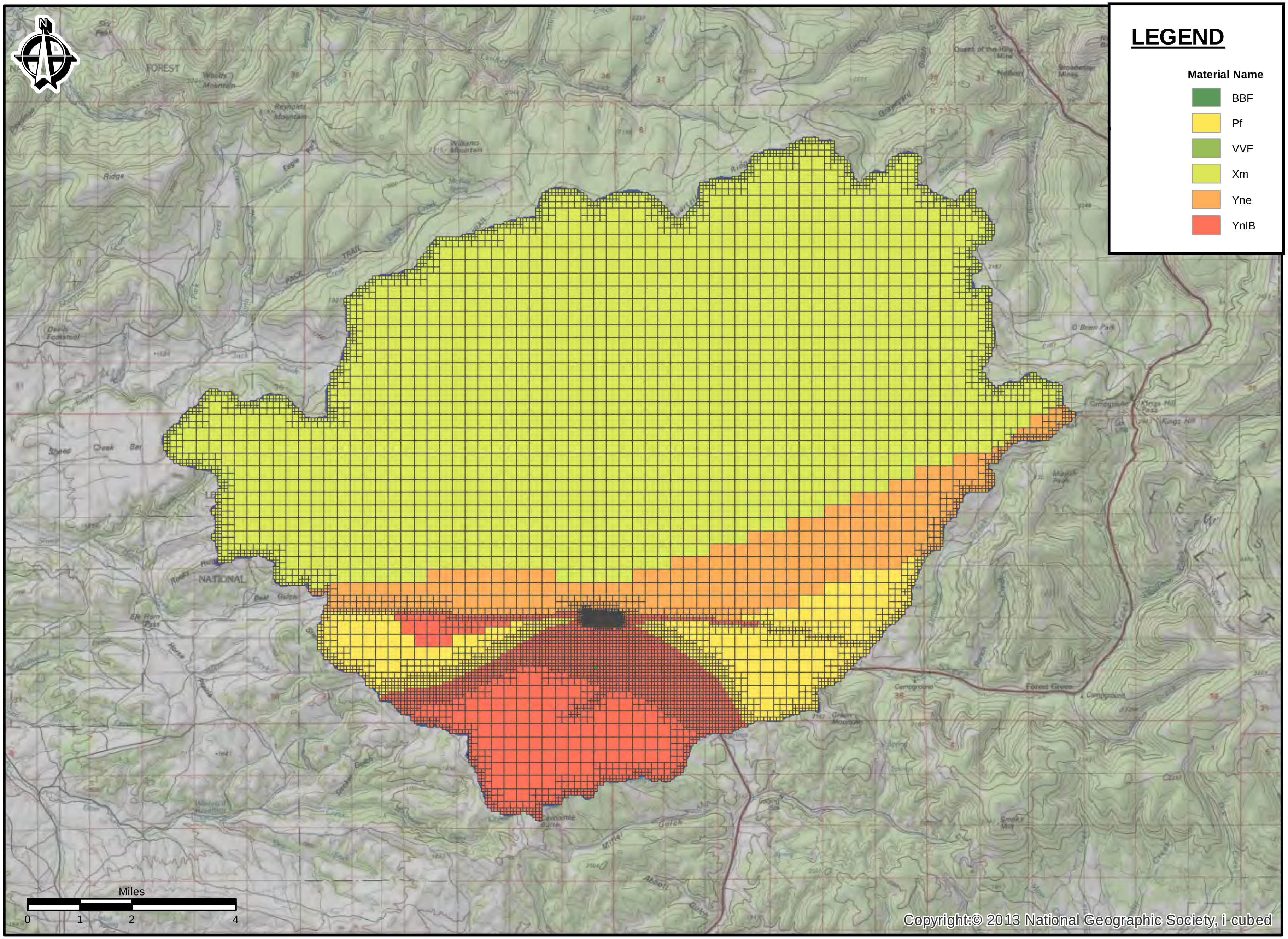

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Figure A-10
Material Properties - Layer 10
Black Butte Copper Project
Meagher County, Montana

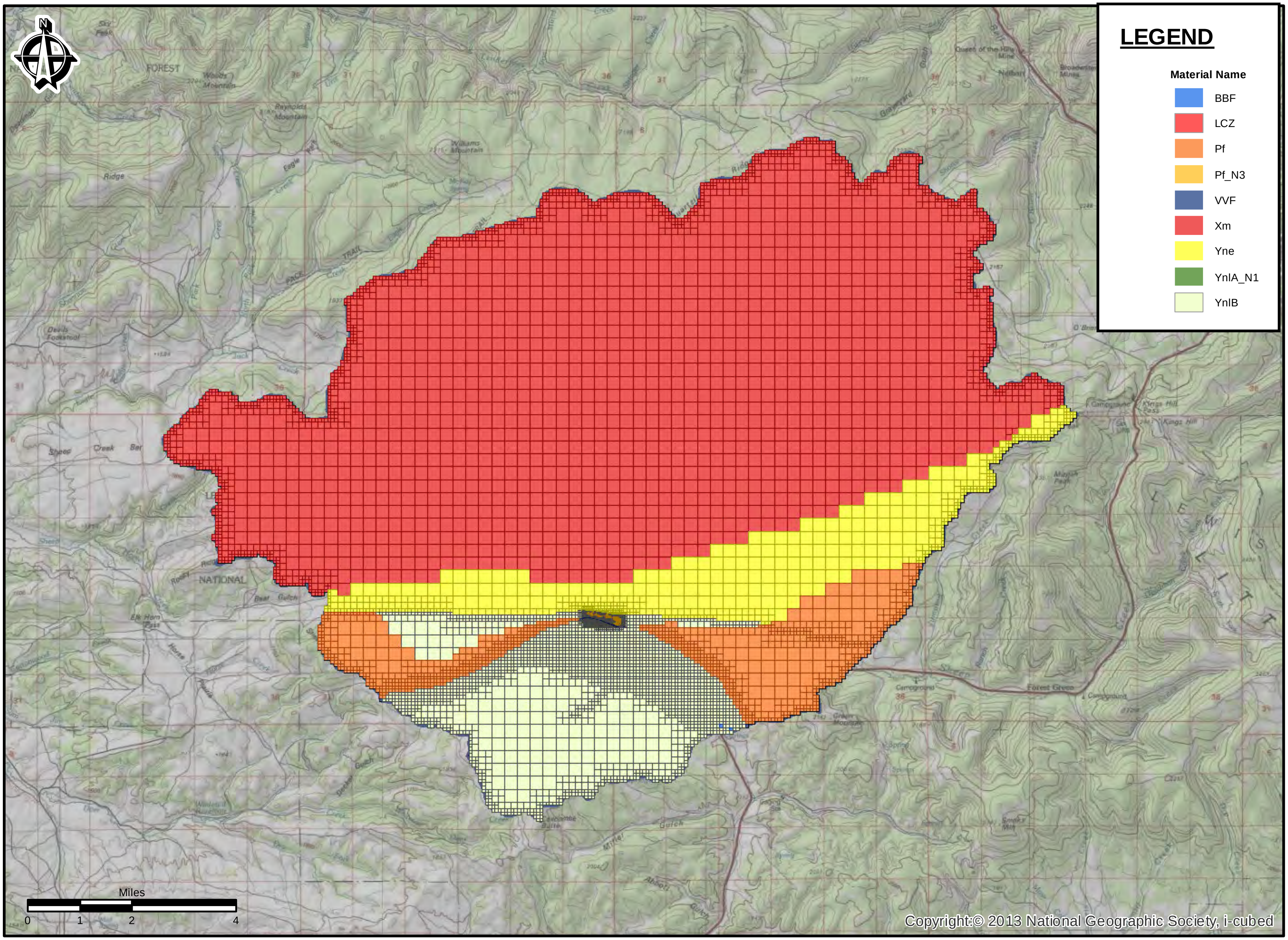

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Figure A-11
Material Properties - Layer 11
Black Butte Copper Project
Meagher County, Montana

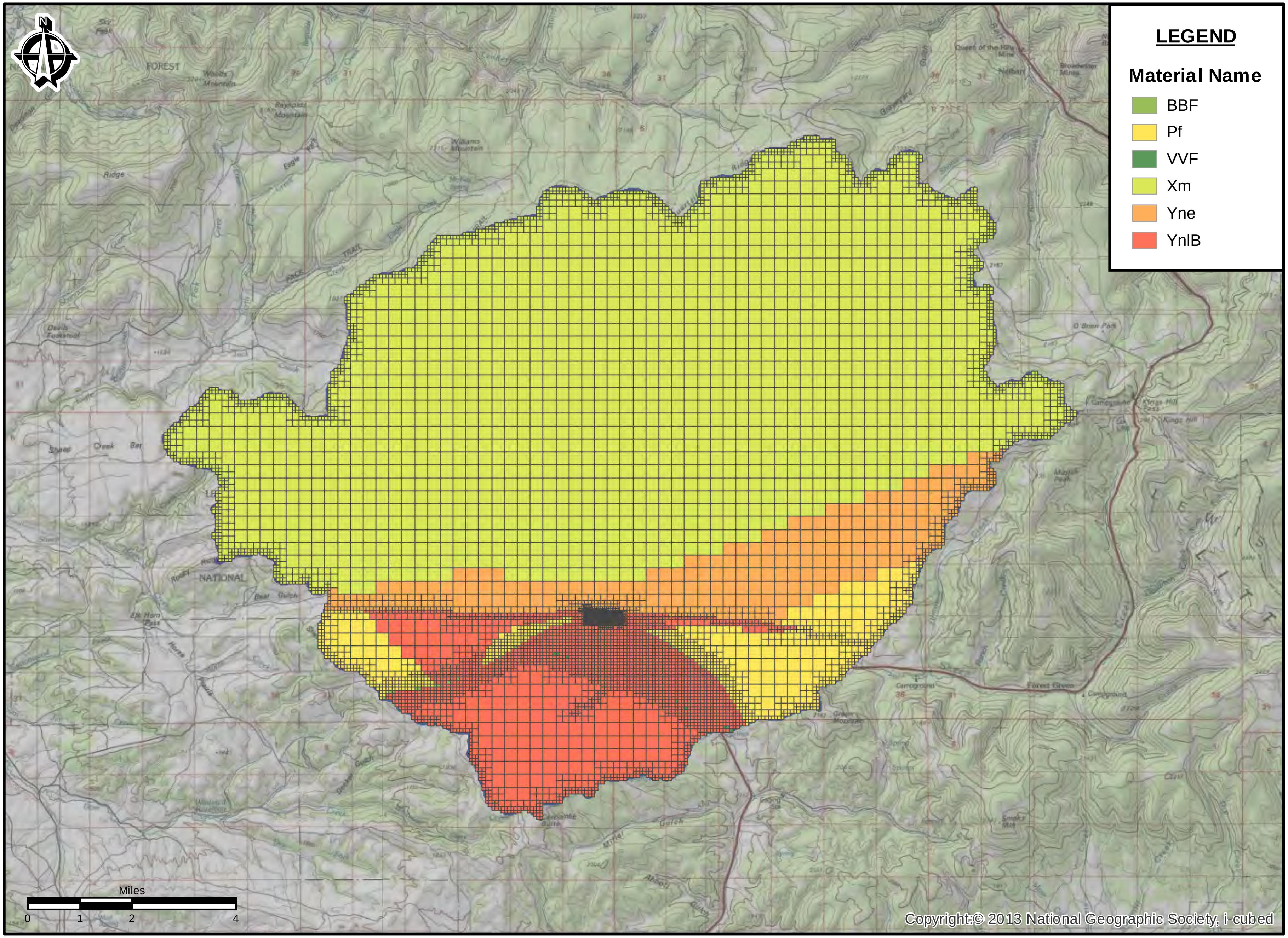

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Figure A-12
Material Properties - Layer 12
Black Butte Copper Project
Meagher County, Montana

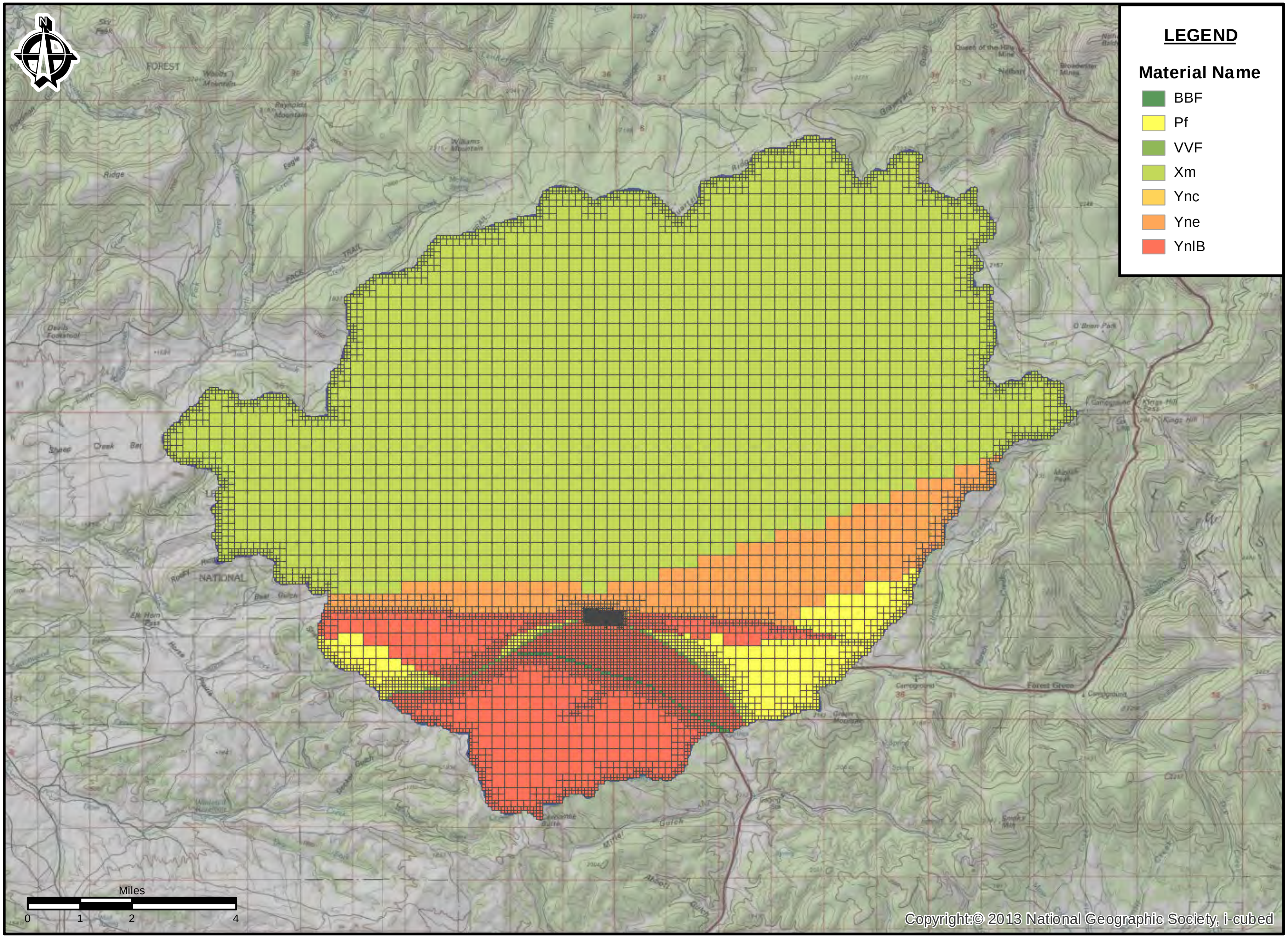

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Figure A-13
Material Properties - Layer 13
Black Butte Copper Project
Meagher County, Montana

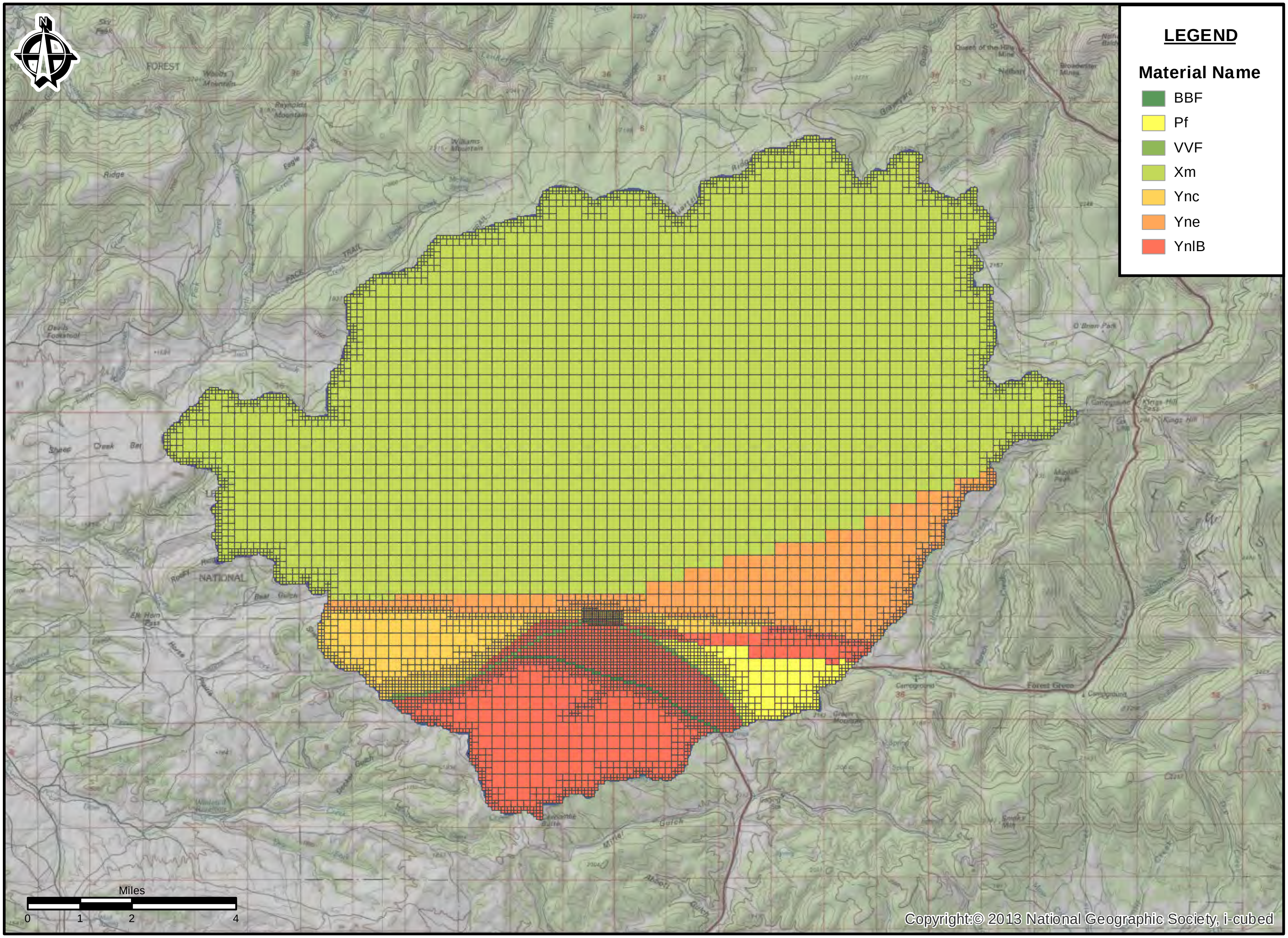

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Figure A-14
Material Properties - Layer 14
Black Butte Copper Project
Meagher County, Montana

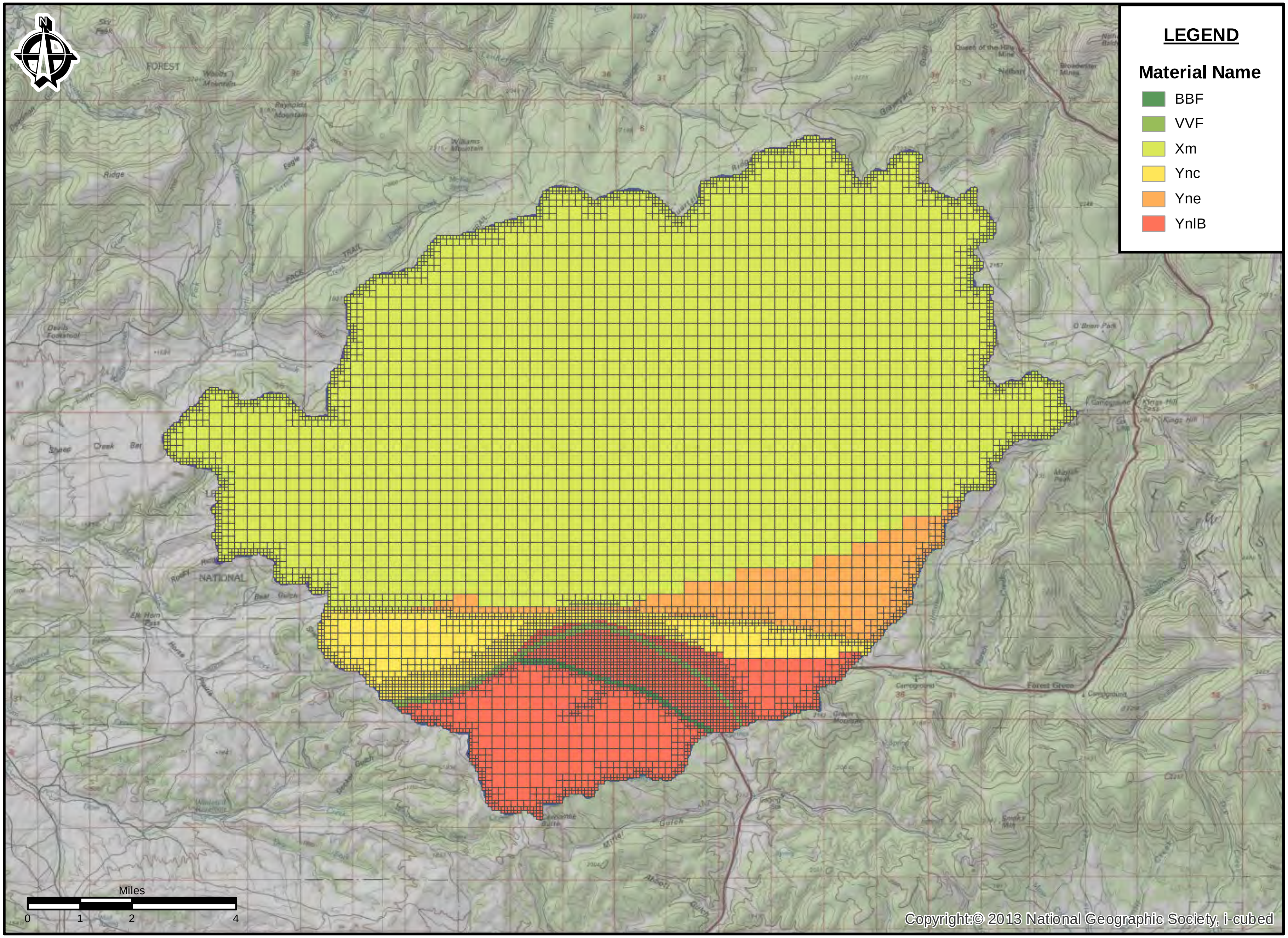

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Figure A-15
Material Properties - Layer 15
Black Butte Copper Project
Meagher County, Montana

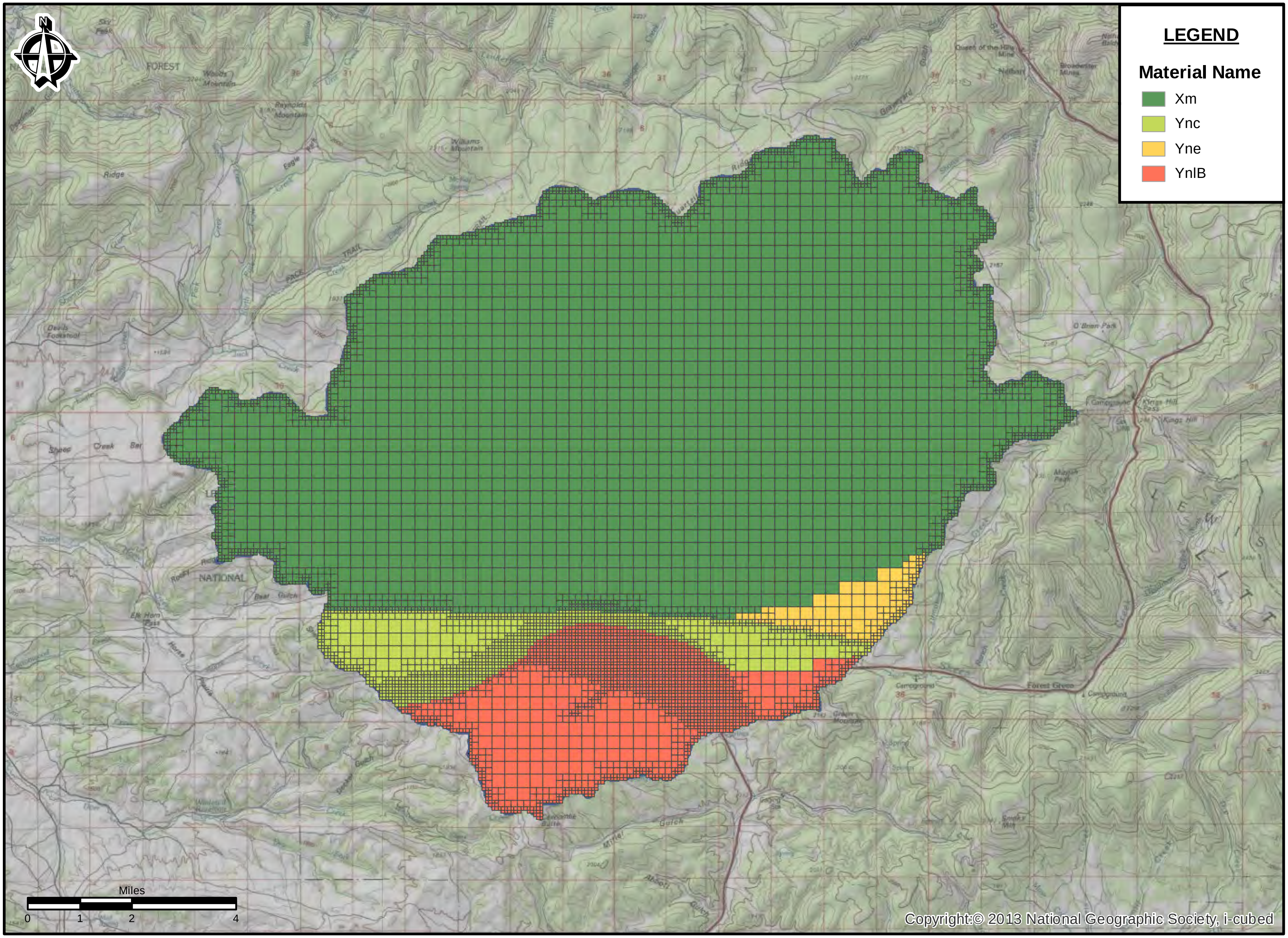

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Figure A-16
Material Properties - Layer 16
Black Butte Copper Project
Meagher County, Montana