Final Groundwater Flow and Transport Modeling Report

Husky 1 North Dry Ridge Mine

Caribou County, Idaho

#117-8510001
August 2021

PRESENTED TO

United States Department of the Interior
Bureau of Land Management and
USDA Forest Service
4350 Cliffs Drive
Pocatello, ID 83204

Idaho Department of Environmental Quality
1410 N. Hilton Street
Boise, ID 83706

PRESENTED BY

Tetra Tech
1100 McCaslin Blvd. Suite 150
Superior, CO 80027

P +1-303-664-4630
F +1-303-665-4391
tetratech.com

Executive Summary

Itafos Conda LLC (Itafos) is proposing to develop the Husky 1 North Dry Ridge (H1NDR) project as an open pit phosphate mine utilizing leases on private and federal lands in Caribou County, Idaho (**Figure 1-1**). Tetra Tech was contracted to prepare an Environmental Impact Statement (EIS) including the development of a numerical groundwater flow and contaminant transport model that simulates the hydrogeologic conditions pre-mining and post-mining. The model was developed with input from and consultation with the Bureau of Land Management (BLM), the Idaho Department of Environmental Quality (IDEQ), Itafos, and ARCADIS.

H1NDR would mine phosphate ore from the Meade Peak Member of the Phosphoria Formation in two open pit mines aligned north-northwest along the strike of the outcrop of this formation. The North Dry Ridge (NDR) Mine would consist of one open pit that would occupy a portion of the NDR Lease. The Husky 1 (H1) Mine would consist of a series of adjacent pits and would occupy portions of the H1 Lease, the lease modification area, and the Maybe Canyon Mine (MCM) Lease (**Figure 1-1**). One temporary overburden storage area (OSA) and one permanent OSA are planned. Most of the overburden would be transported directly from the active phase of mining to the backfill area in the historic Maybe Canyon Mine open pits, the H1 pit, or the NDR pit. Reclamation of the mine pits would proceed concurrently with mining. During reclamation, the backfill would be graded to resemble the natural topography, and a cover designed to promote revegetation and limit infiltration of precipitation and runoff into the backfill would be placed over the backfill.

Groundwater in the area occurs in alluvium, colluvium, the Thaynes Formation, Dinwoody Formation, Wells Formation, Monroe Canyon Formation, and, to a lesser degree, in the Rex Chert Member and Meade Peak Member of the Phosphoria Formation. The Meade Peak Member generally acts as an aquitard that separates the overlying local and intermediate groundwater flow systems from the deeper regional groundwater flow system in the Wells Formation and Monroe Canyon Formation. The Quaternary-age alluvium and colluvium form alluvial fans and extensive valley-fill deposits in Dry Valley, Diamond Creek Valley, and the Blackfoot River Valley west, east, and north, respectively, of the proposed mine site. The smaller valleys tributary to Diamond Creek, the Blackfoot River, and Dry Valley Creek contain thinner alluvium and colluvium. Several springs discharge from the Thaynes Formation, the Dinwoody Formation, and the Rex Chert Member of the Phosphoria Formation east of the proposed mine pits. Regional recharge and deep groundwater flow occur in the Wells Formation and Monroe Canyon Formation. Recharge to the regional groundwater system in the study area generally occurs through infiltration of precipitation and snowmelt on the Wells Formation outcrop, losing reaches of Dry Valley Creek, Maybe Creek, Diamond Creek, and the Blackfoot River, and downward flow from the alluvial aquifers in those valleys to the Wells Formation.

Geochemistry baseline studies characterized run-of-mine waste material and identified constituents of potential concern (COPCs) for use as source term inputs to the groundwater model. The Meade Peak Member of the Phosphoria Formation is the primary geologic source of selenium. The following COPCs were identified based on geochemical testing results: antimony, arsenic, cadmium, copper, iron, manganese, nickel, selenium, sulfate, thallium, total dissolved solids (TDS), uranium, and zinc. Laboratory column testing showed most of the COPC concentrations calculated for the run-of-mine backfill decrease to below the IDEQ water quality standards by the second pore volume flush. Sulfate and manganese concentrations showed a decreasing trend, but they did not appear to reach equilibrium or decrease to below the IDEQ water quality standards by the fifth pore volume flush. Three COPCs were retained for transport modeling: selenium, manganese, and sulfate.

The groundwater model domain is approximately 16.5 miles long and 11.3 miles wide, encompassing an area of about 186 square miles. The model grid extends vertically from the land surface to the base of the regional groundwater system. The hydrostratigraphic units are represented in the model cells by their different hydraulic properties and structural geologic configuration. Bedrock faults were included as partial barriers to horizontal groundwater flow, with differing degrees of flow restriction. The modeling was implemented with the MODFLOW-SURFACT finite-difference code.

The model was calibrated in steady-state mode to groundwater elevation targets measured in 156 monitoring wells and in transient mode to seasonal water-level fluctuations targets in 84 wells. Flows in the Blackfoot River and Diamond Creek were used as qualitative targets. Aquifer properties, recharge, evapotranspiration rates, regional flow rates into and out of the model area, streambed properties, and fault barrier properties were adjusted during calibration.

The mine backfill was simulated as a source of manganese, selenium, and sulfate to the groundwater system. Recharge would enter the backfill in the reclaimed mine pit areas by infiltrating through the engineered cover placed over the backfill. The cover was designed to limit the infiltration rate and thereby limit the contribution of COPCs leached from the backfill. The simulated COPC concentrations in the water recharging the groundwater through the mine pit backfill were based on the geochemical testing. To replicate the concentration decreases observed during the geochemical testing, the model simulated COPC concentrations as decreasing stepwise over time. The modeled timing of these decreases was determined from the infiltration rates and the volume and porosity of the backfill placed in the pits.

Predictive simulations were used to estimate infiltration rates and predict potential effects that mining and mine reclamation would have on surface water and groundwater flows and water quality. Two scenarios were simulated, including the Proposed Action and one alternative called the Alternative Cover. The Proposed Action simulation represented the activities as presented in the MRP Addendum and uses four cover types. The Alternative Cover cap and cover system configuration was developed as a revised backfill design that optimizes material handling throughout the mine site and to meet performance objectives for protection of surface water and groundwater quality. Additional simulations were performed to evaluate the sensitivity of the model-predicted results to changes and uncertainties in the model input. None of the simulations included chemical or biochemical reactions that would attenuate concentrations of COPCs within the backfill or in the receiving groundwater.

Simulation of the Proposed Action predicted that plumes of groundwater containing manganese, selenium, and sulfate at concentrations exceeding their respective groundwater standards would extend approximately one mile downgradient and downdip of the mine pits. The modeling predicted that COPC plumes would migrate downdip from the mine pits and then laterally within the Wells Formation, except for minor lateral migration within the shallower formations (e.g., Dinwoody Formation and Rex Chert Member of the Phosphoria Formation) immediately adjacent to the pits due to groundwater mounding within the backfill. Modeling of the Proposed Action also showed that groundwater with selenium concentrations above aquatic standards would discharge into East Mill Creek, Maybe Creek, and Stewart Creek.

Simulation of the Alternative Cover also predicted plumes of groundwater containing manganese, selenium, and sulfate at concentrations exceeding their respective groundwater standards, but the maximum plume extents were reduced by approximately 30 to 40 percent due to the use of flexible membrane liners (FMLs) and lateral drains within the covers. Similar to the Proposed Action, the COPC plumes would migrate downdip from the mine pits and then laterally within the Wells Formation, except for minor lateral migration within the shallower formations. However, the Alternative Cover simulation showed that groundwater would not discharge into any surface water body within the model domain with selenium concentrations above method detection limits.

Numerical simulations using different values of selected input parameters were run to determine the sensitivity of the modeling results to such changes. The conclusions drawn from the sensitivity analysis are that changes in backfill infiltration rate have the largest effect on selenium plume migration from the mine pits since the infiltration rate controls the amount of mounding within the pit backfill. Increasing or decreasing the backfill infiltration rate also has the largest effect on selenium groundwater concentrations discharging into East Mill Creek, Maybe Creek, and Stewart Creek. Horizontal and vertical hydraulic conductivity of select units along Dry Ridge are also sensitive parameters. Changes in model parameters for the Alternative Cover option produce similar changes in selenium plume extent as in the Proposed Action option.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

ACRONYMS/ABBREVIATIONS

Acronyms/Abbreviations	Definition
ABA	Acid-base accounting
amsl	above mean sea level
bgs	below ground surface
BLM	United States Department of the Interior, Bureau of Land Management
cfd	cubic feet per day
cfs	cubic feet per second
COPC	Constituent of potential concern
CSM	Conceptual Site Model
EIS	Environmental Impact Statement
ET	Evapotranspiration
GHB	General head boundary
GWQS	Groundwater quality standard
HFB	Horizontal flow barrier
H1	Husky 1 lease area
H1NDR	Husky 1 North Dry Ridge project
HUC	Hydrologic Unit Code
IDEQ	Idaho Department of Environmental Quality
MCM	Maybe Canyon Mine
Mmc	Monroe Canyon Formation
MRP	Mine and Reclamation Plan
NCDC	National Climatic Data Center
NDR	North Dry Ridge lease area
NMM	North Maybe Mine
OSA	Overburden Storage Area
Ppg	Grandeur Tongue Member of Park City Formation
Ppm	Meade Peak Member of Phosphoria Formation
Ppr	Rex Chert Member of Phosphoria Formation
PPw	Wells Formation
ROM	Run of Mine
SFR	Stream flow routing
SMCM	South Maybe Canyon Mine
SNOTEL	Snow Telemetry
SPLP	synthetic precipitation leaching procedure
SWE	snow water equivalent

Acronyms/Abbreviations	Definition
USFWS	United States Department of the Interior, Fish and Wildlife Service
TDS	total dissolved solids
TOC	total organic carbon
Trd	Dinwoody Formation
Trt	Thaynes Formation
USFS	United States Department of the Interior, Forest Service
USGS	United States Department of the Interior, Geological Survey
WRCC	Western Regional Climate Center
XRD	X-ray diffraction
°F	degrees Fahrenheit

1.0 INTRODUCTION

The Husky 1 North Dry Ridge project (H1NDR) proposed by Itafos would mine phosphate ore from leases on private and federal land in southeastern Idaho (**Figure 1-1**). The Husky 1 area on the south is separated from the North Dry Ridge (NDR) area on the north by the previously mined areas North Maybe Mine and South Maybe Canyon Mine.

Tetra Tech was contracted to prepare an Environmental Impact Statement (EIS), including development of a numerical groundwater flow and transport model to simulate the hydrogeologic conditions in the H1NDR project area and vicinity and the proposed mining and reclamation. This report presents the background for and development of the numerical model and describes the results of the model's simulation of the proposed activities.

The groundwater modeling scope of work included the following tasks:

- Developing the conceptual site model (CSM) and preparing a CSM report (Tetra Tech, 2019);
- Developing and calibrating a 3-D finite-difference numerical groundwater flow model using MODFLOW-SURFACT;
- Developing a fate and transport model using MODFLOW-SURFACT;
- Using the fate and transport model to simulate post-mining conditions related to the H1NDR project; and
- Preparing a groundwater modeling report.

The groundwater model was developed with input from and in consultation with the Bureau of Land Management (BLM), the Idaho Department of Environmental Quality (IDEQ), United States Forest Service (USFS), ARCADIS, and Itafos.

1.1 Site Location and Description

The H1NDR leases and modification areas are approximately 16 miles northeast and east of Soda Springs, Idaho (**Figure 1-1**). The project area is mountainous, with elevations ranging from 6,340 feet above mean sea level (amsl) along the Blackfoot River at the north end to 8,950 feet amsl along the highest parts of Dry Ridge. Dry Ridge is part of a series of generally parallel, north to northwest-trending ridges and valleys developed in response to erosion of the folded and faulted sedimentary rock strata in the area.

The project area is in the Blackfoot River Sub-basin, fourth-order Hydrologic Unit Code (HUC 4) 17040207, within the Lanes Creek-Diamond Creek and the Upper Blackfoot River HUC 5 watersheds. The Blackfoot River is on the north side of the Project area, and Dry Valley and Diamond Creeks are on the west and east sides, respectively. This area is drained by these low-gradient, wide-valley streams, and their tributaries. The tributaries occupy relatively narrow, high-gradient channels surrounded by steep, mountainous slopes.

1.2 Proposed Project Summary

H1NDR would mine phosphate ore from the Meade Peak Member of the Phosphoria Formation in two open pit mines aligned north-northwest along the strike of the outcrop of this formation. The Mine and Reclamation Plan (MRP) prepared by Itafos (2020a) would result in the development of two primary areas where mining and reclamation activities would occur. The NDR Mine would consist of one open pit that would occupy a portion of the NDR Lease. The Husky 1 (H1) Mine would consist of a series of adjacent pits and would occupy portions of the H1 Lease, the lease modification area, and the Maybe Canyon Mine (MCM) Lease (**Figure 1-1**). One temporary overburden storage area (OSA) and one permanent OSA are planned (Itafos, 2020a).

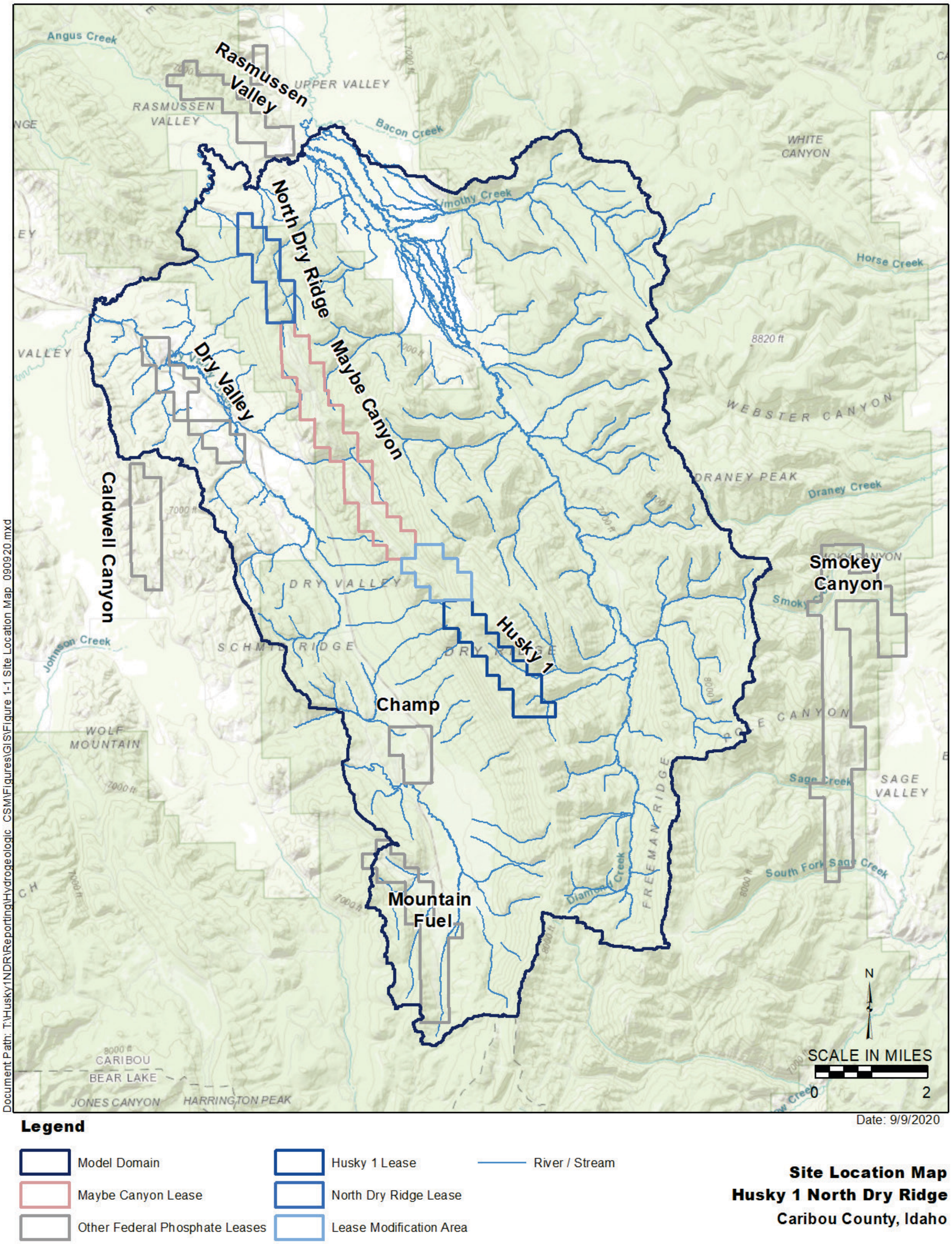


Figure 1-1. Location Map

The H1 and NDR pits would be mined as open pits and sequenced through several phases at each respective site. H1 would be mined first in nine phases from north to south. The NDR deposit would be mined in three phases from south to north with some overlap in time with H1 mining. Overburden would be placed directly as backfill, stored in temporary OSAs for use as backfill later, or stored in a permanent OSA. Most of the overburden would be transported directly from the active phase of mining to backfill the historical MCM open pits or H1 and NDR pits (Itafos 2020a).

Backfill would require closure cap and cover systems to support a stable vegetative cover and overall hydraulic performance for acceptable infiltration rates following mining. Itafos designed and evaluated four cap and cover systems (Itafos 2020b).

1.3 Purpose and Objectives

The numerical groundwater flow and transport model was developed to:

- Simulate groundwater flow under pre-mining and post-mining conditions, including alternative post-mining conditions;
- Simulate the transport of mine-derived constituents of potential concern (COPCs) in groundwater; and
- Predict changes in groundwater and surface water flow and quality that may occur because of mining and reclamation following mining.

The model was designed to provide output that would allow evaluation of: (1) predicted groundwater quality compared to Idaho groundwater quality standards in IDAPA 58.01.11.200, (2) predicted COPC groundwater concentrations discharging into surface water, and (3) predicted changes in groundwater levels and surface water flow and their effects on groundwater and surface water rights and beneficial uses.

2.0 SUMMARY OF THE CONCEPTUAL SITE MODEL

The CSM provides the framework for development of the numerical groundwater flow and transport model. The CSM identifies relevant components of the hydrologic system and allows the information to be translated into a numerical model that represents the hydrologic system and the proposed activities that may affect the hydrologic system.

The CSM for H1NDR and its supporting data were provided in *Hydrogeologic Conceptual Site Model Final* (Tetra Tech, 2019). During model calibration, the understanding of site hydrogeology is often improved and updated, resulting in modifications to the CSM.

2.1 Climate

The climate is semi-arid to semi-humid, with a wide range of seasonal climatological conditions and regional and local topography. Meteorological data for modeling purposes were obtained from snow telemetry (SNOTEL) stations at Somsen Ranch (Idaho), Slug Creek Divide (Idaho), and Willow Creek (Wyoming). Because annual precipitation varies with elevation, SNOTEL stations were selected to be near the project area and representative of the elevation range present in the model area from the Blackfoot River to Dry Ridge. The Somsen Ranch, Slug Creek Divide, and Willow Creek SNOTEL stations have elevations of 6,800, 7,225, and 8,080 amsl, respectively.

Average annual precipitation varies directly with elevation, from approximately 16 inches in the low valleys, such as at Soda Springs, to over 37 inches on Dry Ridge near the Husky 1 lease area (PRISM Climate Group 2019). The geographic distribution of precipitation based on PRISM data is further discussed in Section 3.3.1.

Summer is the driest season, and winter is generally the wettest. Because most of the precipitation at higher elevations occurs as snow, there is little infiltration during December and almost none during January and February. SNOTEL data provide information on rain and snow. The precipitation measurements are collected using a heated rain gage, so that snow is melted, and its water equivalent included in the total. The amount of water contained in the snow is also calculated separately using a snow pad. Both incremental (daily totals) and accumulated (water year totals to date) precipitation values are provided.

Because the accumulated snow (i.e., snow that has not melted and is present on the snow pad) is measured separately from total precipitation by the SNOTEL stations, the data can be processed to identify when the snow melts into water and runs off and/or infiltrates. The 30-year average precipitation and potential recharge for each month are provided in **Table 2-1.** As shown in **Table 2-1**, SNOTEL data from the Somsen Ranch (Site Number 770), Slug Creek Divide (Site Number 761), and Willow Creek (Site Number 868) stations (https://www.nrcs.usda.gov/wps/portal/wcc/home/) indicate that most of the precipitation occurs as snow in winter and is not available for recharge until spring. **Figure 2-1** shows the daily snow water equivalent (SWE), using a 30-year daily average. The daily SWE values are calculated from the weight of the water in the snowpack on the measuring and recording instrumentation. Increasing SWE indicates water accumulation from precipitation, while decreasing SWE indicates water loss from snowmelt, evaporation, sublimation, or another process. Snowmelt is minor up through March, and during the subsequent spring snowmelt, about 65-80 percent of the annual precipitation (previously stored as snow) suddenly becomes available for infiltration and runoff. Somsen Ranch and Slug Creek Divide experience snowmelt, on average, mostly during April and May. The typical snowmelt runs a little later at the Willow Creek station, often extending into June.

Evaporation and evapotranspiration (ET) are highest during July and lowest during December. The CSM utilized an ET station located at Soda Springs, Idaho that was approximately 14 miles west of the model area; however, data collection for the Soda Springs station ended in December 2012 (University of Idaho, 2017). The data considered for groundwater modeling began in June 2012, so the amount of overlap with the Soda Springs ET station was insufficient for the model. Evapotranspiration data used after 2012 are from the Afton, Wyoming AgriMet Station, located about 10 miles east of the model area and at an elevation of 6,210 feet amsl (https://www.usbr.gov/pn/agrimet/agrimetmap/aftyda.html). **Figure 2-2** shows the monthly ET measured at the Afton AgriMet Station for each month represented in the model.

Table 2-1. Precipitation and Potential Recharge Summary

Month	Somsen Ranch		Slug Creek Divide		Willow Creek	
	Total Precipitation (inches)	Potential Recharge (inches)	Total Precipitation (inches)	Potential Recharge (inches)	Total Precipitation (inches)	Potential Recharge (inches)
October	2.2	2.1	2.4	2.2	3.8	2.8
November	2.7	1.0	3.2	1.3	5.5	0.9
December	3.2	0.2	4.0	0.4	5.9	0.2
January	3.2	0.0	4.0	0.3	6.3	0.0
February	2.4	0.0	3.4	0.2	5.4	0.0
March	2.4	1.9	3.3	1.7	5.4	0.2
April	2.5	9.7	3.2	10.5	5.7	7.2
May	2.8	6.5	3.4	10.1	5.0	22.9
June	1.8	1.8	1.9	2.2	3.2	12.0
July	0.8	0.8	0.8	0.8	1.4	1.6
August	1.3	1.3	1.2	1.2	1.7	1.7
September	1.8	1.8	1.8	1.8	2.6	2.6
Totals	**27.2**		**32.8**		**52.1**	

Notes:
Potential recharge includes rainfall and snowmelt.
Snow Telemetry (SNOTEL) stations are reported by the Natural Resources Conservation Service. Precipitation and snow water equivalent data are for the Somsen Ranch (770), Slug Creek Divide (761), and Willow Creek (868) stations.

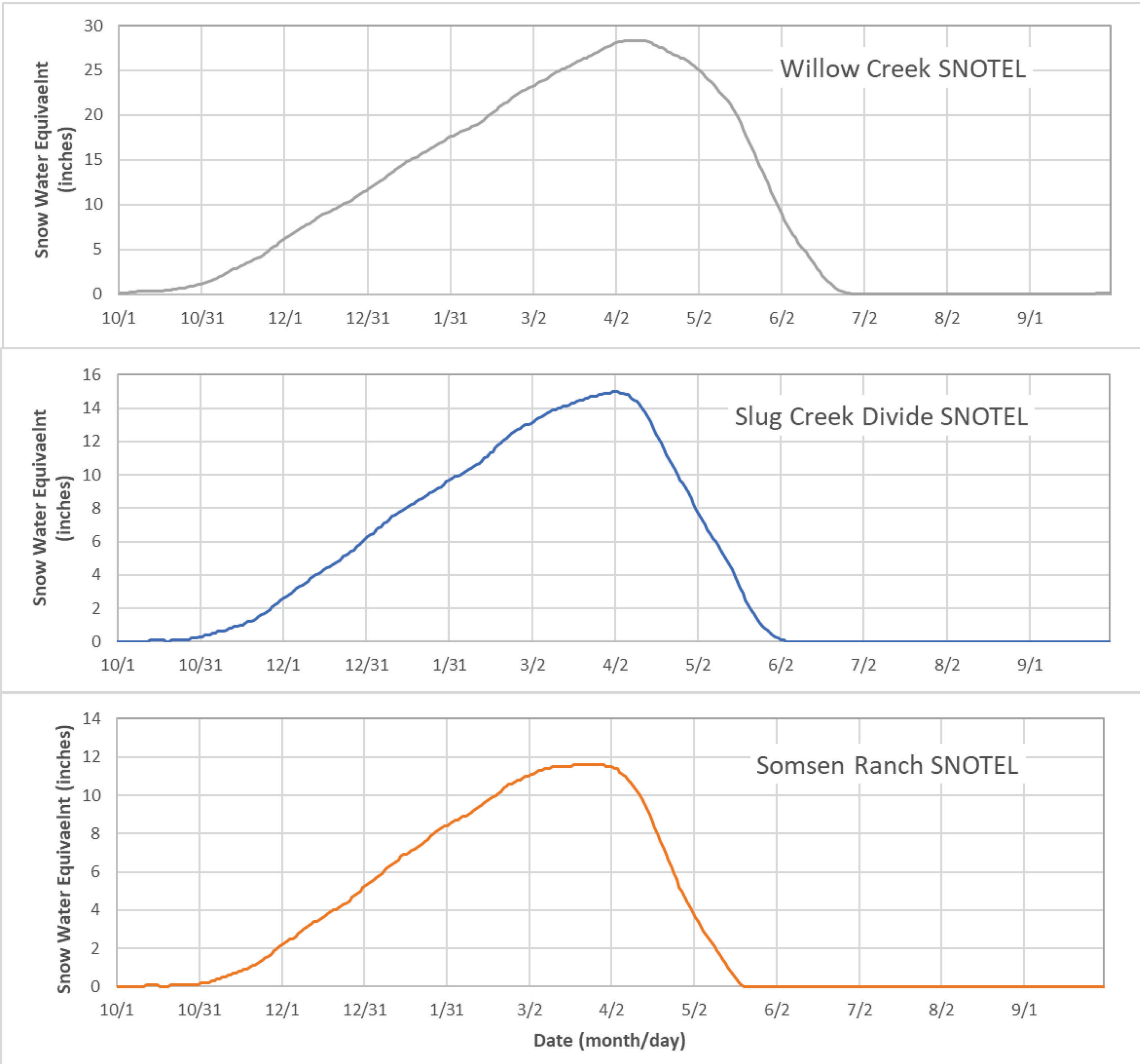


Figure 2-1. Daily Snow Water equivalent (30-Year Average)

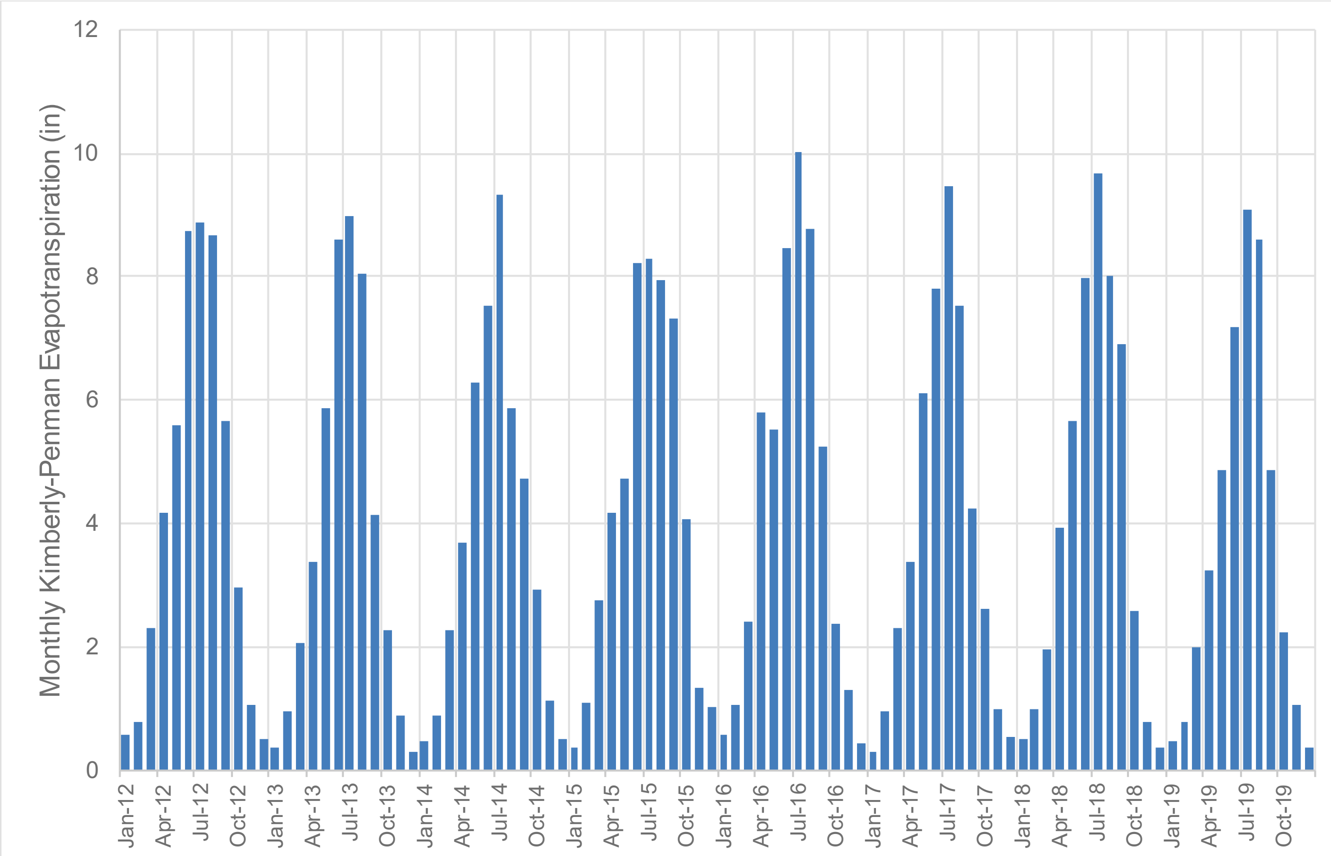


Figure 2-2. Monthly Evapotranspiration at the Afton, Wyoming AgriMet Station

2.2 Geology

The geology was characterized by the United States Geologic Survey (USGS) and others. Drilling to install wells for the groundwater baseline study confirmed the general geology expected based on these geologic maps and associated cross-sections. Therefore, the geologic maps and cross-sections referenced in this report are reproduced and/or modified from published geologic maps.

2.2.1 Geologic Setting

H1NDR is in the Western Phosphate Field, which extends across portions of eastern Idaho, western Wyoming, northern Utah, and southwestern Montana. Sedimentary rocks exposed in the area range in age from Mississippian to Quaternary (recent); additional Paleozoic-age rocks are present in the subsurface but are not exposed in the area. Quaternary-age alluvial and colluvial sediments are present in the valleys, and small areas of Quaternary-age basalt flows are present at the surface adjacent to and south of the Blackfoot River (**Figure 2-3**). Phosphate ore is mined from the Meade Peak Member of the Permian-age Phosphoria Formation.

Structurally, the model area is in a portion of the Cordilleran Overthrust Belt (**Figure 2-4**). The rocks exposed at the surface are part of the Meade thrust plate, which lies above the Meade thrust fault. Royse (1993) shows the Meade thrust plate as up to 13,000 feet thick and extending down to about 4,600 feet below mean sea level beneath Dry Ridge (**Figure 2-5**). According to Mayo et al. (1985), the Meade thrust plate is about 5,000 to 9,000 feet thick in the model area and extends down to an elevation between approximately sea level and 2,000 feet below mean sea level (**Figure 2-6** and **Figure 2-7**). The area is dominated by north-trending to northwest-trending folds and faults that have resulted in a landscape consisting of alternating ridges and valleys following that trend.

2.2.2 Stratigraphy

The exposed geologic units described in the previous section total between about 7,000 and 9,000 feet of stratigraphic thickness. Because of folding and faulting, the thickness of the bedrock geologic units in the subsurface varies with location. The stratigraphic section is summarized in **Table 2-2**.

The Quaternary-age alluvium and colluvium form alluvial fans and extensive valley-fill deposits in Dry Valley, Diamond Creek valley, and the Blackfoot River Valley west, east, and north, respectively, of the proposed mine site (**Figure 2-3**). Drilling has shown variable thicknesses of alluvium and colluvium, but drill holes have penetrated 400 feet of sediments in Dry Valley (Ralston and Williams 1979a, 1979b), 270 feet at the junction of Slug Creek Valley and the Blackfoot River Valley (NewFields 2016), and 150 feet in Diamond Creek valley (IDWR 2014, Well Tag #D0051399) without encountering bedrock. The smaller valleys tributary to Diamond Creek, the Blackfoot River, and Dry Valley Creek contain thinner alluvium and colluvium. Most of the upland areas are mantled with a layer of material that grades from highly weathered to relatively unweathered bedrock.

Bedrock crops out primarily on the ridges adjacent to the valley floors and as isolated hills on the floor of Dry Valley (**Figure 2-3**). **Figure 2-3** shows the locations of the various bedrock outcrop areas. Phosphate ore in the lower Meade Peak Member of the Phosphoria Formation is the proposed target of mining at H1NDR. Both the Wells Formation and Monroe Canyon Limestone subcrop beneath the alluvial fill in Dry Valley. The Wells Formation subcrops beneath the alluvial fill in the south portion of Diamond Creek valley, as well, while the Thaynes and Dinwoody Formations are the primary lithologies underlying the alluvium in the remainder of Diamond Valley. Because of their limited extent at the extreme northeastern edge of the model domain (**Figure 2-3**), the Twin Creek, Nugget, and Ankareh are not significant to the hydrogeologic CSM or groundwater model.

Table 2-2. Generalized Stratigraphic Section

Age	Formation	Geologic Unit		Approximate Thickness (feet)	Description	Flow System
Quaternary	None	Qal	Alluvium & Colluvium	Variable, up to at least 400	Alluvium – gravel, sand, silt and clay.	Local and Intermediate
		Qc, Qs			Colluvium and slope wash – clay, silt, and sand, with some larger clasts.	
		Qb	Basalt	20 - 150	Dark gray, finely crystalline, vesicular basalt.	
Jurassic	Twin Creek Limestone	Jtc	Twin Creek	300	Limestone, siltstone, sandstone, and shale.	
	Nugget Sandstone	Jn	Nugget	1000	Fine-grained sandstone.	
Triassic	Ankareh Sandstone	Tra	Ankareh	750	Shale and limestone with minor very fine-grained sandstone.	
	Thaynes	Trt	Thaynes	2,600 - 3,700	Sandstone, limestone, siltstone, with some thin-bedded shale in lower portion.	
	Dinwoody	Trd	Dinwoody	1,500 - 2,500	Gray limestone, brown to grayish-green siltstone, and pale-olive-brown calcareous siltstone and shale.	
Permian	Phosphoria	Ppc	Cherty Shale Member	100 - 200	Thin-bedded, dark-brown to black cherty mudstone, siliceous shale, and argillaceous chert.	
		Ppr	Rex Chert Member	150 - 350	Thin- to thick-bedded, red to brown to black argillaceous chert, with interbedded mudstone and limestone.	
		Ppm	Meade Peak Member	110 - 180	Interbedded black mudstone, phosphatic mudstone, limestone, and oolitic phosphate rock.	Aquitard
Pennsylvanian	Park City	Ppg	Grandeur Tongue Member	75 - 110	Thin- to thick-bedded dolomite, fine to coarsely crystalline; contains nodules, pods, and thin beds of bluish-gray chert and yellowish-gray sandstone.	Regional
	Wells	PPw	Upper & Lower Members	2,200 - 2,400	Interbedded gray limestone, dolomite, sandy limestone, and sandstone.	
Mississippian	Chesterfield Range Group	Mmc	Monroe Canyon Limestone	800 – 1,300	Gray limestone (weathers to light gray to bluish gray), dense to medium- to thick-bedded, fossiliferous.	

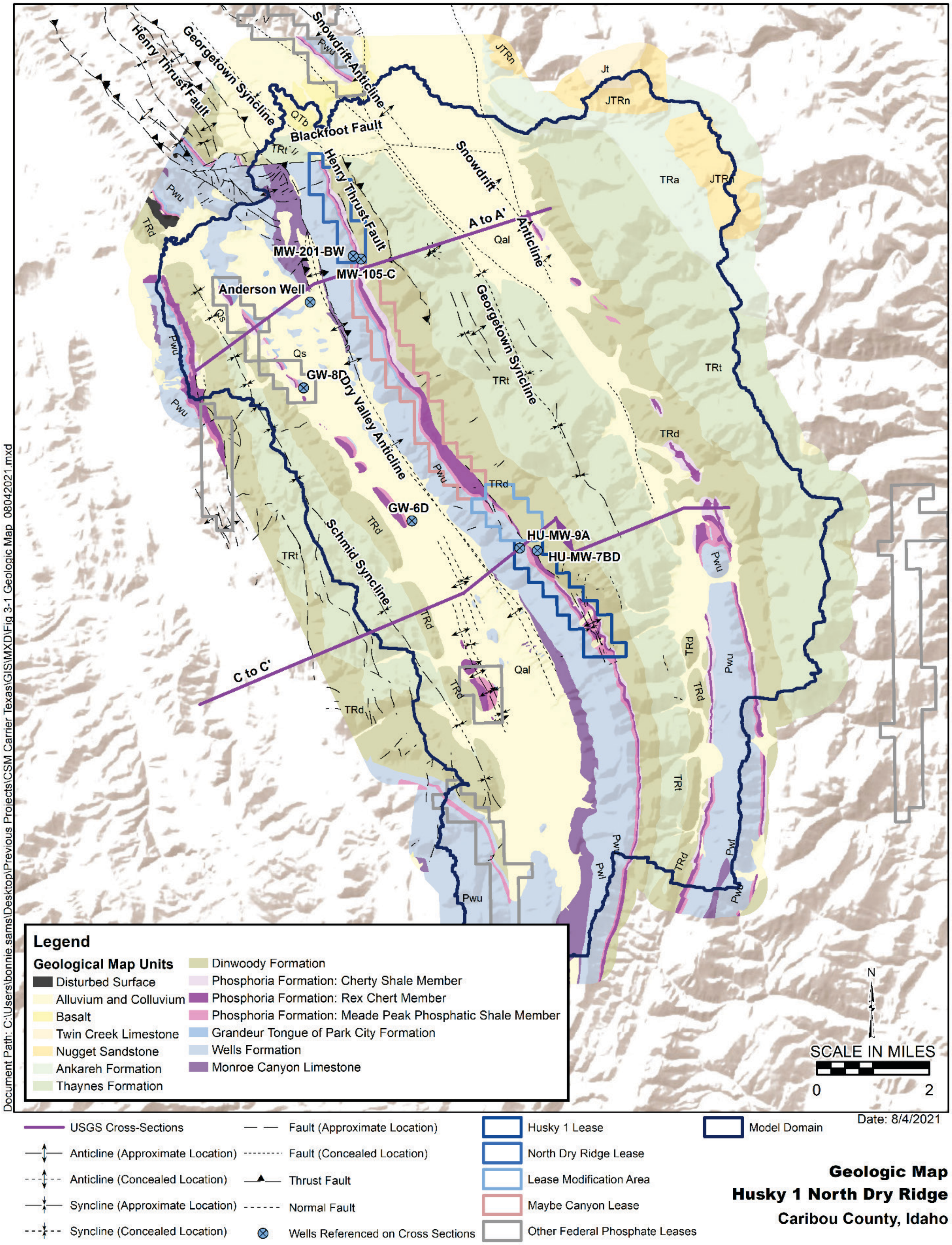


Figure 2-3. Geologic Map

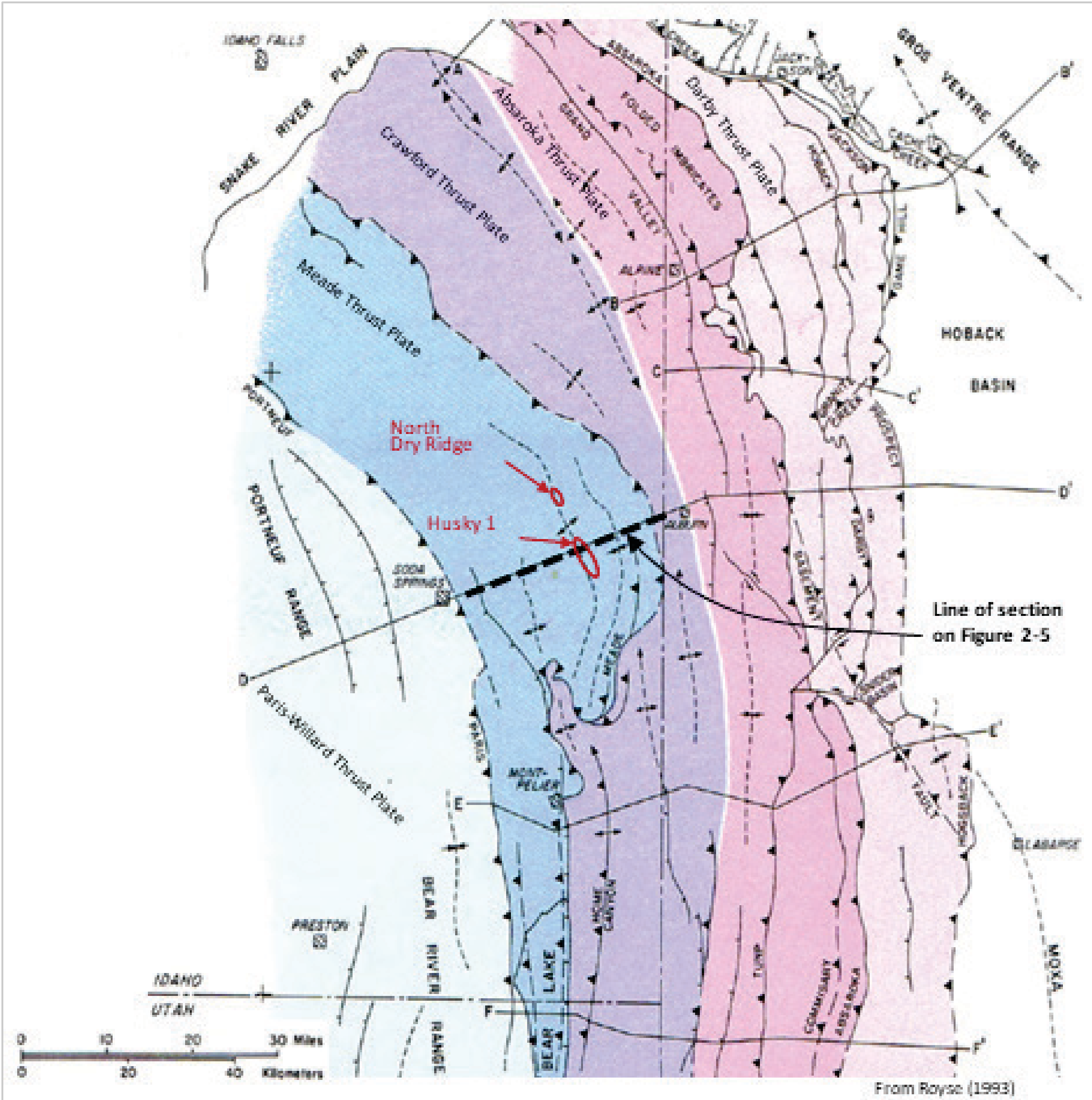


Figure 2-4. Regional Structural Geologic Setting

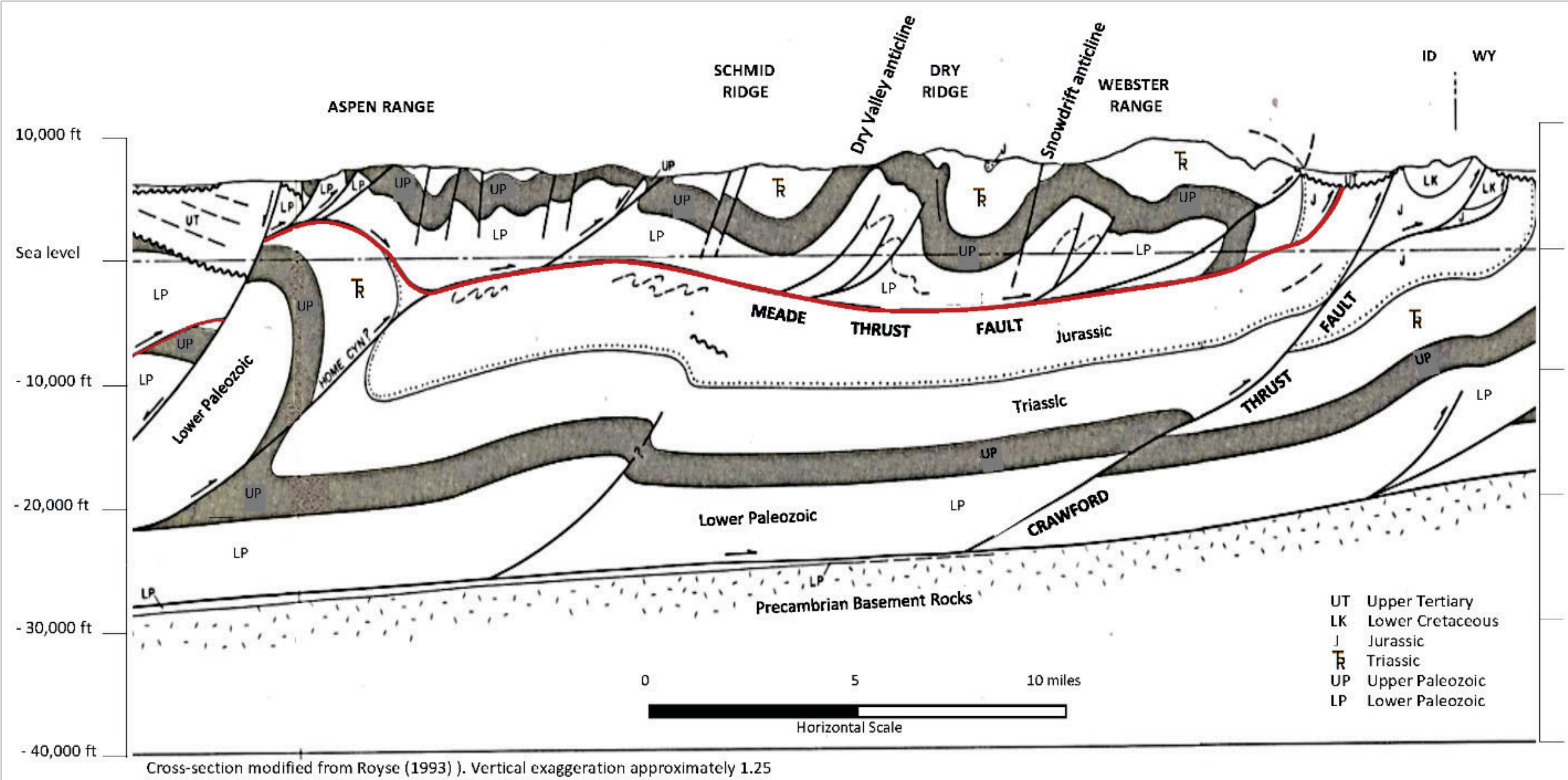


Figure 2-5. Regional Geologic Cross-Section D-D’

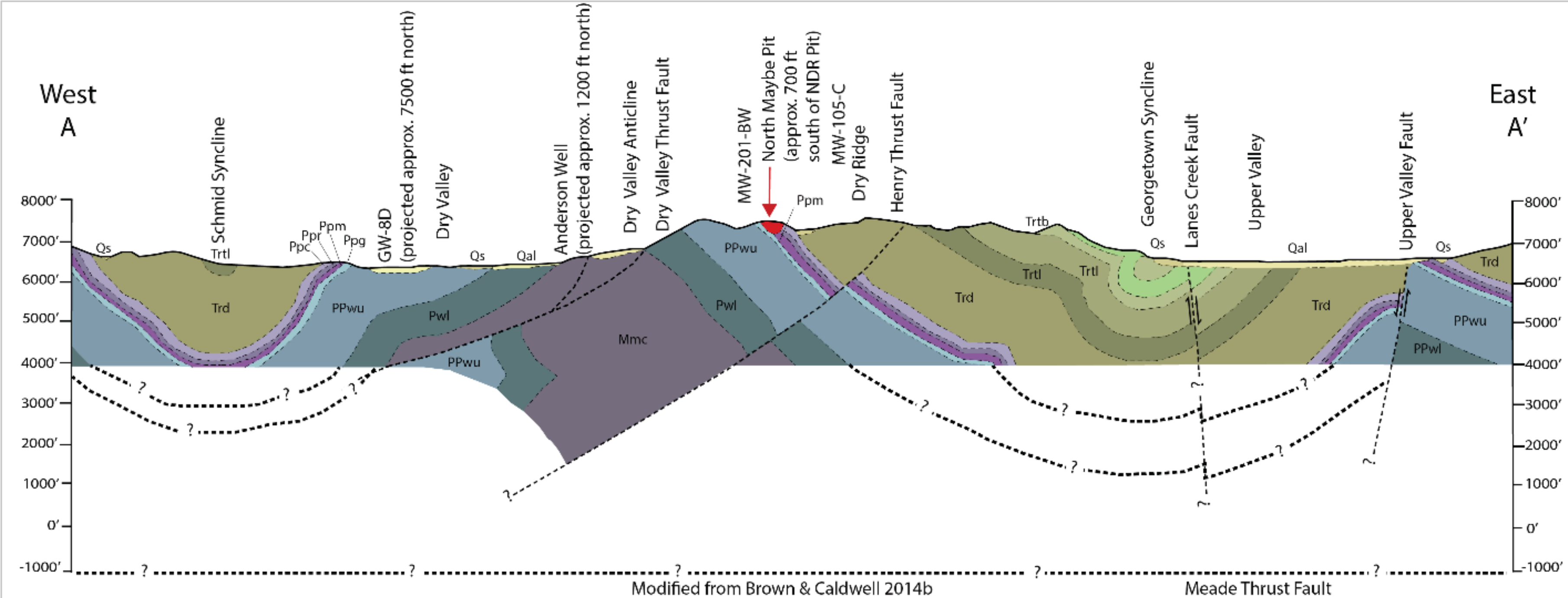
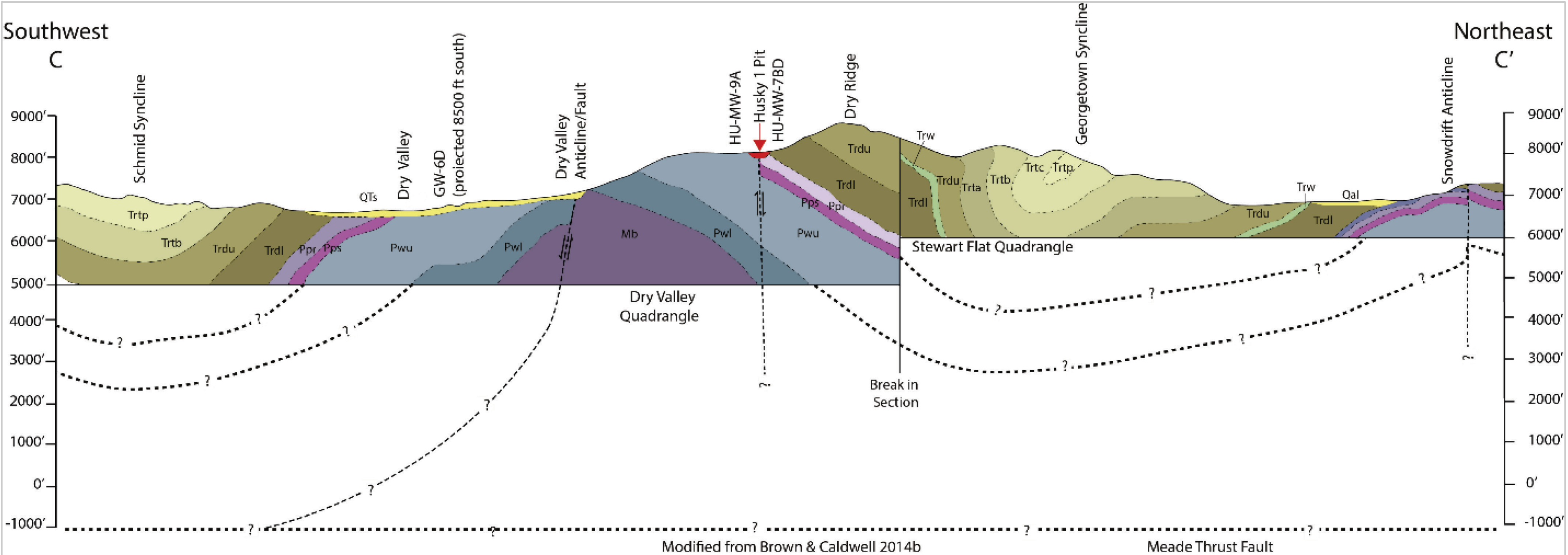


Figure 2-6. Geologic Cross-Section A-A'



Note: The normal (west side down) displacement on the Henry thrust fault as shown on Figure 2-6 was reversed in the geologic model, consistent with later interpretation by Derkey et al. (1983, Plate 1, cross-section C-C').

Figure 2-7. Geologic Cross-Section C-C'

2.2.3 Structural Geology

As previously mentioned, H1NDR is on the Meade thrust plate, which is about 5,000 to 13,000 feet thick in the model area (**Figure 2-5, Figure 2-6,** and **Figure 2-7**). Compressional stress in the late Cretaceous to Eocene caused eastward movement of the thrust plates and created a series of large-scale, generally north- to northwest-trending anticlines and synclines offset by east- to northeast-trending strike-slip faults. Later extensional stress starting in the Miocene produced high-angle normal faults that typically are roughly parallel to the folds, downthrown to the west, may have relatively large displacements (i.e., hundreds of feet), and may occur along reactivated subsidiary thrust faults (Royse 1993). The faulting has broken the sedimentary rocks into numerous small and large structural blocks. In some cases, the faulting has truncated geologic units or juxtaposed rocks of the different scale groundwater flow systems (i.e., regional, intermediate, and local) against one another.

The dominant north- to northwest-trending structural features in the model area are, from west to east, the Schmid syncline, the Dry Valley anticline and Dry Valley thrust fault, the Henry thrust fault, the Georgetown syncline, and the Snowdrift anticline (**Figure 2-5, Figure 2-6,** and **Figure 2-7**). The Dry Valley and Henry thrust faults are subsidiary to the Meade thrust fault and are contained within the Meade thrust plate. The Dry Valley thrust fault follows the west side of Dry Ridge, and the Henry thrust fault parallels Dry Ridge on the east. The proposed mine areas are on the eastern limb of the Dry Valley anticline, and the sedimentary strata in the mine areas dip generally eastward (**Figure 2-6** and **Figure 2-7**). In the northern part of Dry Ridge, outside of the proposed mine area, the Dry Valley anticline is overturned in the subsurface (Rioux et al., 1975), and the bedding planes on the western limb of the anticline dip steeply toward the east. Similarly, Meade Peak strata are overturned in the northern part of the proposed North Dry Ridge mine area (Derkey et al., 1983) and in a portion of the proposed Husky 1 mine area (Montgomery and Cheney, 1967). The Georgetown syncline is overturned in the southern part of Dry Ridge, and the bedding planes on the west limb of the syncline dip steeply toward the west.

The north end of Dry Ridge is terminated by the Blackfoot fault (**Figure 2-3**), the dominant east-trending structural feature in the area. The Blackfoot fault is an oblique-slip fault with approximately one mile of left-lateral displacement and substantial vertical displacement with the north side downthrown. Numerous faults of smaller lateral extent are also present in the model area. In general, these are normal faults that typically trend either north/northwest or east and do not exhibit large displacements.

Other north- to northwest-treading structures include the Stewart syncline and anticline, the Enoch Valley fault, Upper Valley fault, and the Lanes Creek fault (see **Figure 2-6**). In the southern part of the Husky 1 area, the Stewart syncline and anticline add structural complexity and create locally overturned beds, but the general dip is toward the east. The structural low of the sedimentary strata east of the proposed mine areas is along the axis of the Georgetown syncline, and in the eastern part of the model domain, the strata dip to the west, rising upward along the eastern limb of the Georgetown syncline (which is coincident with the western limb of the Snowdrift anticline) (**Figure 2-7**).

Outcrops of the Wells and Monroe Canyon Formations frequently exhibit fracturing perpendicular to the bedding planes. This fracturing is likely a result of folding and faulting of these brittle units in combination with weathering associated with exposure at the surface. Outcrops of the more shaley and less brittle Meade Peak, Dinwoody, and Thaynes formations typically do not exhibit extensive fracturing perpendicular to bedding planes.

2.3 Hydrogeology

The hydrogeology of the model area is complex and includes local, intermediate, and regional scale groundwater flow systems (see Section 2.3.3). The following sections describe the properties of each geologic unit, the regional and local recharge and discharge, the characteristics of the resulting groundwater flow systems, and the interaction of surface water with the groundwater flow systems.

2.3.1 Hydraulic Properties

Hydraulic properties (hydraulic conductivity and storage coefficient) for the geologic units described above, based on reported values for aquifer tests in the model domain, are summarized in **Table 2-3** (AECOM, 2014; AMEC Geomatrix, 2010; Brown and Caldwell, 2013; Brown and Caldwell, 2014b; Global Environmental Technologies, 2007; McGregor, 1993; Montgomery Watson, 1998b; NewFields, 2016; Pincus, 1985; Ralston and Williams, 1979b; Ralston et al., 1980; Raviv and Patricio, 1990; Whetstone, 2003; Whetstone, 2009). No hydraulic property data are available for the basalt, Twin Creek Limestone, Nugget Sandstone, Ankareh Formation, or Thaynes Formation. Reported hydraulic conductivities for each unit typically span 3 to 4 orders of magnitude. Possible causes include lithologic heterogeneities, varying degrees of weathering, fracturing related to faulting or folding, or combinations of those. Spatial patterns are not discernable from the available data; however, anecdotal evidence from Dry Ridge, hydraulic testing at MW-201 BW at North Maybe Mine (see Upper Wells Formation entry in **Table 2-3**), and other nearby ridges indicates that the Wells Formation is less permeable in some places.

Table 2-3. Hydraulic Properties Summary - Model Area

Geologic Unit	Hydraulic Conductivity (K)					Storage Coefficient			
	Min.	Max.	Median	Geometric Mean	n	Min.	Max.	Median	n
	(feet/day)					(unitless)			
Alluvium/Colluvium	0.01	574	6.8	6.7	58	0.2	0.36	0.28	2
Dinwoody Formation	0.01	153	0.8	1.2	53	1.0×10^{-10}	0.1	0.002	9
Rex Chert Member of Phosphoria Formation	0.05	75	5.7	1.6	40	0.000014	0.028	0.007	5
Meade Peak Member of Phosphoria Fm	0.000099	75	0.6	0.35	34	0.001	0.002	0.0015	2
Grandeur Tongue of Park City Formation	0.00011	0.57	0.0016	0.0029	14	--	--	--	0
Wells Formation (undifferentiated)	0.04	1591	8.6	9.5	102	0.00006	0.31	0.0074	16
Wells Formation (Upper)	0.36	0.43	0.4	0.4	2	--	--	--	0
Wells Formation (Lower)	86	1591	580	331	8	--	--	--	0
Monroe Canyon	42	320	100	85	6	7.0×10^{-5}	7.0×10^{-5}	7.0×10^{-5}	1

Note: *n* is the number of aquifer test analyses conducted in each geologic unit for either hydraulic conductivity or storage coefficient.

2.3.2 Groundwater Recharge and Discharge

Recharge to the groundwater system occurs primarily in April and May, during spring runoff. Seasonal water-level fluctuations in wells and seasonal recession of discharge from most springs support this conclusion (**Figure 2-8**). Monthly data for snow water equivalent gain/loss and snow-adjusted precipitation (**Table 2-1**) and transient calibrations of groundwater flow models for the Rasmussen Valley mine (ARCADIS, 2015), the Caldwell Canyon mine (Tetra Tech, 2018), and the current groundwater model to seasonal fluctuations in water levels suggest that about 60 percent of the total annual recharge occurs during April and May. Less than six percent (two percent per month) occurs during December, January, and February, and three to six percent occurs during each of the remaining months. Recharge rates vary with elevation and precipitation (**Table 2-4**); higher areas receive more precipitation, and, as precipitation increases, a greater percentage of that precipitation infiltrates to recharge the groundwater system (Buck and Mayo, 2004).

Table 2-4. Precipitation – Groundwater Recharge Relationship

Annual Precipitation (inches per year)	Estimated Percent Recharge	Elevation (ft)
0 to 12	0%	NP
12 to 16	4%	NP
16 to 20	7%	NP
20 to 25	11%	6,500 to 7,500
25 to 30	14%	6,600 to 7,600
30 to 35	18%	7,300 to 8,300
>35	21%	8,300+

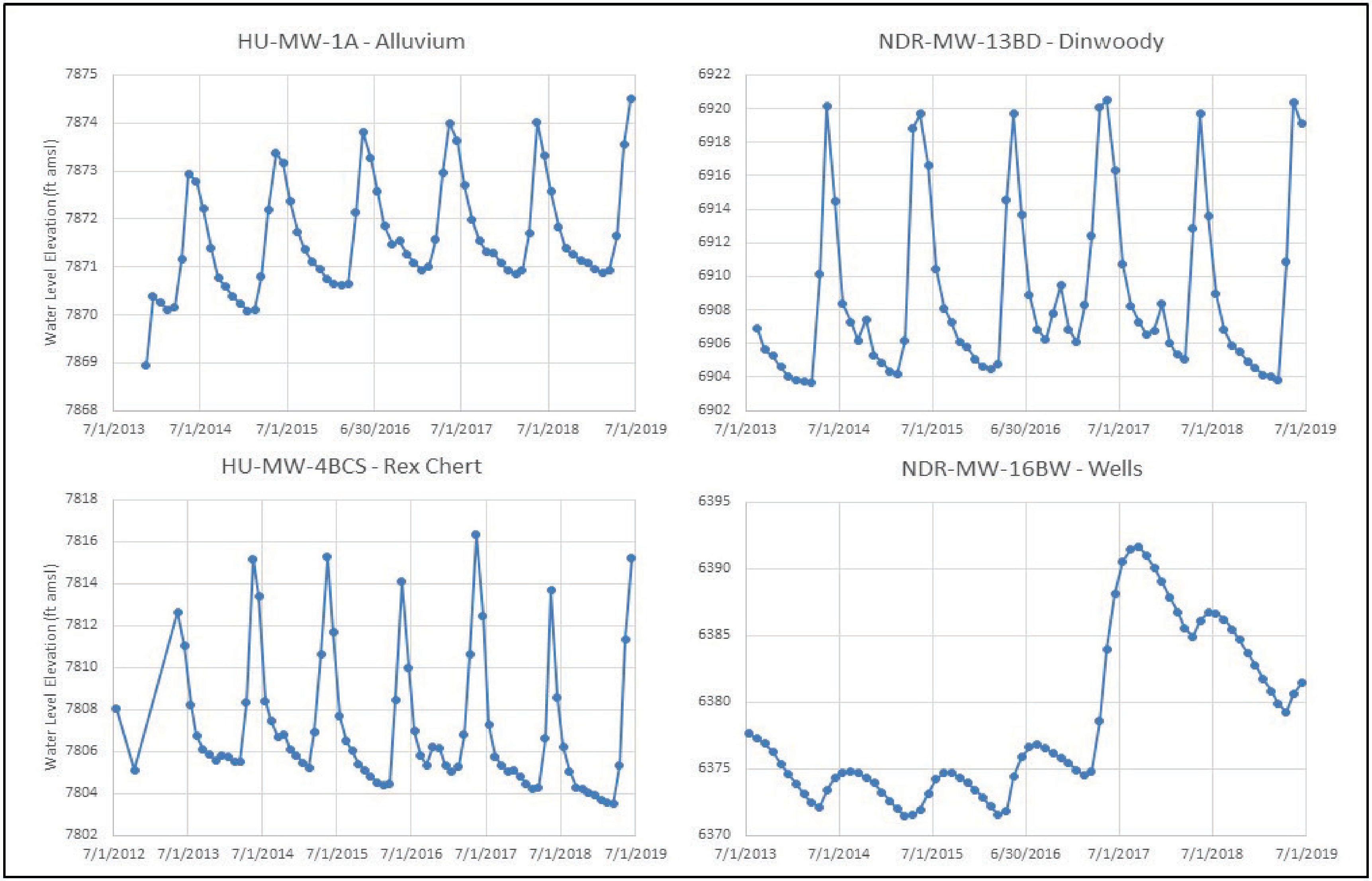
From Buck and Mayo, 2004; NP – Not present within groundwater model domain

Typically, water entering the groundwater system as precipitation and snowmelt has a different fate depending on which stratigraphic unit it enters. Water that infiltrates stratigraphic units above the Meade Peak Member of the Phosphoria Formation tends to discharge into streams and springs, migrates downward into underlying aquifers, or is removed via ET. Often, the infiltrating water migrates downward through the weathered zone and into more-permeable portions of the exposed unit. At that point, it continues laterally through the more-permeable sections until it discharges to a spring, seep, or gaining reach of a stream. Gaining reaches are found in the headwaters of most streams draining the project area. There are less-permeable sections within the Thaynes, Dinwoody, and Upper Wells (Grandeur Tongue) Formations, and the Meade Peak Member is a competent aquitard which also has less water infiltrating at the surface as recharge than the other stratigraphic units present along North Dry Ridge. As a result, most springs and seeps exit from the Thaynes Formation, Dinwoody Formation, or Rex Chert Member (which overlies the Meade Peak Member).

Conversely, groundwater entering the regional aquifer in the Wells and Monroe Canyon Formations underlying the Meade Peak Member tends to continue migrating long distances in those aquifers in a generally westward direction. This groundwater ultimately discharges at the extensional fault bounding the west side of the Aspen Range about 15 miles from the project area (Ralston et al., 1983). Also, in valleys such as Dry Valley and Diamond Creek Valley, where these deeper aquifers subcrop beneath alluvium, there is likely exchange of groundwater between the alluvium and underlying bedrock. Losing reaches of Dry Valley Creek, Maybe Creek, Diamond Creek, and the Blackfoot River occur in sections of those valleys where the alluvial aquifers overlie the Wells and Monroe Canyon Formations. The streams lose water to the alluvial aquifers, and downward flow from the alluvial aquifers provides recharge to the Wells and Monroe Canyon Formations in those areas. Further discussion of stream flow and surface water hydrology is provided in Section 2.4.

The groundwater system at H1NDR typically does not reach steady state over the course of a year because water levels have not equilibrated from the spring snowmelt. In fact, in many years the water table still appears to be elevated from the previous spring snowmelt when the next spring snowmelt occurs. A good example is shown on **Figure 2-8** where water levels in well NDR-MW-16BW are still elevated after the 2017 spring snowmelt compared to previous years. As a result, the transient response to snowmelt and precipitation is particularly important to groundwater model calibration.

Withdrawal of groundwater from water supply wells is a negligible component of groundwater discharge in the model area. Groundwater extraction wells tend to serve low-volume domestic, livestock, or slightly larger-volume industrial uses. No large-scale groundwater extraction occurs in the study area.



Representative Water Level Hydrographs
Husky 1 North Dry Ridge
Caribou County, Idaho

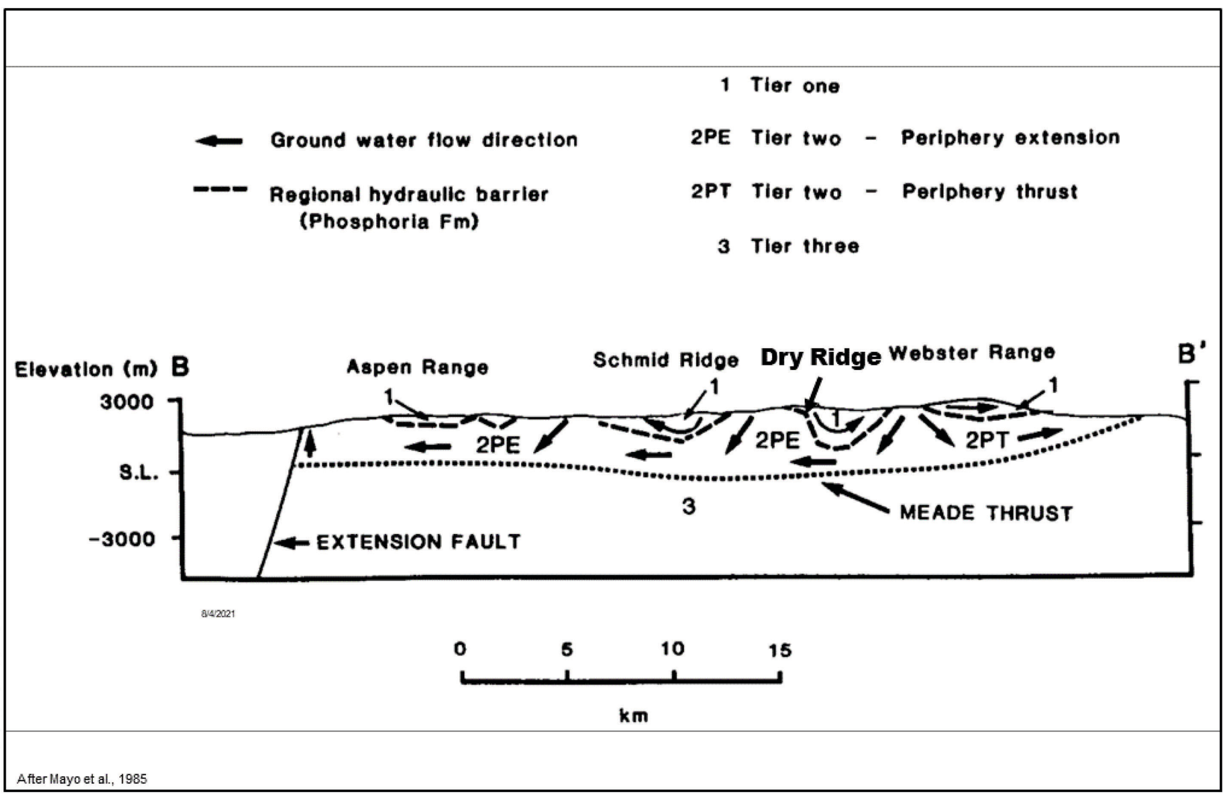
Figure 2-8. Representative Water Level Hydrographs

2.3.3 Groundwater Flow Systems

The interaction of the regional geologic structure, differing hydraulic properties of the geologic units, and the recharge and discharge patterns has led to the identification of multiple groundwater flow systems. Regional groundwater studies (Ralston and Williams, 1979a and 1979b; Ralston et al., 1981; Ralston et al., 1983; Mayo et al., 1985) identify three tiers of groundwater flow systems associated with the Meade thrust plate of southeastern Idaho (**Figure 2-9**). Tier 1 includes local- and intermediate-scale flow systems in the bedrock above the low-permeability Meade Peak Member of the Phosphoria Formation and in the alluvium and colluvium near the land surface. Tier 2 includes the regional-scale flow systems in the bedrock below the Meade Peak Member but within the Meade thrust plate. Tier 3 includes very deep flow systems below the Meade thrust plate.

Groundwater flow in the Tier 1 (local- and intermediate-scale) systems is controlled by topography, stratigraphy and geologic structure, whereas groundwater flow in the Tier 2 (regional-scale) system is controlled primarily by geologic structure and only secondarily by stratigraphy. Tier 1 aquifers are recharged locally and discharge locally. Tier 2 aquifers are recharged where exposed at the surface and where they subcrop beneath saturated alluvium. They typically discharge at springs along the extensional fault that bounds the west side of the Aspen Range and along the eastern edge of the Meade thrust plate (**Figure 2-9**), although local discharge points within the thrust sheet also exist. Very little is known about Tier 3 aquifers since very few wells have penetrated below the Meade thrust over a mile below land surface in the project area.

The groundwater flow and transport model includes the Tier 1 and Tier 2 aquifers. The model is terminated at approximately 4,000 feet below mean sea level, the approximate location of the Meade Thrust fault, which is postulated to be a barrier to groundwater flow. The Tier 1 and Tier 2 groundwater flow systems are described in further detail below.



Schematic Cross-Section of Regional Flow
Husky 1 North Dry Ridge
Conceptual Site Model
Caribou County, Idaho

Figure 2-9. Groundwater Flow Systems Conceptual Diagram

2.3.3.1 Local and Intermediate Flow Systems

Local flow systems are present continuously in the alluvium along the Blackfoot River, Dry Valley Creek, Mill Canyon, Maybe Creek, and Diamond Creek. Secondary local flow systems are present in the alluvium and colluvium in the smaller drainages tributary to those just mentioned. Local- and intermediate-scale flow systems also exist in the Thaynes and Dinwoody formations and in the Rex Chert Member of the Phosphoria Formation.

Flow paths in the local- and intermediate-scale aquifers are relatively short. Flow generally is from higher-elevation areas toward lower-elevation areas, and as a result, the potentiometric surface is typically a subdued replica of topography (**Figure 2-10, Figure 2-11, Figure 2-12**). The topography is dramatic and highly variable, so the potentiometric surface is expected to vary in a similar manner. **Table 2-5** lists coordinates, groundwater surface elevation, total depth, depth of well screen interval and geologic unit screened for monitoring wells that provided potentiometric data for **Figure 2-10**. Contours provided on **Figure 2-10** are combined from alluvium, Dinwoody Formation, and Rex Chert Member to illustrate the generalized water-level pattern shown by the posted data.

Recharge to the local and intermediate flow systems is from infiltration of precipitation and snowmelt on the outcrops and from seepage of surface water along losing reaches of streams crossing the outcrops. Losing reaches are present on all the monitored streams that drain the project area; further discussion is presented in Section 2.4.1. Discharge from the local and intermediate aquifers in the Thaynes and Dinwoody Formations and the Rex Chert Member of the Phosphoria Formation is typically to the alluvial and colluvial aquifers along the drainages, to the numerous springs in the area, to the underlying regional flow system, particularly in areas where the rocks are heavily fractured, and through ET. Alluvial aquifers discharge to gaining reaches of streams, to ET (particularly in wetland areas), and, notably in Dry Valley, as downward seepage to bedrock aquifers of the regional flow system.

Table 2-5. Wells Used for Potentiometric Surface Maps

Well ID	Easting	Northing	Ground Surface Elevation (feet amsl)	Total Depth (feet)	Screened Interval (feet bgs)	Unit
			Local / Intermediate Map			
HU-MW-1A	904048.048	376375.318	7880	22	7-17	Alluvium
HU-MW-4BCS	904250.973	376166.071	7847	100	75-95	Rex Chert
HU-MW-5BCS	906656.254	374257.715	7602	230	185-225	Rex Chert
HU-MW-6BR	907259.308	371978.298	7932	175	110-170	Rex Chert
HU-MW-7BD	900733.527	380633.618	8373	303.8	242-302	Dinwoody
HU-MW-8BCS	898301.439	383862.523	7870	214.6	150-210	Rex Chert
NDR-MW-13BD	883154.009	410920.108	6941	65	40-60	Dinwoody
NDR-MW-14BD	882637.112	412202.042	6911	195	170-190	Dinwoody
NDR-MW-15BD	881525.485	415252.372	6801	65	35-55	Dinwoody
NDR-MW-19A	882634.092	412187.787	6911	25	10-20	Alluvium
MW-104-BD	884328.777	407544.328	7376	222.55	-	Dinwoody
MW-106-BD	885541.267	407415.038	7524	286.65	272-282-	Dinwoody
MW-107-BD	885692.055	406522.33	7637	420	357-417	Dinwoody
NM-MW-12A	887574.834	402482.279	7196	25.2	5-20	Alluvium
DV-2	882980.19	395419.68	6551	63	50-60	Alluvium
DV-3	880105.42	397385.90	6482	22	10-20	Alluvium

Well ID	Easting	Northing	Ground Surface Elevation (feet amsl)	Total Depth (feet)	Screened Interval (feet bgs)	Unit
MC-6	889798.10	394933.52	6821	21	8-18	Alluvium
MC-10	890500.19	394824.54	6866	30.2	8-28	Alluvium
MC-13	891008.7	394021.29	6885	26	4-24	Alluvium
PZ-1	893446.69	389587.66	7242	23	10-20	Alluvium
MW-801-A	886822.23	419222.06	6472	35	12-22	Alluvium
MW-811-A	888883.1	419328.74	6448	26	10-25	Alluvium
MW-815-A	888469.51	417925.7	6455	26	10-25	Alluvium
MW-816-A	885853.96	421367.67	6431	26	10-25	Alluvium
MW-817-A	888160.47	421849.79	6435	26	10-25	Alluvium
MW-818-A	885996.09	422463.87	6427	26	10-25	Alluvium
Regional Map						
MW14-14W	867178.525	398662.273	7223	970	938-958	Wells
MW14-15W	863926.619	395702.032	6366	72	50-70	Wells
MW14-18W	868619.413	393795.374	7153	890	860-880	Wells
MW14-19W	869246.428	390620.023	6523	240.8	224-239	Wells
MW14-27W	869481.732	387602.827	6924	668.5	635-655	Wells
MW14-29W	869022.601	382695.478	6363	68	52-67	Wells
MW14-31W	871072.511	381125.471	6368	66	49-64	Wells
MW-BLR-05	871702.121	377341.162	6357	30	10-25	Wells
MW-BLR-09	870892.131	378564.542	6361	105	28-98	Wells
MW-2W	881475.88	427046.347	6850	-	542-562	Wells
MW-3W	883607.742	425094.541	6569	-	238-258	Wells
MW-12W (SR)	878041.532	429760.052	6882	645	616-636	Wells
MW-13W	875491.893	430848.422	7041	799	742-762	Wells
MW-16W	881175.272	425823.083	6675	875	-	Wells
MW-17W (SR)	882831.593	424092.528	6549	770	-	Wells
SR-Well-7W	871383.197	433066.275	-	-	-	Wells
CHMWW-19	897066.62	365457.79	6558	-	-	Wells
CHMWW-20	895438	368157	6597	-	-	Wells
CHMWW-21	897339.48	369304.7	6665	376	322-372	Wells
GW-6D	888956.554	383402.618	6652	302	256-296	Wells
GW-8D	878781.941	395892.096	-	234	150-200	Wells
GW-9D	883532.798	390611.241	6540	260.5	197-217	Wells
GW-11D	879652.835	392005.85	6655	945	900-920	Wells
GW-12D	881565.929	389380.048	6776	1110	1065-1085	Wells

Well ID	Easting	Northing	Ground Surface Elevation (feet amsl)	Total Depth (feet)	Screened Interval (feet bgs)	Unit
GW-13D	883822.873	387522.41	6594	695	660-680	Wells
GW-14D	884940	385441	6603	908	868-888	Wells
GW-15D	887118.012	383053.66	6612	896	861-881	Wells
GW-16D	880252.16	393532.255	6511	215	176-196	Wells
HU-MW-3BW	904265.63	376179.77	7847	1175	1000-1170	Wells
HU-MW-9A	899091.224	380848.028	8028	45	20-40	Wells
NDR-MW-16BW	879692.595	416445.88	7114	895	727-827	Wells/Monroe Canyon
NDR-MW-18BMC	877231.119	410026.425	6658	317	285-305	Wells/Monroe Canyon
Anderson Well	879406.643	403942.274	6586	260	-	Wells/Monroe Canyon
MW-201-BW	883436.45	408256.63	7458	665	655-665	Wells
MW-301-BW	882880.15	399079.82	6654	302	290-300	Wells/Monroe Canyon
MW-501-BW	884948.04	396473.11	6748	405	390-400	Wells/Monroe Canyon
SM-MW-17BW	888519.992	387599.556	6645	332	290-330	Wells/Monroe Canyon

Notes: Easting and Northing coordinates are Idaho State Plane East (FIPS 1101) NAD83 US feet. bgs = below ground surface.

2.3.3.2 Regional Flow System

The geologic units comprising the regional flow system include the Grandeur Tongue Member of the Park City Formation (typically mapped with the Wells Formation), the Wells Formation, and the Monroe Canyon Formation. They are present continuously throughout the CSM area and are compartmentalized by geologic structure. About 3,000 feet of older Paleozoic-age sedimentary strata underlie the Monroe Canyon Formation in the Meade thrust sheet. These lower Paleozoic rocks may contain aquifers that are part of the regional flow system.

Recharge to the regional flow system is derived from infiltration of precipitation, snowmelt, and runoff on outcrops along Dry Ridge, Dry Valley, and the east side of upper Diamond Creek Valley. Losing reaches of Dry Valley Creek, Maybe Creek, and Diamond Creek provide recharge to the underlying alluvial aquifers, which in turn recharge the regional aquifer system beneath the alluvium. Groundwater in the regional system also enters as deep underflow from the east where the aquifers are present in the subsurface.

Based on potentiometric data from monitoring wells, groundwater flow is generally toward the west-southwest (**Figure 2-13**). Although the Wells and Monroe Canyon Formations dip steeply eastward just east of the axis of the Dry Valley anticline, the groundwater monitoring well data do not indicate an eastward component of flow in the regional aquifer in this area. Rather, groundwater in the regional flow system likely flows westward as shown on **Figure 2-14**. Exceptions to the westward flow may occur at relatively shallow depths beneath anticlinal recharge areas such as Wells and Monroe Canyon formation outcrops along the western side of Dry Ridge and along the axis of the Snowdrift Anticline on the east side of upper Diamond Creek valley.

A strong downward vertical gradient is present in regional flow system recharge areas. For example, the potentiometric surface elevations in wells MW-201-BW and HU-MW-9A, screened in the Wells Formation near the southern end of the North Dry Ridge lease area and the northern end of the Husky 1 lease area, respectively, are approximately 400 feet and 1,500 feet higher than would be expected from contouring of potentiometric surface elevations in the regional flow system using potentiometric surface elevations in other wells within the CSM area. The strong downward hydraulic gradient indicated by the relatively high water-level elevations in these wells is likely due to a combination of hydraulic properties, recharge, and compartmentalization. Low hydraulic conductivities were shown by testing in monitoring well MW-201-BW in the Wells Formation and packer testing in the corehole for monitoring well MW-701-BG in the Grandeur Tongue of the Park City Formation at the North Maybe Mine open pit. The existence of transient pit lakes in the North Maybe and South Maybe Canyon open pits (Global Environmental Technologies, 2007; AECOM, 2014; ARCADIS, 2019) supports the packer test results showing low hydraulic conductivities in the uppermost unit of the regional aquifer in that area, the Grandeur Tongue of the Park City Formation.

Further evidence for a strong downward gradient is provided by drilling and monitoring data from well HU-MW-3BW in the northern part of the H1 lease area (Brown and Caldwell, 2014a). Groundwater was encountered about 500 feet below the top of the Wells Formation, at a depth of 1,003 feet below ground surface (bgs), entering the borehole from a fracture. The well was drilled to 1,175 feet bgs, and the water level initially stabilized between about 1,058 and 1,075 feet bgs. After the well was completed, the water level declined gradually until it was below the well casing. Gradual draining of one or more disconnected fractures intersected by the borehole would likely produce this result. The observed water level decline supports the concept of permeability dominated by fractures oriented perpendicular to bedding and of relatively small lateral extent relative to the bedding, and thus poorly interconnected. Such a fracture-dominated system, combined with steeply-dipping to overturned bedding and low primary permeability, could result in groundwater appearing to be perched.

Three vibrating wire piezometers were installed in the HU-MW-3BW borehole and set in the Cherty Shale and Meade Peak Members of the Phosphoria Formation and the Grandeur Tongue of the Park City Formation at depths of 170, 425, and 680 feet bgs, respectively. The water level elevation data from these vibrating wire piezometers and the Wells Formation indicated a downward gradient of approximately one foot per foot, within the intermediate flow system and between the intermediate and regional systems.

West of the H1NDR mine areas and the axis of the Dry Valley anticline, the groundwater in the regional aquifer passes beneath Dry Valley and Schmid Ridge and continues moving west-southwest toward regional discharge points at the extensional fault bounding the west side of the Aspen Range approximately 15 miles from the Project area (ARCADIS, 2015, Ralston et al., 1983). A groundwater divide in the regional flow system exists east of the Project area (**Figure 2-9**), likely in the vicinity of the Snowdrift anticline. East of the divide, the regional groundwater flow is generally east and southeast; west of the divide the regional flow is west and southwest. The divide would be produced by recharge to the regional aquifer east of the Project area. Such recharge could occur where the regional aquifer is exposed along the axis of the anticline in the Diamond Creek drainage east and southeast of the Husky 1 lease areas and where it subcrops beneath the alluvial aquifer in the Diamond Creek Valley downstream of those outcrops.

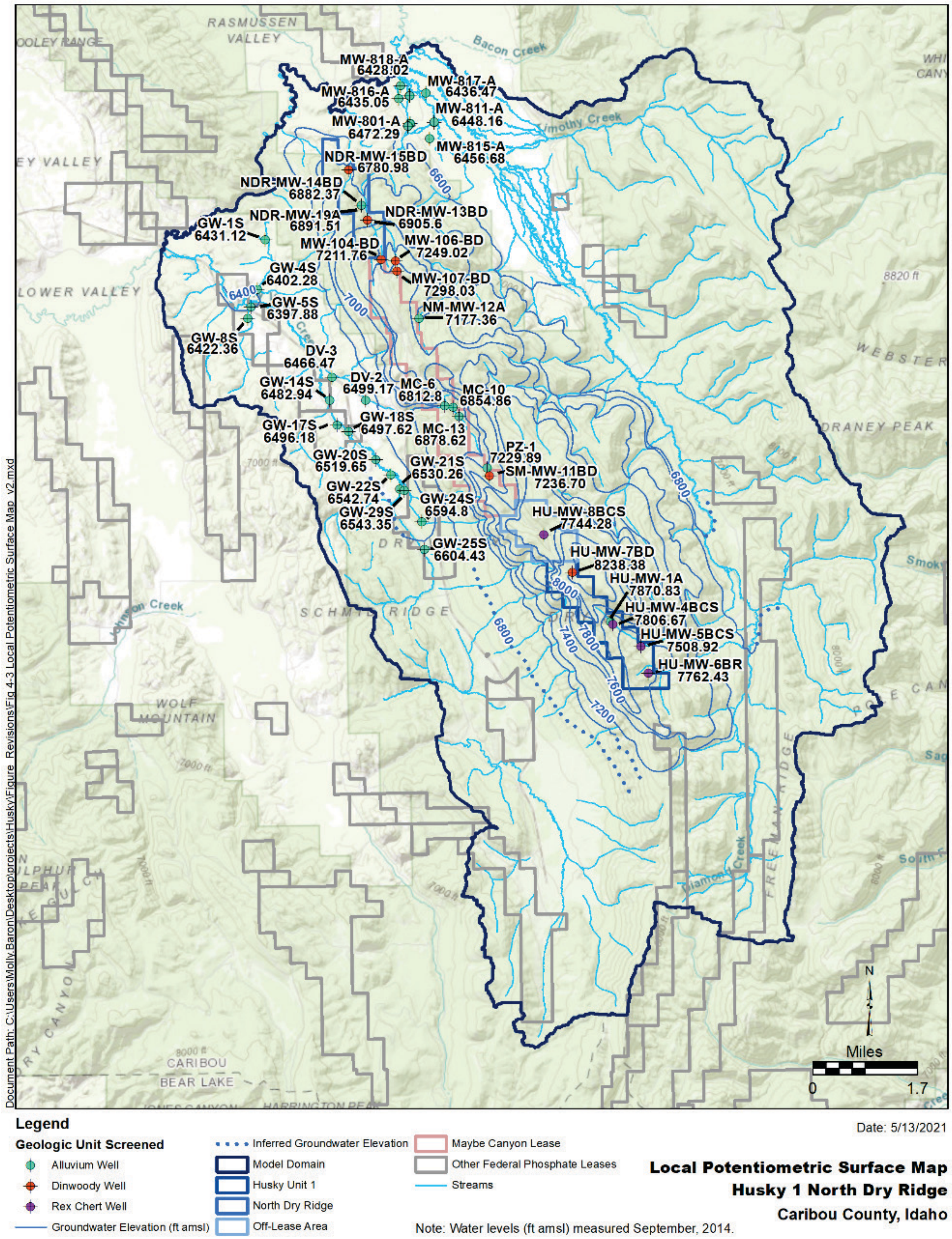


Figure 2-10. Potentiometric Surface Elevation Map, Local and Intermediate Flow Systems

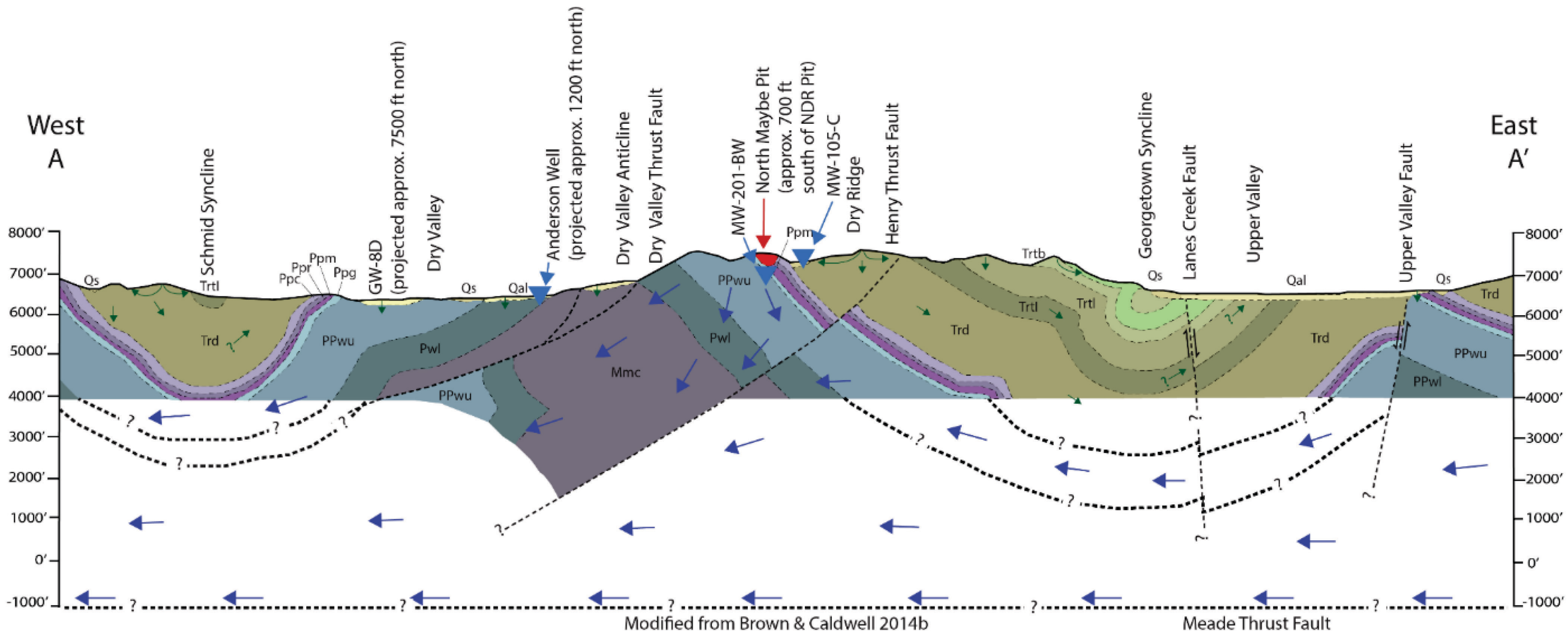


Figure 2-11. Conceptual Groundwater Flow Cross Section A-A'

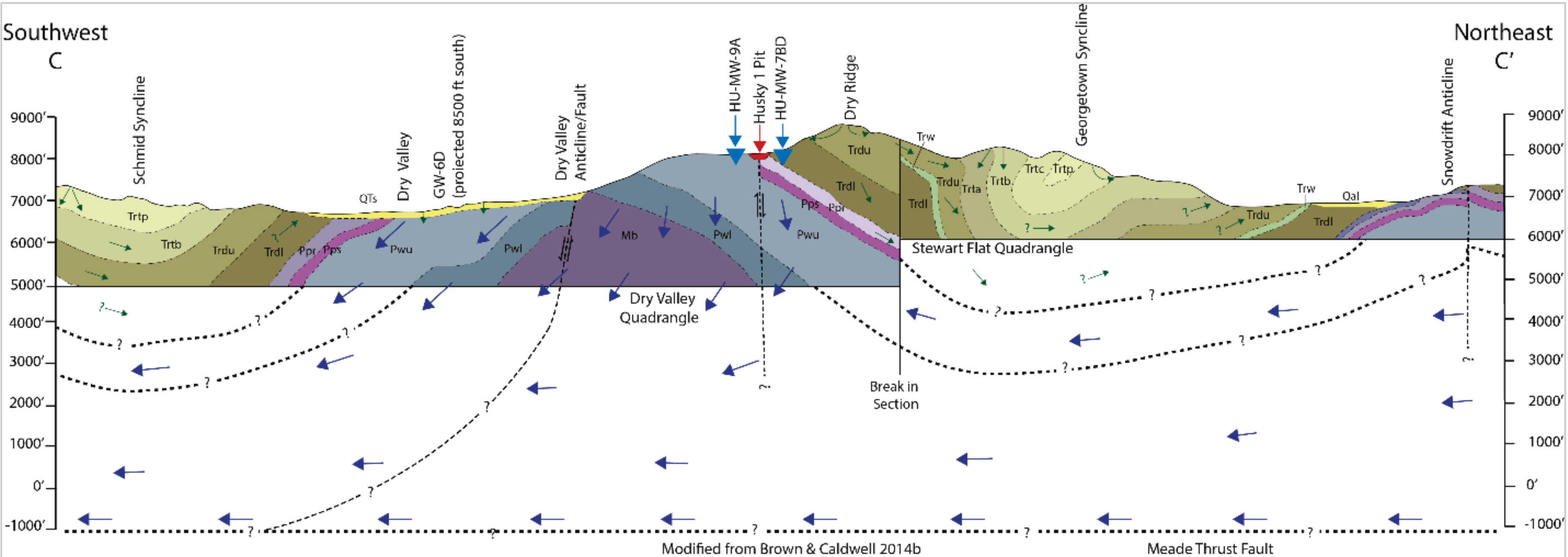


Figure 2-12. Conceptual Groundwater Flow Cross Section C-C'

Potentiometric data suggest a change or discontinuity across the Blackfoot fault north of the North Dry Ridge lease area. North of the fault, in the vicinity of the Rasmussen Valley Mine, groundwater flow in the regional aquifer is generally toward the north and northwest. In contrast, south of the fault, in the H1NDR area and the Dry Valley and Caldwell Canyon Mine areas, regional flow is toward the west-southwest, and potentiometric data, although sparse just south of the Blackfoot fault, suggests that flow in the regional flow system at the north end of the NDR area is to the north-northwest (**Figure 2-13**). The apparent change in flow direction across the Blackfoot fault occurs where the lower Thaynes and Dinwoody Formations (both of which have lower permeability) are adjacent to the Wells and Monroe Canyon Formations. The presence of fault gouge and/or breccia along the faults in the H1NDR area is not well documented but may be suggested by groundwater flow patterns, particularly in cases where lower-permeability units are in contact with higher-permeability units. In addition to the apparent change in flow direction across the Blackfoot fault north of H1NDR, steep hydraulic gradients or changes in flow direction across faults are associated with some faults in the Caldwell Canyon Mine area (Tetra Tech, 2018).

Brecciated zones can provide pathways for enhanced flow of groundwater along a fault, and clayey fault gouge can impede groundwater flow across a fault. Brecciated, higher-permeability zones are expected to be more common in limestone, dolomite, or sandstone units (typically, rocks of the Grandeur Tongue, Wells Formation, or Monroe Canyon Formation), particularly where these rock types are juxtaposed across a fault. In that case, the fault could serve as a conduit to flow along the fault while not impeding flow across the fault. Lower-permeability gouge is expected to be more common where fine-grained sedimentary rocks (typically, rocks of the Thaynes Formation, Dinwoody Formation, or Meade Peak Member of the Phosphoria Formation) are adjacent to a fault. Where fine-grained rocks are present on both sides of a fault, flow along and across the fault may be impeded or unaffected, but it would not be expected to be enhanced. Where brecciated rocks on one side of a fault are juxtaposed against fine-grained sedimentary rocks across the fault, flow along the fault may be enhanced and flow across the fault may be impeded. Ralston et al. (1981) concluded that because of the relatively high porosities and permeabilities of thrust-related features, thrusting within the Meade plate is unlikely to have created a barrier to any flow systems. Considering this, portions of the Dry Valley thrust fault, the deeper parts of the Henry thrust fault, and the Meade thrust fault that consist of the Wells Formation and Monroe Canyon Formation on both sides of the fault may exhibit higher permeability and act as preferential conduits for groundwater flow. It is unlikely that those parts of the faults would impede groundwater flow either along or across the faults.

2.4 Surface Water Hydrology

The model area is in the Blackfoot River Sub-Basin (fourth-order Hydrologic Unit Code [HUC 4] 17040207) and is drained by the Blackfoot River. The area contains the Lanes Creek-Diamond Creek and the Upper Blackfoot River HUC 5 watersheds. Watershed boundaries and streams in the area are shown in **Figure 2-14**. The Blackfoot River is located along the north side of the Project area, and Dry Valley Creek and Diamond Creek are located along the west and east sides, respectively. These streams are characterized as low-gradient, wide-valley streams. Their tributaries in the Project area are relatively high-gradient channels surrounded by steep, mountainous slopes.

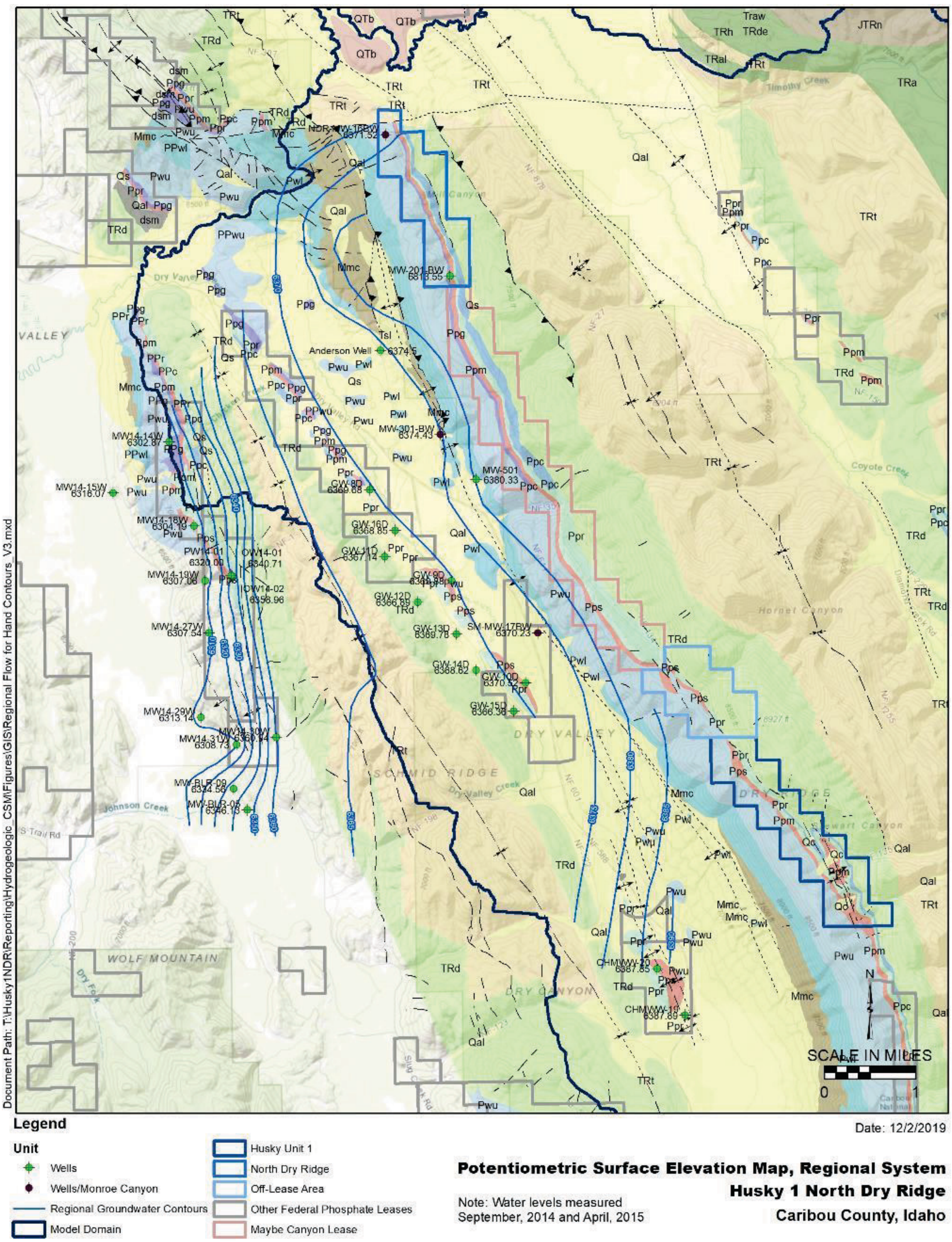


Figure 2-13. Potentiometric Surface Elevation Map, Regional Flow System

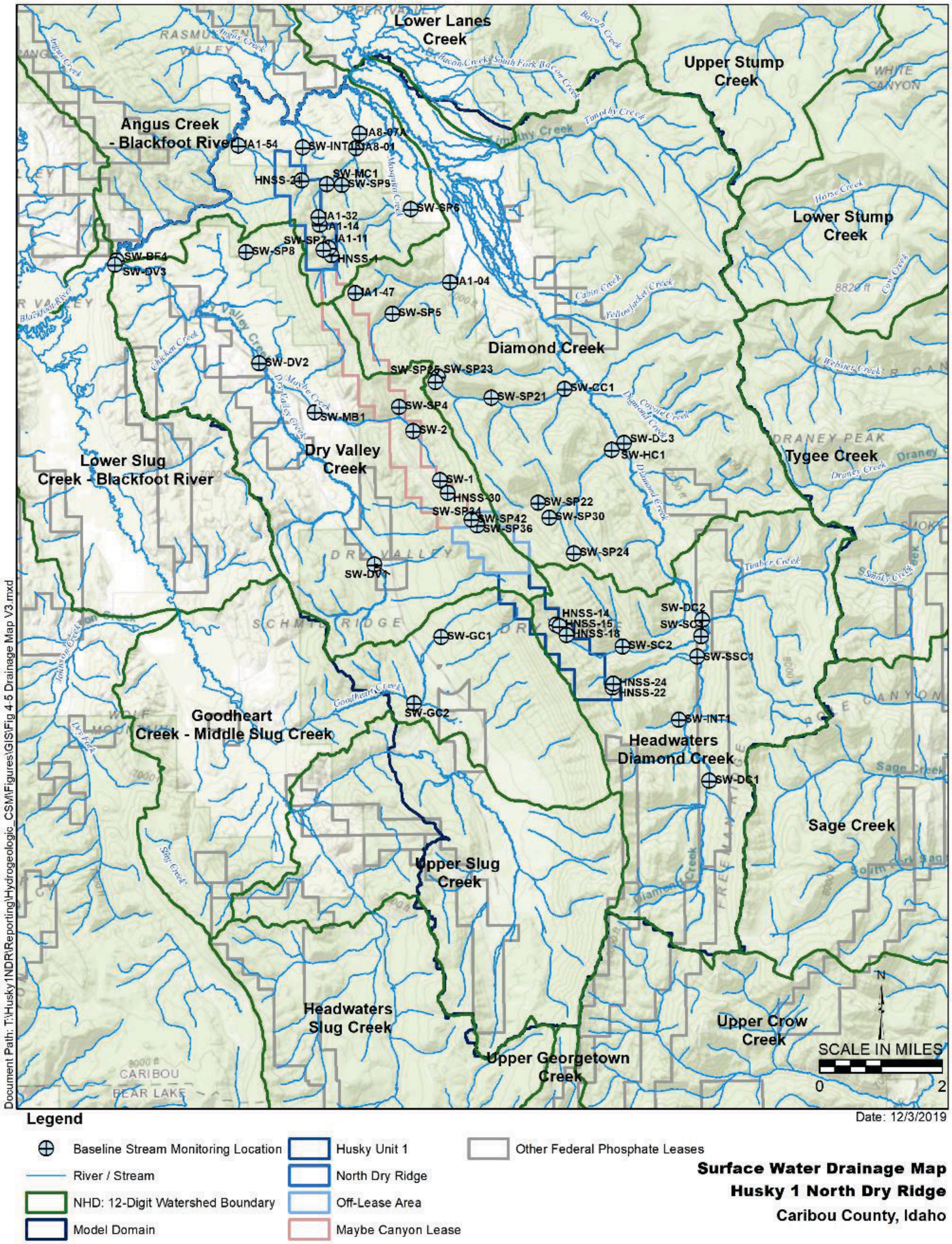


Figure 2-14. Surface Water Drainages and Monitoring Locations

2.4.1 Gain-Loss Surveys

Groundwater and surface water interrelationships in the area vary in both location and time. Synoptic gain-loss surveys were completed on the Blackfoot River, Maybe Creek, Mill Canyon, Kendall Canyon, Campbell Canyon, Hornet Canyon, Stewart Canyon, and South Stewart Canyon for this Project, and similar data on Diamond Creek and Dry Valley Creek are available. **Figure 2-15** shows the reaches of these streams identified as losing water to the groundwater system or gaining water from the groundwater system; however, the exact locations of gain and loss would be expected to vary based on transient annual recharge conditions. Gaining reaches included segments in the upper, middle, and lower reaches of Diamond Creek (separated by losing reaches); upper and middle Dry Valley Creek (separated by losing reaches), the upper reach of Maybe Creek, and isolated reaches of the creeks in South Stewart Canyon, Stewart Canyon, Hornet Canyon, Kendall Canyon, and Mill Canyon. Although not shown on **Figure 2-15**, the Blackfoot River also receives groundwater from the alluvial aquifer in a reach about 400 to 800 feet downstream of the confluence of Spring Creek with the river (AECOM, 2015). Two transects, each including a stilling well in the river to provide the river water surface elevation, two piezometers in the alluvial aquifer 10 and 20 feet from the southern side of the river, and one piezometer in the river bed adjacent to the stilling well, exhibited hydraulic gradients horizontally and vertically toward the river from the alluvial aquifer. The remaining reaches lose water to the groundwater system or to ET.

The stream channels and alluvium in South Stewart, Stewart, Hornet, Kendall, and Mill Canyons are in the outcrop area of the geologic units that comprise the local and intermediate groundwater flow system. Because these valleys are expected to be discharge areas for the local and intermediate flow system, the combined flow of surface water in the stream and groundwater in the alluvium should increase downstream. Only the stream flow, not the combined stream flow and alluvial groundwater flow, was measured during the synoptic gain-loss surveys. No detailed studies of these alluvial aquifers were made, so groundwater flow has not been quantified. Exchange of water between the streams and the alluvial aquifers can result from down-valley changes in the capacity of the alluvial aquifer to transmit groundwater (increases or decreases in transmissivity, cross-sectional area, and/or hydraulic gradient). Thus, gaining reaches of the streams may occur because the stream receives water from springs or interflow, or because the alluvial aquifer's carrying capacity decreases and some of the alluvial groundwater enters the stream. Synoptic flow measurements along Mill Canyon (AECOM, 2009) identified at least 14 losing reaches and 13 gaining reaches. The gains were attributed to inflows from springs emanating from the local/intermediate bedrock aquifer and the alluvial aquifer, and discharge from the alluvial aquifer directly into the stream, particularly where the alluvial aquifer became constricted or the gradient flattened. The stream flow gains and losses should therefore be considered in the broader context of combined surface water and alluvial groundwater flow within the valleys.

In Dry Valley, the flow in the ephemeral drainages on the east side of the valley is lost into the alluvial aquifer before reaching Dry Valley Creek, and Dry Valley Creek itself loses water to the alluvial aquifer through more than half of its length. Maybe Creek, after gaining flow from the local and intermediate flow system aquifers in its upper reaches, loses water to the regional groundwater system where it crosses the Wells Formation outcrop just before leaving Maybe Canyon and to the Dry Valley alluvial aquifer where it flows across alluvium before joining Dry Valley Creek. Water levels in the Dry Valley alluvial aquifer are on the order of 100 feet higher than water levels in the underlying regional aquifer, and groundwater derived from direct recharge to the alluvial aquifer and losses from Dry Valley Creek recharges the underlying regional aquifer. The relationship between the alluvial aquifers in other areas and the underlying bedrock aquifers, except at a few specific locations (as opposed to along segments of the alluvial aquifers), has not been sufficiently characterized to draw similar conclusions regarding exchange of groundwater between the alluvial and bedrock aquifers.

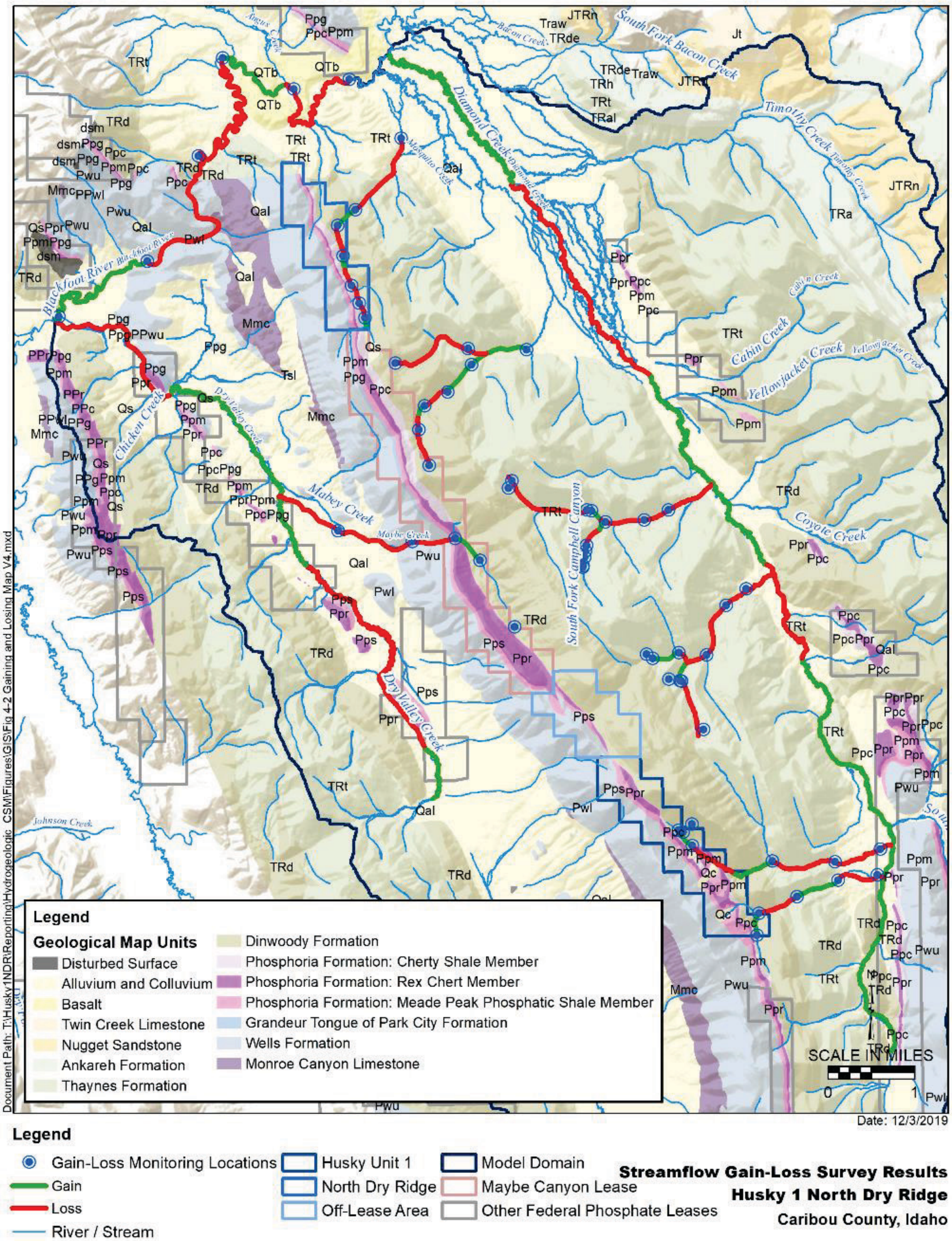


Figure 2-15. Streamflow Gain-Loss Survey Results

3.0 GROUNDWATER FLOW MODEL CONSTRUCTION AND CALIBRATION

The CSM was used to guide the groundwater flow and transport model construction. The model code selection, model grid and layering, and boundary conditions selected based on the CSM are described in the following sections. Groundwater flow model calibration is also discussed in this chapter.

3.1 Model Code

The groundwater flow model was constructed for the MODFLOW family of modeling codes using the Groundwater Vistas graphical user interface (Version 7.24, Build 185; Environmental Simulations, Inc., 2017). The groundwater flow and transport model was implemented using the MODFLOW-SURFACT finite-difference code (Version 4; HydroGeoLogic, 2011). MODFLOW-SURFACT was selected over MODFLOW-NWT due to its improved and computationally more efficient Pre-conditioned Conjugate Gradient solver (PCG5), and the adaptive time stepping and output (ATO) package that reduces simulation time.

3.2 Model Grid and Layering

The groundwater model domain is approximately 16.5 miles long and 11.3 miles wide, encompassing about 186 square miles (**Figure 3-1**). The model grid is shown in plan view on **Figure 3-2** and in cross section on **Figure 3-3** and **Figure 3-4**; the cross section locations are indicated on **Figure 3-2**. The model grid is rotated 30 degrees counterclockwise from north, so the long axis is oriented North 30° West to match the average strike of the stratigraphic units and the alignment of the mine pits. The active portion of the model domain covers about 115 square miles, including Dry Valley Creek and Diamond Creek drainages. External model boundaries coincide with the Blackfoot River, hydrologic basin divides, and/or groundwater divides. The model grid is 616 rows and 178 columns, with horizontal grid spacing from a minimum of 100 feet by 100 feet in the mine areas (**Figure 3-2**) to a maximum of 750 feet by 750 feet at the edges of the model domain.

Vertically, the model domain extends from the land surface to an average depth of approximately 11,000 feet. The depth includes the entire Tier 1 and Tier 2 flow systems (**Figure 2-9**) down to the Meade thrust fault. The model includes 12 layers of variable thickness, representing the hydrostratigraphic units described in **Table 2-2** plus the Lower Paleozoic unit. Model layers and corresponding hydrostratigraphic units are listed in **Table 3-1**. Some hydrostratigraphic units were present in multiple model layers, such as the Monroe Canyon in Layers 8-10, where it outcrops. However, the purpose of **Table 3-1** is to list the primary hydrostratigraphic unit in each model layer. Also, some model layers were subdivided as needed for flow calibration and transport simulations. The layer elevations vary throughout the model domain to closely follow the geologic structure in the model domain. The geologic model on which the layer elevations are based was constructed from geologic maps and cross sections published by the United States Geological Survey (Cressman and Gulbrandson, 1955; Montgomery and Cheney, 1967; Oriel and Platt, 1980; Rioux et al., 1975).

Mathematical constraints in the MODFLOW-SURFACT code require that the model layers be present continuously throughout the model domain, and the minimum thickness assigned to any model layer was 1 foot. Where a hydrogeologic unit is exposed at the surface or directly below alluvium/colluvium/weathered bedrock, the thicknesses of the overlying model layers were set to a minimum thickness and assigned to the weathered bedrock zone. To compensate for the thicknesses of the overlying weathered bedrock layers in model Layers 1 through 6, the thickness of the layer normally used to represent that unit was decreased such that the sum of the layers representing that unit represents the actual thickness of that unit as present in the subsurface at that location.

The model layers were first assigned aquifer properties of hydraulic conductivity, specific yield, and specific storage according to the hydrogeologic unit(s) represented by the model layer. During calibration, zones were assigned within a hydrogeologic unit as needed, such as the alluvium in layer 1, to allow different property values within a hydrogeologic unit. The zonal assignments are shown in **Table 3-2** and in **Figure 3-5, Figure 3-6, Figure 3-7,**

Figure 3-8, Figure 3-9, and **Figure 3-10**. The ranges of the property values for the hydrogeologic units are summarized in **Table 2-2**. These zonal values were adjusted during calibration of the flow model, as described in Section 3.4.3.

Table 3-1. Hydrostratigraphic Units Represented by Model Layers

Model Layer	Primary Hydrogeologic Unit Represented[1]
1	Alluvium/Colluvium, Backfill, and Weathered Bedrock
2	Thaynes Formation
3	Upper Dinwoody Formation
4	Lower Dinwoody Formation
5	Rex Chert Member of the Phosphoria Formation
6	Meade Peak Member of the Phosphoria Formation
7	Grandeur Tongue Member of the Park City Formation
8	Upper Wells Formation
9	Middle Wells Formation
10	Lower Wells Formation
11	Monroe Canyon
12	Lower Paleozoic

[1] Where the primary unit was present, the layer thickness represents that unit. Where the primary unit is absent, the layer thickness is a minimum of 1 foot and represents the uppermost unit.

Table 3-2. Model Hydraulic Conductivity and Storage Zones

Geologic Unit	Model Zone
Alluvium/Colluvium (Dry valley) Diamond Valley	1 and 15 16
Thaynes Formation	2
Dinwoody Formation: Upper – Dry Ridge Lower – Dry Ridge	3 12 17
Rex Chert Unspecified Rex Chert – Dry Ridge	4 13 and 20
Meade Peak Unspecified Meade Peak – Dry Ridge	5 21
Grandeur Tongue Unspecified Grandeur Tongue – Dry Ridge	6 14
Weathered Zone (Layers 1-6) Maybe Creek Weathered Zone	9 18
Wells Formation: Upper – Dry Ridge Middle – Dry Ridge Lower	6 19 19 7
Monroe Canyon Formation	8
Lower Paleozoic	10
Backfill – North Maybe Mine, South Maybe Mine, and Cross Valley Fill	22 and 23

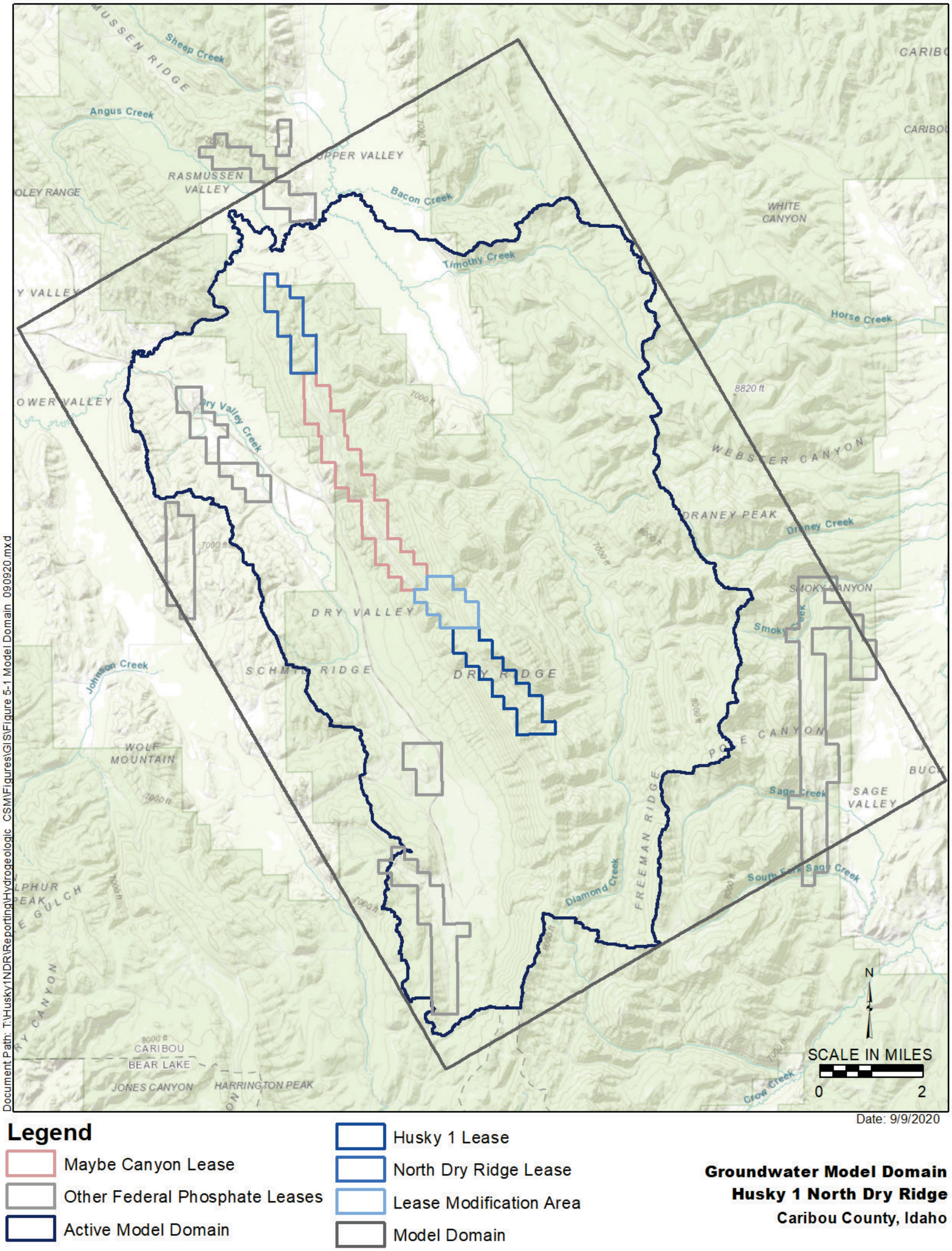


Figure 3-1. Groundwater Model Domain

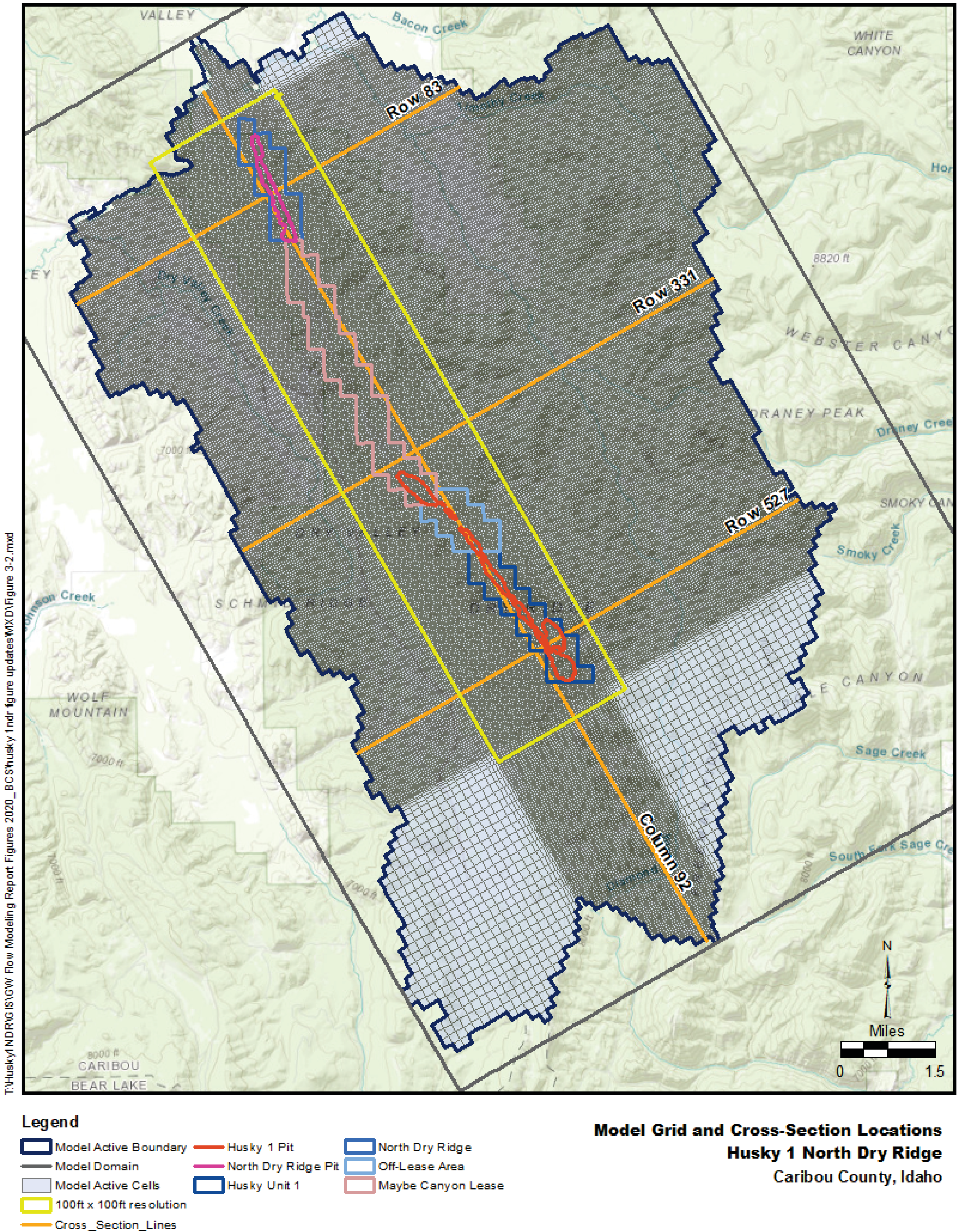


Figure 3-2. Model Grid and Cross-Section Locations

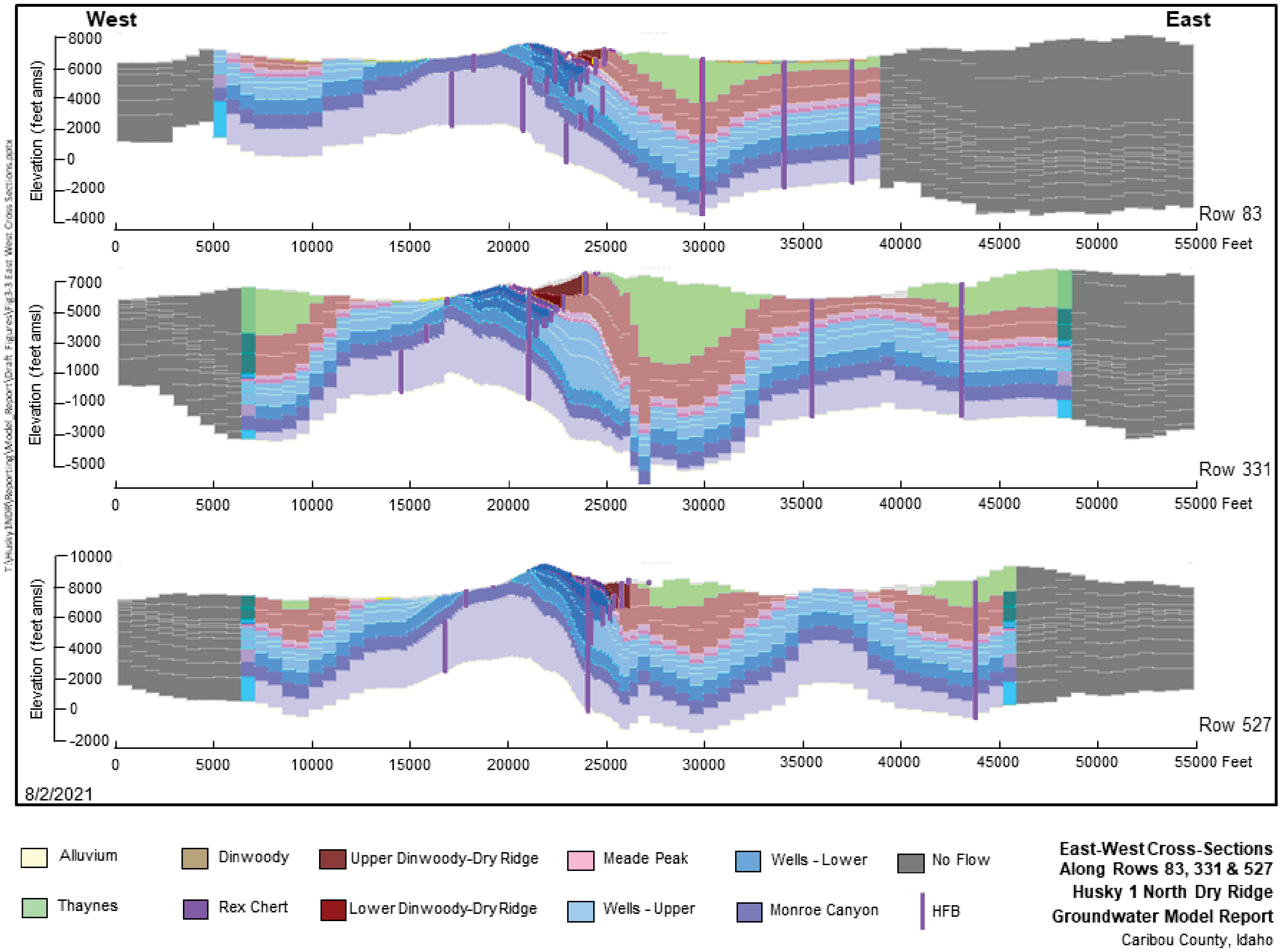


Figure 3-3. West-East Cross-Sections Along Rows 83, 331, & 527

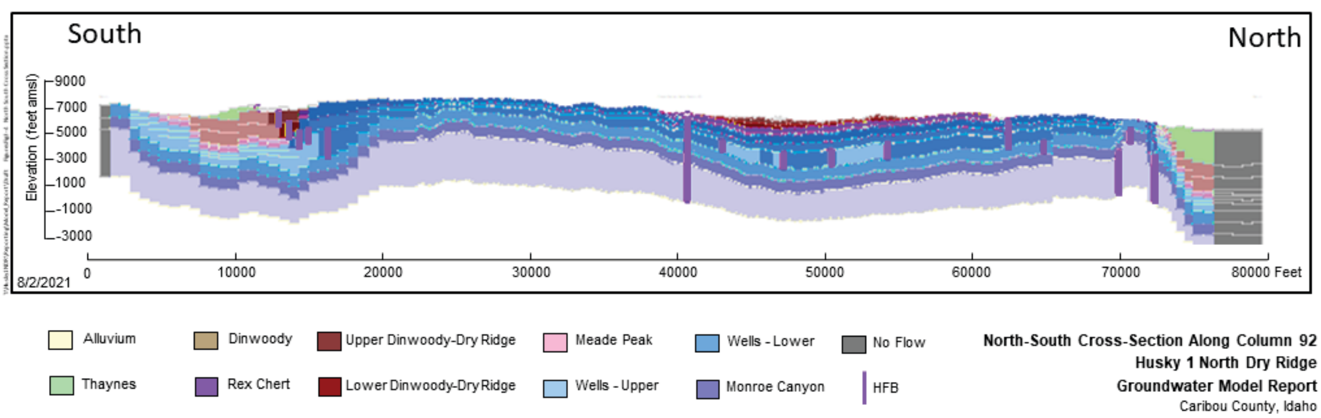


Figure 3-4. South-North Cross-Section Along Column 92

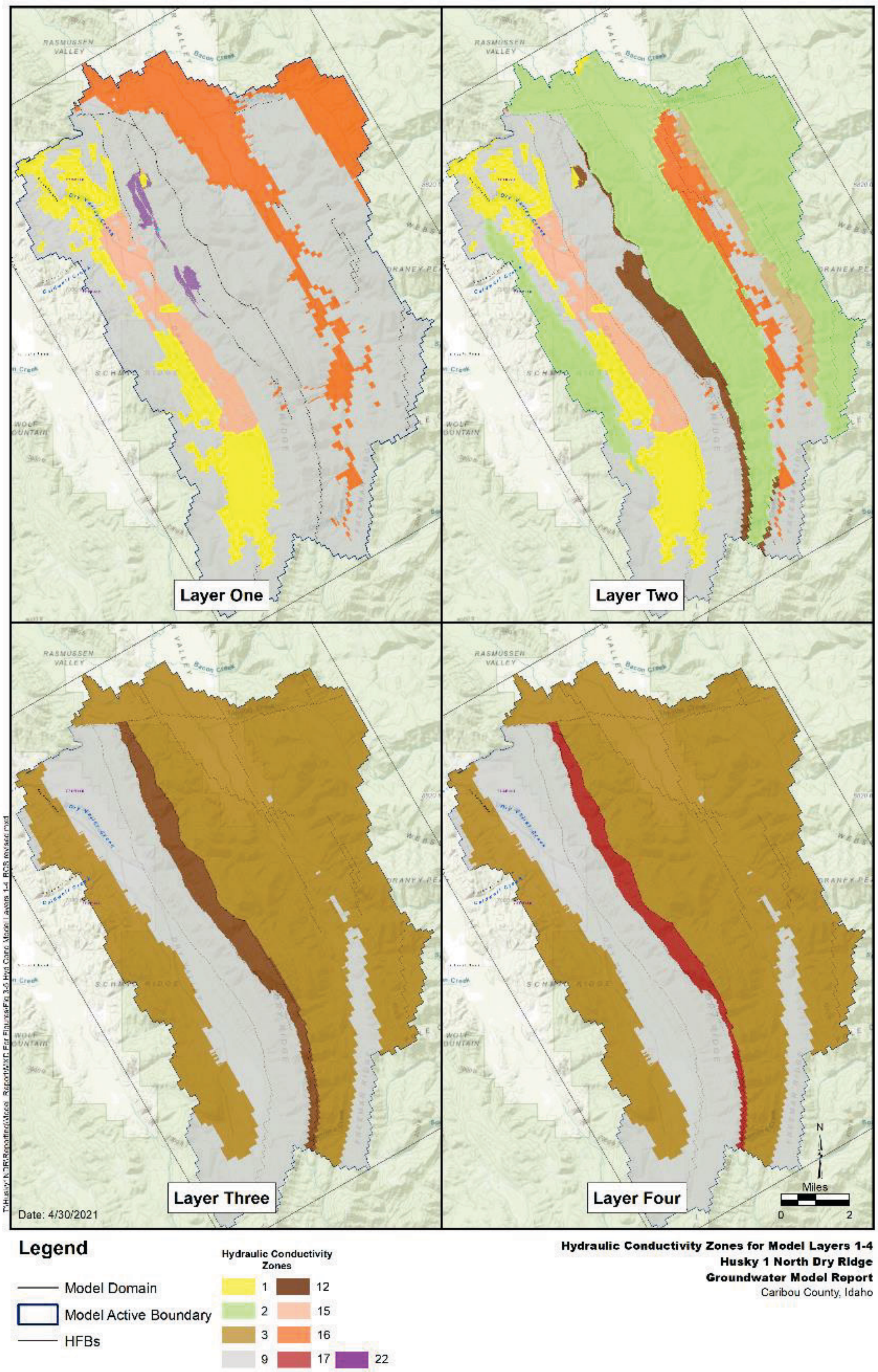


Figure 3-5. Hydraulic Conductivity Zones for Model Layers 1-4

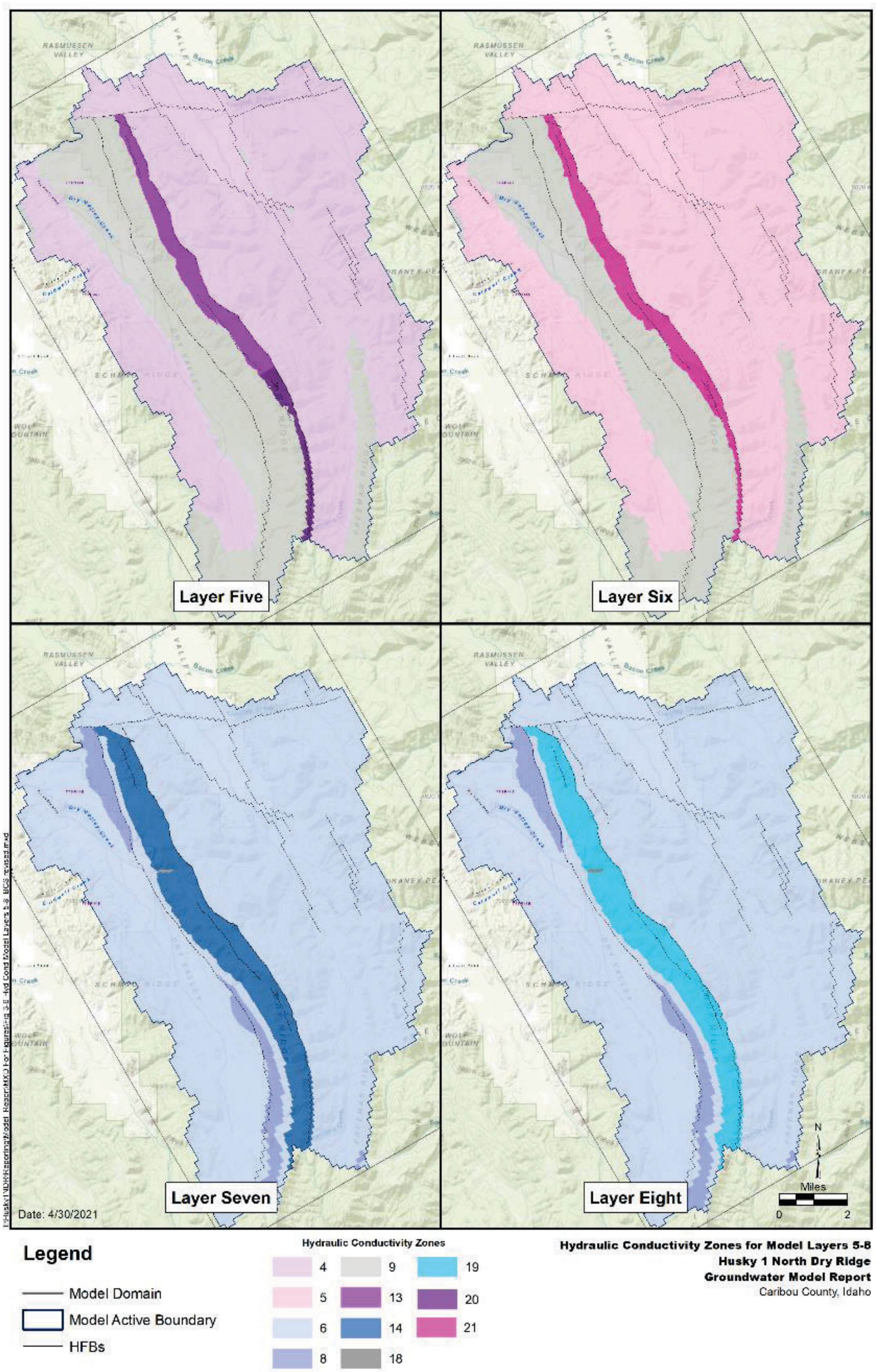


Figure 3-6. Hydraulic Conductivity Zones for Model Layers 5-8

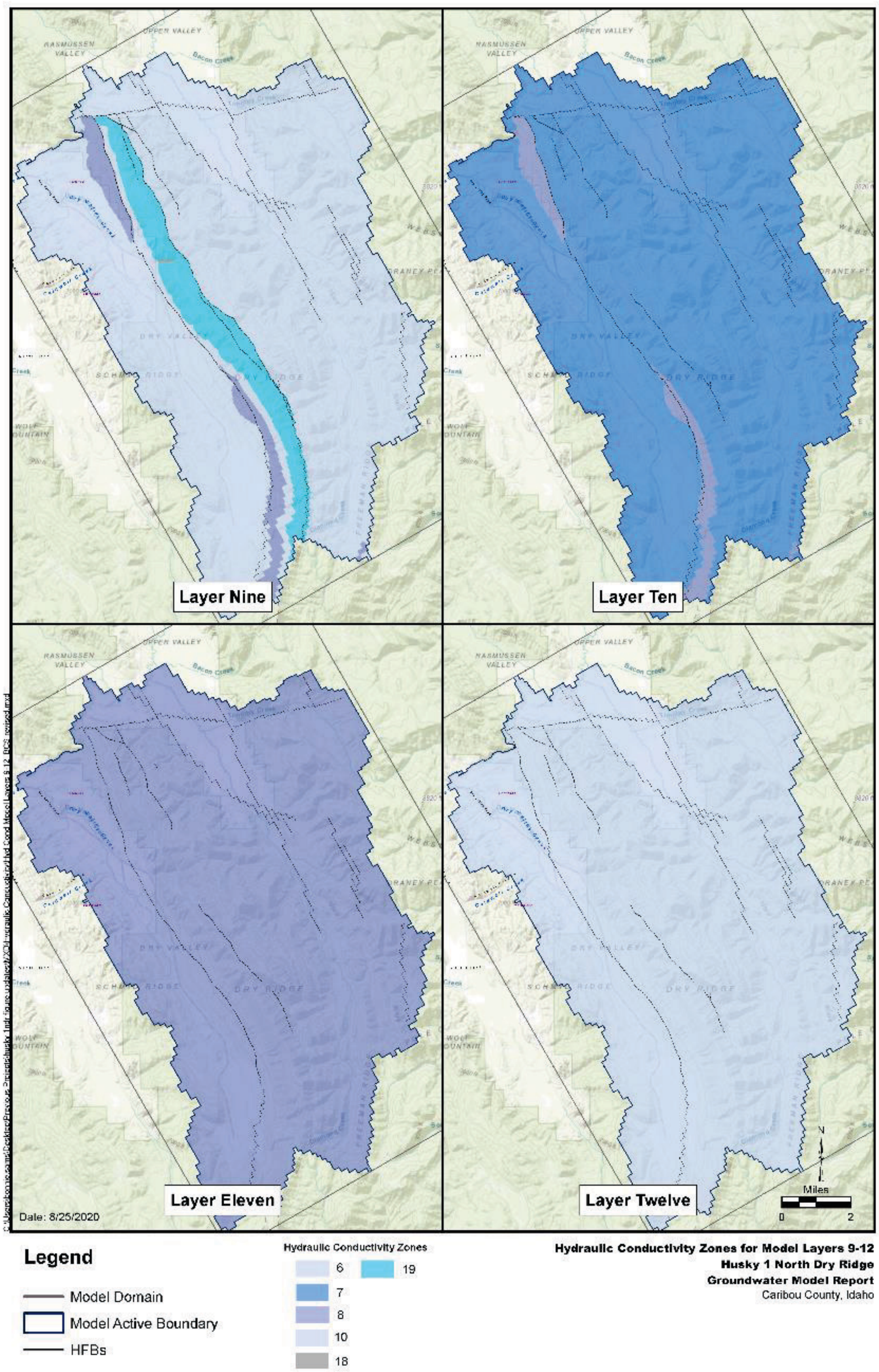


Figure 3-7. Hydraulic Conductivity Zones for Model Layers 9-12

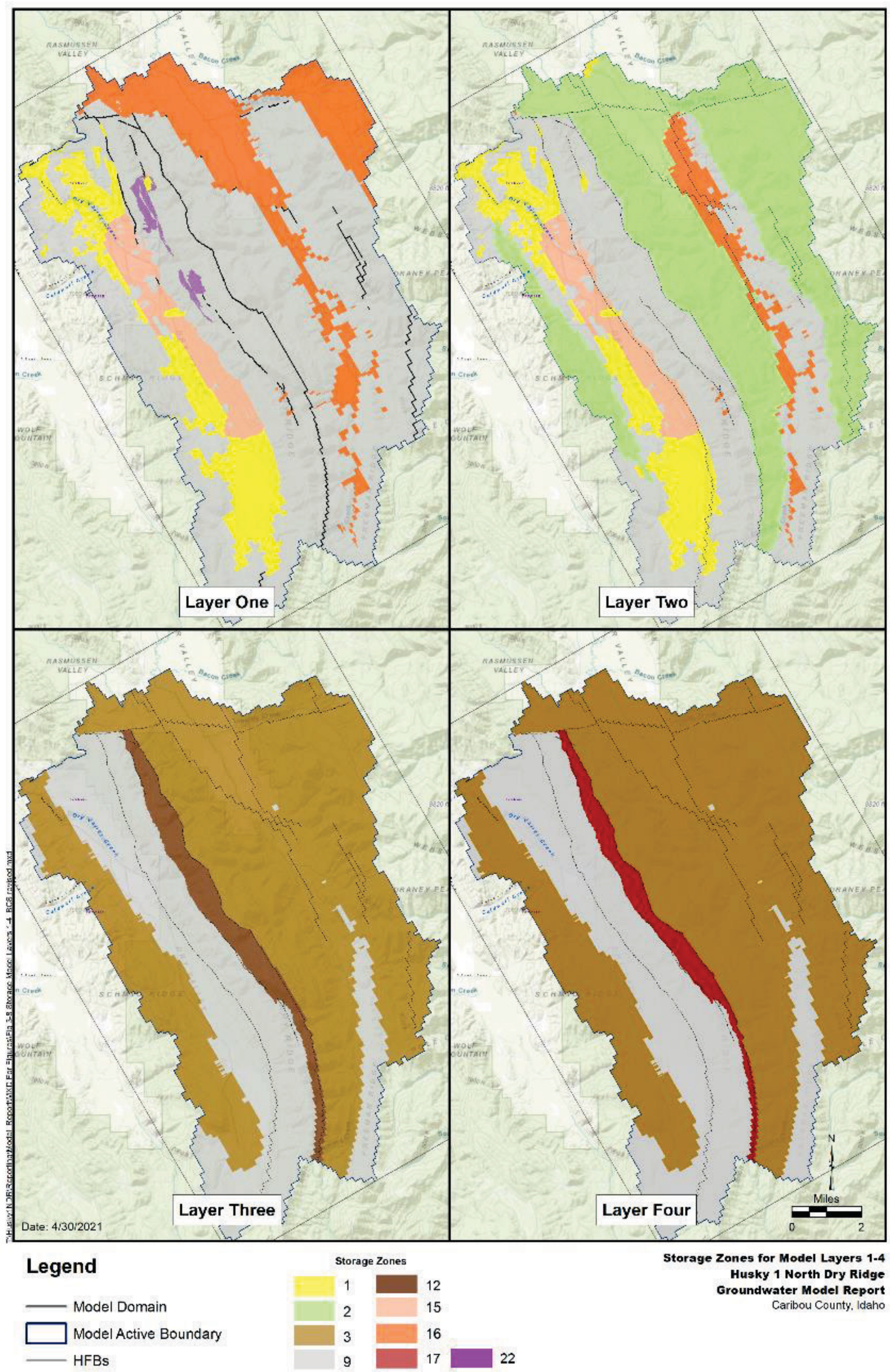


Figure 3-8. Specific Storage Zones for Model Layers 1-4

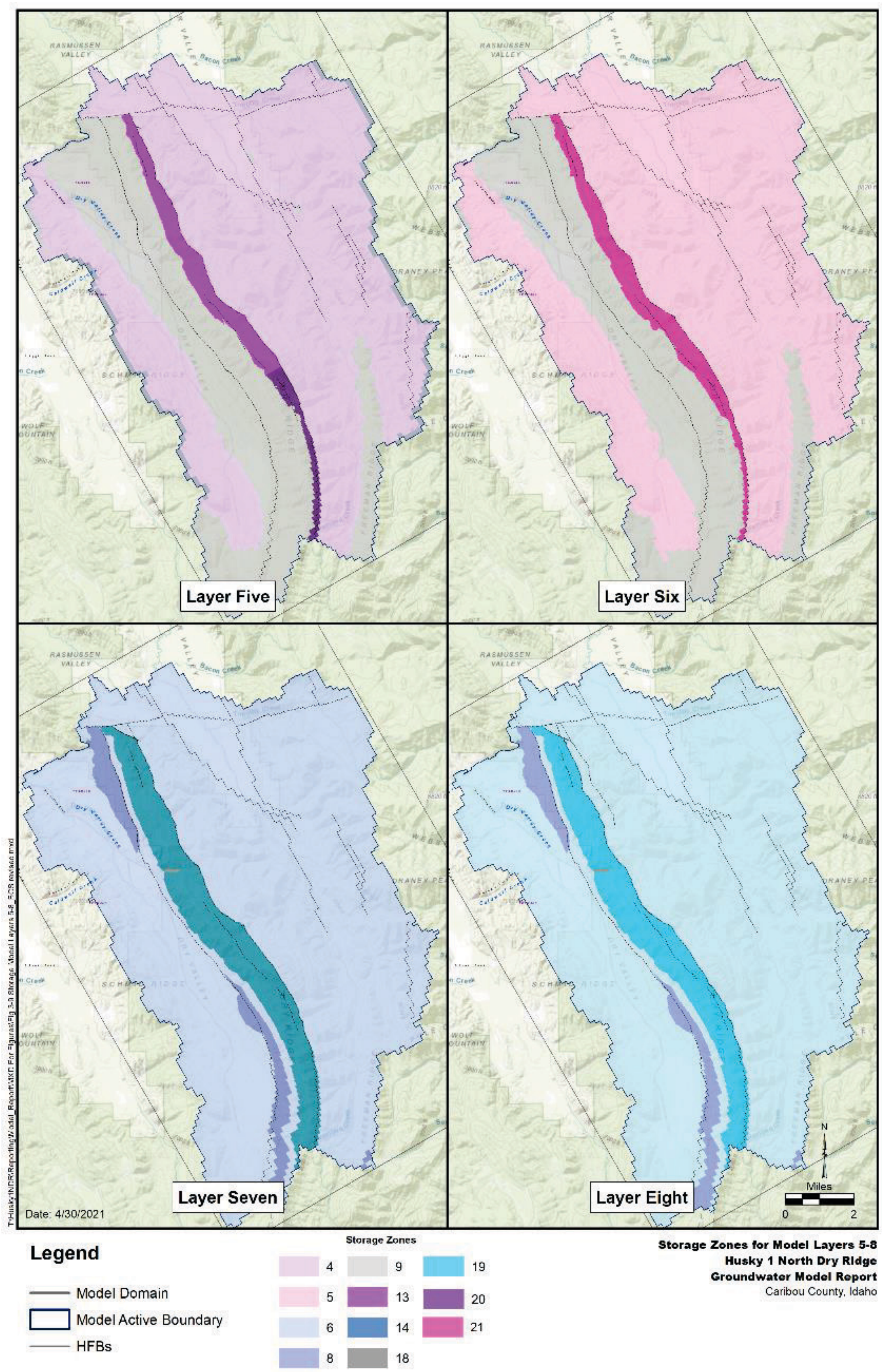


Figure 3-9. Specific Storage Zones for Model Layers 5-8

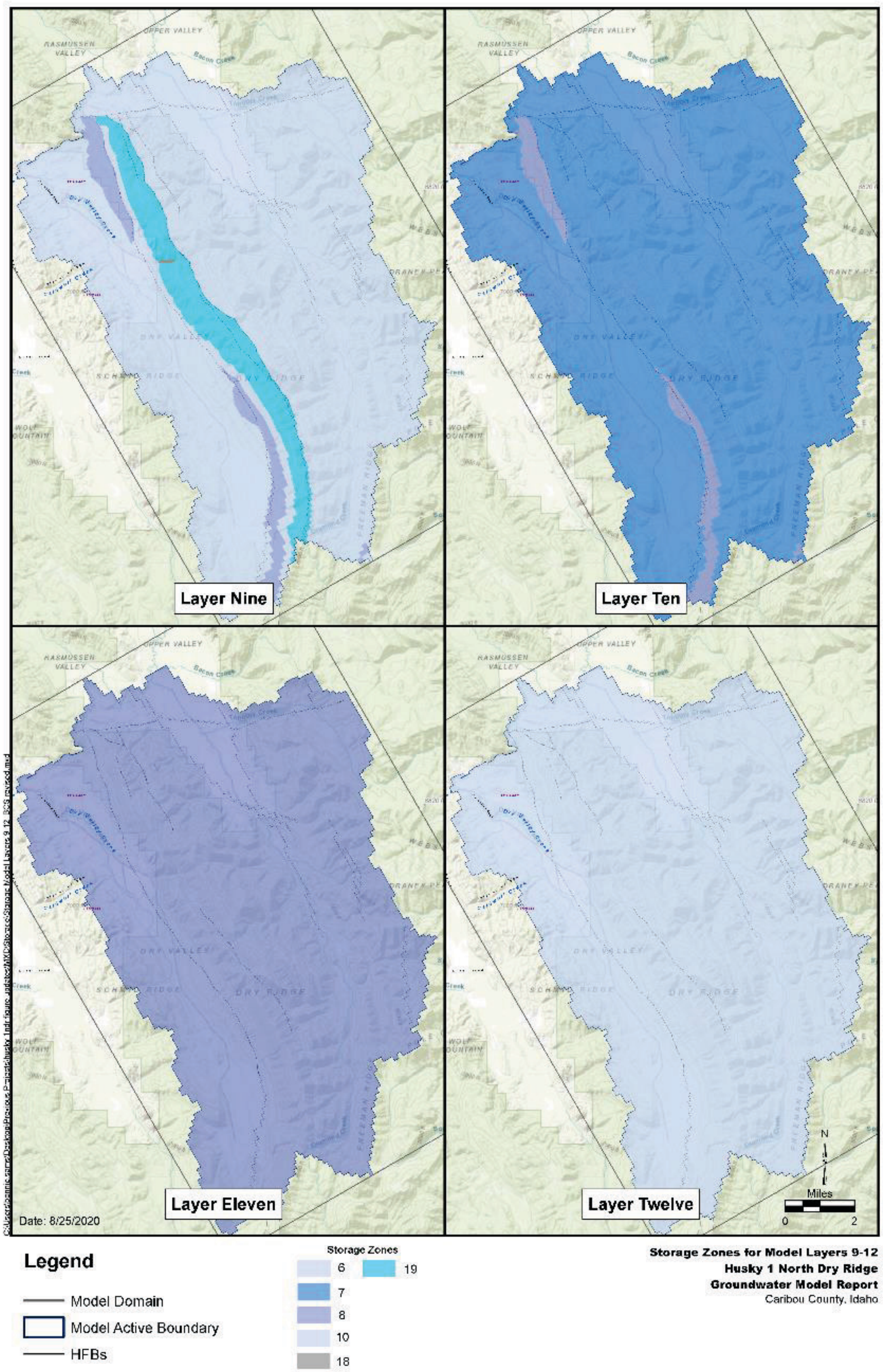


Figure 3-10. Specific Storage Zones for Model Layers 9-12

3.3 Boundary Conditions

Hydrogeologic features or conditions represented as boundary conditions within the model are described in this section. MODFLOW and MODFLOW-SURFACT boundary conditions are of three types: specified head, specified flux, and head-dependent flux; the latter two types were used in the H1NDR groundwater model. Head-dependent flux boundaries within the model include Stream Flow Routing (SFR) boundary conditions to represent the streams, Evapotranspiration (ET) boundary conditions to represent water consumption by wetland vegetation, and General Head Boundary (GHB) boundary conditions to represent groundwater flow into or out of the model at the outer edges of the model. Specified-flux boundary conditions used in the model include Recharge (referred to as a "property" in Groundwater Vistas). The MODFLOW Horizontal Flow Barrier (HFB) package, which simulates thin, vertical, low-permeability geologic features that impede horizontal flow of groundwater, was used to represent major faults. No-flow boundaries were established along external model boundaries where groundwater divides are assumed to exist. Boundary conditions in the twelve model layers are shown in **Figure 3-11, Figure 3-12, Figure 3-13,** and **Figure 3-14**.

3.3.1 Recharge

Recharge to the groundwater system from precipitation throughout the model domain was assigned to model layer 1 as a percentage of average annual precipitation. Average annual precipitation values for 2,640 feet by 2,640 feet blocks were obtained from the PRISM database (PRISM Climate Group, 2019), and the PRISM precipitation values were contoured to better reflect the smoothly changing elevations. The average annual precipitation generally increases with elevation, as illustrated in **Figure 3-15**. Precipitation within the model domain ranges from approximately 21 inches along the Blackfoot River near the confluence of Diamond Creek to 37 inches per year at Husky 1 and the Webster Range along the eastern boundary of the model. Areas with average annual precipitation between 20 and 25 inches per year were assigned initial recharge of 11 percent of precipitation, areas with 25 to 30 inches per year were assigned initial recharge of 14 percent of precipitation, and areas with more than 30 inches per year of precipitation were assigned initial recharge of 18 percent of precipitation (**Table 2-4**). However, recharge to the subsurface varies based on the geologic unit and the ground cover present at the surface. For example, very tight formations such as the Meade Peak Member cannot accept significant recharge, so water either runs off to streams or infiltrates farther downslope into more permeable material. Additionally, the model represents net recharge after ET, so the surface vegetation type affects net recharge. Therefore, the initial values were adjusted during calibration to reproduce measured hydraulic heads and prevent mounding of water at the land surface. Final groundwater recharge values after model calibration (**Figure 3-15**) ranged from 0.32 inches per year over the Meade Peak Member outcrops to 10.96 inches per year in high-elevation areas along Dry Ridge and the Webster Range.

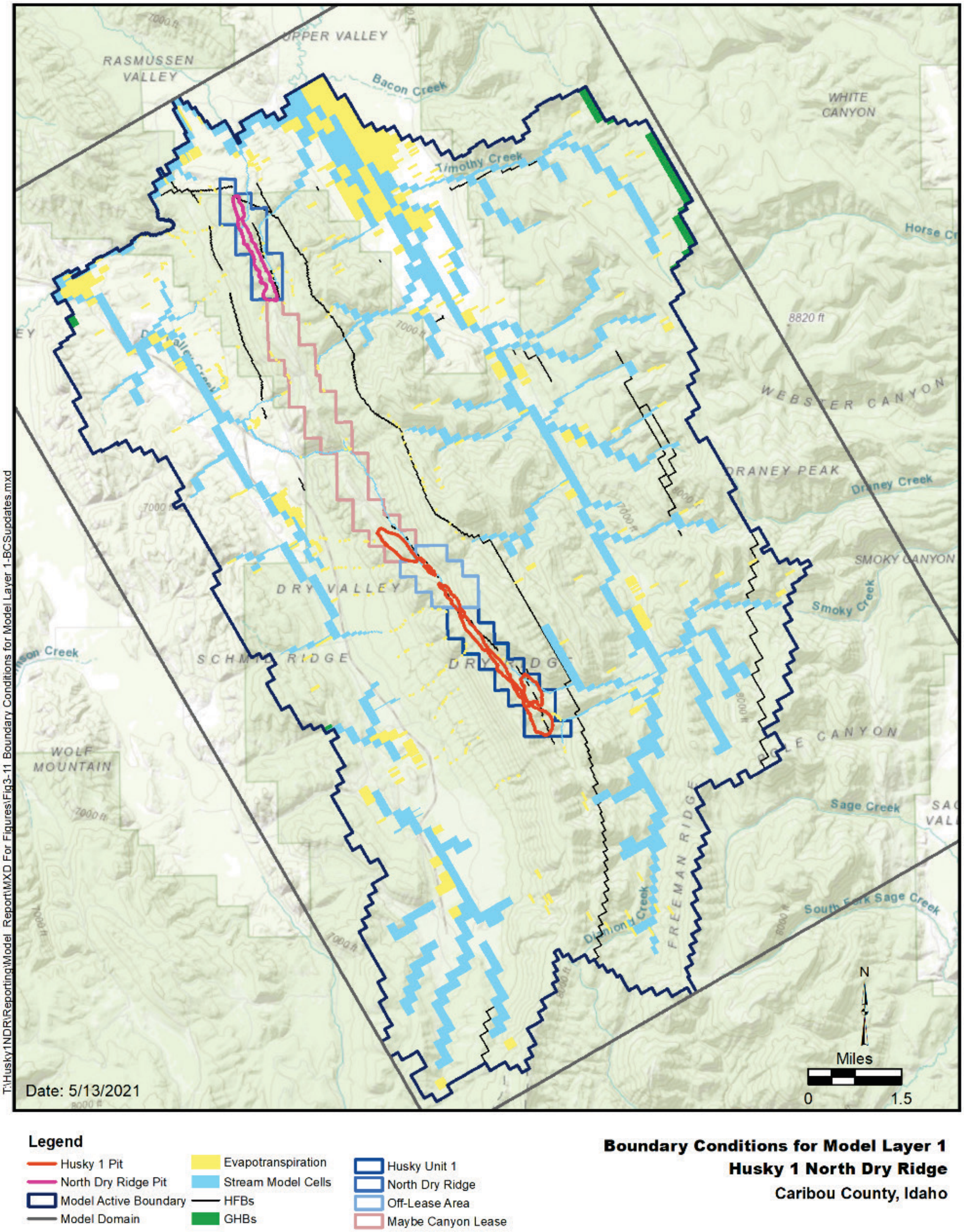


Figure 3-11. Boundary Conditions for Model Layer 1

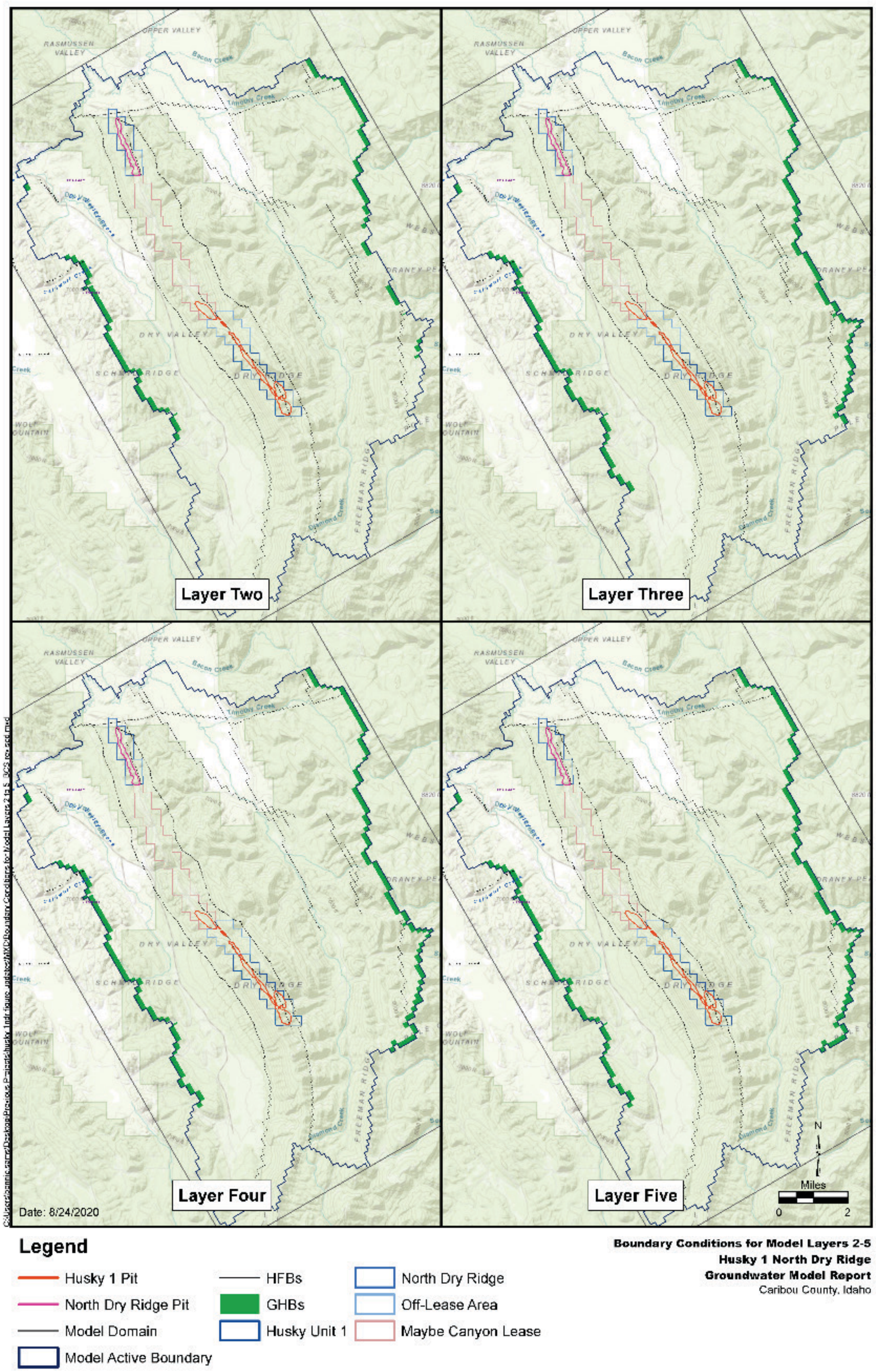


Figure 3-12. Boundary Conditions for Model Layers 2-5

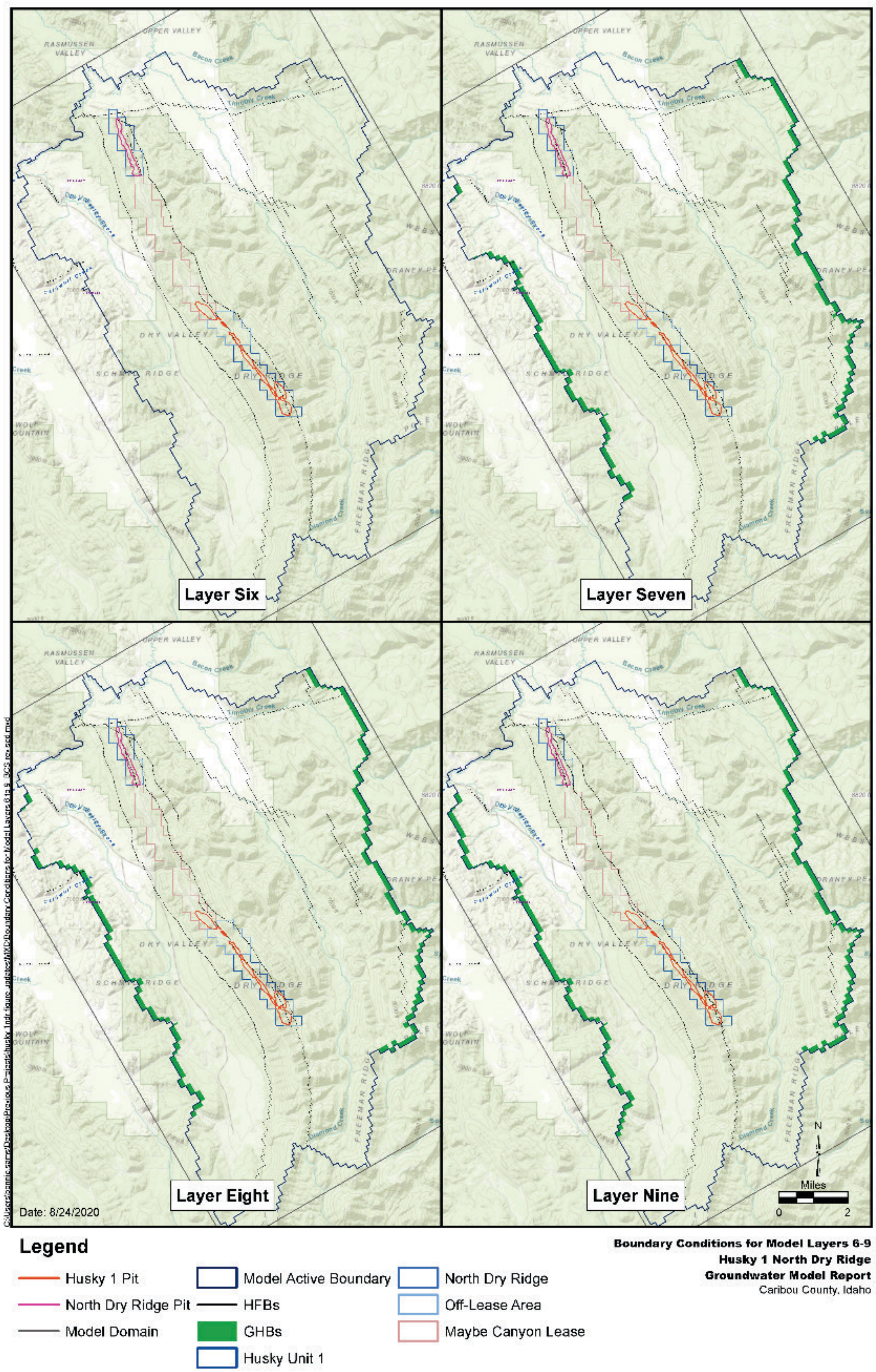


Figure 3-13. Boundary Conditions for Model Layers 6-9

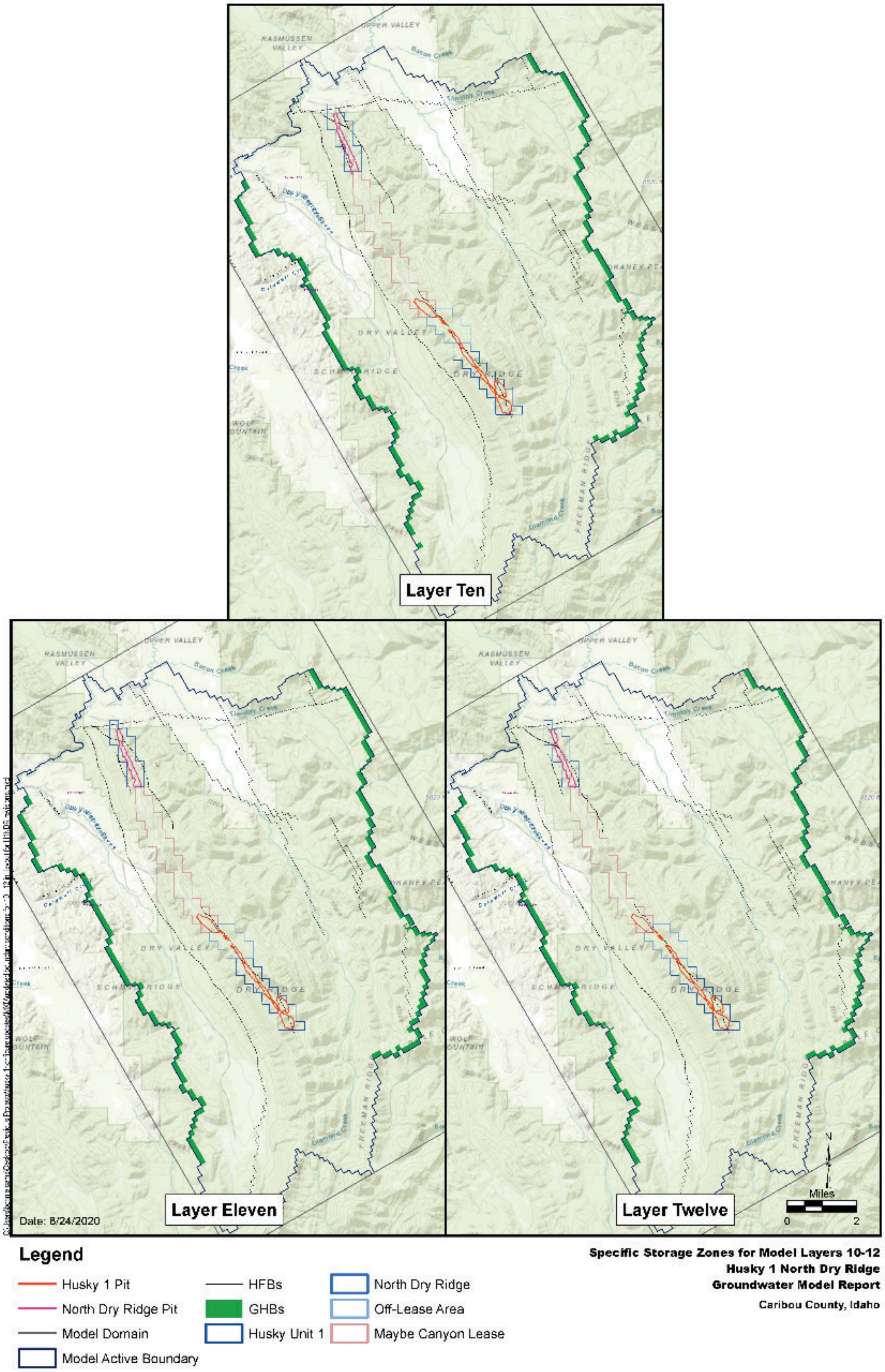


Figure 3-14. Boundary Conditions for Model Layers 10-12

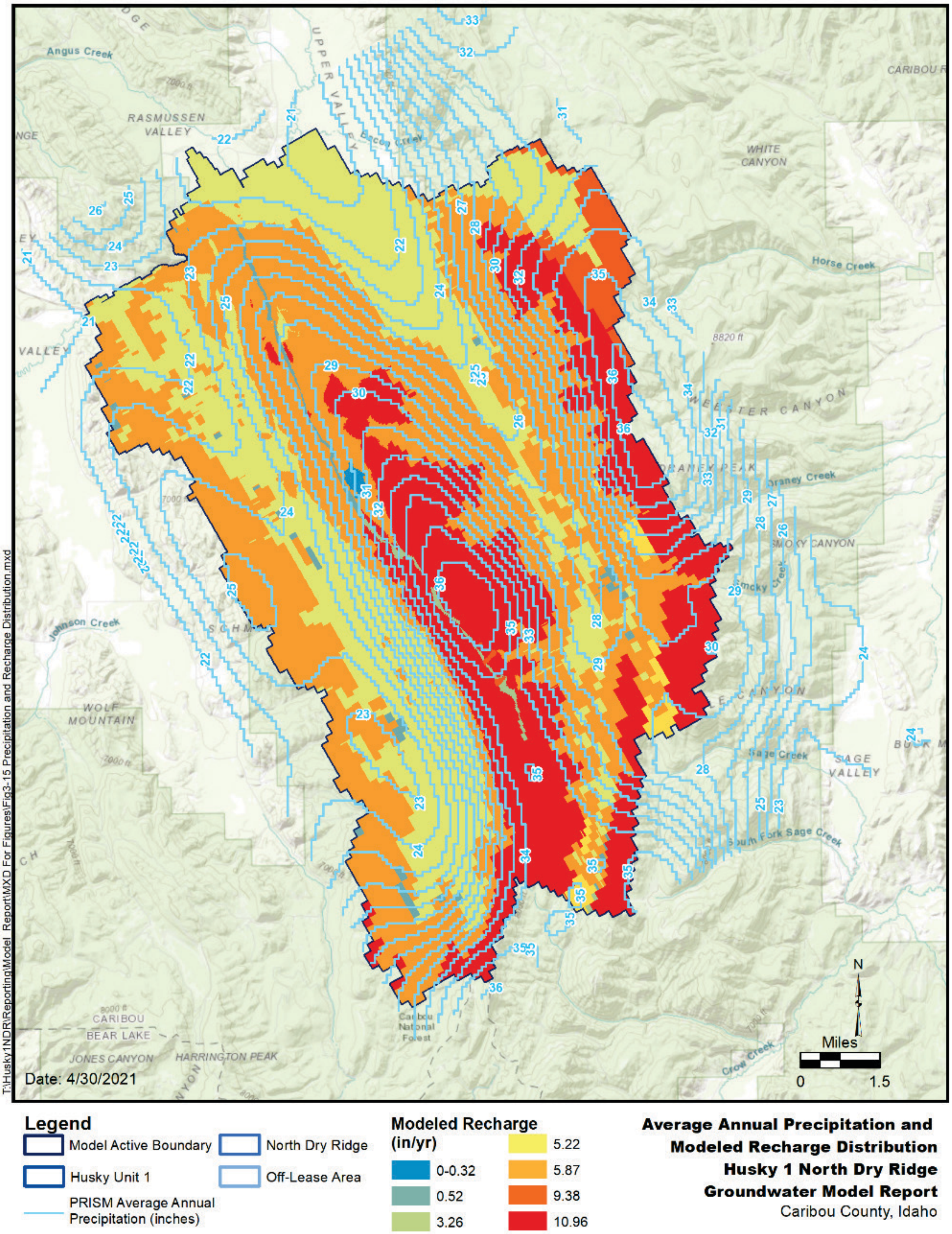


Figure 3-15. Average Annual Precipitation and Modeled Recharge Distribution

3.3.2 Evapotranspiration

Groundwater use associated with vegetation in wetland areas within the model domain was simulated with the MODFLOW ET package. The lateral extents of the simulated wetland areas (**Figure 3-11**) were based on mapping obtained from the U.S. Fish and Wildlife Service National Wetlands Inventory Wetlands Mapper (USFWS, 2019). Model cells that had already been assigned as stream cells were then removed from the ET coverage to improve model stability and convergence.

Initial estimates of ET rate and extinction depth were discussed in the Hydrogeologic CSM Report (Tetra Tech 2019). Wetlands monthly ET data from Soda Springs NWS-108535 station were used to estimate evapotranspiration rates for the model (University of Idaho 2017). An average annual ET rate of 14.8 inches per year was assigned based on analyzing these data.

ET rates generally decrease as the depth to the water table increases. MODFLOW-SURFACT implements a linear-decrease function, with the rate decreasing to zero at a user-specified depth termed the extinction depth. The extinction depth was set to three feet during model calibration and based on evapotranspiration studies performed by Shah et al. (2007).

3.3.3 Streams

Streams within the model domain were simulated with the MODFLOW SFR package; all major streams and many smaller tributary streams were included (**Figure 3-11**). For example, the Blackfoot River comprises the majority of the northern model boundary. The SFR package allows exchange of water in either direction between the stream and the groundwater system. The rate of exchange depends on the conductance of the stream bed and the difference between the head in the aquifer and the assigned or computed water-surface elevation in the stream. If the stream water-surface elevation is higher than the head in the aquifer, seepage occurs from the stream into the aquifer, and vice-versa.

Stream properties including streambed elevation, slope, roughness, thickness, and hydraulic conductivity were assigned. Elevation and slope were based on digital elevation model (DEM) average elevations for each model cell containing a stream boundary. Roughness and thickness were assigned the same values for all stream reaches, 0.03 (typical of a gravelly channel) and 1 foot, respectively. Hydraulic conductivity of the streambed material varied from approximately 0.05 to 0.12 feet/day based on calibration to nearby monitoring well data and stream flow measurements.

3.3.4 General Head

General head boundary conditions (GHBs) were used to represent groundwater flow into or out of the model at the western and eastern model boundaries (**Figure 3-11, Figure 3-12, Figure 3-13,** and **Figure 3-14**). GHBs were established to represent the local- and intermediate-scale flow systems in the alluvium/colluvium, Thaynes Formation, Dinwoody Formation, and Rex Chert Member of the Phosphoria Formation and the regional-scale flow system in the Wells Formation, Monroe Canyon, and Lower Paleozoic rocks. No GHBs were simulated in the Meade Peak Member of the Phosphoria Formation because this unit is a competent aquitard. Conductance terms for the GHBs were calculated and modified as part of model calibration; calibrated values ranged from approximately 1 to 1,100,000 square feet per day depending on variations in cell size and hydraulic properties. Calibrated hydraulic head values for the GHBs by model layer are provided in **Table 3-3** and discussed below.

Hydraulic heads for GHBs in the local and intermediate-scale flow systems (model layers 1 through 5) were estimated based on measured water-level elevations at Caldwell Canyon, Champ, and Mountain Fuel Mines on the western side of the model domain and measured water-level elevations along Dry Ridge. No water-level elevation data are available for the Webster Range along the eastern side of the model domain for layers 1 through 5, so these hydraulic heads were estimated during groundwater flow model calibration. However, water-level elevations in the Dinwoody Formation at Smoky Canyon Mine on the eastern side of the Webster Range groundwater divide ranged from approximately 6,687 to 6,855 feet amsl in fourth quarter 2014, and these data were used to aid in the estimation of GHB head values along the eastern boundary of the model (J. R. Simplot, 2019).

Hydraulic heads for GHBs in the regional-scale flow system (model layers 7 through 12) were also estimated based on measured water-level elevations at Caldwell Canyon, Champ, and Mountain Fuel Mines and along Dry Ridge. No water-level elevation data are available for the Webster Range along the east side of the model domain for layers 7-12, so these hydraulic heads were estimated during groundwater flow model calibration. However, water-level elevations in the Wells Formation at Smoky Canyon Mine on the eastern side of the Webster Range groundwater divide ranged from approximately 6,638 to 6,682 feet amsl in August 2013, and these data were used to aid in the estimation of GHB head values along the eastern boundary of the model (J. R. Simplot, 2019).

Table 3-3. General Head Boundary Hydraulic Heads by Model Layer

Model Layer	Primary Hydrostratigraphic Units	Western Hydraulic Head (feet amsl)	Eastern Boundary Hydraulic Head (feet amsl)
1	Alluvium/Weathered Bedrock	6,600	6,800
2	Thaynes Formation	6,600	6,800
3	Upper Dinwoody Formation	6,550	6,800
4	Lower Dinwoody Formation	6,550	6,800
5	Rex Chert Member of the Phosphoria Formation	6,550	6,800
6	Meade Peak Member of the Phosphoria Formation	N/A	N/A
7	Grandeur Tongue Member of the Park City Formation	6,370	6,800
8	Upper Wells Formation	6,370	6,800
9	Middle Wells Formation	6,300	6,800
10	Lower Wells Formation	6,300	6,675
11	Monroe Canyon	6,275	6,675
12	Lower Paleozoic	6,275	6,675

N/A – Not Applicable

3.3.5 Horizontal Flow Barriers

Faults which potentially could impede groundwater flow were represented by the MODFLOW HFB package (Hsieh and Freckleton, 1993). HFBs are not true "boundary conditions" but are discussed in this section because of their effects on simulated groundwater flow. They function by lowering the horizontal hydraulic conductivity between adjacent model cells that the HFB separates. An HFB with a hydraulic conductivity lower than that of the adjacent cells reduces the modeled groundwater flux between those cells.

The locations of faults simulated with HFB boundary conditions are shown in **Figure 3-11, Figure 3-12, Figure 3-13,** and **Figure 3-14**. HFBs which simulate flow-limiting faults generally represent larger-displacement faults or faults inferred to cause local steepening of the hydraulic gradient. For example, the Dry Valley thrust fault follows the western side of Dry Ridge, and the Henry thrust fault parallels Dry Ridge on the east. In between these two faults is another unnamed fault that required a lower hydraulic conductivity to simulate the local steepening of the hydraulic gradient during model calibration. Also, the north end of Dry Ridge terminates against the Blackfoot fault, the dominant east-trending structural feature in the area, which creates a local steepening of the hydraulic gradient there. The remainder of the faults in the model shown in **Figure 3-11, Figure 3-12, Figure 3-13,** and **Figure 3-14**.

are not barriers to groundwater flow (i.e., their hydraulic conductivity is not lower than the adjacent cells) but are mapped on USGS geologic maps discussed in Chapter 2 and were evaluated during model calibration.

3.4 Model Calibration

The objectives of the groundwater flow model calibration were to 1) determine appropriate model input parameter values that are representative of the hydrogeologic conditions and 2) to achieve a scaled root mean squared error (scaled RMSE) for head and water-level-change residuals (the difference between measured and model-calculated values) of 10 percent or less for the steady-state head targets set and 15 percent or less for the water-level change targets set. These objectives were based on the goal to calibrate the flow model adequately to match the large (i.e., 1,000 to 2,000 ft) hydraulic head changes along North Dry Ridge between the local, intermediate, and regional groundwater flow systems.

Calibration of the groundwater flow model was performed manually. Quantitative calibration targets included water-level elevations (hydraulic heads) in 156 wells and piezometers and seasonal water-level fluctuations in 84 wells. As discussed in Section 2.3.2, the groundwater system is not at steady-state; therefore, multiple groundwater elevations over the course of multiple years were used to create an average calibration data point for each of the 156 locations included in the steady-state calibration. The data included in the average calibration dataset were from the 2014-2015, 2015-2016, and 2016-2017 water years. For the seasonal transient calibration, an average data set was generated as well. Available transducer data were used to calculate the average daily water level for each date in the period of record, such that if a well had three years of transducer data, then it would have three daily average data points for each day of the year. Those daily average data points were then used to calculate an average water level on each day of the year so that the transient model could simulate change in water level (“drawdown”) over the course of an average water year. To ensure that the data were adequately representative of the seven-year time frame, wells with less than two available daily average data points were not included, and wells with large breaks in continuity of the data were not included. A total of 84 wells were included in the seasonal transient calibration.

Qualitative calibration targets included flow rates at stream gaging stations, such as the Blackfoot River, for which reliable flow data are available, and the potentiometric surface configuration (horizontal hydraulic gradients and gradient directions) for the Wells Formation. Average streamflow was calculated using the 2014 and 2018 water years, which had the most available data and the hydrographs appeared to reasonably approximate steady-state. Qualitative goals also included achieving random (as opposed to spatially or vertically biased) distribution of residuals, matching where Maybe Creek changes from gaining to losing, and matching water-level change in monitoring wells adjacent to North Maybe Mine pit lake. The locations of the model calibration targets are shown on **Figure 3-16**.

Calibration was performed in steady-state mode, using the 156 water level elevations as head targets, and in transient mode, using the water-level fluctuations as head-change targets. Initial calibration used only the steady-state mode and was intended to identify parameters to which the model calibration was most sensitive and to allow preliminary modification of pertinent model parameters. During the second phase of calibration, the steady-state and transient calibration targets were combined, and the model was run in steady-state and transient modes during each model run. Final calibration focused on finer adjustment of parameters identified as most sensitive. During calibration, adjustments were made to the following model parameters:

- horizontal and vertical hydraulic conductivity,
- specific storage,
- specific yield,
- recharge,
- ET rates,
- GHB conductance and GHB head elevation,

- streambed conductance, and
- HFB conductance.

As stated in the objectives above, numerical calibration goals included achieving a scaled RMSE for head and water-level-change residuals of 10 percent or less for the steady-state head targets set and 15 percent or less for the water-level change targets set. Scaled RMSE is the square root of the sum of squared residuals divided by the range of measured values for the target set. Calculated values smaller than the target value have positive residuals, while calculated values greater than the target value have negative residuals. The absolute values of the residuals and squared residuals are also considered, because averaging of positive and negative residuals could give an average residual close to zero even though large positive and large negative residuals may be present. Using absolute values or squaring the residuals has the effect of removing the sign of the residual and thereby emphasizing the magnitude of the residual.

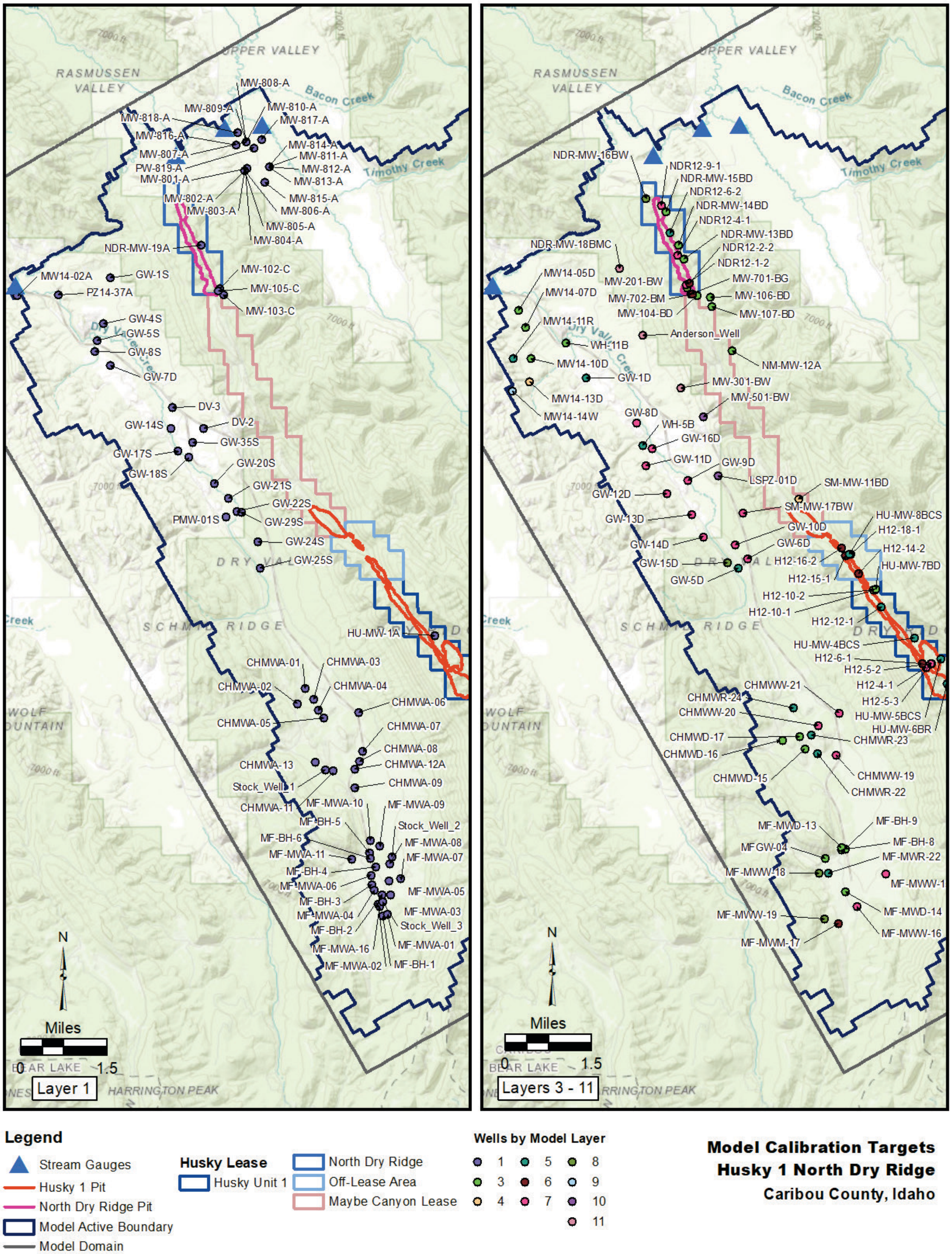


Figure 3-16. Model Calibration Targets

3.4.1 Steady-State Calibration

The steady-state calibration results are shown graphically on **Figure 3-17** through **Figure 3-20** and in **Appendix A**. Observed water-level elevations versus simulated water-level elevations calculated by the model for the steady-state calibration targets are plotted on **Figure 3-17**. The one-to-one line and the lines for plus or minus 10 percent of the range are also shown. The head residuals (difference between observed and simulated water-level elevations) at the steady-state head targets are shown on **Figure 3-18**. Residuals are positive when the simulated water-level elevation is lower than the observed water-level elevation and negative when the simulated water-level elevation is higher than the observed water-level elevation. **Appendix A** also shows the simulated water-level elevations and head residuals by model layer.

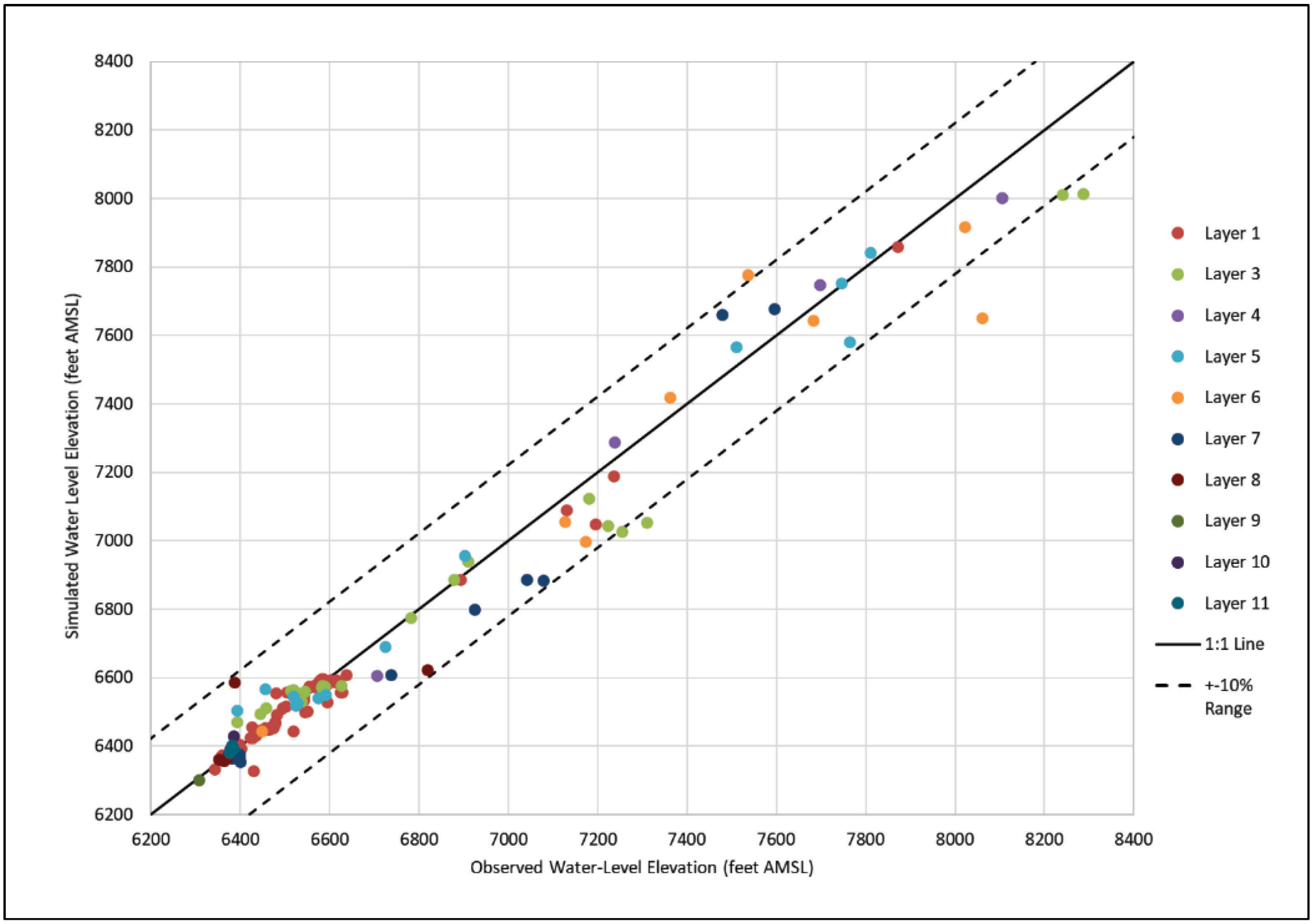


Figure 3-17. Steady-State Calibration Results

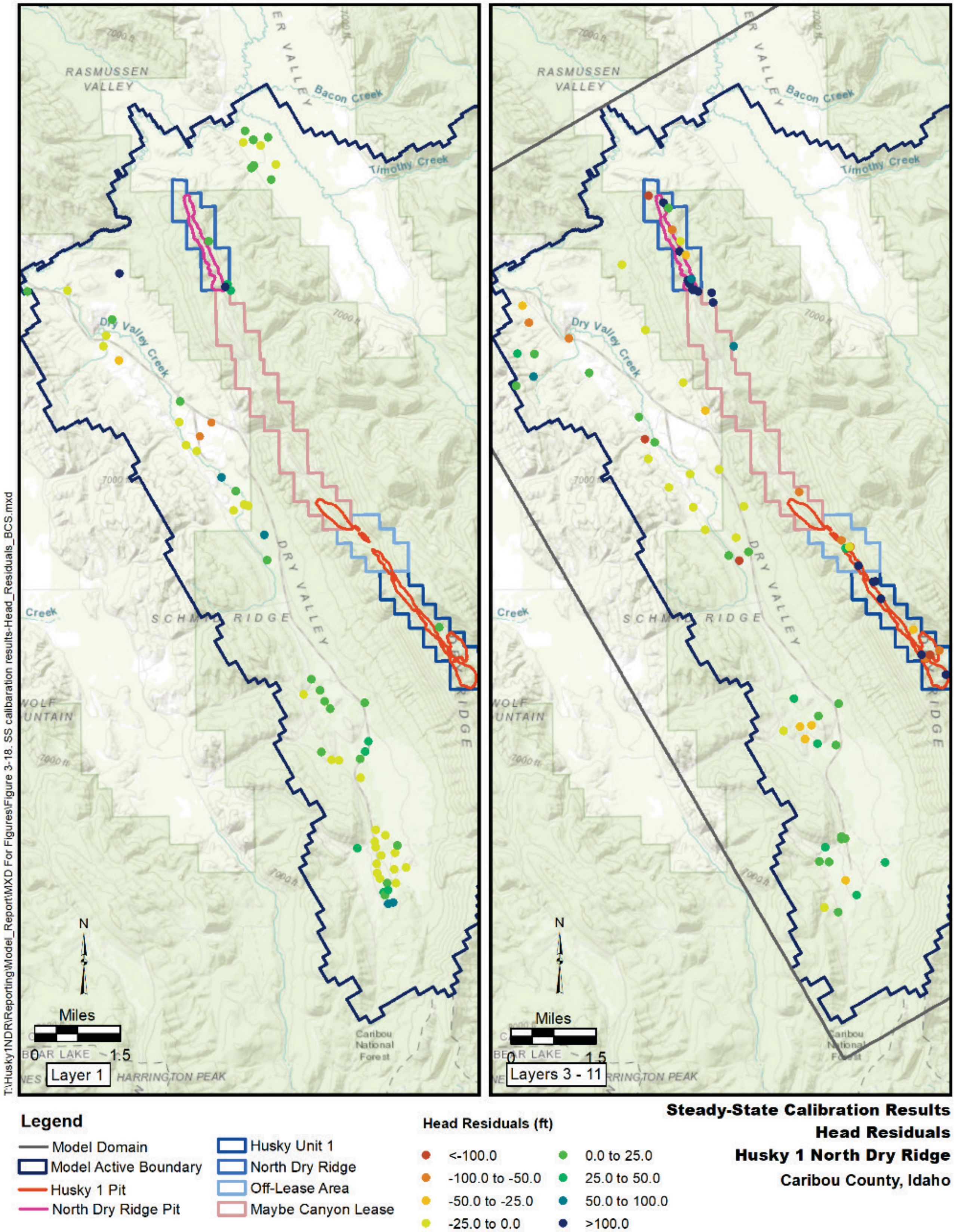


Figure 3-18. Steady-State Calibration Results – Head Residuals

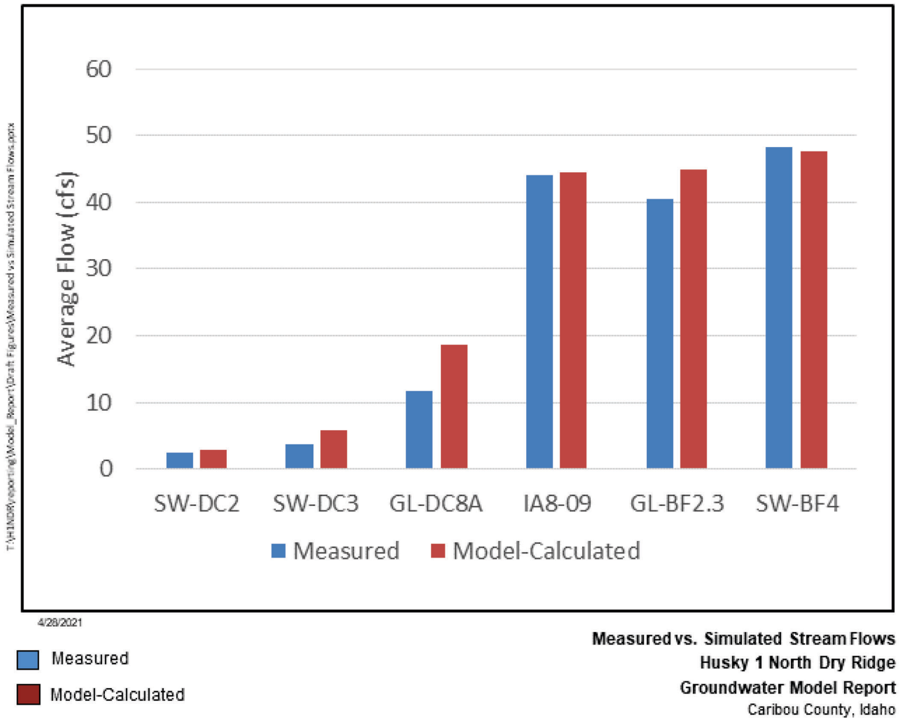


Figure 3-19. Steady-State Measured vs. Simulated Stream Flows

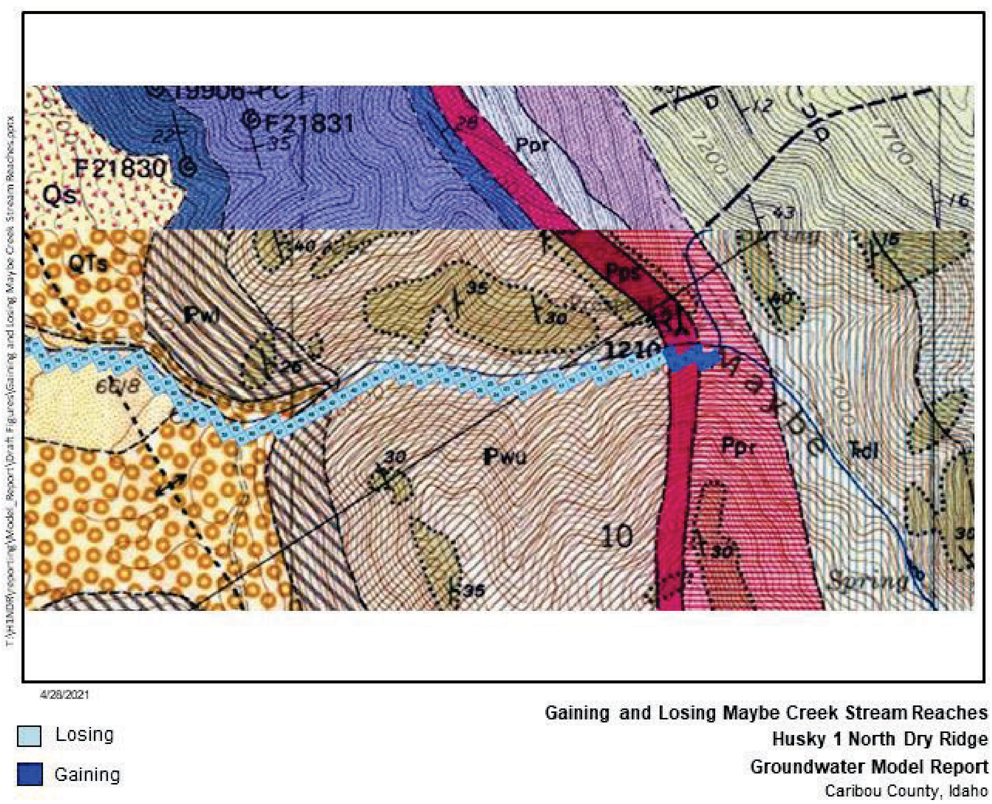


Figure 3-20. Gaining and Losing Maybe Creek Stream Reaches

Figure 3-19 shows a plot of average measured stream flows and the steady-state, model-calculated stream flows at six surface-water monitoring stations along Diamond Creek and the Blackfoot River. The stream flows were qualitative targets; comparison of measured versus simulated flows shows general agreement in relative magnitudes.

Figure 3-20 shows the Maybe Creek segment from the "bend" (Reach 1) into Dry Valley. Maybe Creek flows on top of the upper Wells Formation starting in Reach 7, which also coincides with the creek changing from gaining to losing based on gain-loss surveys discussed in Section 2.4.1. **Table 3-4** shows the Streamflow Routing model output for a portion of this segment of Maybe Creek (Stream Segment 38). The "Flow to Aquifer" amount switches from a negative value (i.e., gaining stream) to a positive value (i.e., losing stream) after Reach 6, which matches the conceptual model. A separate zone in model layers 7 through 9 with a higher vertical hydraulic conductivity value (i.e., 1 foot/day, intended to represent weathering associated with Maybe Creek) than the surrounding zones was required during calibration to simulate the switch from a gaining to a losing stream at this location.

Table 3-4. Maybe Creek Streamflow Routing Output

Layer	Row	Column	Stream Segment Number	Reach Number	Flow into Stream Reach (cfs)	Flow to Aquifer (cfs)	Flow Out of Stream Reach (cfs)
1	269	84	38	1	0.51	-0.010	0.52
1	269	83	38	2	0.52	-0.002	0.52
1	268	83	38	3	0.52	-0.006	0.53
1	268	82	38	4	0.53	-0.008	0.54
1	268	81	38	5	0.54	-0.002	0.54
1	267	81	38	6	0.54	-0.002	0.54
1	267	80	38	7	0.54	0.001	0.54
1	267	79	38	8	0.54	0.001	0.54
1	267	78	38	9	0.54	0.0004	0.54
1	266	78	38	10	0.54	0.0006	0.54
1	266	77	38	11	0.54	0.001	0.54
1	266	76	38	12	0.54	0.001	0.54

cfs = cubic feet per second

3.4.2 Transient Calibration

For the transient calibration to seasonal water-level fluctuations, the groundwater flow model was set up to simulate a 14-month period from November 1 of the starting year through December 31 of the following year. A decision was made after consultation with BLM and IDEQ to calibrate the model to a synthetic transient data set that represented average water-level changes from 2012 through 2019 for the following reasons. First, there are large increases in water level elevations in vibrating wire piezometers (VWPs) and monitoring wells during and after snowmelt each year (See **Figure 2-8**) which would have required prohibitively small time steps and long model run times. Second, bias from mine sites with multiple years of water-level elevation data (i.e., Champ Mine) versus monitoring locations with a smaller water-level elevation dataset but in the primary area of interest (i.e., VWPs on Dry Ridge) would have more weight on the calibration statistics. Third, the transient flow model was going to be used to simulate average climatic conditions instead of explicitly simulating wet years, such as 2017, which was abnormally above 30-year precipitation normals.

Drawdown targets included water-levels at nominal five-day increments at 84 wells. Stress periods covering the spring months (i.e., March through June) when recharge increases rapidly were subdivided to allow more gradual changes in recharge rates and improve the computational efficiency of the model. Stress period lengths ranged from 5 days to 70 days. The initial stress period of each calibration simulation was set to steady state and this stress period used the same hydraulic properties as the subsequent transient stress periods. Therefore, the simulated hydraulic heads at the start of the transient seasonal stress periods (i.e., stress period 2) were consistent with the simulated steady-state heads for conducting calibration simulations.

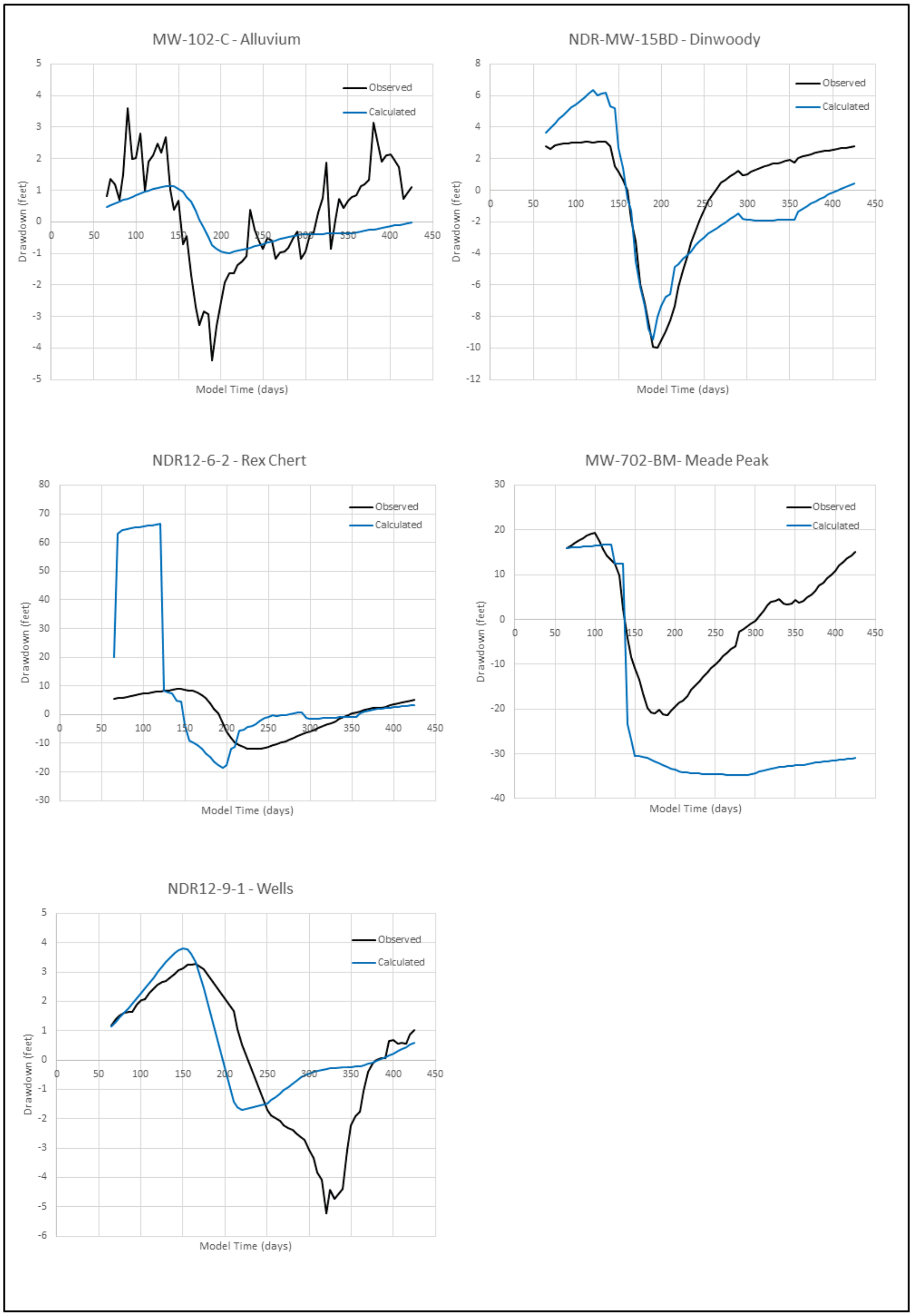
Changes to recharge were made by applying a multiplier to the average annual recharge rate, which varied by location in the model. The recharge multiplier was based on daily and monthly data for snow water equivalent and precipitation from the Somsen Ranch (Station Number 770), Slug Creek Divide (Station Number 761), and Willow Creek (Station Number 868) SNOTEL stations as reported by the Natural Resources Conservation Service (https://www.wcc.nrcs.usda.gov/snow/). The timing and magnitude of the recharge multipliers were adjusted during the calibration to improve the match between observed and simulated water-level changes. Based on the hydrogeological CSM report (Tetra Tech, 2019), net percolation, which represents net recharge to the groundwater system, ranged from 2.6 to 8.4 inches per year (8 to 28 percent of precipitation). Net recharge into the active model domain, after adjustment during calibration, ranged from 0.32 to 10.96 inches per year and averaged approximately 6.3 inches per year or 21 percent of precipitation, which falls within the range stated in the hydrogeological CSM report.

Evapotranspiration rates for the model calibration were taken from the University of Idaho's ET_{Idaho} website (2017), which provided data for actual ET from large stands of wetlands as monthly time series for the National Weather Service's Soda Springs station for January 1979 through December 2010. The initial, steady-state stress period of the calibration runs used the annual average value obtained by summing the average monthly actual ET values. The subsequent, transient stress periods of the calibration runs used the average monthly ET values.

Besides evapotranspiration, groundwater discharge or outflow from the model domain occurs into streams and through the western model boundary in the regional aquifer system via GHBs. More than 93% of the groundwater outflow from the model domain is through the western model boundary. Similarly, groundwater inflow from the eastern model boundary through GHBs accounts for approximately 85% of the inflows. Thus, most of the groundwater flowing into and out of the model domain is within the regional aquifer system.

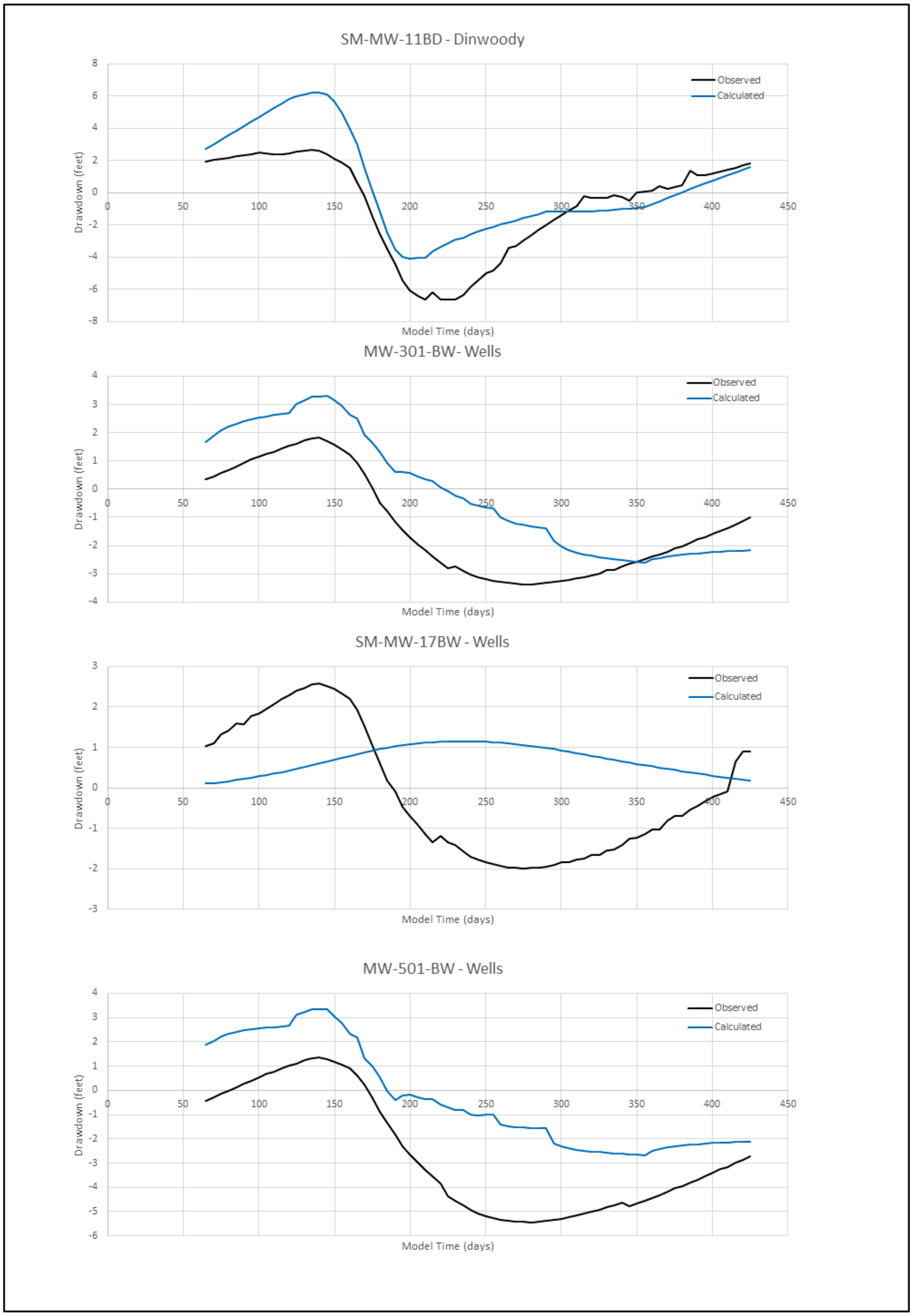
Figure 3-21, Figure 3-22, and **Figure 3-23** show hydrographs of the observed and simulated seasonal water-level changes at target locations resulting from the transient calibration at NDR, Maybe Canyon, and H1, respectively. **Figure 3-24** shows hydrographs in alluvial and Wells Formation monitoring wells in Dry and Diamond Valleys. A good match typically can simulate the trends of water levels increasing and decreasing over the course of a 14-month period and the approximate magnitude of the change. At H1NDR, the extreme variations in the snowmelt signal timing, magnitude, and recovery are affected by compartmentalization and fractured weathered geologic units along Dry Ridge and elsewhere. The hydrograph matches are generally reasonable both qualitatively and quantitatively. Differences between observed and simulated hydraulic heads are attributed to fractured media causing varied responses from infiltration along Dry Ridge.

Statistics for the calibration residuals allow quantitative evaluation of the match between observed and simulated hydraulic heads and water-level changes. A summary of statistics for the steady-state and transient calibration results is presented in **Table 3-5**. The quantitative goals for both the steady-state and transient calibration targets were met, indicating that a statistically good match was achieved between measured values at calibration target locations and model-calculated values at those locations. For steady state, scaled statistics are below 5%. For the transient model, the scaled residual mean, the scaled residual absolute mean, and the scaled standard deviation meets the objective of less than 15%.



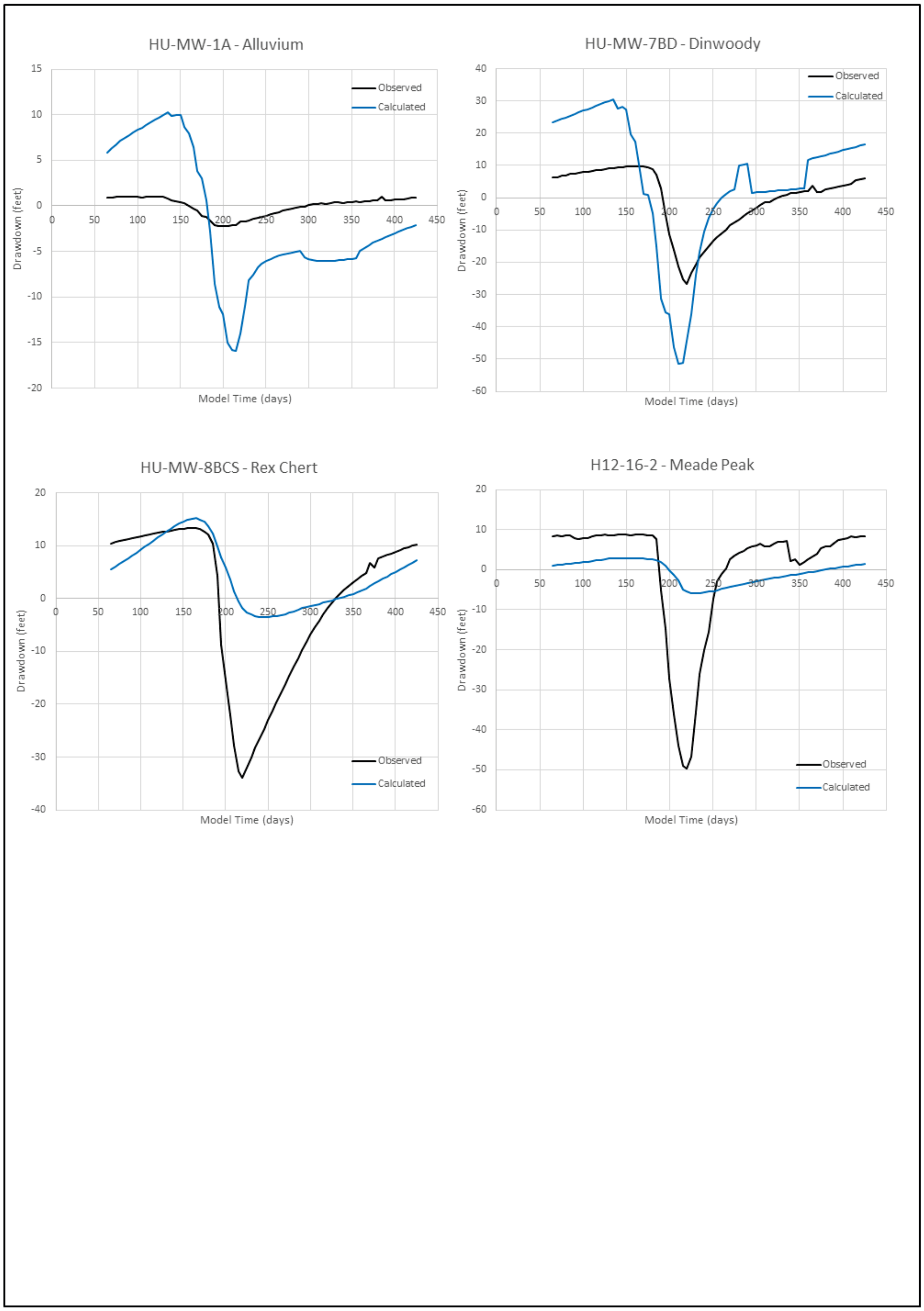
Representative Transient Calibration Hydrographs
North Dry Ridge
Caribou County, Idaho

Figure 3-21. Transient Seasonal Calibration Hydrographs – North Dry Ridge



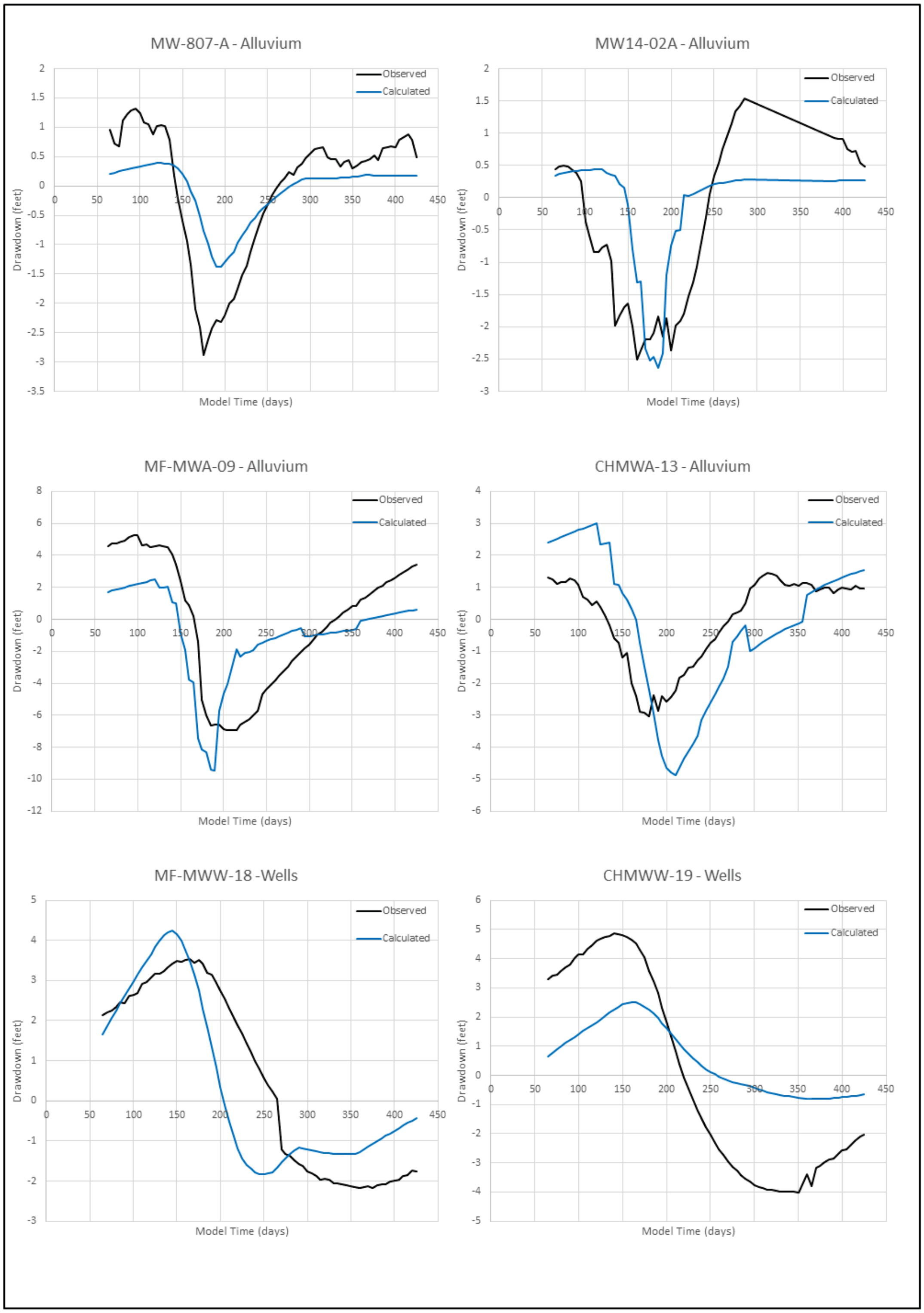
Representative Transient Calibration Hydrographs
Maybe Canyon
Caribou County, Idaho

Figure 3-22. Transient Seasonal Calibration Hydrographs – Maybe Canyon



Representative Transient Calibration Hydrographs
Husky 1
Caribou County, Idaho

Figure 3-23. Transient Seasonal Calibration Hydrographs – Husky 1



Representative Transient Calibration Hydrographs
Dry and Diamond Valleys
Caribou County, Idaho

Figure 3-24. Transient Seasonal Calibration Hydrographs – Dry and Diamond Valleys

Table 3-5. Calibration Statistics

Statistic	Steady-State (Average) Groundwater Elevations	Transient (Seasonal) Groundwater Elevation Changes
Residual Mean (feet)	16.8	-1.07
Minimum Residual (feet)	-241.5	-59.1
Maximum Residual (feet)	408.3	89.0
Range (feet)	2,209.1	68.9
Standard Deviation (feet)	78.1	9.74
Absolute Residual Mean (feet)	44.5	5.03
Scaled Residual Mean	0.008	-0.015
Scaled Absolute Mean	0.020	0.073
Scaled Standard Deviation	0.035	0.141
Number of Observations	156	5636
Scaled Residual Root Mean Squared Error	0.036	0.142

3.4.3 Calibrated Model Hydraulic Properties

Table 3-6 summarizes the hydraulic conductivities and storage properties of the hydrogeologic units in the calibrated model and compares the model values to reported values for the H1NDR project site. The zonation of the hydraulic properties for each layer of the calibrated model is shown in **Figure 3-5** through **Figure 3-10**. Reported hydraulic conductivity values for the Southeastern Idaho Phosphate District refer only to horizontal hydraulic conductivity, whereas the model uses both horizontal and vertical hydraulic conductivity. Most horizontal hydraulic conductivities in the calibrated model were within the range of reported values. Exceptions were the Rex Chert, for which some values in the calibrated model were smaller than the reported values, the Lower Wells Formation, for which values in the calibrated model were smaller than the eight reported ranges, and for the Monroe Canyon Formation, for which the modeled value was lower than the six reported values. Reported storage values are specific yield (Sy) where the tested aquifer is unconfined and storage coefficient (S) where the aquifer is confined. Storage coefficient is the product of specific storage times aquifer saturated thickness. Because specific storage (Ss) is used in the model and saturated thicknesses vary considerably, only the modeled specific storage values are listed. Modeled specific yield values, rather than specific storage, apply where the hydrogeologic unit represented by the model cell is unconfined. Modeled values of storage coefficient and specific yield were within the range of values reported for the modeled hydrogeologic units. Alluvium specific yield values were lower than reported at H1NDR but were within range of Southeastern Idaho Phosphate District specific yield values (Tetra Tech, 2018).

Table 3-6. Hydraulic Properties in Calibrated Model

Geologic Unit	Model Zone	Hydraulic Conductivity (feet/day)				Storage			
		Reported Kxy		Modeled		Reported		Modeled	
		Min.	Max.	Kxy	Kz	Min.	Max.	Ss	Sy
Alluvium/Colluvium (Dry valley)	1	0.01	574	1.0	0.001	0.2	0.36	--	0.05
Diamond Valley	15	--	--	0.1	0.0002	--	--	--	0.08
	16			10	1				
Thaynes Formation	2	--	--	0.15	0.015	--	--	1.0×10^{-6}	0.05
Dinwoody Formation:	3								
Unspecified		0.01	153	0.5	0.0073	1.0×10^{-10}	0.1	5.0×10^{-7}	0.03
Upper – Dry Ridge	12	--	--	0.2	0.02	--	--	5.0×10^{-7}	0.01
Lower – Dry Ridge	17	--	--	0.02	0.1	--	--	5.0×10^{-7}	0.03
Rex Chert Unspecified	4	0.05	75	0.011	0.0013	1.4×10^{-5}	0.028	1.0×10^{-7}	0.01
Rex Chert – Dry Ridge	13			0.05	0.1			5.0×10^{-7}	0.03
	20			0.1	0.1			9.0×10^{-7}	0.04
Meade Peak Unspecified	5	0.07	75	4.0×10^{-4}	9.0×10^{-5}	0.001	0.002	1.0×10^{-6}	0.05
Meade Peak – Dry Ridge	21	0.0001	1.6	4.0×10^{-4}	9.0×10^{-5}			1.0×10^{-6}	0.04
Grandeur Tongue Unspecified	6	--	--	2.0	0.01	--	--	5.0×10^{-7}	0.03
Grandeur Tongue – Dry Ridge	14	0.00011	0.57	0.1	0.002			5.0×10^{-7}	0.01
Weathered Zone (Layers 1-6)	9	--	--	4.0	4.0	--	--	5.0×10^{-7}	0.02
Maybe Creek Weathered Zone	18	--	--	1.0	1.0	--	--	1.0×10^{-6}	0.15
Wells Formation:									
Unspecified	6	0.04	1591	2.0	0.01	6×10^{-5}	0.31	5.0×10^{-7}	0.03
Upper – Dry Ridge	19	0.36	43	2.0	0.0005	--	--	5.0×10^{-7}	0.008
Middle – Dry Ridge	19	--	--	2.0	0.0005	--	--	5.0×10^{-7}	0.008
Lower	7	86	153	55	0.55	--	--	1.0×10^{-6}	0.05
Monroe Canyon Formation	8	42	320	12	0.12	7×10^{-5}	7×10^{-5}	1.0×10^{-6}	0.05
Lower Paleozoic	10	--	--	1.0	1.0	--	--	1.0×10^{-6}	0.05
Backfill – North Maybe Mine, South Maybe Mine, and Cross Valley Fill	22	--	--	5.0	5.0			--	0.02

Kxy = horizontal hydraulic conductivity; Kz = vertical hydraulic conductivity; Ss = specific storage; Sy = specific yield.
Specific yield is unitless; Specific storage units are 1/foot.

4.0 SOLUTE TRANSPORT MODEL CONSTRUCTION

The solute transport model was developed by adjusting the hydraulic properties and boundary conditions in the project area to account for the proposed mine development and by adding transport-related parameters to the groundwater flow model to allow simulation of solute transport. Three conditions were incorporated:

1) Original material mined and replaced with backfill. Hydraulic conductivity and storage coefficients were adjusted where mining would remove the native geologic materials and replace them with backfill; this was done by changing the properties of the native geologic materials to those of the backfill at the end of mining. The model top elevation was modified to reflect the proposed cap and cover elevation (sometimes significantly different than the original land surface), and the thickness of the backfill was equally distributed amongst the replaced model layers.
2) Original material removed but no backfill emplaced. In these cases, the model top elevation was adjusted to reflect the pit elevation, and the removed model layers were adjusted to minimum thicknesses with weathered bedrock properties.
3) Backfill emplaced on existing ground surface (OSA). In this case, the backfill was represented by adjusting the top of Layer 1 to the proposed cap and cover elevation and changing the hydraulic properties to those of backfill.

Boundary conditions were implemented or modified to simulate changes to recharge when reclaimed mine backfill would replace the native geologic materials, and when mining would remove segments of some faults and streams within the mine pit areas.

Transport-related parameters not used in the flow model were added to allow simulation of solute transport by advection and dispersion. Advection refers to the migration of COPCs as a result of groundwater movement through the pore spaces in the rock. Dispersion refers to the lateral and vertical spreading of the COPCs over a wider and deeper area than would be predicted solely from the average velocity of the groundwater. Chemical reactions during transport were not incorporated into the model. The reactions most likely to occur during solute transport would result in decreases, rather than increases, in the concentrations of the modeled COPCs. For example, Hay et al. (2016) reported evidence that transport of selenium in phosphate mine waste rock piles and pit backfill in southeastern Idaho is affected by reductive precipitation, whereby selenium released in the oxic upper portions of the waste rock is subsequently attenuated at depth in unsaturated, low-oxygen portions of the waste rock, resulting in lower selenium concentrations in the underlying and downgradient groundwater. Omitting such chemical reactions provides a conservative prediction of COPC concentrations (i.e., higher predicted concentrations) in the area potentially affected by the proposed mine.

4.1 Solute Transport Model Code

The solute transport model was implemented with the Analysis of Contaminant Transport (ACT) modules of the MODFLOW-SURFACT code (HydroGeoLogic, 2011). The ACT modules provide for advective-dispersive transport of multiple chemical species in steady-state or transient flow fields under saturated or partially-saturated conditions. Although not implemented in this model, the ACT modules also allow linear or nonlinear retardation for each species, first-order decay, and biochemical degradation of contaminants in water and soil, and generation of transformation products. The code uses total variation diminishing (TVD) flux-limiting schemes to provide accurate and strictly mass-conserved numerical solutions. The transport modules are integrated with the flow modules to provide seamless, coupled simulation of both flow and transport.

4.2 Solute Transport Parameters

The solute transport model was developed by addition of transport-related parameters to the groundwater flow model. The transport-related parameters provide information regarding aquifer properties that govern the migration of the COPCs through the groundwater system and away from the source areas, the COPC source locations, COPC concentrations, and attenuation rates of the sources. The additional information required for the Phase 2 transport model is summarized in **Table 4-1** and described in more detail in subsequent sections.

Table 4-1. Solute Transport Model Input Parameters and Values

Parameter	Values	Data Source
Aquifer Properties		
Backfill Hydraulic Conductivity	5 ft/day	Based on decision from May 14, 2020 water model conference call.
Backfill Specific Yield	0.14	O'Kane (2009, Table 3).
Backfill Effective Porosity	0.15	Whetstone (2009) and based on decision from May 14, 2020 water model conference call.
Longitudinal dispersivity	49 ft	Xu and Eckstein (1995); value based on plume length of approximately 2000 m, ($\alpha_x = 0.83[\log_{10}(Lp)]^{2.414}$).
Horizontal transverse dispersivity	15 ft	Tetra Tech (2018) and ASTM (2015); value is 30% of longitudinal dispersivity.
Vertical transverse dispersivity	2.4 ft	Tetra Tech (2018) and ASTM (2015); value is 5% of longitudinal dispersivity.
Effective Porosity	0.008 to 0.15	Based on calibration values of specific yield; See **Table 3-5**.
Potential COPC Source Locations		
Proposed mine pit backfill horizontal and vertical extent	(see **Figure 4-1**, **Figure 4-2,** and **Figure 4-3**)	Electronic ArcGIS files received from ARCADIS.
COPC Concentrations		
Source concentrations in mg/L for pit backfill post-mining	(see **Table 4-5**)	ARCADIS (2020b)
Source area infiltration rates	(see **Table 4-4**)	ARCADIS (2020b)

4.3 Constituents of Potential Concern

The results of geochemical characterization studies reported by ARCADIS (2020a) were used to identify COPCs for inclusion in the solute transport model. The studies included screening using hand-held x-ray fluorescence (XRF) analysis, testing of single-lithology samples by elemental or whole rock analysis, total organic carbon (TOC), acid-base accounting (ABA), mineralogical analyses via X-ray diffraction (XRD), synthetic precipitation leaching procedure (SPLP), and kinetic column leaching methods. The testing was performed to identify and quantify COPCs that could be leached to the environment and to provide data by which source terms for input to the solute transport model could be calculated.

The results of the SPLP tests were used to identify a list of leachable COPCs with the potential for concentrations in leachate to exceed IDEQ groundwater quality standards in IDAPA 58.01.11.200. The following COPCs were identified based on SPLP results: antimony, arsenic, cadmium, copper, iron, manganese, nickel, selenium, sulfate, thallium, total dissolved solids (TDS), uranium, and zinc. The kinetic column leaching tests are a multiple leach testing method that was used to confirm those COPCs most likely to leach from the backfill material. These tests involve consecutive leaching cycles that are equivalent to passing one pore volume (ratio of volume of pore spaces to the total volume of the sample) of water through the column of material per leaching cycle.

Column test effluents were consistent with results from other open-pit phosphate mining operations in southeast Idaho, with most COPCs relatively elevated in the first ½ pore volume and decreasing with continued flushing to approximately stable concentrations. Analytes that remained at stable concentrations above water quality standards or exhibited an increase in concentration included iron, manganese, and arsenic, which is consistent with release due to geochemical reduction. Rock samples tested in columns operated under unsaturated (oxic) conditions exhibited concentrations of the following COPCs equal to or exceeding groundwater quality standards (GWQS): antimony, cadmium, iron, manganese, selenium, and sulfate. Antimony only exceeds the 0.006 mg/L standard for the first ½ pore volume at H1-S (0.0062 mg/L); thus, antimony was not retained. Cadmium exceeds the 0.005 mg/L standard for the first ½ pore volume at North Maybe Mine and NDR only; thus, cadmium was not retained as well. Iron is ubiquitous in groundwater underlying the Project site and was present in numerous groundwater samples from the Wells Formation and other lithologies at concentrations exceeding the 0.3 mg/L standard. Consequently, iron was not retained on the COPC list. Sulfate is a primary component of TDS and is used as a proxy for TDS; therefore, TDS was not retained on the COPC list. The three COPCs carried forward into the solute transport modeling are presented in **Table 4-2**.

Table 4-2. Constituents of Potential Concern

Constituent	Groundwater Quality Standard (mg/L) [1]	
	Primary Standard	Secondary Standard
Manganese	--	0.05
Selenium	0.05	--
Sulfate	--	250

[1] From IDAPA 58.01.11.200

4.4 Source Areas

The H1 and NDR pits would be mined as open pits and sequenced through several phases at each respective site (**Figure 4-1**). H1 would be mined first in nine phases from north to south. The NDR deposit would be mined in three phases from south to north with some overlap in time with H1 mining. Overburden would be placed directly as backfill, stored on temporary OSAs for use as backfill later, or stored in a permanent OSA. Most of the overburden would be transported directly from the active phase of mining to backfill the historical Maybe Canyon Mine open pits or H1 and NDR pits (Itafos, 2020a).

The nine pit backfill/OSA locations (listed in order of filling during mining) include:

- South Maybe Canyon Mine – South (SMCM-S): open pit south of the land bridge;
- South Maybe Canyon Mine – North (SMCM-N): open pit north of the land bridge;
- Five distinct areas associated with the Husky 1 Mine:
  - Husky 1 North Pit (H1-N);
  - Husky 1 Ex-Pit and external OSA (H1-X);
  - Husky 1 Long Pit (H1-L);
  - Husky 1 East Pit (H1-E);
  - Husky 1 South Pit (H1-S);
- North Maybe Mine (NMM); and
- North Dry Ridge (NDR).

The solute transport model considers and includes existing waste rock backfilled into the historically mined NMM and SMCM pits as contributing to the future impacts. Like the H1NDR waste rock that would be generated, samples of the existing historic NMM and SMCM backfill were collected and geochemically characterized, column tests conducted, and the results mathematically combined with the results from the H1NDR backfill columns to develop source terms for the solute transport modeling. The net result is a H1NDR source term that represents the leachate that results from the H1NDR backfill when placed over or combined with the historic NMM and SMCM backfill. However, for simplicity and because a complete data set of current plumes and historic loading rates is not available, only new impacts from H1NDR were modeled, not existing conditions.

Pit backfill would require cap and cover systems to support a stable vegetative cover and overall hydraulic performance for acceptable infiltration rates after the completion of backfill activities at each pit. Itafos designed and evaluated four cap and cover systems: store-and-release cover, low-permeability clay cover, flexible membrane liner cover, and lateral drain cover (Itafos, 2020b). The infiltration rates by cover type simulated in the transport model were provided in ARCADIS (2020d) and USBLM (2021) and are also shown in **Table 4-3**. Two scenarios were simulated with the transport model: Proposed Action and one alternative called the Alternative Cover. The Proposed Action simulation represents the activities as presented in the MRP Addendum (ARCADIS, 2020e), and the Alternative Cover cap and cover system simulation represents a revised backfill design that optimizes material handling throughout the mine site. Both scenarios use four cover types but simulate different amounts of backfill acreage and different amounts and locations of cover type acreages that differ by mine pit location. Cover type locations for the two modeled scenarios are further discussed in Section 5.1.

Table 4-3. Infiltration Rates by Cover Type

Cover	Infiltration Rate as a Percentage of Precipitation	Source
Store-and Release	37%	USBLM(2021)
Low-Permeability Clay	33%	USBLM (2021)
Flexible Membrane Liner	0.5%	ARCADIS (2020d)
Lateral Drain	21%	USBLM (2021)

During reclamation of the mined-out pits, the backfill materials would be contoured to approximate the natural topography of the area. This graded backfill would be covered with a multi-layer store-and-release cover system and revegetated. The cover system is designed to limit infiltration of precipitation and runoff into the backfill. Several cover designs were evaluated by ARCADIS (2020b). The areas to be mined are shown in plan view on **Figure 4-1**. The pit backfill materials would be subject to leaching of COPCs by precipitation and runoff that infiltrate through the cover and percolate through the backfill. The water that percolates through the backfill would ultimately enter the groundwater system. Consequently, the reclaimed backfill areas were included as COPC source areas in the transport modeling.

Geochemical testing indicates that COPC concentrations in the water entering the groundwater system would change over time (ARCADIS, 2020b). These changes were incorporated into the COPC source terms for the groundwater model in a stepwise manner, based on the time required for one pore-volume of water to be transmitted through the cover and into the backfill areas.

Pore-volume times were calculated from the infiltration rate for each pit, backfill pore volume, backfill area, and effective porosity of the backfill as provided by ARCADIS (2020c); these parameters and calculations are summarized in **Table 4-4a** through **Table 4-4d** for the Proposed Action and Alternative Cover.

Table 4-4a. Proposed Action Pore-Volume Time Calculation Summary for NDR, NMM, SMCM, and H1-N

Parameter	NDR	NMM	SMCM-N	SMCM-S	H1-N
Backfill Pore Volume at 15% Porosity (ft^3)	80,678,637	39,562,911	39,703,065	8,170,336	85,706,643
Backfill Area (acres)	137	79	70	30	89
Annual Infiltration Volume (ft^3/yr)	4,551,791	2,947,189	2,611,433	712,209	4,198,492
Pore-Volume time (yrs)	17.7	13.4	15.2	11.5	20.4

Table 4-4b. Alternative Cover Pore-Volume Time Calculation Summary for NDR, NMM, SMCM, and H1-N

Parameter	NDR	NMM	SMCM-N	SMCM-S	H1-N
Backfill Pore Volume at 15% Porosity (ft^3)	78,690,338	39,982,908	36,036,811	6,818,321	54,811,469
Backfill Area (acres)	109	37	57	23	61
Annual Infiltration Volume (ft^3/yr)	51,160	1,380,329	25,775	10,401	1,647,563
Pore-Volume time (yrs)	1540	29.0	1400	656	33.3

Table 4-4c. Proposed Action Pore-Volume Time Calculation Summary for H1-X, H1-L, H1-E, and H1-S

Parameter	H1-X	H1-L	H1-E	H1-S
Backfill Pore Volume at 15% Porosity (ft^3)	20,768,570	55,278,025	66,225,879	83,052,151
Backfill Area (acres)	54	126	66	78
Annual Infiltration Volume (ft^3/yr)	2,296,594	4,886,740	3,099,630	3,572,934
Pore-Volume time (yrs)	9.0	11.3	21.4	23.2

Table 4-4d. Alternative Cover Pore-Volume Time Calculation Summary for H1-X, H1-L, H1-E, and H1-S

Parameter	H1-X	H1-L	H1-E	H1-S
Backfill Pore Volume at 15% Porosity (ft^3)	27,709,659	69,358,093	63,465,444	97,768,215
Backfill Area (acres)	63	119	64	74
Annual Infiltration Volume (ft^3/yr)	1,701,581	3,775,632	32,926	885,902
Pore-Volume time (yrs)	16.3	18.4	1930	110

The mass loading of each COPC from the source areas was applied as recharge containing the time-dependent concentration of each COPC. The recharge rates and first pore-volume COPC concentrations for the backfill area in each pit were applied in the model in the first stress period, and COPC concentrations subsequently were reduced at the end of each pore-volume time. **Table 4-5a** through **Table 4-5e** present the modeled concentrations of COPCs by pore volume at the nine backfill areas and each COPC groundwater standard.

Table 4-5a. Source Term COPC Concentrations at NDR and NMM

Pore Volume	NDR Concentration (mg/L)			NMM Concentration (mg/L)		
	Manganese	Selenium	Sulfate	Manganese	Selenium	Sulfate
1	1.429	2.787	1,035.2	1.649	3.842	1,027.8
2	1.285	0.0425	827.9	1.368	0.0514	819.1
3	1.408	0.0249	610	1.683	0.0281	722.4
4	0.906	0.0244	311.6	1.176	0.0274	459.4
Groundwater Standard	0.05	0.05	250	0.05	0.05	250

Table 4-5b. Source Term COPC Concentrations at SMCM-N and SMCM-S

Pore Volume	SMCM-N Concentration (mg/L)			SMCM-S Concentration (mg/L)		
	Manganese	Selenium	Sulfate	Manganese	Selenium	Sulfate
1	1.453	0.884	1,034.7	1.497	0.909	1,069.8
2	1.925	0.0066	830.6	1.994	0.0065	865.5
3	1.833	0.0045	681.1	1.876	0.0039	709.2
4	1.603	0.0045	659.2	1.647	0.0039	686.3
Groundwater Standard	0.05	0.05	250	0.05	0.05	250

Table 4-5c. Source Term COPC Concentrations at H1-N and H1-X

Pore Volume	H1-N Concentration (mg/L)			H1-X Concentration (mg/L)		
	Manganese	Selenium	Sulfate	Manganese	Selenium	Sulfate
1	1.751	1.091	1,267.8	2.435	1.61	1,810
2	2.389	0.0072	1,041.7	3.477	0.0094	1,513.8
3	2.237	0.0039	848.9	3.281	0.0056	1,220.3
4	1.972	0.0037	821.9	2.904	0.0047	1,183.1
Groundwater Standard	0.05	0.05	250	0.05	0.05	250

Table 4-5d. Source Term COPC Concentrations at H1-L and H1-E

Pore Volume	H1-L Concentration (mg/L)			H1-E Concentration (mg/L)		
	Manganese	Selenium	Sulfate	Manganese	Selenium	Sulfate
1	2.473	1.494	1,800.1	2.737	1.629	1,982.6
2	3.242	0.0105	1,348.9	3.535	0.0112	1,466.9
3	3.074	0.0063	1,091.2	3.352	0.0066	1,187
4	2.706	0.0051	1,054.6	2.949	0.0053	1,146.5
Groundwater Standard	0.05	0.05	250	0.05	0.05	250

Table 4-5e. Source Term COPC Concentrations at H1-S

Pore Volume	H1-S Concentration (mg/L)		
	Manganese	Selenium	Sulfate
1	2.664	1.654	1,954.4
2	3.577	0.0109	1,503.4
3	3.391	0.0066	1,213.1
4	2.991	0.0052	1,173.5
Groundwater Standard	0.05	0.05	250

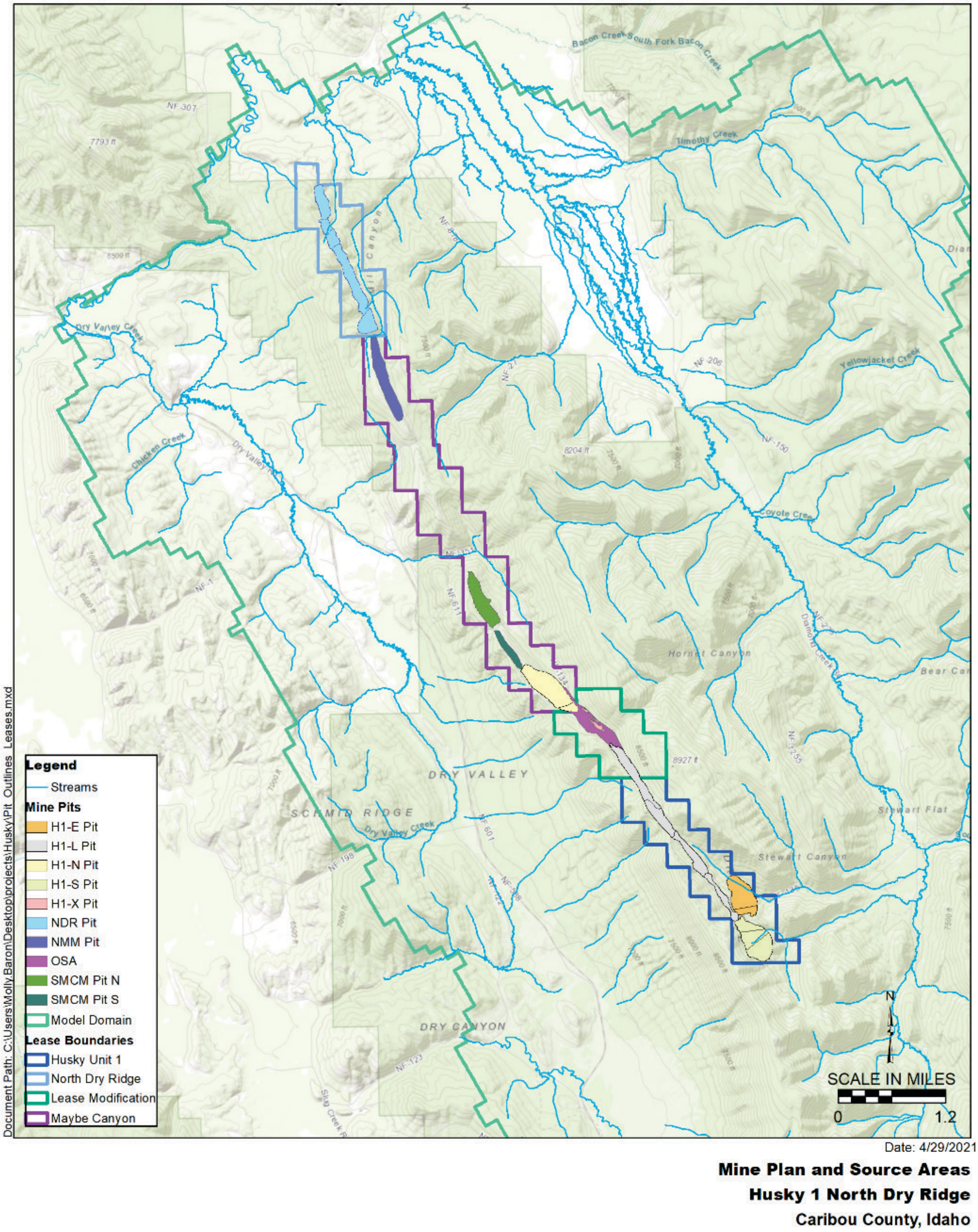


Figure 4-1. Mine Plan and Source Areas

5.0 PREDICTIVE SIMULATIONS

This section describes the setup and results of the groundwater modeling predictive simulations. Predictive simulations were made of the proposed action and one alternative (Alternative Cover) for the following purposes:

- Predict the effects that mining (including dewatering and re-infiltration) and mine reclamation would have on groundwater and surface water flows; and
- Predict the effects that mining and mine reclamation would have on the quality of groundwater and surface water.

The Proposed Action cover presented in The Mine Reclamation Plan was revised to reduce COPC transport. The revised Proposed Action configuration includes four proposed cap and cover types: store-and-release cover, low-permeability clay cover, flexible membrane liner (FML), and lateral drain cover. The choice of cover type to be constructed in each mine pit area was made by Itafos to reduce transport of COPCs both in the subsurface (groundwater) and into surface water bodies compared to the cover proposed in the Mine Reclamation Plan. The Proposed Action cover configuration is mostly comprised of store-and-release and low-permeability clay cover types.

The Alternative Cover cap and cover system configuration was developed as a revised backfill design that optimizes material handling throughout the mine site and is intended to meet performance objectives for protection of surface water and groundwater. The Alternative Cover did not propose additional cover types, but instead modified the locations and acreages of the cover types to further reduce transport of COPCs both in groundwater and into surface water compared to the Proposed Action. The Alternative Cover configuration is mostly comprised of FML and lateral drain cover types, which significantly reduced infiltration into the backfill by replacing store-and-release and low-permeability clay cover types.

The effects of mining and mine reclamation on groundwater and surface water flows, including water quality predictions, were made using the combined flow and transport model for both of these predictive scenarios.

5.1 Simulated Scenarios

As stated above, the scenarios simulated with the groundwater flow and transport model include the Proposed Action and one alternative, the Alternative Cover. The difference between the two scenarios is the area-weighted average recharge rate at the nine pits, the cap and cover acreage of each pit, and the type and amount of cap and cover material at each of the nine pits. There are four proposed cap and cover types in both scenarios: store-and-release cover, low-permeability clay cover, FML, and lateral drain cover. Each of the four cover types is described in detail in ARCADIS (2020d). Using the acreages provided by ARCADIS (2020d) and ARCADIS (2021), and net percolation rates as a percentage of precipitation, provided in **Table 4-3** for each cover type at each pit, area-weighted average recharge rates were calculated to apply in the groundwater model. The areas in which the four cover types would be placed in the proposed action and alternative cover scenarios are shown in **Figure 5-1** and **Figure 5-2**. These figures also show the existing Cross Valley Fill cover at the South Maybe Canyon Mine. Setup of the groundwater model for simulation of these two scenarios was the same except for the area-weighted average recharge rate, number and length of stress periods, and horizontal and vertical extent of each pit backfill area. Additional details are provided in Section 5.1.1.

Additional simulations were also performed for sensitivity analysis, as described and discussed in Section 6. Sensitivity analyses are designed to evaluate the sensitivity of the model-predicted results to changes in the values of input parameters. Sensitivity analyses also help determine if the model is behaving as intended, and it aids understanding what model parameters are most important and how relatively important they are. Input values for selected parameters are varied over realistic ranges, and the results are compared to those of the base-case model. The comparison allows assessment of the range of uncertainty in the model predictions.

5.1.1 Model Development

The two transport simulations included 28 and 14 stress periods to accommodate source term locations and concentrations in the Proposed Action and Alternative Cover scenarios, respectively. The stress period setup for the Proposed Action and Alternative Cover scenarios are summarized in **Table 5-1** and **Table 5-2**, respectively. The Proposed Action simulations were run for a period of 100 years, which was more than four times the maximum time for one pore volume of water to infiltrate through the reclamation cover system of the Proposed Action. For the Alternative Cover scenario, the pore volume times for pits with a majority of their acreage covered by FMLs (i.e., NDR, SMCM-N, SMCM-S, H1-E) were greater than 600 years. Given these longer pore volume times, the Alternative Cover scenario was simulated for a period of 150 years, with results output at 20, 40, 60, 80, and 100 years for direct comparison to the Proposed Action scenario.

The appropriate COPC concentrations for pore-volume 1 were applied to the recharge. Reductions in source area COPC concentrations were made at the end of each pore-volume time for each mine area; these reductions were applied in stress periods 2 through 28 in the Proposed Action scenario, as summarized in **Table 5-1.** The same approach was used for the Alternative Cover scenario by applying reduction in COPC concentrations at the end of each pore volume time except for pit areas where the pore volume time exceeded 150 years. In those areas the first pore volume concentration was applied at each of the 14 stress periods for the Alternative Cover scenario (**Table 5-2**).

Table 5-3 lists the details on the cap and cover acreages, and recharge rates applied at each of the mine pits for the Proposed Action and Alternative Cover scenarios. The acreages of FML and lateral drain are larger in the Alternative Cover scenario compared to the Proposed Action scenario. Conversely, the acreages of store-and-release and clay cover decrease in the Alternative Cover scenario compared to the Proposed Action scenario. The recharge rates provided by ARCADIS (2020d) are based on net percolation rates as a percentage of precipitation for each cover type at each mine pit. If more than one type of cover was used at a mine pit (e.g., H1-S), then an area-weighted average recharge rate was calculated to apply at that pit in the groundwater model.

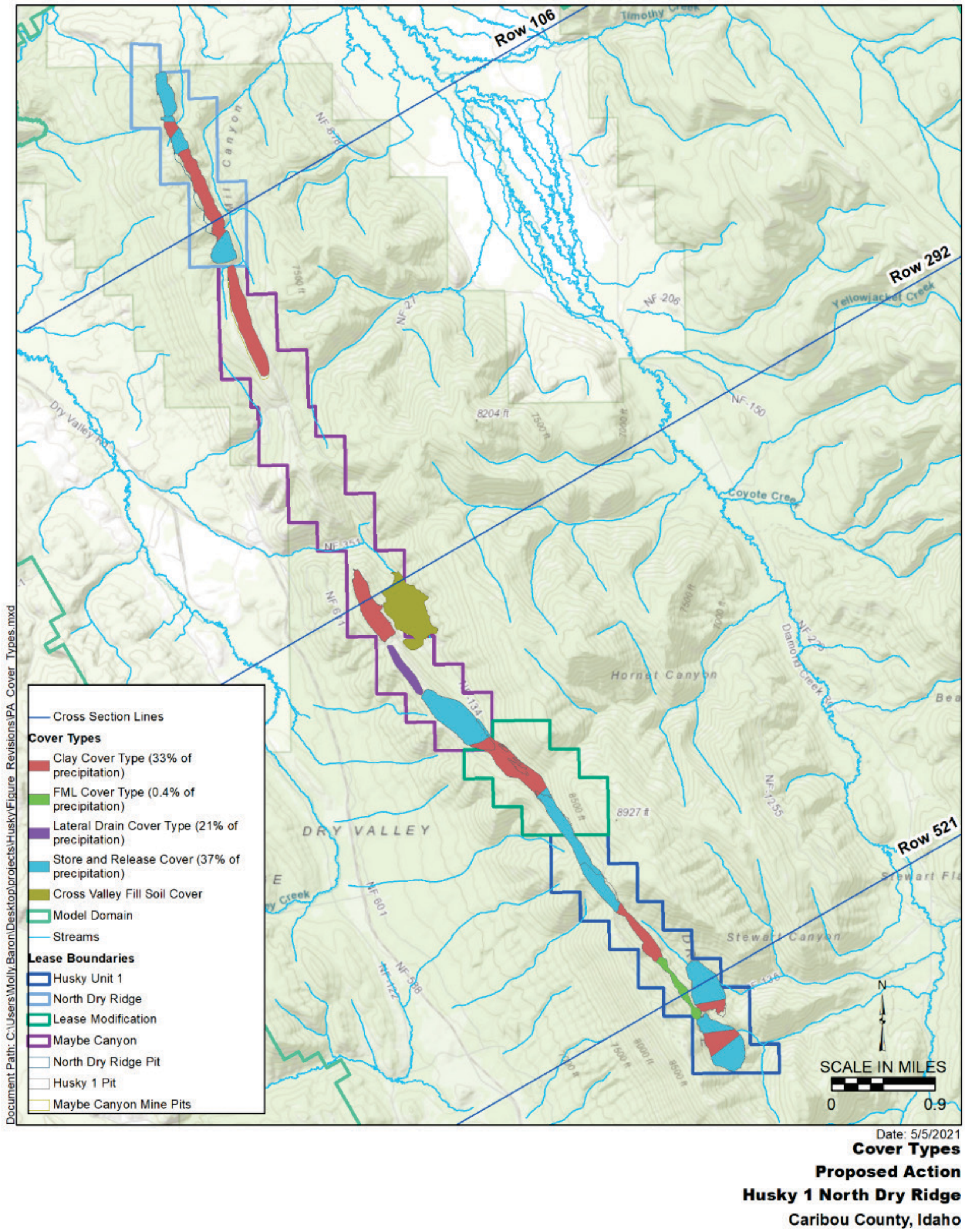


Figure 5-1. Proposed Action Scenario – Cover Types

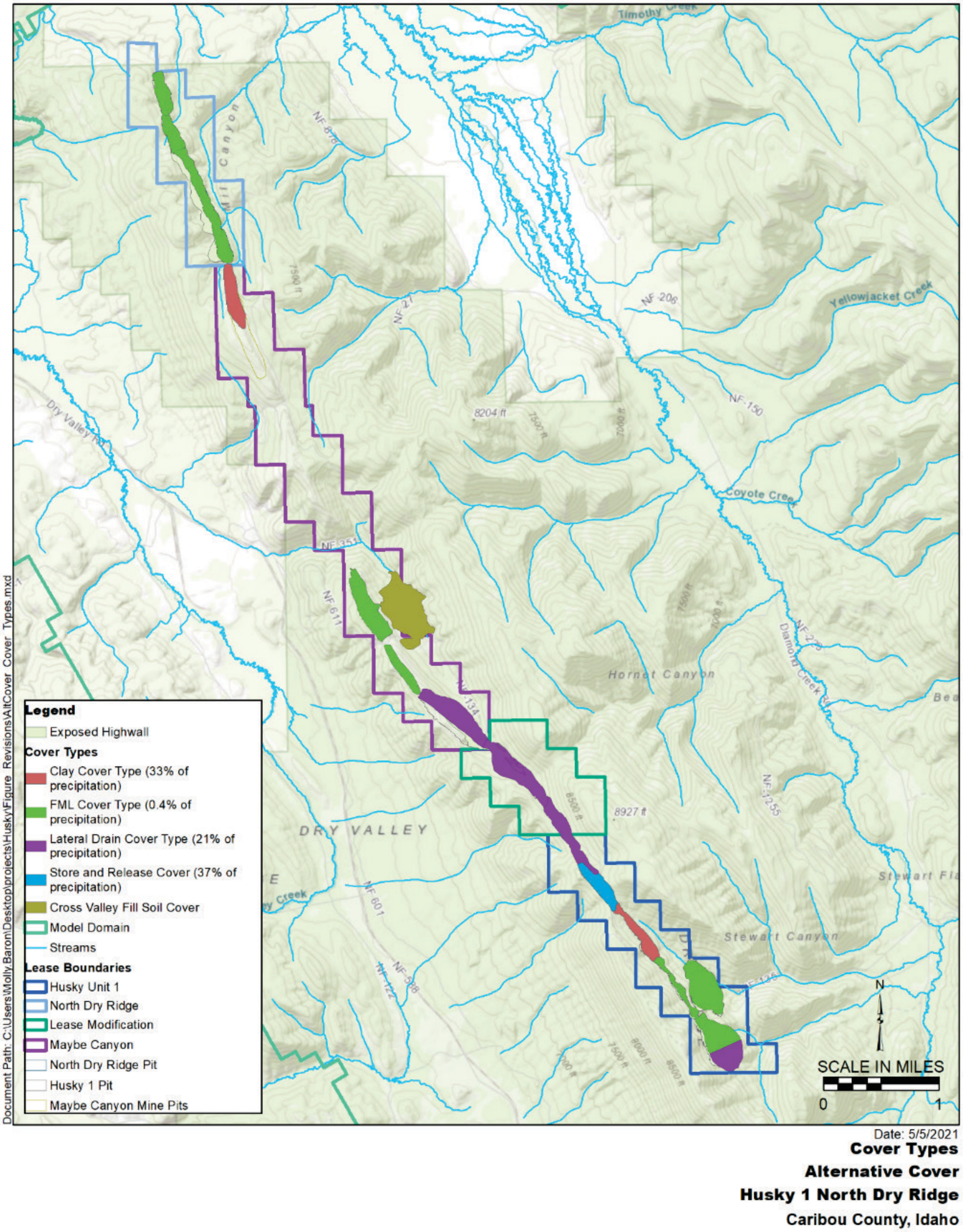


Figure 5-2. Alternative Cover Scenario – Cover Types

Table 5-1. Predictive Model Stress Period Setup for Proposed Action

Stress Period	Duration (days)	Starting Time (years)	Ending Time (years)	Description
1	3,303	0	9	Apply pore-volume 1 concentrations at all pit areas
2	829	9	11.3	Apply pore-volume 2 concentrations at H1-X
3	58	11.3	11.5	Apply pore-volume 2 concentrations at H1-L
4	713	11.5	13.4	Apply pore-volume 2 concentrations at SMCM-S
5	650	13.4	15.2	Apply pore-volume 2 concentrations at NMM
6	921	15.2	17.7	Apply pore-volume 2 concentrations at SMCM-N
7	132	17.7	18.1	Apply pore-volume 2 concentrations at NDR
8	850	18.1	20.4	Apply pore-volume 3 concentrations at H1-X
9	348	20.4	21.4	Apply pore-volume 2 concentrations at H1-N
10	459	21.4	22.6	Apply pore-volume 2 concentrations at H1-E
11	117	22.6	22.9	Apply pore-volume 3 concentrations at H1-L
12	110	22.9	23.2	Apply pore-volume 3 concentrations at SMCM-S
13	1,316	23.2	26.8	Apply pore-volume 2 concentrations at H1-S
14	103	26.8	27.1	Apply pore-volume 3 concentrations at NMM
15	1,197	27.1	30.4	Apply pore-volume 4 concentrations at H1-X
16	1,289	30.4	33.9	Apply pore-volume 3 concentrations at SMCM-N
17	175	33.9	34.4	Apply pore-volume 4 concentrations at H1-L
18	378	34.4	35.4	Apply pore-volume 4 concentrations at SMCM-S
19	1,761	35.4	40.3	Apply pore-volume 3 concentrations at NDR
20	203	40.3	40.8	Apply pore-volume 4 concentrations at NMM
21	695	40.8	42.7	Apply pore-volume 3 concentrations at H1-N
22	1,052	42.7	45.6	Apply pore-volume 3 concentrations at H1-E
23	321	45.6	46.5	Apply pore-volume 4 concentrations at SMCM-N
24	2,441	46.5	53.2	Apply pore-volume 3 concentrations at H1-S
25	2,947	53.2	61.2	Apply pore-volume 4 concentrations at NDR
26	1,043	61.2	64.1	Apply pore-volume 4 concentrations at H1-N
27	2,059	64.1	69.7	Apply pore-volume 4 concentrations at H1-E
28	11,055	69.7	100	Apply pore-volume 4 concentrations at H1-S

See Figure 4-1 for locations of mine pits.

Table 5-2. Predictive Model Stress Period Setup for Alternative Cover

Stress Period	Duration (days)	Starting Time (years)	Ending Time (years)	Description
1	5,948	0	16.3	Apply pore-volume 1 concentrations at all pit areas
2	762	16.3	18.4	Apply pore-volume 2 concentrations at H1-X
3	3,870	18.4	29.0	Apply pore-volume 2 concentrations at H1-L
4	1,316	29.0	32.6	Apply pore-volume 2 concentrations at NMM
5	255	32.6	33.3	Apply pore-volume 3 concentrations at H1-X
6	1,268	33.3	36.7	Apply pore-volume 2 concentrations at H1-N
7	4,425	36.7	48.9	Apply pore-volume 3 concentrations at H1-L
8	2,285	48.9	55.1	Apply pore-volume 4 concentrations at H1-X
9	1,031	55.1	57.9	Apply pore-volume 4 concentrations at H1-L
10	3,143	57.9	66.5	Apply pore-volume 3 concentrations at NMM
11	7,437	66.5	86.9	Apply pore-volume 3 concentrations at H1-N
12	4,714	86.9	99.8	Apply pore-volume 4 concentrations at NMM
13	3,855	99.8	110.4	Apply pore-volume 2 concentrations at H1-N
14	14,479	110.4	150.0	Apply pore-volume 2 concentrations at H1-S

See Figure 4-1 for locations of mine pits.

Table 5-3. Backfill Acreage and Area-Weighted Recharge Rates

Scenario and Location	Total Cap and Cover Acreage	Store and Release Cover Acreage	Clay Acreage	FML Acreage	Lateral Drain Acreage	Area-Weighted Recharge Rate (ft/d)
Proposed Action						
NDR Pit 1	25	25				2.18E-03
NDR Pit 2	23	16	7			2.11E-03
NDR Pit 3	89	41	48			2.06E-03
NMM	79		79			2.35E-03
SMCM Pit 1 (North)	70		70			2.35E-03
SMCM Pit 2 (South)	30				30	1.49E-03
H1-N	81	81				2.99E-03
H1-N	9		9			2.67E-03
H1-X	54		54			2.67E-03
H1-L Pit 1	49	49				2.99E-03
H1-L Pit 2	29	29				2.99E-03
H1-L Pit 3	28		28			2.67E-03
H1-L Pit 4	20			20		3.23E-05
H1-E Pit	66	58	8			2.95E-03
H1-S Pit	78	51	27			2.88E-03

Scenario and Location	Total Cap and Cover Acreage	Store and Release Cover Acreage	Clay Acreage	FML Acreage	Lateral Drain Acreage	Area-Weighted Recharge Rate (ft/d)
Alternative Cover						
NDR Pit 1	26			26		2.95E-05
NDR Pit 2	22			22		2.95E-05
NDR Pit 3	61			61		2.95E-05
NMM	37		37			2.35E-03
SMCM Pit 1 (North)	57			57		2.84E-05
SMCM Pit 2 (South)	23			23		2.84E-05
H1-N	61				61	1.70E-03
H1-X	63				63	1.70E-03
H1-L Pit 1	41				41	1.70E-03
H1-L Pit 2	30	30				2.99E-03
H1-L Pit 3	29		29			2.67E-03
H1-L Pit 4	19			19		3.23E-05
H1-E Pit	64			64		3.23E-05
H1-S Pit	74			42	32	7.52E-04

See Figure 4-1 for locations of mine pits.

5.2 Simulation Results

The following subsections present results for the Proposed Action and the Alternative Cover simulations. For plume lateral extent maps in the alluvium, Rex Chert Member, and Upper Wells Formation, please see **Appendix B and Appendix C**.

5.2.1 Proposed Action

Figure 5-3 through **Figure 5-7** show the locations of the IDAPA 58.01.11.200 groundwater standard concentration contours (0.05 mg/L for selenium and manganese and 250 mg/L for sulfate) at 20-year intervals after mine closure. Figures for each COPC were divided into two figures that focus on the northern and southern mining areas to aid the reader in viewing the contour differences. Also, these plan-view figures show the maximum lateral extent of the COPC plume in all model layers, not by geologic unit. For plume maps showing COPC concentrations in the alluvium, Rex Chert Member, and Upper Wells Formation for the Proposed Action, please see **Appendix B**. Further discussion of these figures is provided below.

The area with selenium concentrations above the 0.05 mg/L groundwater standard is predicted to extend 1,000 to 3,000 ft downgradient and downdip from NDR pit in the Rex Chert 100 years after mine closure (**Figure 5-3 and Figure B-2)**. Selenium migrated toward the north from NDR pit and turns northwest due to the Blackfoot fault (**Figure 5-3** and **Figure B-3**). Selenium also migrated into the weathered bedrock and alluvium into the East Mill Creek drainage after groundwater mounding in the pit backfill (**Figure B-1**). Selenium migration from the North Maybe Mine pit was less than the NDR pit due to the use of a low-permeability clay cover at the NMM pit (**Figure 5-1**). At the South Maybe Canyon Mine, selenium migration occurred to the north and then west beneath Maybe Creek in the Grandeur Tongue Member and Upper Wells Formation (**Figure 5-4**). For the Husky 1 area, selenium migration occurred into the Stewart Creek and Maybe Creek drainages through the weathered bedrock and alluvium after groundwater mounding occurred in the pit backfill (**Figure B-4**). At H1-E and H1-S (**Figure B-5**), groundwater mounded more quickly and higher within the backfill due to the proposed store-and-release cover, which produced selenium transport into the Lower Dinwoody Formation and Rex Chert Member and caused the plume to migrate further downgradient and downdip (i.e., approximately one mile after 100 years) compared to the Alternative Cover scenario. Source area selenium concentrations were expected to decrease to below the groundwater standard by the end of the first pore volume at all mine pits except NMM, which had a second pore volume concentration slightly above the 0.05 mg/L groundwater standard (**Table 4-4a**).

The area with manganese concentrations above the 0.05 mg/L groundwater standard was predicted to migrate hundreds of feet farther than selenium (**Figure 5-5, Figure 5-6, and Figures B-7 through B-12**). Because the source area manganese concentrations were expected to exceed the groundwater standard through at least pore volume 4 (**Table 4-5**) and at higher concentrations than selenium at the end of pore volumes 1 through 4 (except pore volume 1 for NDR and NMM), the manganese plume was predicted to extend farther downgradient and downdip through the end of the simulation time. Source area manganese concentrations were expected to remain elevated above groundwater standards after the fourth pore volume.

The area with sulfate concentrations above the 250 mg/L groundwater standard was predicted to be smaller in lateral extent than selenium and manganese (**Figure 5-7, Figure 5-8, Figures B-13 through B-18**). This apparent reduction in sulfate plume extent was due to the ratio of the sulfate pore volume concentrations to the groundwater standard of 250 mg/L. For example, at H1-S the ratio of selenium, manganese, and sulfate concentrations to their respective groundwater standards were approximately 53:1, 33:1, and 8:1, respectively, for the first pore volume. Since chemical reactions were not being simulated in the transport model, the COPC plume extents were proportional to these ratios. Similar to manganese, source area sulfate concentrations were expected to remain elevated above groundwater standards after the fourth pore volume.

Figure 5-9 shows three cross-sectional views of the selenium plume 40 years after mine closure to provide a visual representation of the vertical aspect of COPC plume migration. The plume extent shown in **Figure 5-9** applies to the other COPCs and the other modeled scenarios. The COPC plumes migrated downdip from the mine pits and then laterally within the Wells Formation, except for minor lateral migration within the shallower formations immediately adjacent to the pits due to groundwater mounding within the backfill and where selenium migrated vertically into the Grandeur Tongue Member directly below the backfill due to the Meade Peak Member being mined out completely. Predicted COPC concentrations exceeding the groundwater standard were limited primarily to model layers 7-9, which represent the Wells Formation. Since the backfilled mine pits filled up with infiltrated water over time, there was some COPC transport into overlying units, such as the Rex Chert Member and Lower Dinwoody Formation.

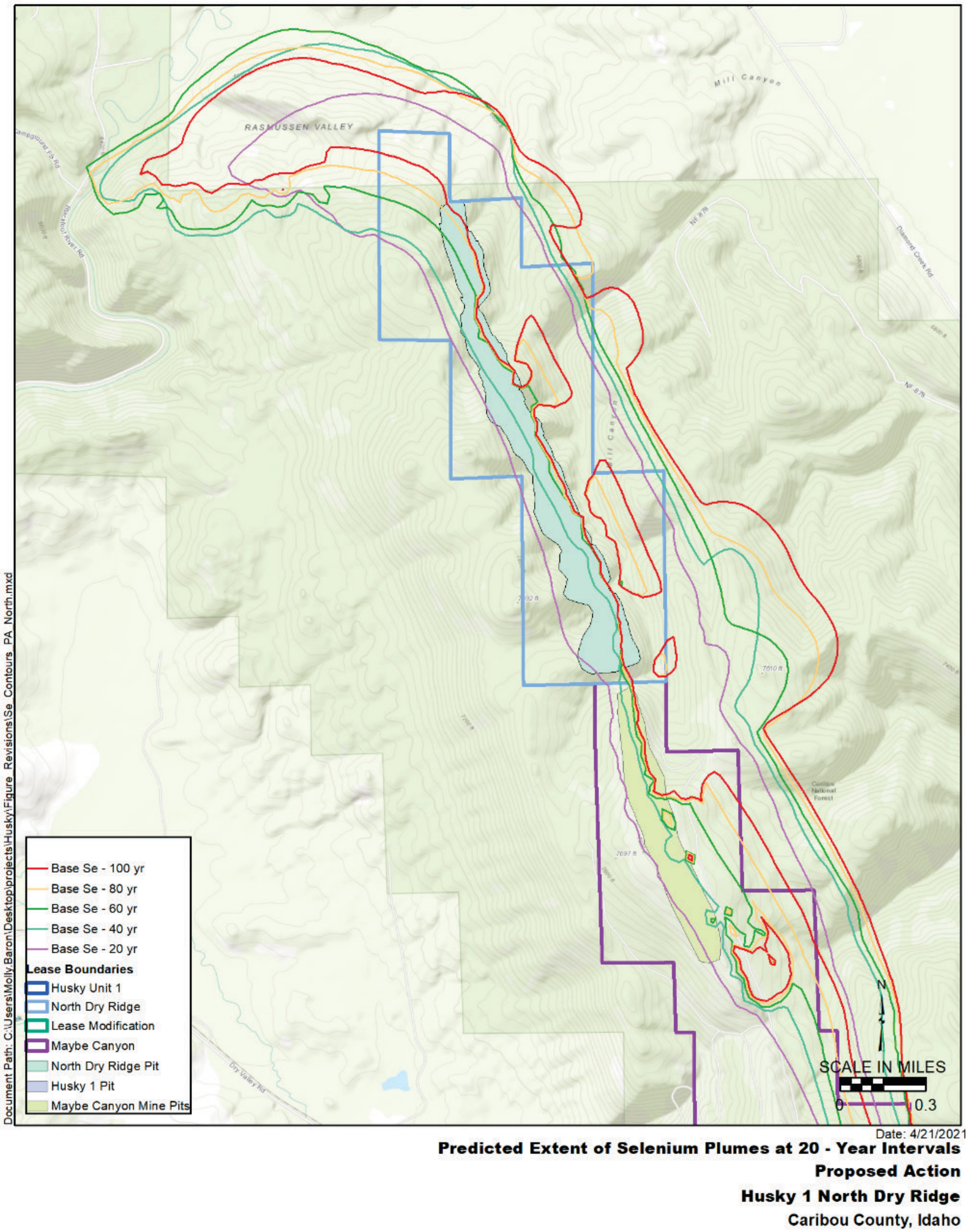
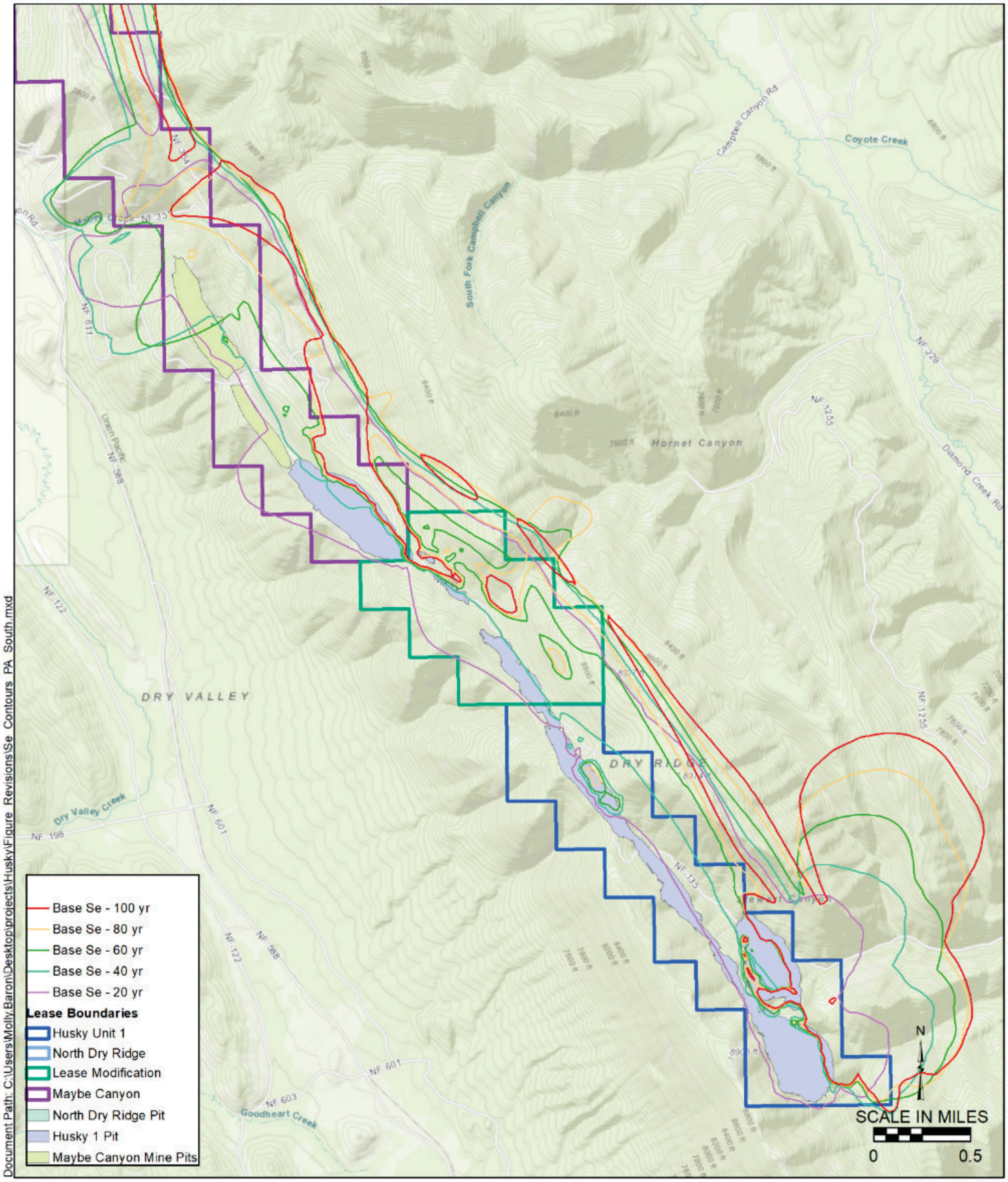


Figure 5-3. Predicted Extents of Selenium Plumes at 20-Year Time Intervals for Proposed Action – North Dry Ridge and North Maybe Mine



Date: 5/24/2021

Predicted Extent of Selenium Plumes at 20 - Year Intervals
Proposed Action
Husky 1 North Dry Ridge
Caribou County, Idaho

Figure 5-4. Predicted Extents of Selenium Plumes at 20-Year Time Intervals for Proposed Action – South Maybe Canyon Mine and Husky 1

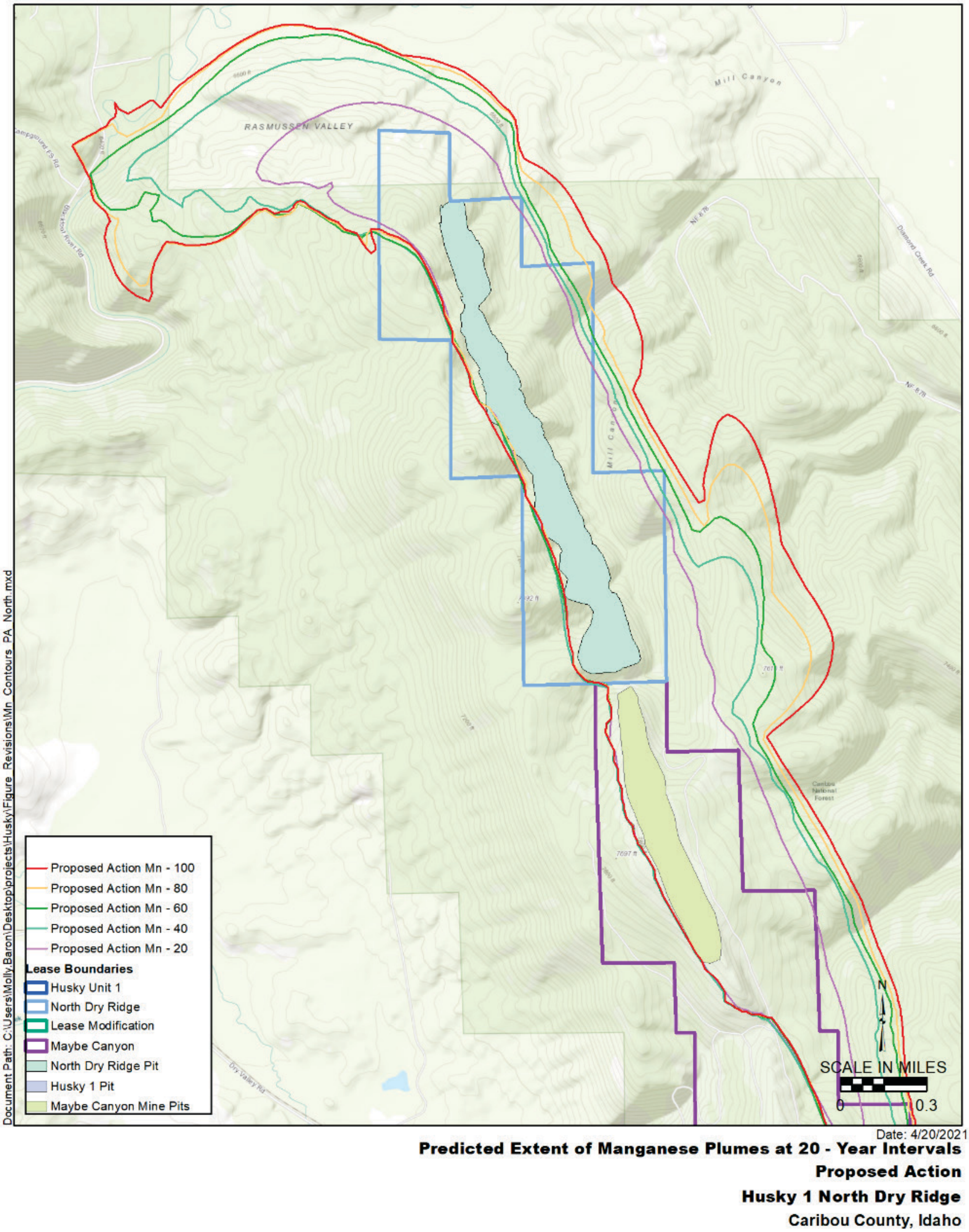


Figure 5-5. Predicted Extents of Manganese Plumes at 20-Year Time Intervals for Proposed Action – North Dry Ridge and North Maybe Mine

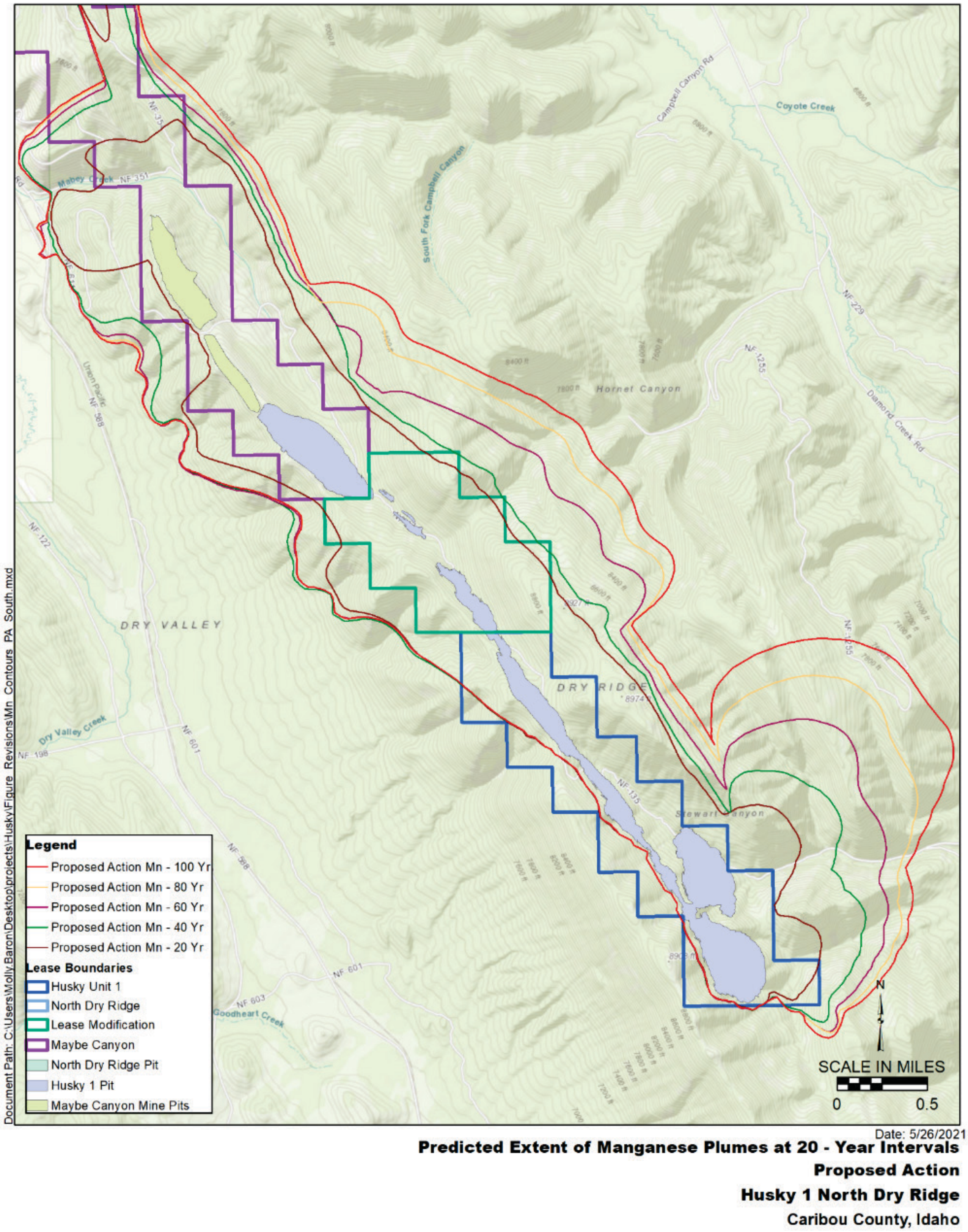


Figure 5-6. Predicted Extents of Manganese Plumes at 20-Year Time Intervals for Proposed Action – South Maybe Canyon Mine and Husky 1

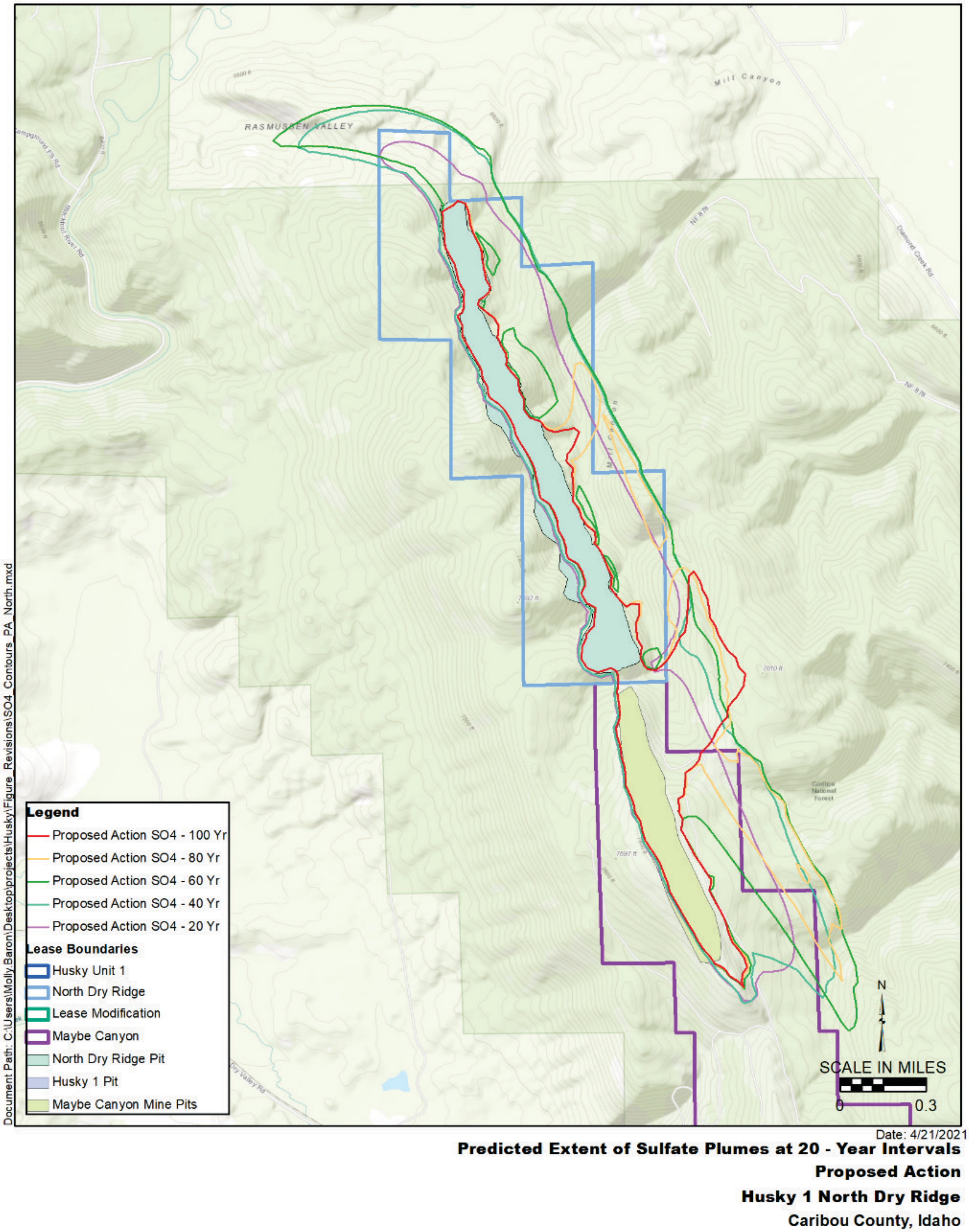


Figure 5-7. Predicted Extents of Sulfate Plumes at 20-Year Time Intervals for Proposed Action – North Dry Ridge and North Maybe Mine

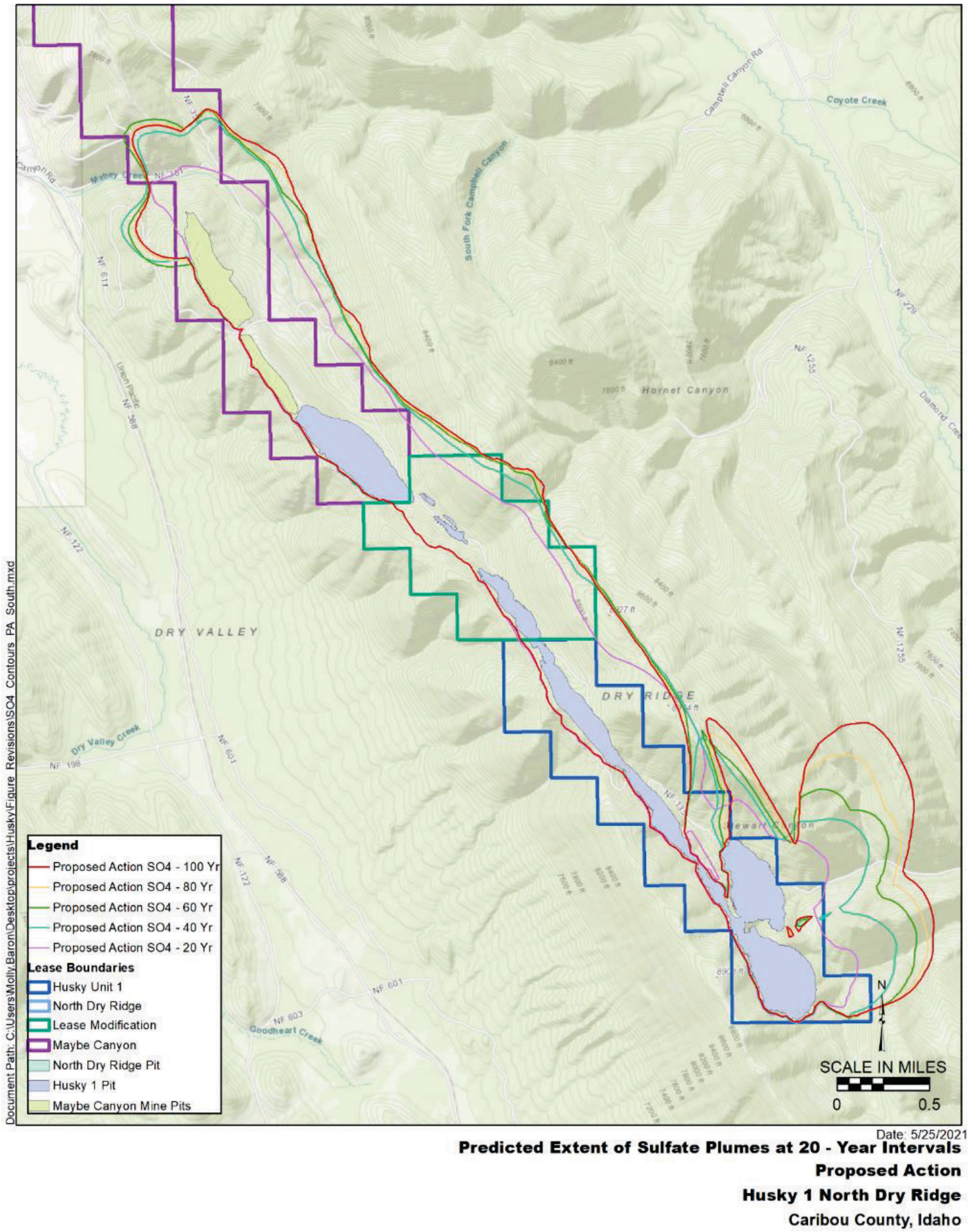


Figure 5-8. Predicted Extents of Sulfate Plumes at 20-Year Time Intervals for Proposed Action – South Maybe Canyon Mine and Husky 1

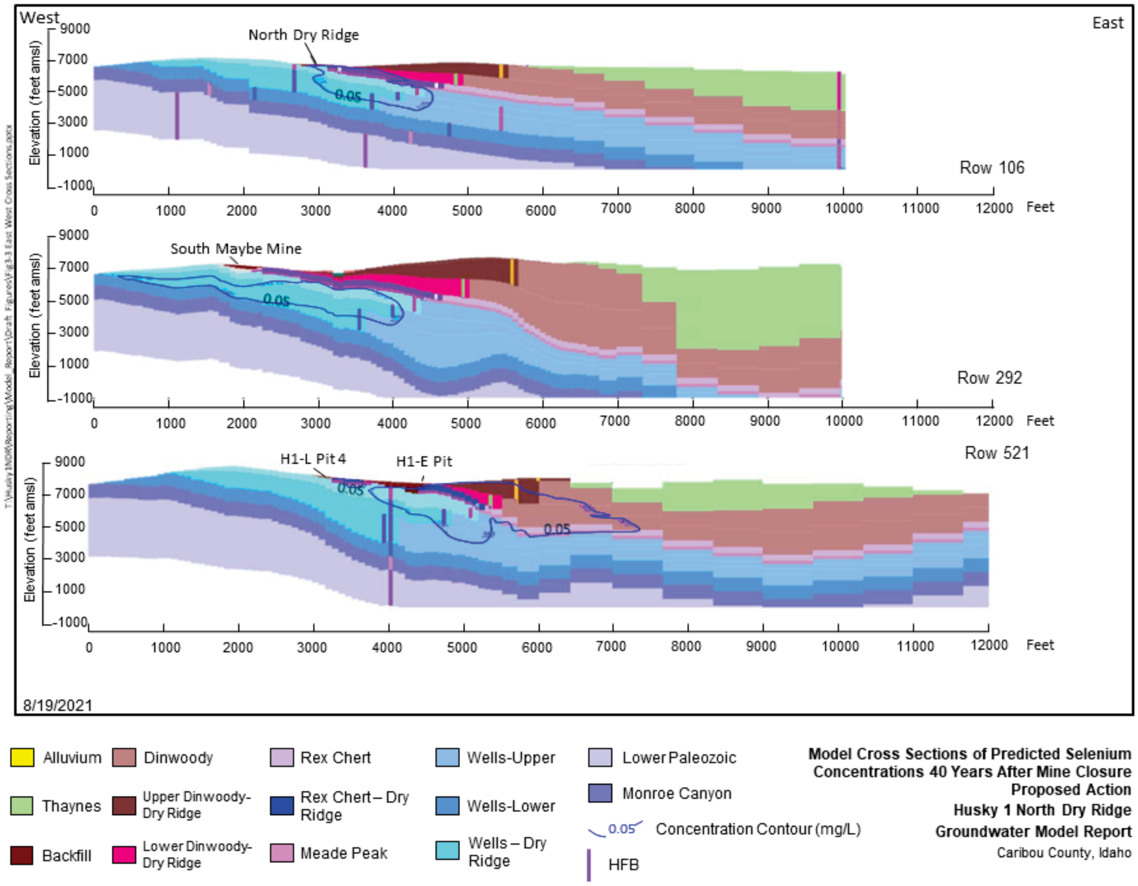


Figure 5-9. Model Cross-Sections of Predicted Selenium Concentrations 40 Years after Mine Closure for Proposed Action (location of cross sections presented on Figure 5-1)

Figure 5-10, Figure 5-11, and **Figure 5-12** show graphs of predicted selenium concentrations in groundwater discharging into stream model cells downgradient of the mine pits for the Proposed Action. Three surface water bodies (Stewart Creek, Maybe Creek, and East Mill Creek) adjacent to the covered and backfilled mine pits were predicted to have groundwater discharging into them at concentrations higher than the surface water standard of 0.0031 mg/L or 3.1 µg/L between approximately 12 and 52 years after mine closure. The locations of these three groundwater discharge points are provided in **Figure 5-13**. These exceedances occurred because the types of covers simulated on top of the backfilled mine pits in the Proposed Action scenario allowed enough infiltration to occur over time that the water mounded in the backfill due to the low permeability of the rock surrounding the mine pits. The mounded water allowed selenium transport into the weathered bedrock or the alluvium and/or overtopped the rim of the pits and allowed discharge directly into the streams (**Figure 5-14**). Effects to surface water quality would be limited to headwater reaches where groundwater interactions occurred, and existing surface water flow would quickly mix with groundwater in the stream. There would be no detectable impacts to surface water quality, or impacts would be negligible in downstream reaches of Stewart Creek and in Diamond Creek. No detectible impacts to water quality would occur in lower Diamond Creek, Kendall Canyon Creek, Dry Valley Creek, or the Blackfoot River. Graphs for manganese and sulfate concentrations in groundwater discharging into streams were not shown since there were no surface water standards for these two COPCs; however, their concentration trends would be similar to selenium at the locations discussed above.

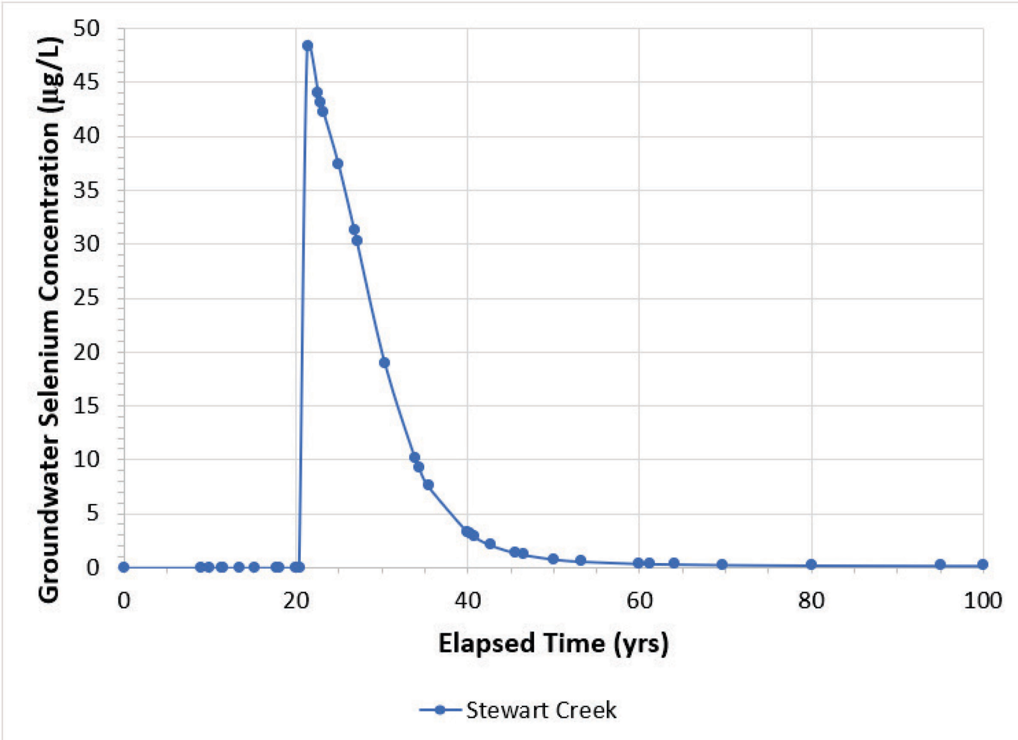


Figure 5-10. Simulated Groundwater Selenium Concentration Discharging into Stewart Creek – Proposed Action

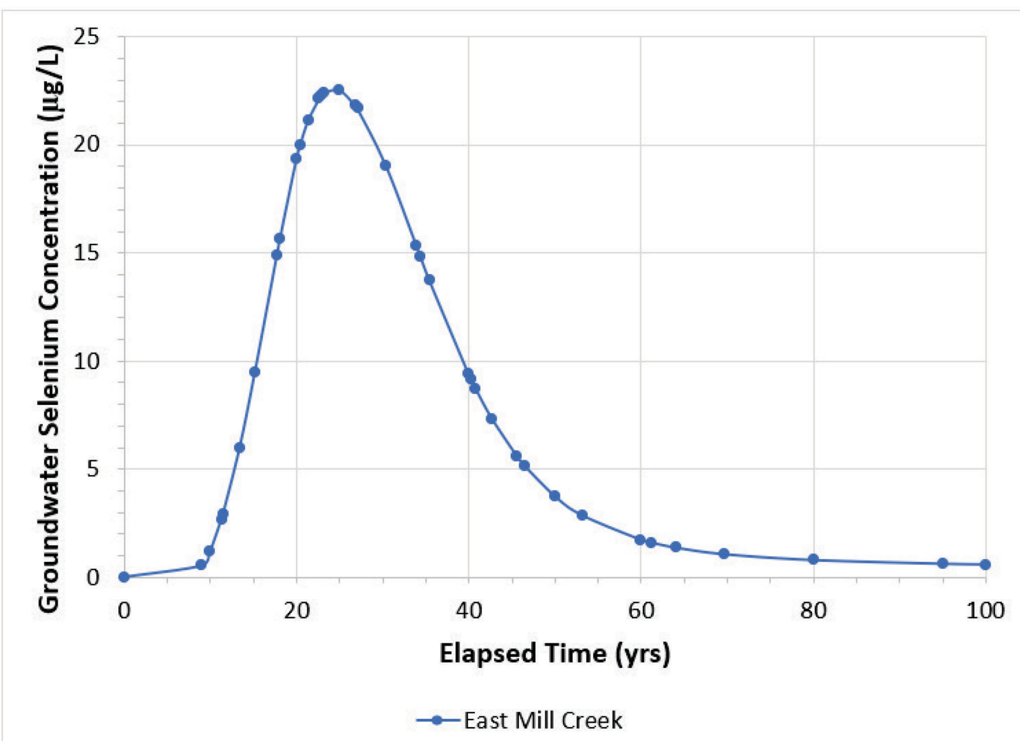


Figure 5-11. Simulated Groundwater Selenium Concentration Discharging into East Mill Creek – Proposed Action

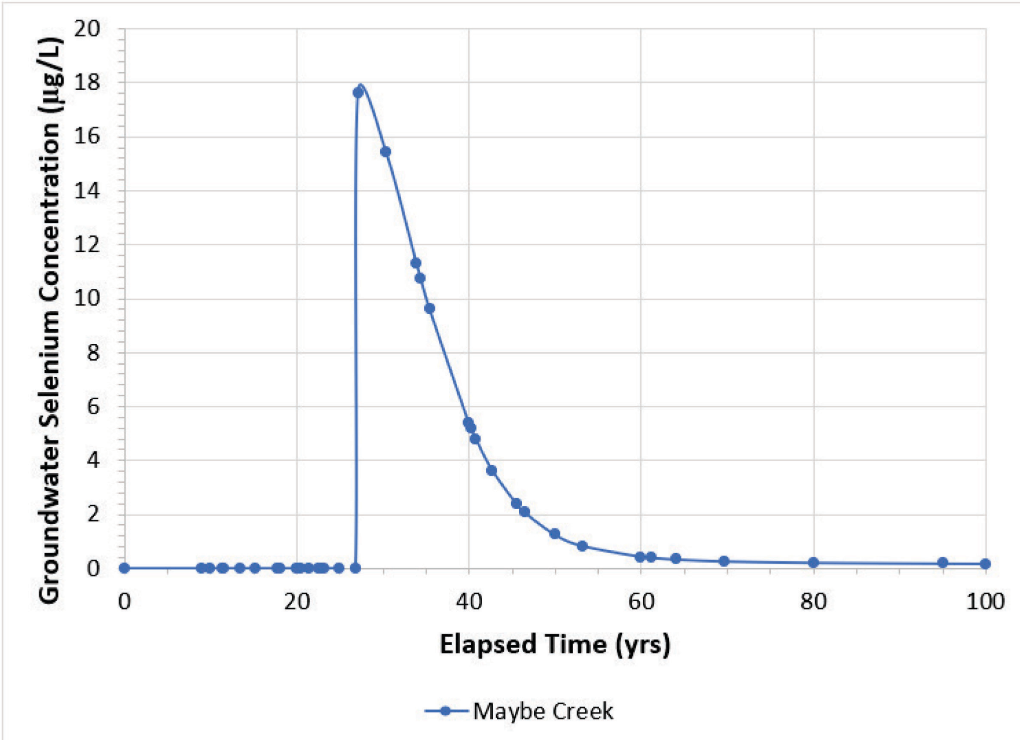


Figure 5-12. Simulated Groundwater Selenium Concentration Discharging into Maybe Creek – Proposed Action

The flow and transport model was also utilized to evaluate potential changes to stream flow for the Proposed Action. Stream flows evaluated by the groundwater flow and transport model include Blackfoot River, East Mill Creek, Mosquito Creek, Kendall Canyon Creek, Diamond Creek, and Dry Creek. Model results showed that there was a negligible increase in base flow and no simulated stream flow reduction at any of these surface water bodies due to the mining activities. It should be noted that the groundwater model was not quantitatively calibrated to streamflow, and the accuracy of small changes in streamflow cannot be evaluated quantitatively. However, because the model output is numerical, model-predicted changes in stream flow can only be reported quantitatively. The predictions regarding changes to stream flow should be considered in light of these limitations.

Potential changes to spring discharge were not explicitly simulated in the flow and transport model. Spring discharges with measurable quantities were used directly as flow into the headwaters of streams in the model. Other springs were likely connected to hydraulically-isolated fractures or perched lenses of groundwater. Springs sourced by isolated fractures or perched groundwater would not be affected by mine-related activities unless they are located within approximately 1,000 feet of the proposed mine pits or within the distributed mining areas where their base flows would be reduced or cease to flow at all. There were 28 mapped springs within 1,000 feet of the proposed H1NDR pit boundaries that could have reduced flow rates from reduced potentiometric heads that would result from mining. The majority of these springs occurred near East Mill Creek, Maybe Creek, and Stewart Creek. These springs do not contribute significant flow to these creeks and would be expected to have minor or negligible effects on stream flows. Note the 1,000 feet distance discussed above was qualitatively chosen based on expected changes in recharge and subsequent water-level elevation declines due to mining activities and post-mining reclamation.

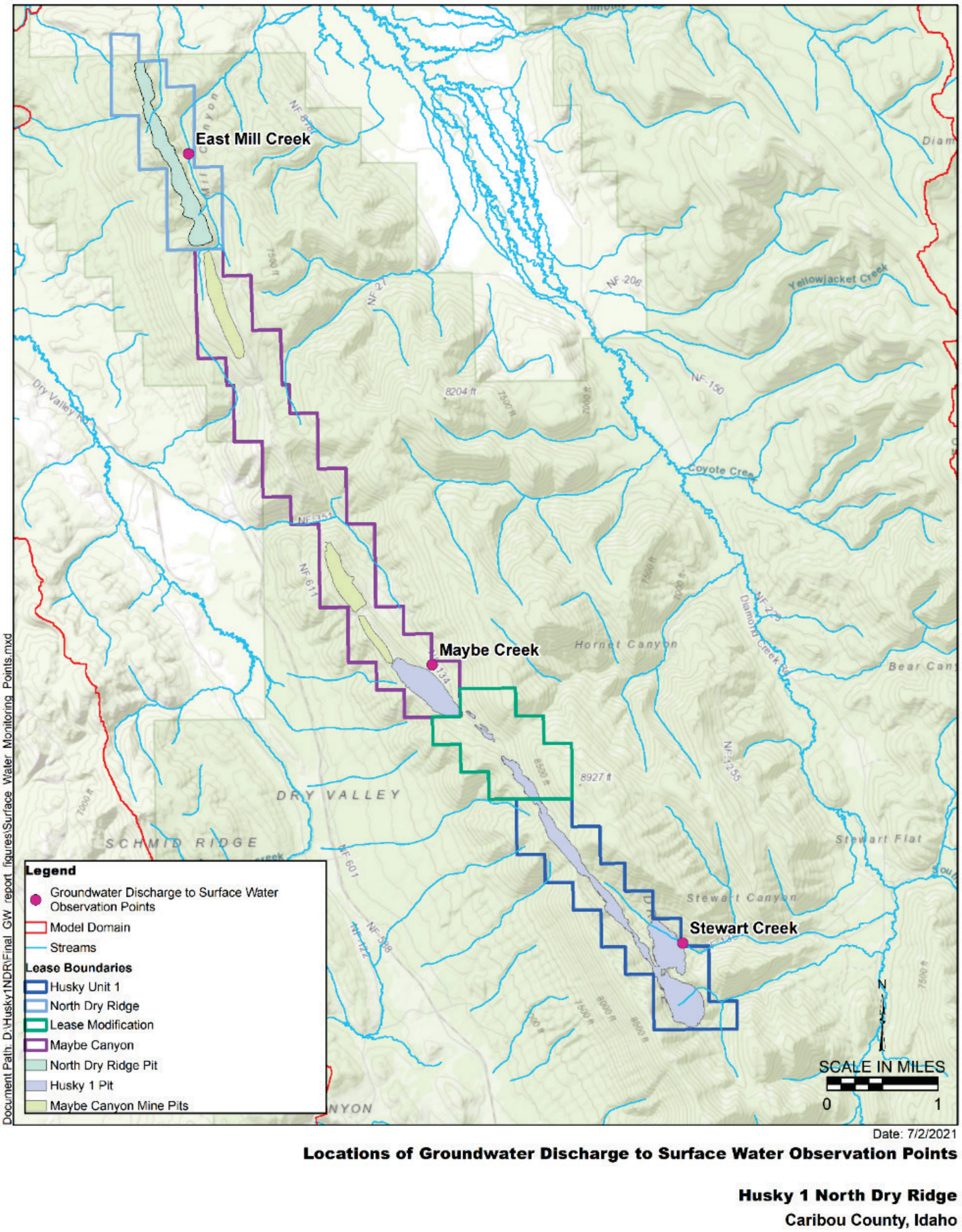


Figure 5-13. Locations of Groundwater Discharge to Surface Water Observation Points

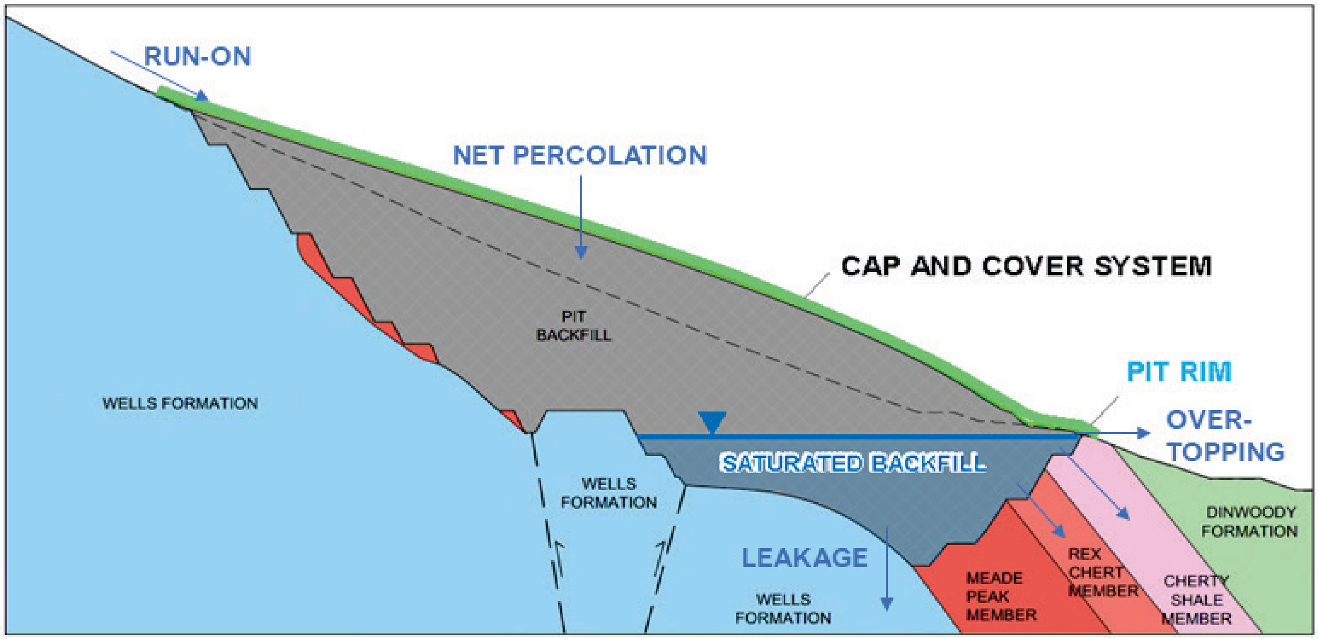


Figure 5-14. Schematic of Groundwater Mounding and Overtopping

5.2.2 Alternative Cover Scenario

The Alternative Cover was designed to reduce COPC mass loading from the pit backfill and thereby reduce potential impacts to surface water and groundwater. The Alternative Cover design incorporated different backfill areas and thicknesses compared to the Proposed Action. The Alternative Cover also reduced the rate and volume of recharge to the backfill in order to reduce the mounding in the backfill and the overflow observed in the Proposed Action. The reduced mass loading was predicted to result in much smaller COPC plumes due to longer pore volume times for lateral drain and FML covers (see **Table 4-4b** and **Table 4-4d**). In all respects, other than construction of the Alternative Cover system in specific locations of the mine pits during reclamation (**Figure 5-1**), mine operation and mine reclamation would be the same as for the Proposed Action.

Figure 5-15, **Figure 5-16, and Figures C-1 through C-6** showed the locations of the groundwater standard concentration contours (0.05 mg/L for selenium) at 20-year intervals after mine closure. The Alternative Cover would result in plume extents in the Wells Formation that were reduced by at least 500 feet downgradient and downdip at most of the mine pits compared to the Proposed Action. The largest reduction in plume extent (approximately 40%) was downgradient and downdip from H1-E and H1-S pits. At these locations, the addition of lateral drain and FML covers has reduced water level elevations within the backfill enough to prevent transport through the Lower Dinwoody Formation near H1-S and H1-E.

The areas with predicted manganese concentrations above the groundwater standard of 0.05 mg/L were shown in **Figure 5-17**, **Figure 5-18, and Figures C-7 through C-12**. The Alternative Cover would result in the manganese plume extent being reduced more than 2,000 feet in the Wells Formation northwest of North Dry Ridge compared to the Proposed Action. Also, the manganese plume for the Alternative Cover extended over a smaller area than the selenium plume downgradient of the NDR mine. Reductions in plume extent were also evident east of North Dry Ridge, H1-X, H1-S, and H1-E in the Rex Chert Member and/or Lower Dinwoody Formation. The reductions in manganese plume extent were also due to the addition of lateral drain and FML covers at these mine pits, which lowered the height of the water level within the backfill.

Figure 5-19, **Figure 5-20, and Figures C-13 through C-18** displayed areas where the sulfate groundwater concentration exceeded its secondary groundwater standard of 250 mg/L. Similar to the other two COPCs, the Alternative Cover would results in the sulfate plume extent being reduced downgradient and downdip of NDR, SMCM, H1-X, H1-S, and H1-E due to the addition of lateral drain and FML covers by up to 2,000 feet. This plume reduction was very evident at NDR and SMCM, where the plumes do not migrate more than a couple hundred feet downgradient and downdip due to the FML covers.

Figure 5-21 showed three cross-sectional views of the selenium plume 40 years after mine closure to provide a visual representation of the vertical aspect of COPC plume migration under the Alternative Cover scenario. Similar to the Proposed Action, the COPC plumes migrated downdip from the mine pits and then laterally within the Wells Formation, except for minor lateral migration within the shallower formations (e.g., Rex Chert Member) immediately adjacent to the pits due to groundwater mounding within the backfill. Predicted COPC concentrations exceeding the groundwater standard were limited primarily to model layers 8 and 9, which represent the upper and middle portions of the Wells Formation. The cross section at Row 521 on **Figure 5-21** showed the lack of a selenium plume within the Lower Dinwoody Formation, as discussed above.

Groundwater concentrations discharging into Maybe Creek, Stewart Creek, and East Mill Creek decreased to below 0.1 µg/L over the model duration due to the use of FML and lateral drain covers over more of the backfilled mine pits in the Alternative Cover simulation. These predicted concentrations were more than an order of magnitude less than the site-specific surface water standard of 3.1 µg/L. In fact, the predicted concentrations were below method detection limit and laboratory reporting limit for selenium (ARCADIS, 2020b) for all surface water locations in the model domain for the Alternative Cover simulations. Model-predicted concentrations below these reporting limits were calculated values that normally would not be measurable in water samples analyzed by typical laboratory methods.

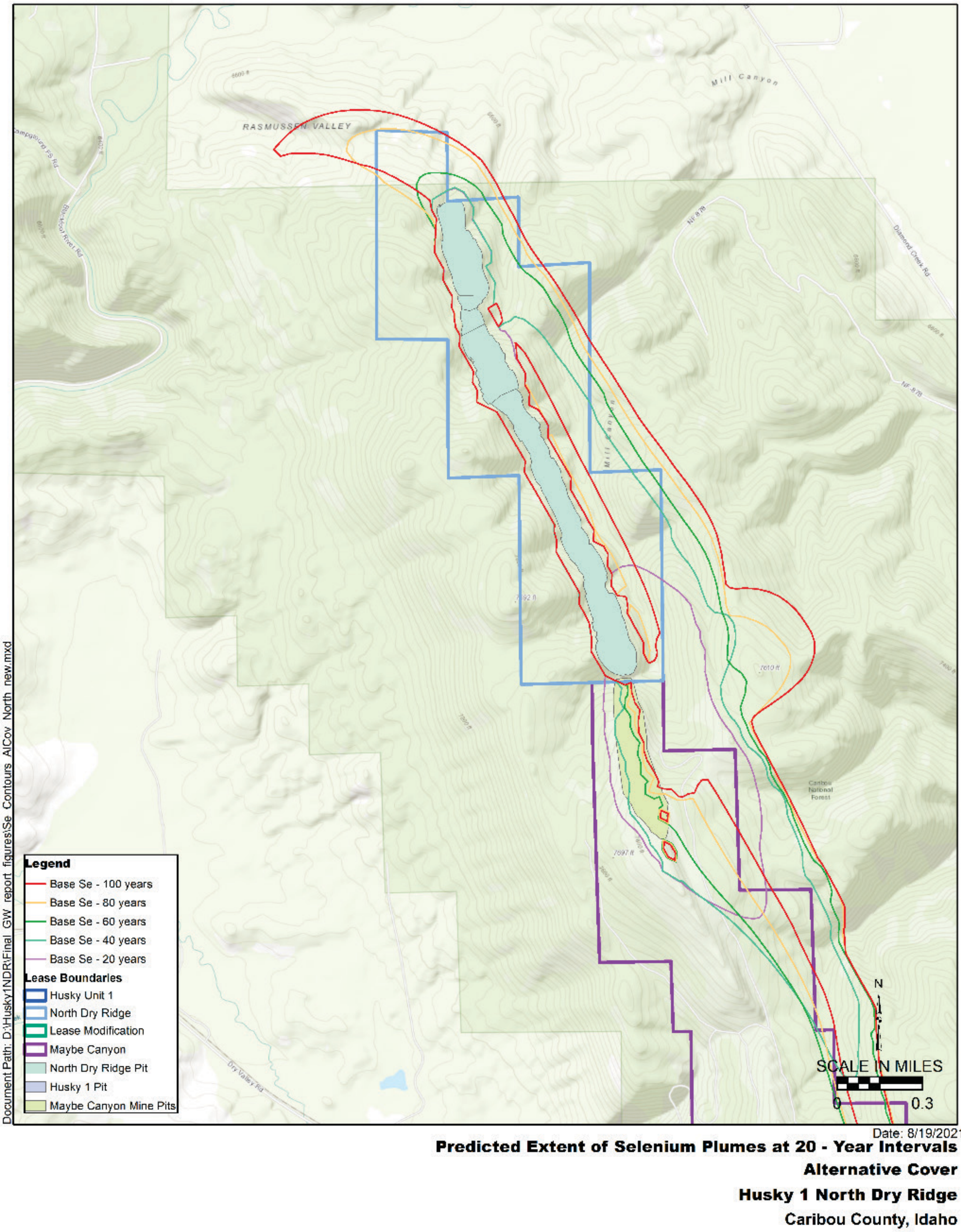


Figure 5-15. Predicted Extents of Selenium Plumes at 20-Year Time Intervals for Alternative Cover – North Dry Ridge and North Maybe Mine

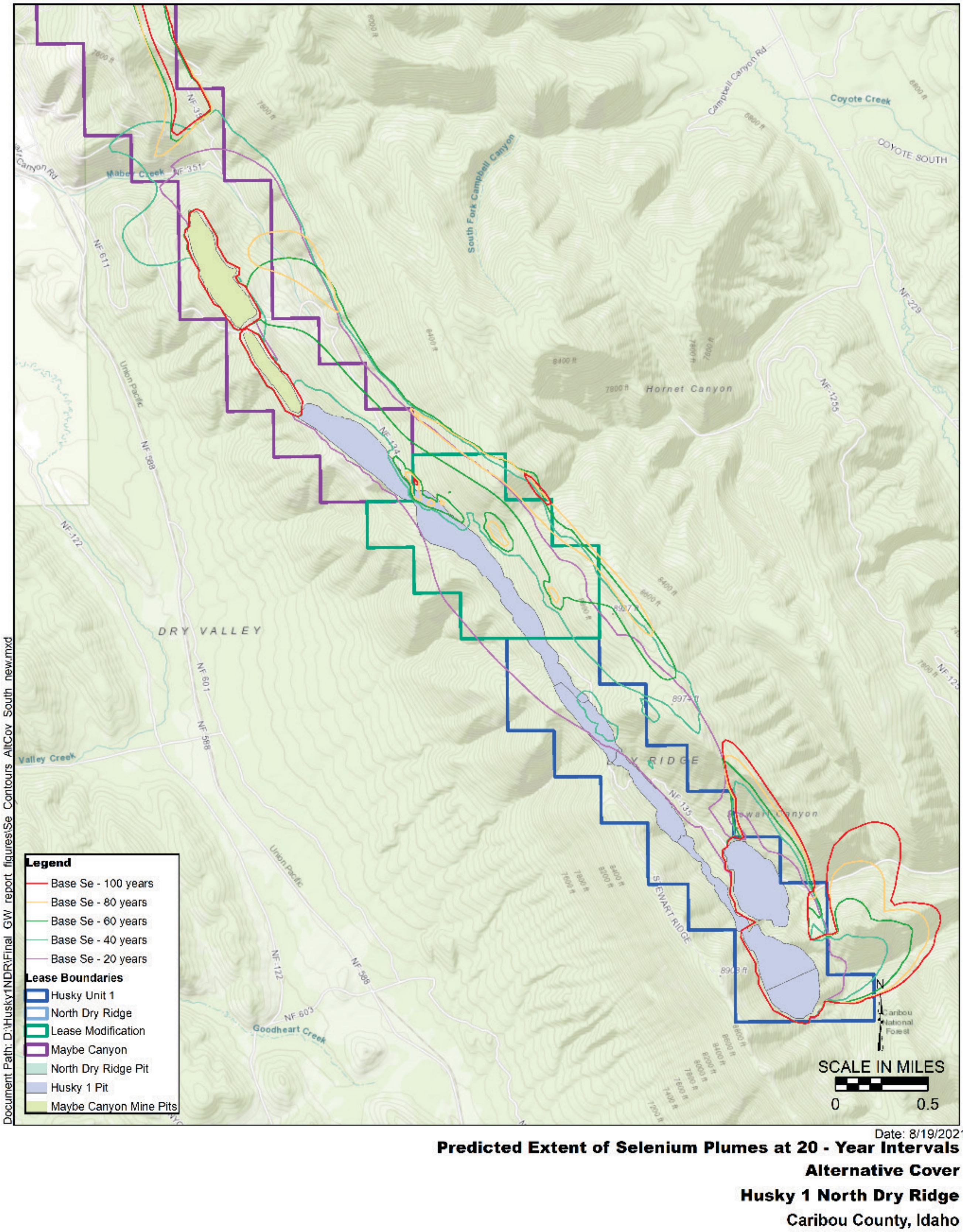


Figure 5-16. Predicted Extents of Selenium Plumes at 20-Year Time Intervals for Alternative Cover – South Maybe Canyon Mine and Husky 1

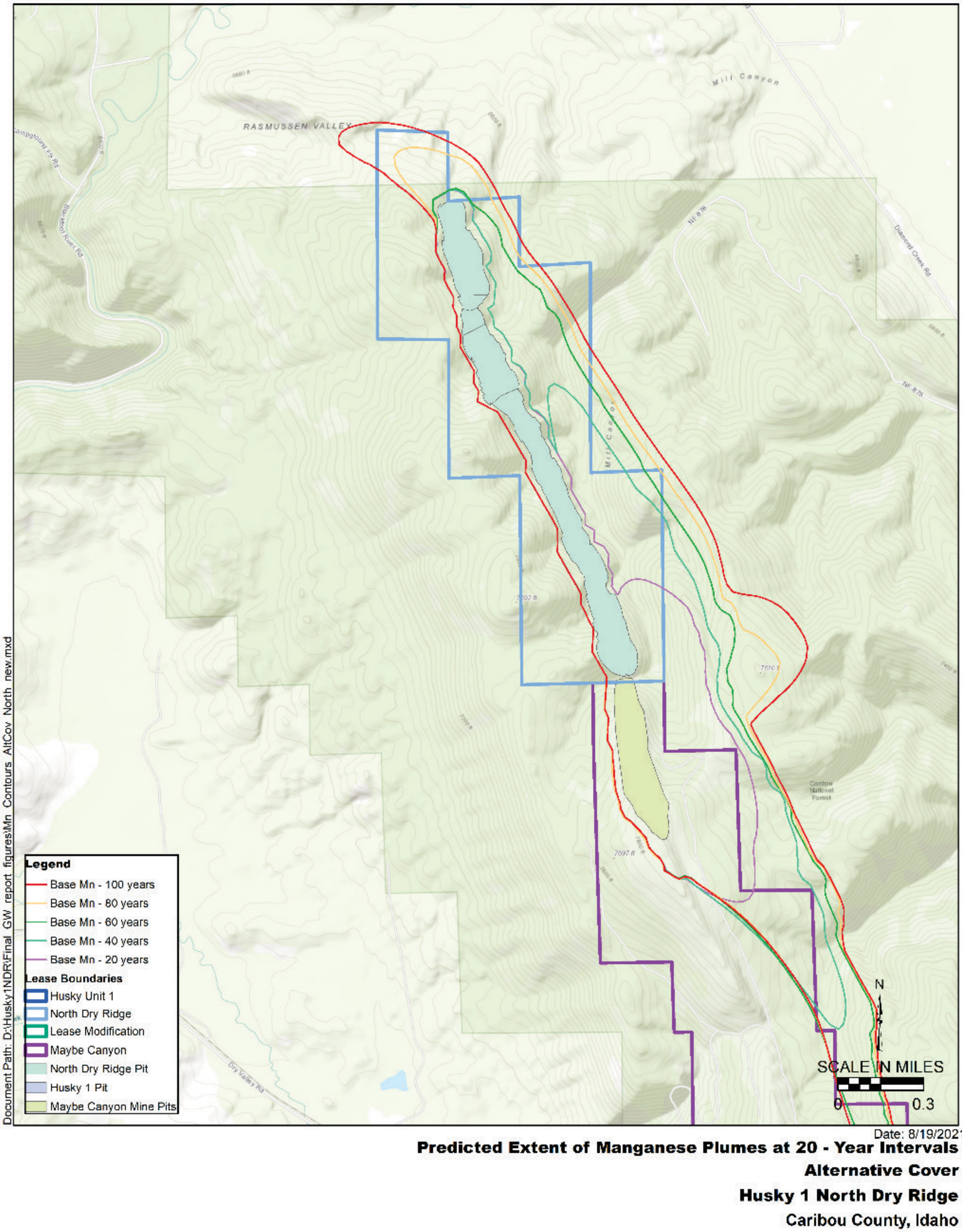
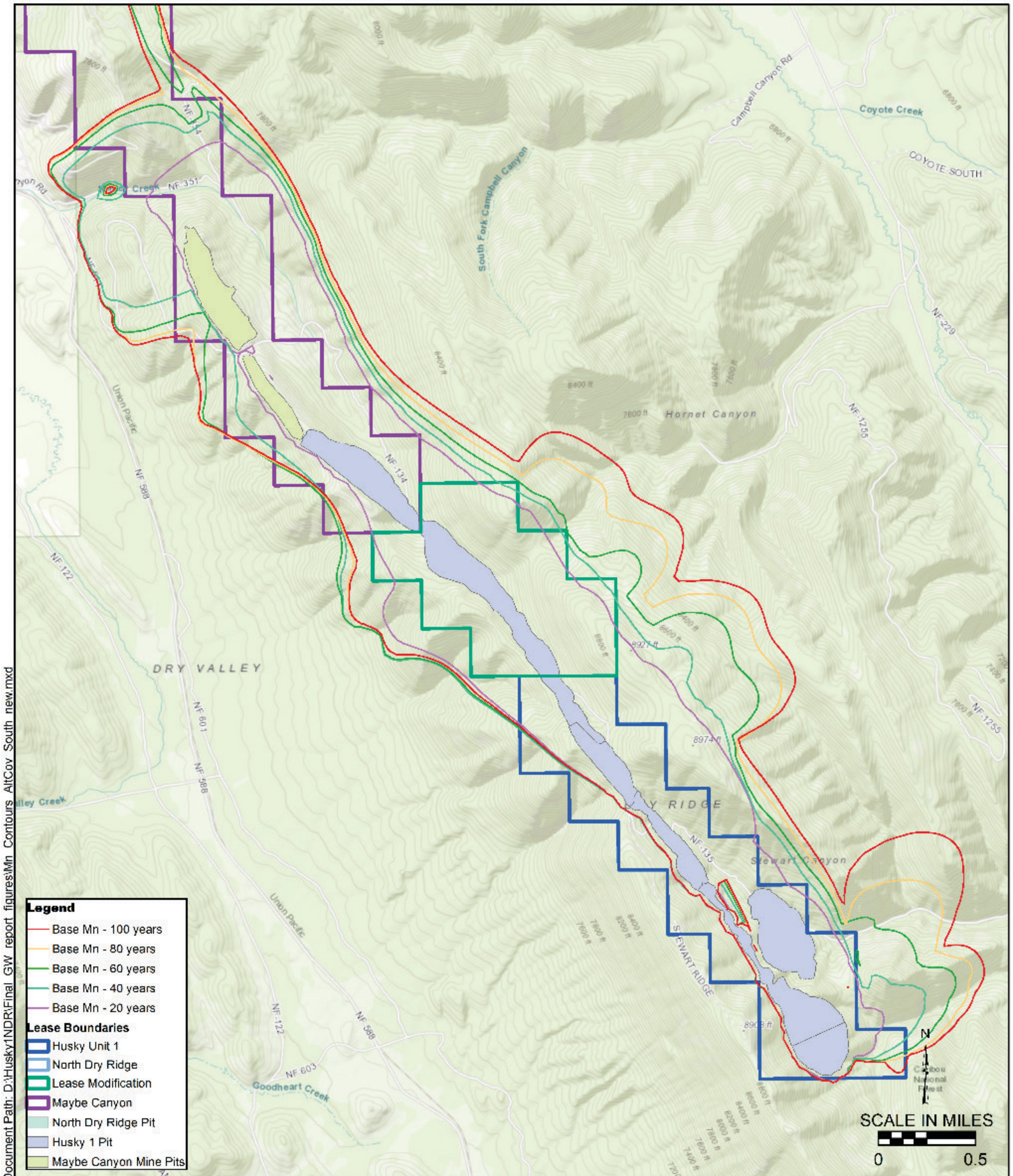


Figure 5-17. Predicted Extents of Manganese Plumes at 20-Year Time Intervals for Alternative Cover – North Dry Ridge and North Maybe Mine



Date: 8/19/2021

Predicted Extent of Manganese Plumes at 20 - Year Intervals
Alternative Cover
Husky 1 North Dry Ridge
Caribou County, Idaho

Figure 5-18. Predicted Extents of Manganese Plumes at 20-Year Time Intervals for Alternative Cover – South Maybe Canyon Mine and Husky 1

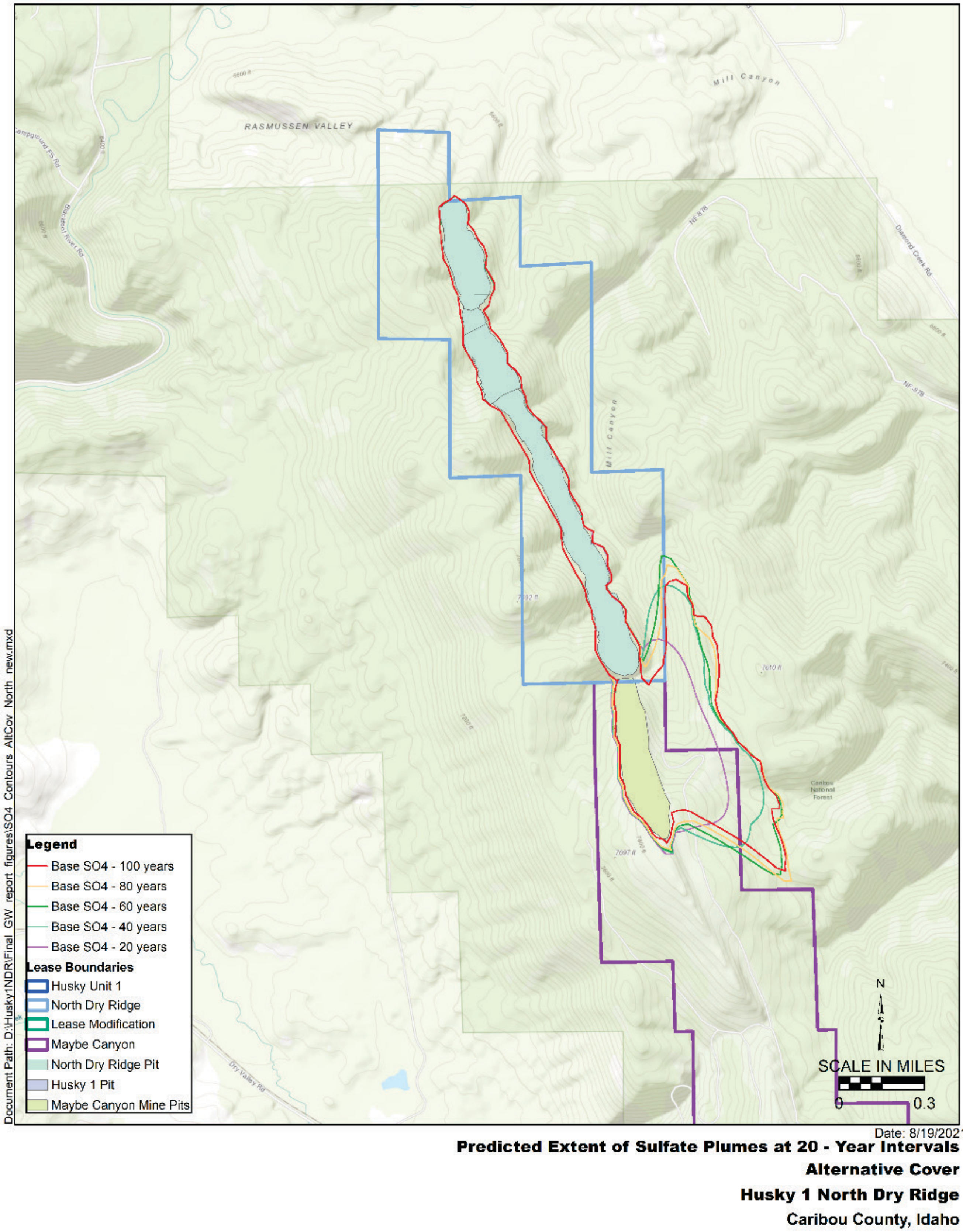


Figure 5-19. Predicted Extents of Sulfate Plumes at 20-Year Time Intervals for Alternative Cover – North Dry Ridge and North Maybe Mine

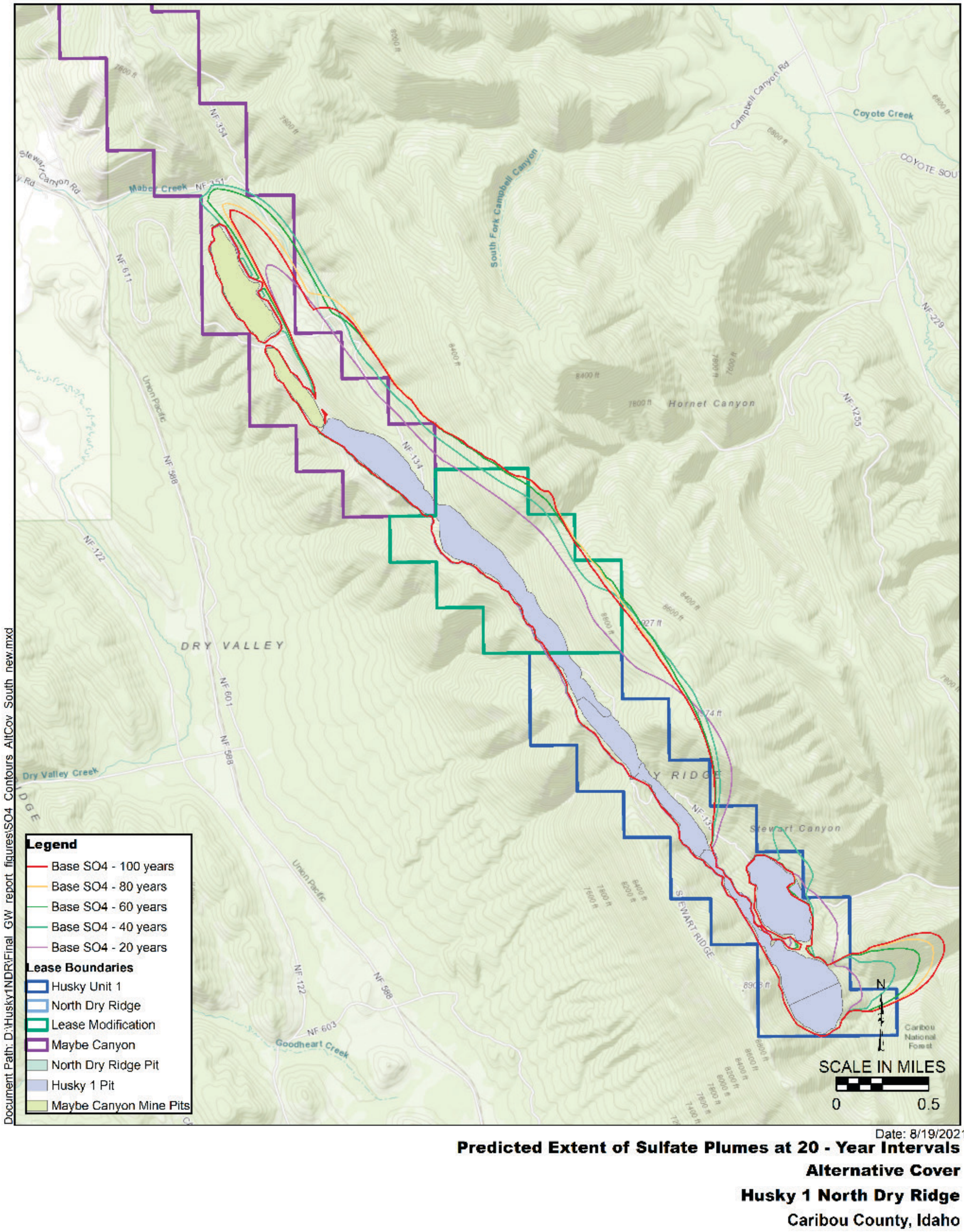


Figure 5-20. Predicted Extents of Manganese Plumes at 20-Year Time Intervals for Alternative Cover – South Maybe Canyon Mine and Husky 1

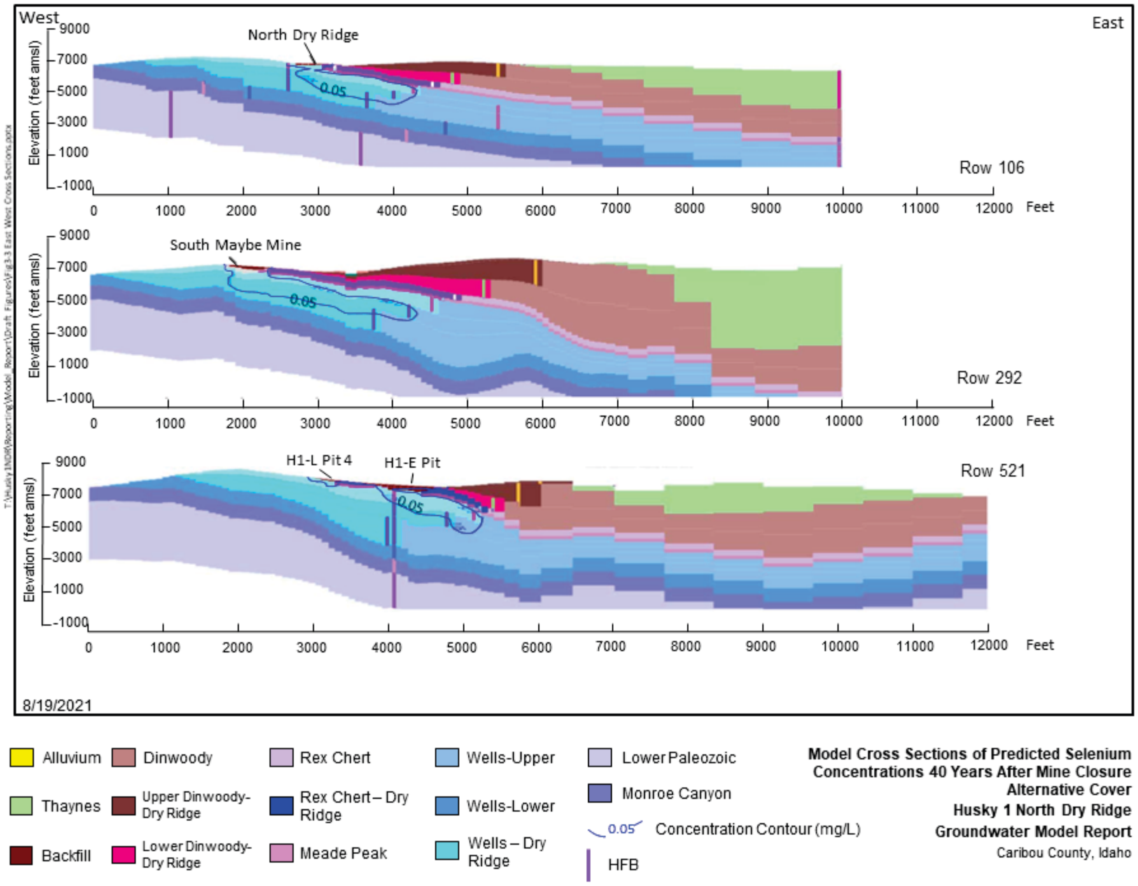


Figure 5-21. Predicted Extents of Selenium Plumes at 20-Year Time Intervals for Alternative Cover – South Maybe Canyon Mine and Husky 1

5.2.3 H1NDR Groundwater Interaction with Existing Conditions

A key consideration in this analysis is estimating how the H1NDR project impacts would interact with existing groundwater impacts from historic mining and mine facilities. The groundwater analysis predicts impacts from the proposed mining activities and alternatives after development and closure of the H1NDR mine. The potential interaction with South Maybe Canyon Mine and North Maybe Mine facilities are briefly discussed below.

5.2.3.1 North Maybe Mine

H1NDR would not affect the East Mill Dump as a potential source of contaminants. The H1NDR backfill would be placed in the same North Maybe Mine pits currently generating some volume of leachate. The analysis of the H1NDR backfill placement indicates that it would affect the shallow alluvial aquifer and would migrate down dip to the east until intersecting the regional aquifer. As described in Sections 5.2.1 and 5.2.2, groundwater would interact with the shallow alluvial system along East Mill Creek, although in the Alternate Cover scenario it would interact to a much lesser degree. The predicted H1NDR plumes for the Proposed Action scenario would occur in the area of impacted groundwater along East Mill Creek but would not add to the existing plumes or create higher concentrations. For the Alternative Cover scenario, the predicted H1NDR plumes would not result in GWQS exceedances in the alluvium. The backfill placed in the proposed North Dry Ridge Pit would generate a contaminant plume to the north and east of the pit. The northern extent of the H1NDR plume would be new and would not interact with any existing plumes. Since the groundwater migration is largely controlled by down-dip flow, the easterly portion of the H1NDR plume would be stratigraphically below any plumes, if they exist, emanating from the East Mill Dump and would mainly stay separated.

5.2.3.2 South Maybe Canyon Mine

The H1NDR backfill would be placed in the same South Maybe Canyon Mine pits currently generating some volume of leachate. The H1NDR backfill would not affect the Cross Valley Fill as a potential source of contaminants. The analysis of the H1NDR backfill placement indicates that it would affect the shallow alluvial aquifer and would migrate down dip to the east until intersecting the regional aquifer. Because the predicted groundwater impacts from the mining activity generally migrate to the east, they would not comingle with shallow groundwater infiltrating from Maybe Creek water west of Dry Ridge. The leachate generated from the H1NDR backfill would follow the same flow paths as any existing baseline leachate or contaminant plumes. The predicted H1NDR plumes for the Proposed Action scenario would occur in the area of impacted groundwater within Maybe Canyon but would not add to the existing plumes or create higher concentrations. For the Alternative Cover scenario, the predicted H1NDR plumes would not result in GWQS exceedances in the alluvium.

6.0 SENSITIVITY ANALYSIS

Numerical simulations using different values of selected input parameters were run to determine the sensitivity of the model results to such changes, specifically the predicted extent of COPC concentrations above groundwater standards. Model sensitivity analysis is designed to show the relationship between uncertainty in the predicted results and uncertainties about the input parameters. Uncertainties regarding input parameter values can be caused by spatial variability, as is often exhibited by aquifer hydraulic properties due to lithologic changes or geologic structures such as faults, or by a lack of available information. Ideally, the important model results are not highly sensitive to variations that have significant uncertainty.

The sensitivity analysis evaluated the following parameters

- the reclamation cover infiltration rate, which directly affects COPC mass loading rate to the groundwater system;
- hydraulic conductivity, which directly affects COPC transport distances from the mine pits;
- effective porosity, which directly affects COPC transport velocity; and
- dispersivity, which affects how the plume spreads horizontally and vertically.

The sensitivity analysis parameters and their modeled values are listed in **Table 6-1**. The base-case models are the Proposed Action and Alternative Cover simulations.

Backfill infiltration rates for the four cover types at North Dry Ridge, North Maybe Mine, South Maybe Canyon Mine, and Husky 1 were provided by ARCADIS (2020c). Higher and lower values for backfill infiltration rates were selected to cover a range of ±50% to represent potential climate change and/or compaction of backfill. Infiltration rates were changed for all four cover types as a group.

Hydraulic conductivity of the aquifer material governs the ability of the fluid or dissolved contaminant to pass through the fractured rocks. Higher and lower values for hydraulic conductivity were selected to cover a reasonable range of measured values from aquifer testing (See Section 2.3.1 for aquifer testing references). Hydraulic conductivity values were changed in the weathered bedrock, Meade Peak Member, and Rex Chert Member in the Dry Ridge area to examine their effect on transport of COPCs from the mine pits. In the sensitivity analysis, horizontal and vertical hydraulic conductivity were changed as a group, rather than individually, to maintain the anisotropy ratio of horizontal to vertical hydraulic conductivity.

Effective porosity, the interconnected porosity available for fluid flow, affects groundwater velocity and the migration rate of solutes transported by the groundwater. Lower porosity should result in COPC plumes migrating more rapidly, because of the increased groundwater velocity, and covering a larger area, because the relative aquifer volume occupied by the solute-bearing groundwater is smaller. The values applied in the sensitivity analysis were selected to span a realistic range based on reported specific yield values, rock types, and professional judgment. Effective porosity values were changed only in the Dry Ridge area and only in the weathered bedrock, Dinwoody Formation, and Rex Chert Member to examine their effect on COPC transport from the mine pits.

Dispersion is the mathematical term in the solute transport equation (Freeze and Cherry, 1979) accounting for dilution or mixing due to divergence of flow paths. Dispersivity has three components: longitudinal (in the groundwater flow direction), horizontal transverse (i.e., lateral spreading of the plume), and vertical. Dispersivity is a scale-dependent property (Xu and Eckstein, 1995). The base case value of 49 ft was calculated using Xu and Eckstein's equation 14b (1995), $\alpha_x = 0.83[\log_{10}(Lp)]^{2.414}$, where α_x is longitudinal dispersivity and Lp is the plume length, which was estimated as 2,000 meters. Note that in this equation, the input and output values are in meters, and the result must be converted to feet. Horizontal and vertical transverse dispersivities in the base case model were calculated to be 30% and 5%, respectively, of the longitudinal dispersivity (Tetra Tech, 2018; ASTM 2015). In the sensitivity analysis, the transverse dispersivity values (horizontal and vertical) were changed as a group, rather than individually.

The Proposed Action scenario model was run with changes made to one set of the sensitivity analysis parameters at a time (e.g., infiltration rate high or low, hydraulic conductivity high or low, effective porosity high or low, and dispersivity changes), to evaluate the effect of that parameter with all other model input unchanged. Subsequently, the Alternative Cover scenario model was run with high infiltration rate, low infiltration rate, high hydraulic conductivity, and low hydraulic conductivity. The following sections compare the results from the sensitivity runs to the original results from the corresponding modeled scenario (Proposed Action or Alternative Cover).

Table 6-1. Sensitivity Analysis Input Parameter Values

Model Parameter	Location (if not throughout model domain)	Backfill Cover Infiltration Rate		Hydraulic Conductivity		Effective Porosity		Dispersivity	
		High	Low	High	Low	High	Low	Longi-tudinal	Transverse
Backfill Cover Infiltration (Recharge) Rates (PA and Alt Cover)	Mine Pits	1.5X base case	0.5X base case	--	--	--	--	--	--
Hydraulic Conductivity (Kh and Kv) – Weathered Bedrock, Meade Peak, and Rex Chert (PA and Alt Cover)	Dry Ridge area	--	--	2X base case	0.5X base case	--	--	--	--
Effective Porosity of Weathered Bedrock, Dinwoody Formation and Rex Chert (PA only)	Dry Ridge area	--	--	--	--	3.3X base case	0.33X base case	--	--
Longitudinal Dispersivity (PA only)		--	--	--	--	--	--	1.5X base case	--
Transverse Dispersivity, Horizontal / Vertical (PA only)		--	--	--	--	--	--	--	1.5X base case

PA = Proposed Action model; Alt Cover = Alternative Cover model; Kh = horizontal hydraulic conductivity; Kv = vertical hydraulic conductivity

6.1 Base-Case Model Sensitivity Results

Parameters for sensitivity analysis of the Proposed Action scenario model resulted in the following changes to the selenium plume development, migration, and persistence:

- High backfill cover infiltration rate (**Figure 6-1** and **Figure 6-2**):
  - Figure 6-1: Increasing the infiltration or recharge rate into the backfill caused the selenium plume to develop more quickly where the store-and-release cover was placed, (e.g., northern portion of North Dry Ridge), and to extend more than 500 feet farther downgradient and downdip than the base case. Furthermore, some leading edges of the plumes extended 1,000 to 4,000 feet farther due to transport into the Rex Chert Member and/or Lower Dinwoody Formation because of

mounded water levels in the backfill. Areas with low-permeability clay cover, such as North Maybe Mine, restricted selenium plume growth (i.e., plume extending less than 200 feet farther downgradient and downdip than the base case).

- Figure 6-2: The sensitivity results for the South Maybe Canyon Mine and Husky 1 portion of the model were similar to the northern model area presented in Figure 6-1. For the mine pits that had the store-and-release cover (i.e., H1-N, H1-L, H1-E, and H1-S), the selenium plume developed quicker and extended more than 500 feet farther downgradient and downdip than the base case. Some downgradient and downdip locations also had farther transport distances (over 1,000 feet) due to additional groundwater mounding in the backfill, which created selenium transport into the Rex Chert Member. The other backfilled pits that have the low-permeability clay cover or lateral drain cover showed less than 200 to 300 feet of plume growth.

- Low backfill cover infiltration rate (**Figure 6-3** and **Figure 6-4**):
  - Figure 6-3: Decreasing the infiltration or recharge rate into the backfill caused the selenium plume to become smaller than in the base case. The selenium plume did not develop into the Lower Dinwoody Formation or Rex Chert Member. Otherwise, the selenium plume contracted approximately 100 to 200 feet, representing a decrease comparable to the increase with the high infiltration sensitivity simulation.
  - Figure 6-4: The sensitivity results for the South Maybe Canyon Mine and Husky 1 portions of the model were similar to the northern model area presented in Figure 6-3. The selenium plume did not migrate into the Lower Dinwoody Formation and Rex Chert Member downgradient of the H1-E and H1-S pits. Elsewhere, the selenium plume reduced in size approximately 100 to 200 feet compared to the base case.

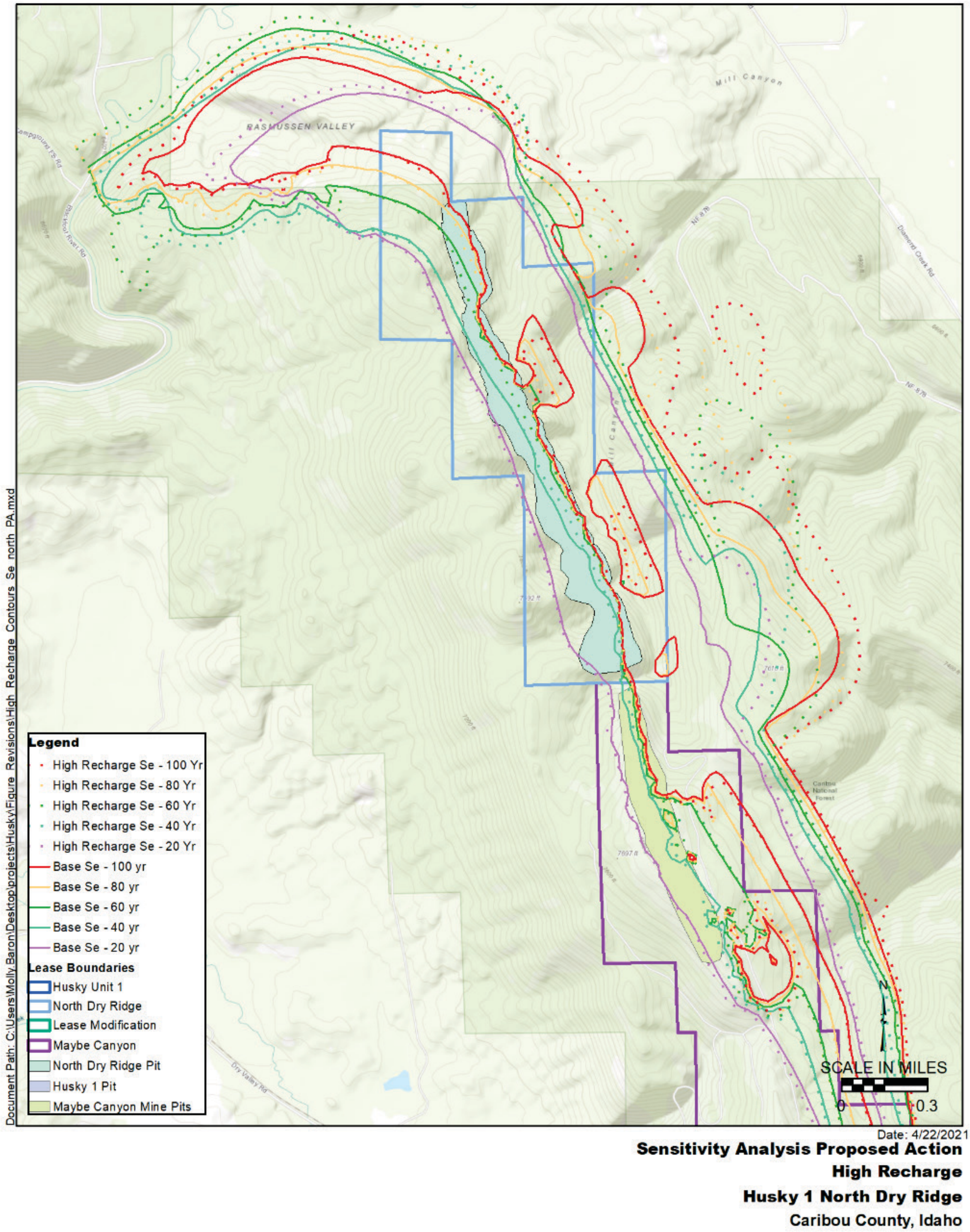


Figure 6-1. Sensitivity Analysis Base Case High Infiltration Rate – North Dry Ridge and North Maybe Mine

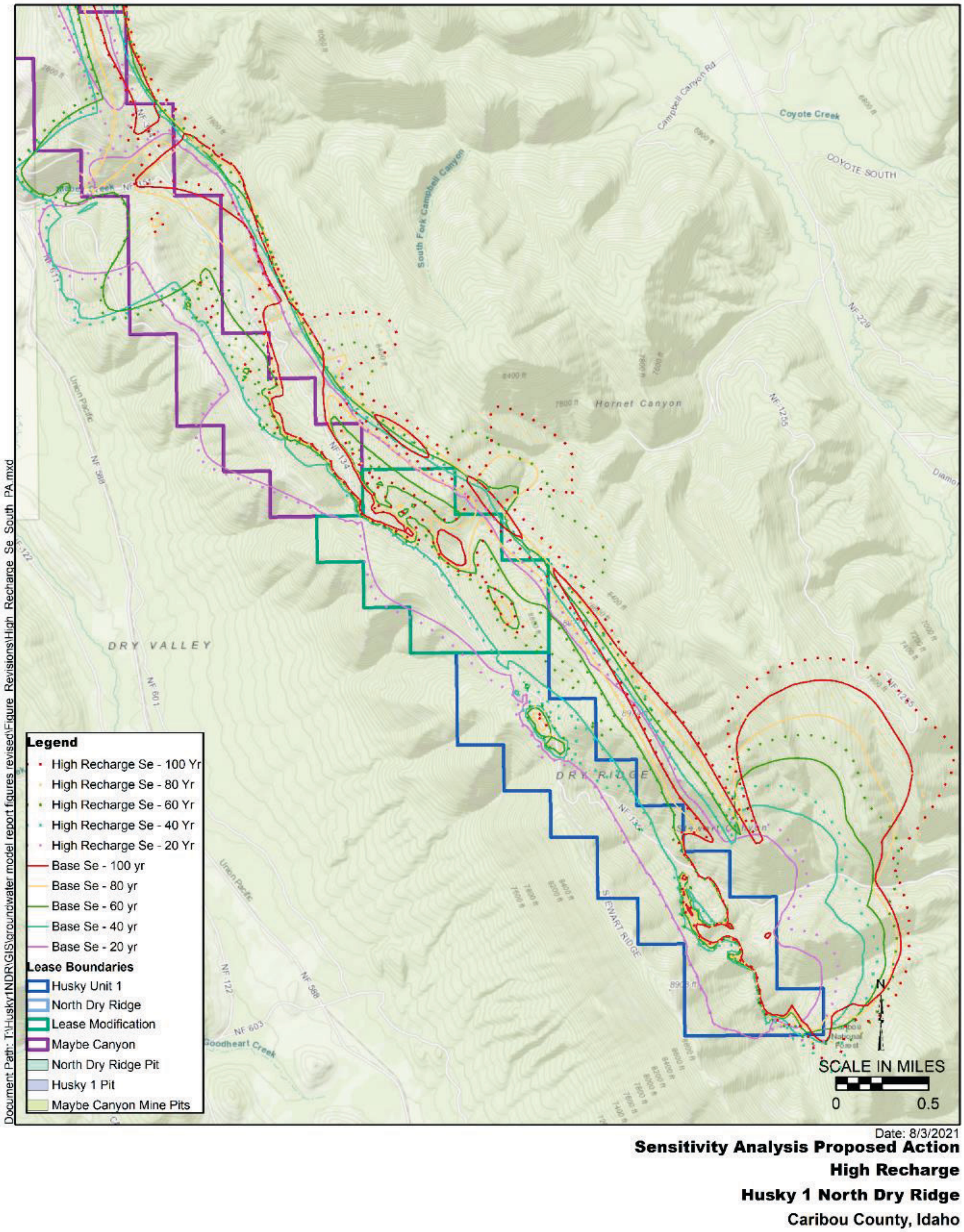


Figure 6-2. Sensitivity Analysis Base Case High Infiltration Rate – South Maybe Canyon Mine and Husky 1

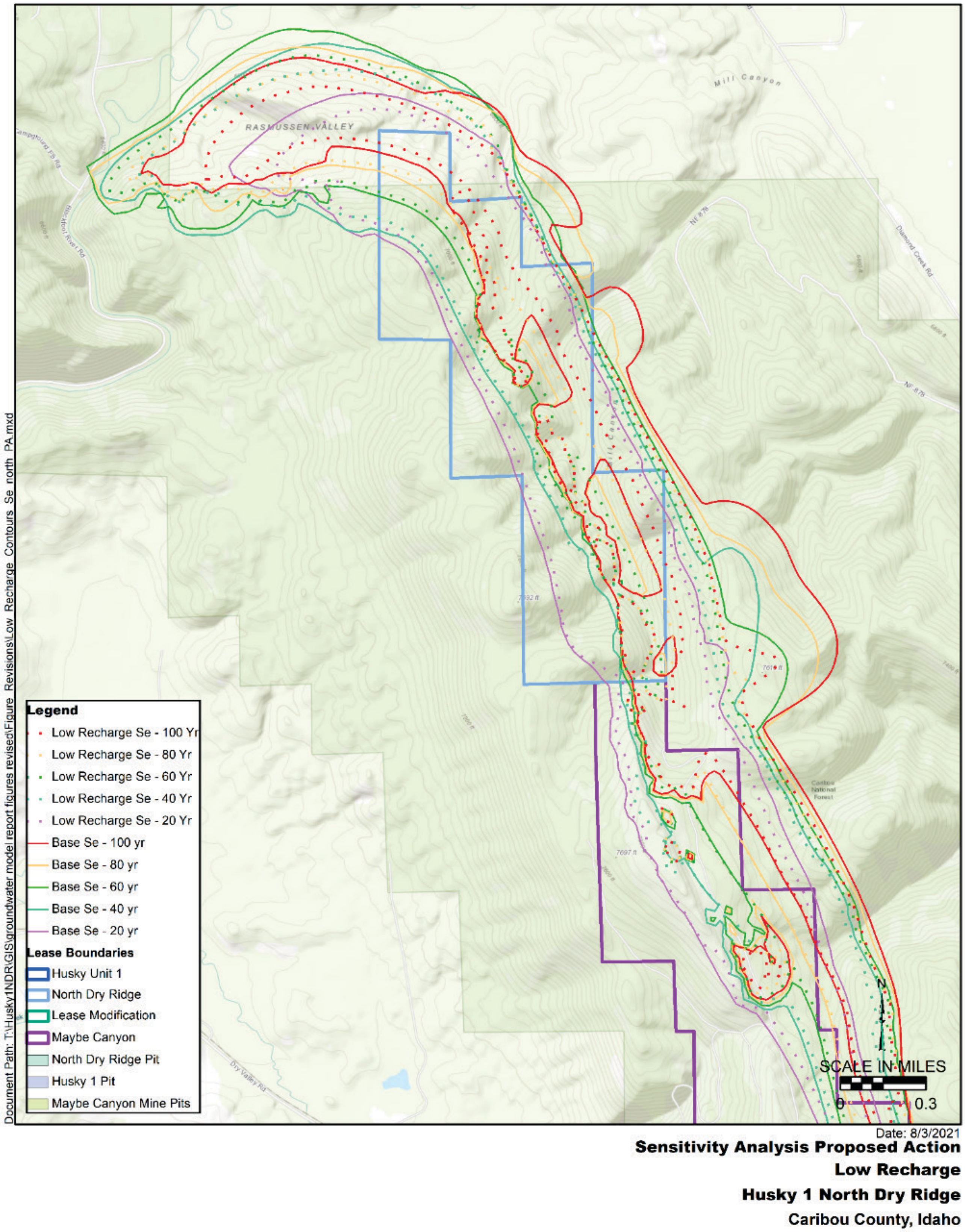


Figure 6-3. Sensitivity Analysis Base Case Low Infiltration Rate – North Dry Ridge and North Maybe Mine

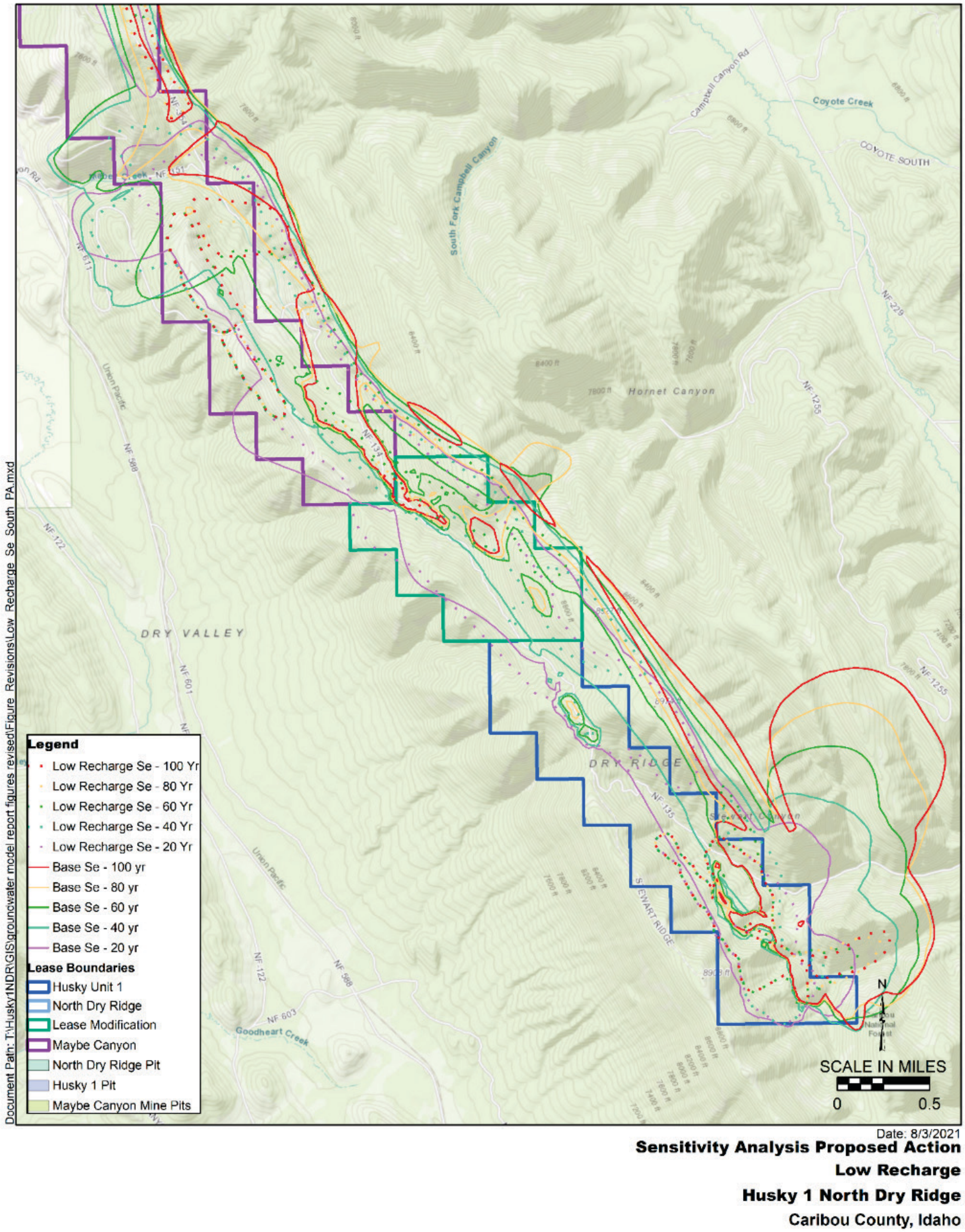


Figure 6-4. Sensitivity Analysis Base Case Low Infiltration Rate – South Maybe Canyon Mine and Husky 1

- High hydraulic conductivity (**Figure 6-5** and **Figure 6-6**)
  - Figure 6-5: Increasing the hydraulic conductivity values in the weathered bedrock, Meade Peak Member, and Rex Chert Member caused selenium to migrate farther downgradient and downdip than the base case where the plume is in these units. Both the horizontal and vertical hydraulic conductivities were increased as a group. Therefore, selenium migrated farther horizontally in the Rex Chert Member and was able to migrate faster vertically into the Wells Formation. The largest increases occurred downgradient and downdip of North Dry Ridge where portions of the selenium plume were within the Rex Chert Member.
  - Figure 6-6: The southern portion of the model had similar results to the northern pits due to increasing the horizontal and vertical hydraulic conductivity. The selenium plume downgradient and downdip of H1-E and H1-S decreased less than 100 feet in extent because that portion of the plume was mostly within the Lower Dinwoody Formation.
- Low hydraulic conductivity (**Figure 6-7** and **Figure 6-8**)
  - Figure 6-7: Decreasing the hydraulic conductivity in the weathered bedrock, Meade Peak Member, and Rex Chert Member caused selenium to migrate a shorter distance than the base case within these geologic units. The largest decreases in plume extent occurred downgradient and downdip of North Dry Ridge where portions of the plume were within the Rex Chert Member.
  - Figure 6-8: The southern portion of the model had similar results to the northern pits due to decreasing the horizontal and vertical hydraulic conductivity. However, there is one exception downgradient and downdip of H1-X. The selenium plume extent increased more than 1,000 feet at this location, likely due to vertical transport from the Lower Dinwoody Formation because of the low-permeability Henry thrust fault.
- High effective porosity (**Figure 6-9** and **Figure 6-10**)
  - Figure 6-9 and Figure 6-10: Increases in effective porosity values of the weathered bedrock, Dinwoody Formation, and Rex Chert Member did not have an observable effect on plume extent. Therefore, these parameters were not sensitive.
- Low effective porosity (**Figure 6-11** and **Figure 6-12**)
  - Figure 6-11 and Figure 6-12: Decreases in effective porosity values of the weathered bedrock, Dinwoody Formation, and Rex Chert Member did not have an observable effect on plume extent. Therefore, these parameters were not sensitive.
- Longitudinal Dispersivity (**Figure 6-13** and **Figure 6-14**):
  - Figure 6-13 and Figure 6-14: Increasing the longitudinal dispersivity value caused the extent of the selenium plume to slightly increase (50 to 100 feet). Therefore, this parameter was more sensitivity than effective porosity but less sensitive than infiltration rate and hydraulic conductivity.
- Transverse Dispersivity (**Figure 6-15** and **Figure 6-16**):
  - Figure 6-15 and Figure 6-16: Increasing the transverse dispersivity values (horizontal and vertical) caused the extent of the selenium plume to increase over 500 feet in portions of the plume (e.g., in the Wells Formation beneath South Maybe Canyon Mine and H1-N at 20 years post closure). Given the higher hydraulic conductivity values in the regional aquifer, increasing the transverse dispersivity values allowed the selenium plume to migrate vertically into these higher permeable units more easily.

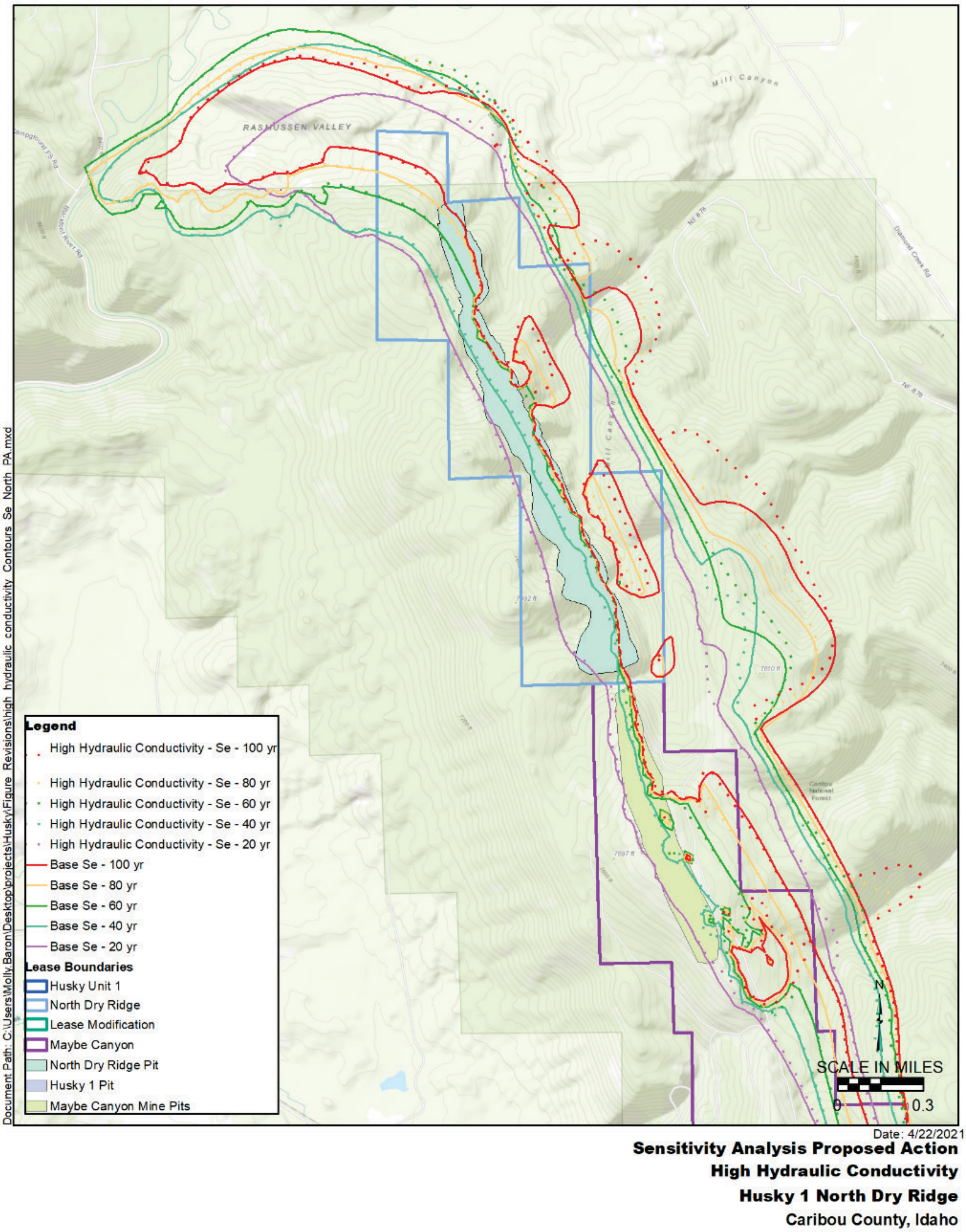
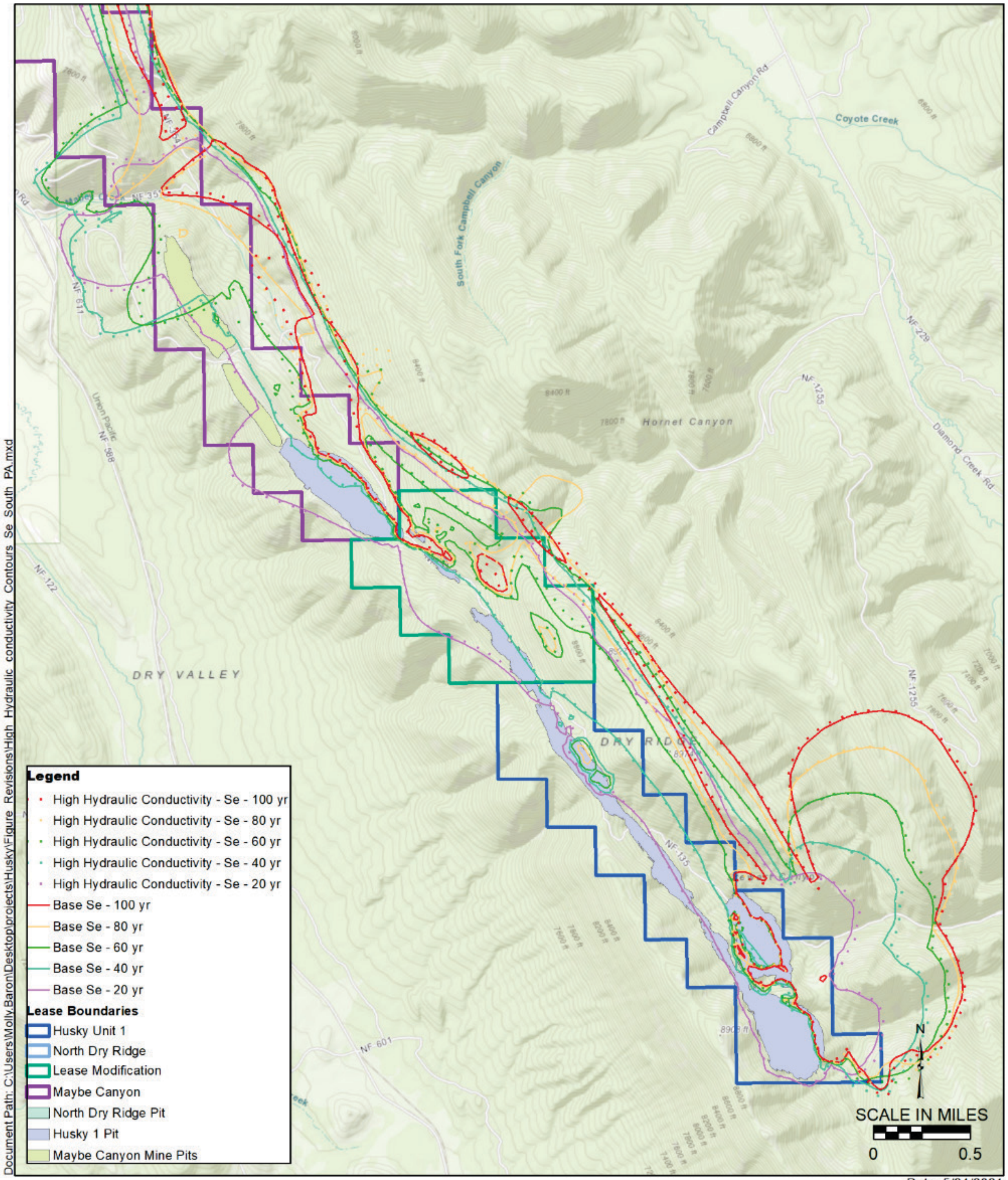


Figure 6-5. Sensitivity Analysis Proposed Action High Hydraulic Conductivity – North Dry Ridge and North Maybe Mine



Date: 5/24/2021

Sensitivity Analysis Proposed Action
High Hydraulic Conductivity
Husky 1 North Dry Ridge
Caribou County, Idaho

Figure 6-6. Sensitivity Analysis Proposed Action High Hydraulic Conductivity – South Maybe Canyon Mine and Husky 1

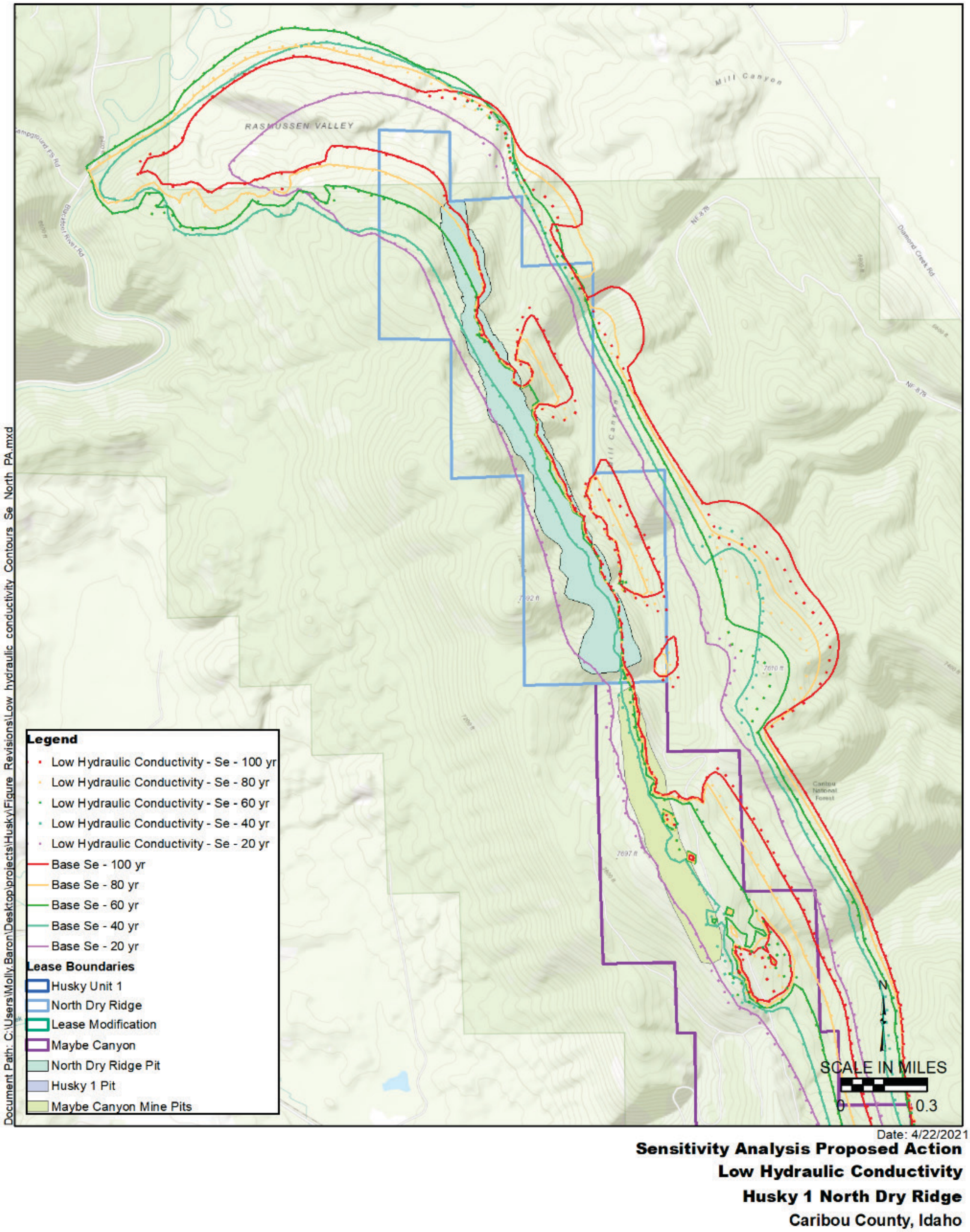


Figure 6-7. Sensitivity Analysis Proposed Action Low Hydraulic Conductivity – North Dry Ridge and North Maybe Mine

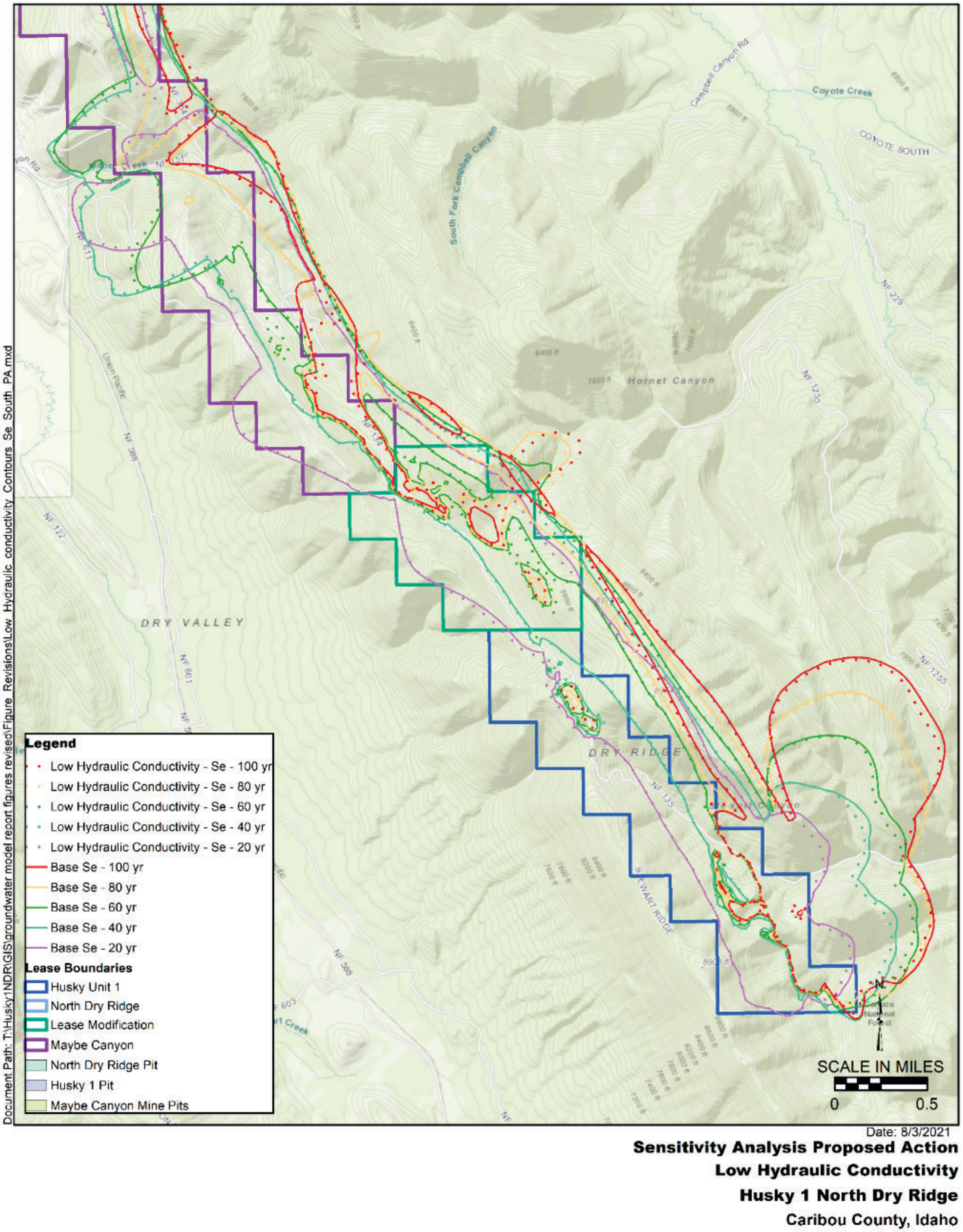


Figure 6-8. Sensitivity Analysis Proposed Action Low Hydraulic Conductivity – South Maybe Canyon Mine and Husky 1

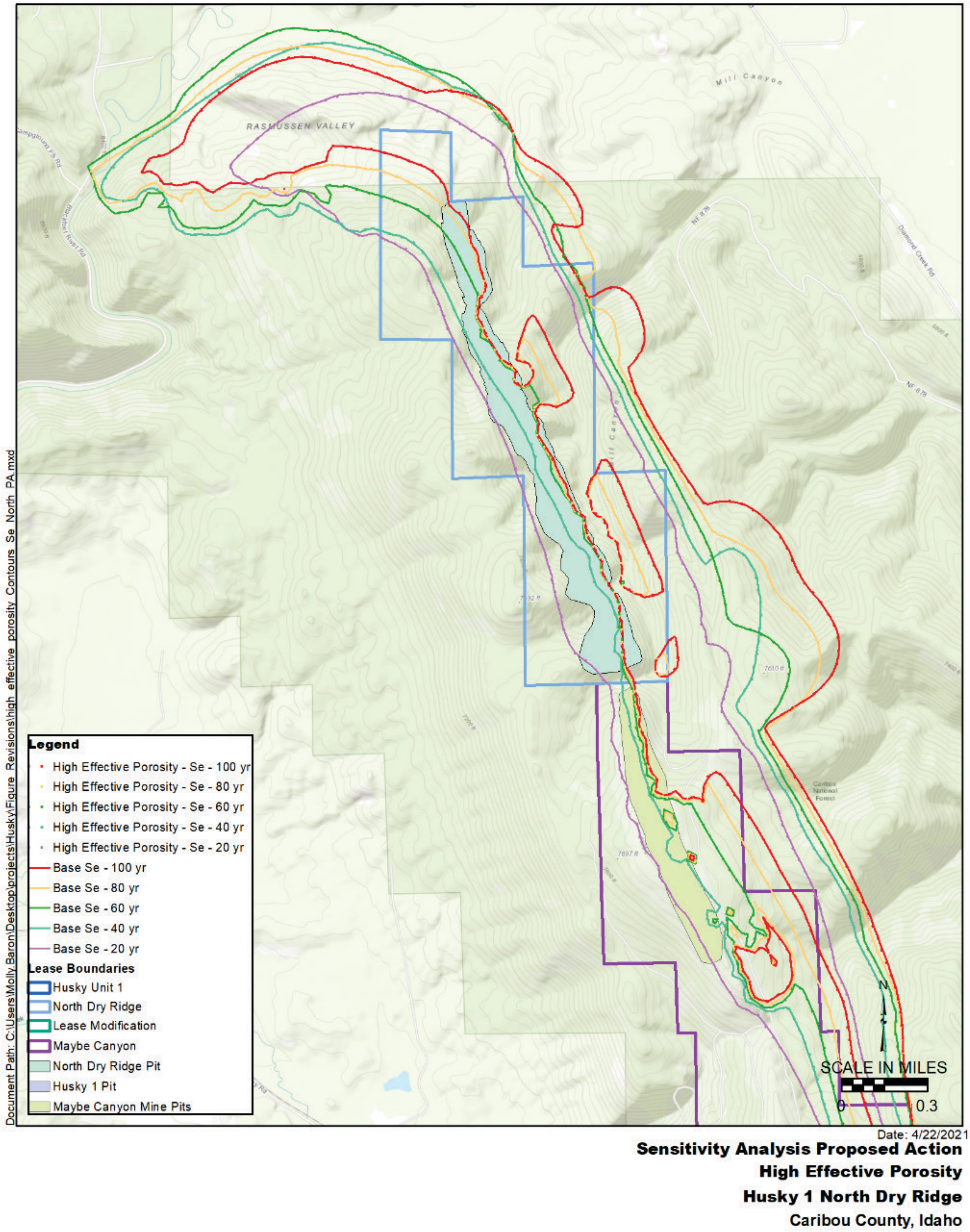


Figure 6-9. Sensitivity Analysis Proposed Action High Effective Porosity – North Dry Ridge and North Maybe Mine

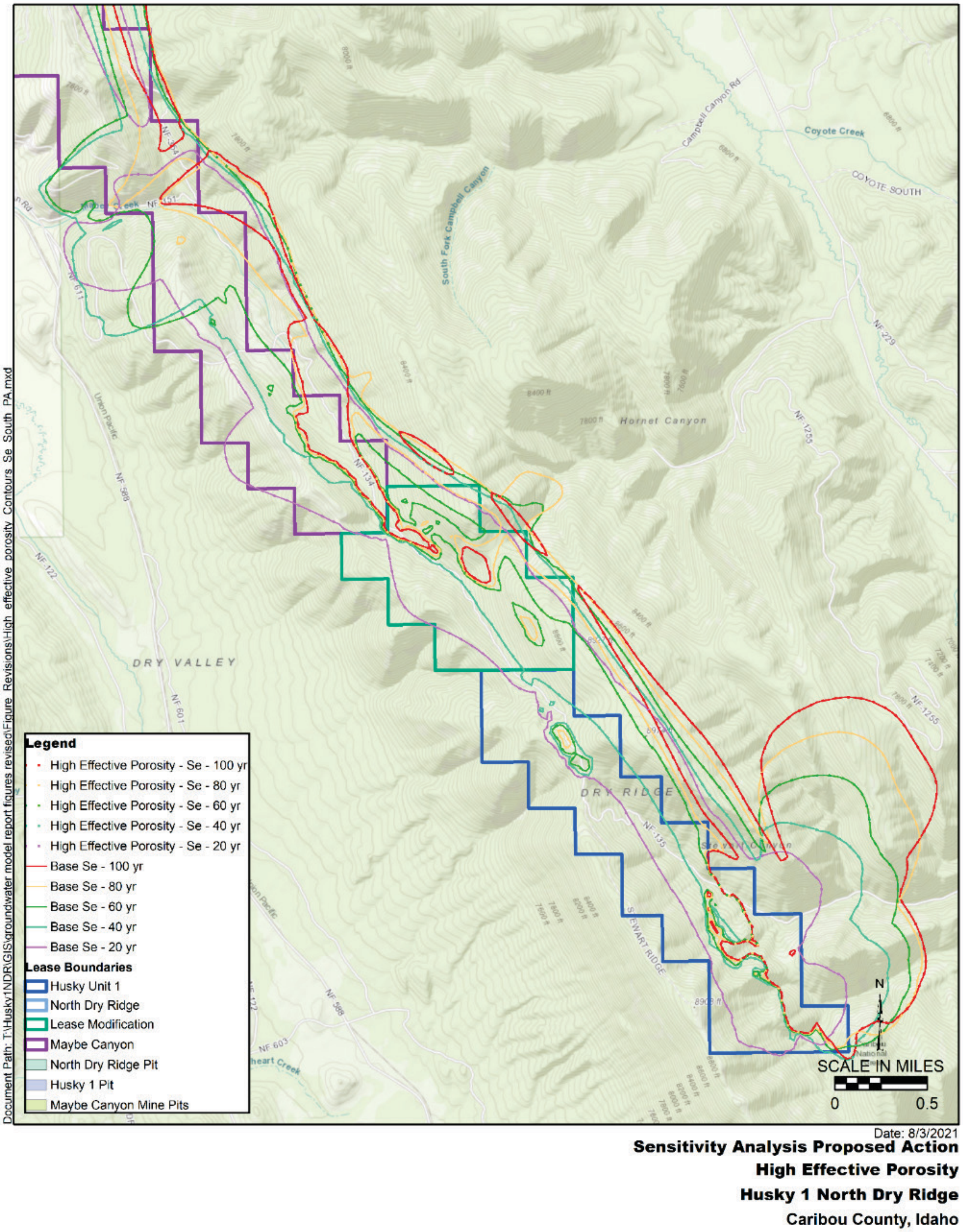


Figure 6-10. Sensitivity Analysis Proposed Action High Effective Porosity – South Maybe Canyon Mine and Husky 1

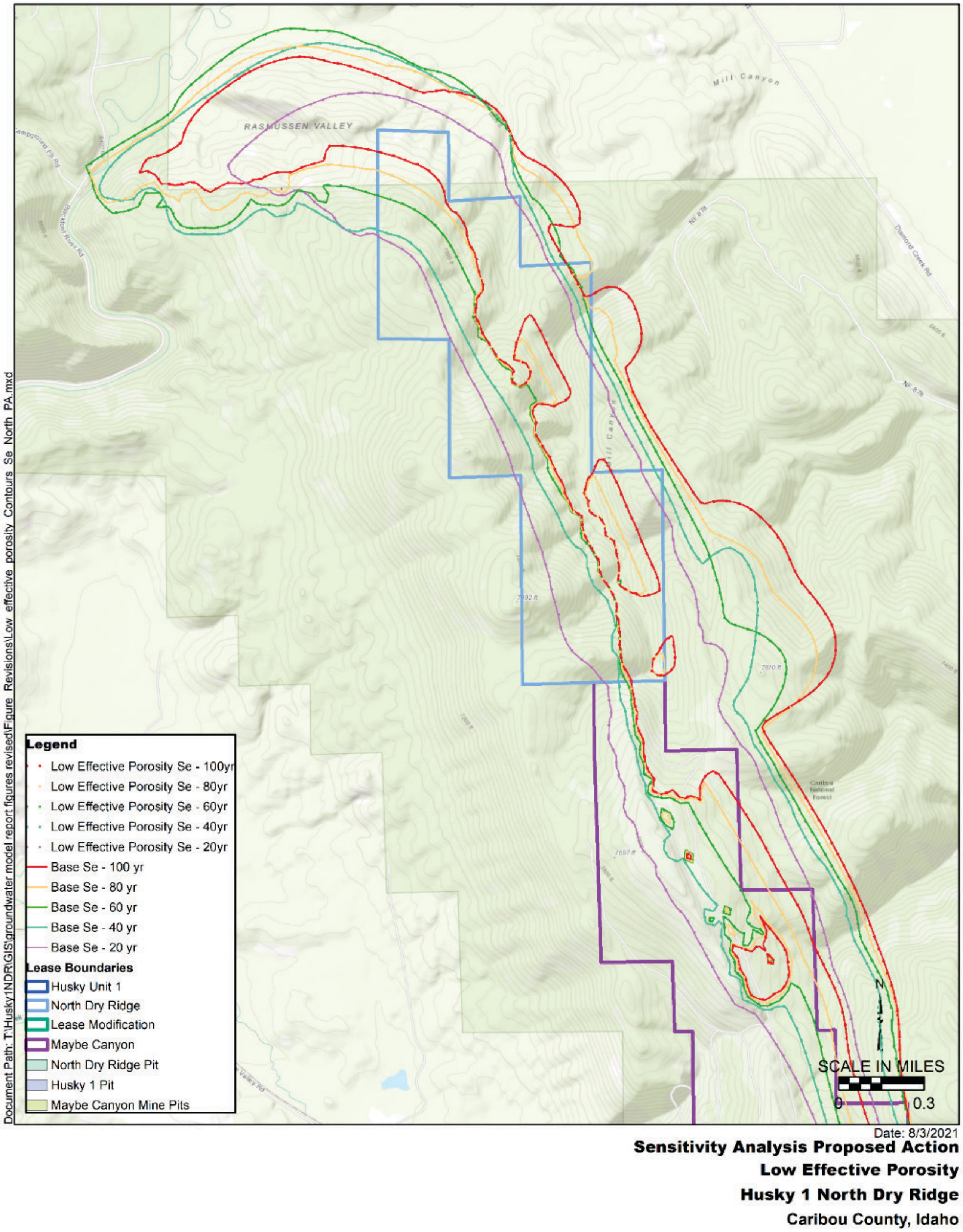


Figure 6-11. Sensitivity Analysis Proposed Action Low Effective Porosity – North Dry Ridge and North Maybe Mine

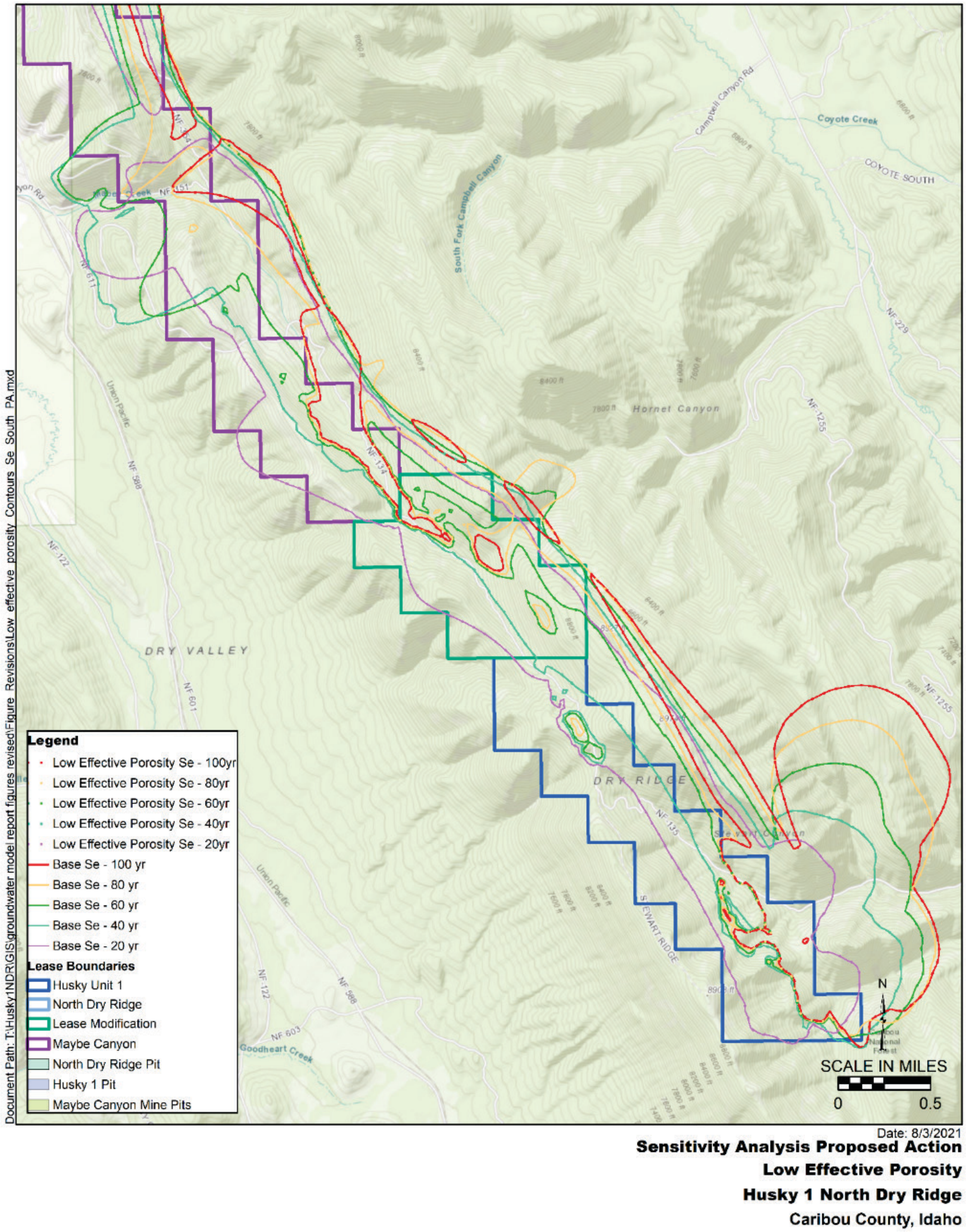


Figure 6-12. Sensitivity Analysis Proposed Action Low Effective Porosity – South Maybe Canyon Mine and Husky 1

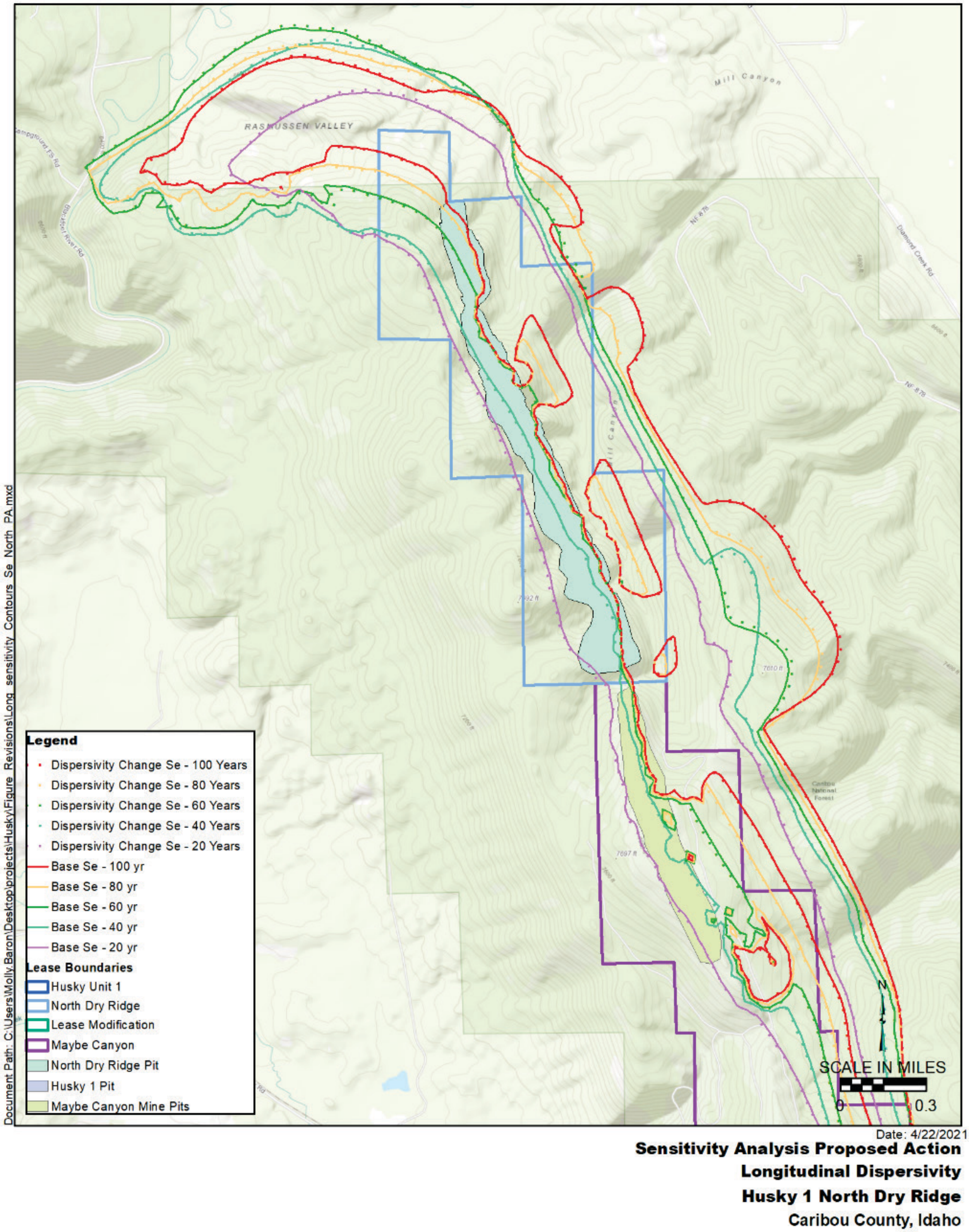
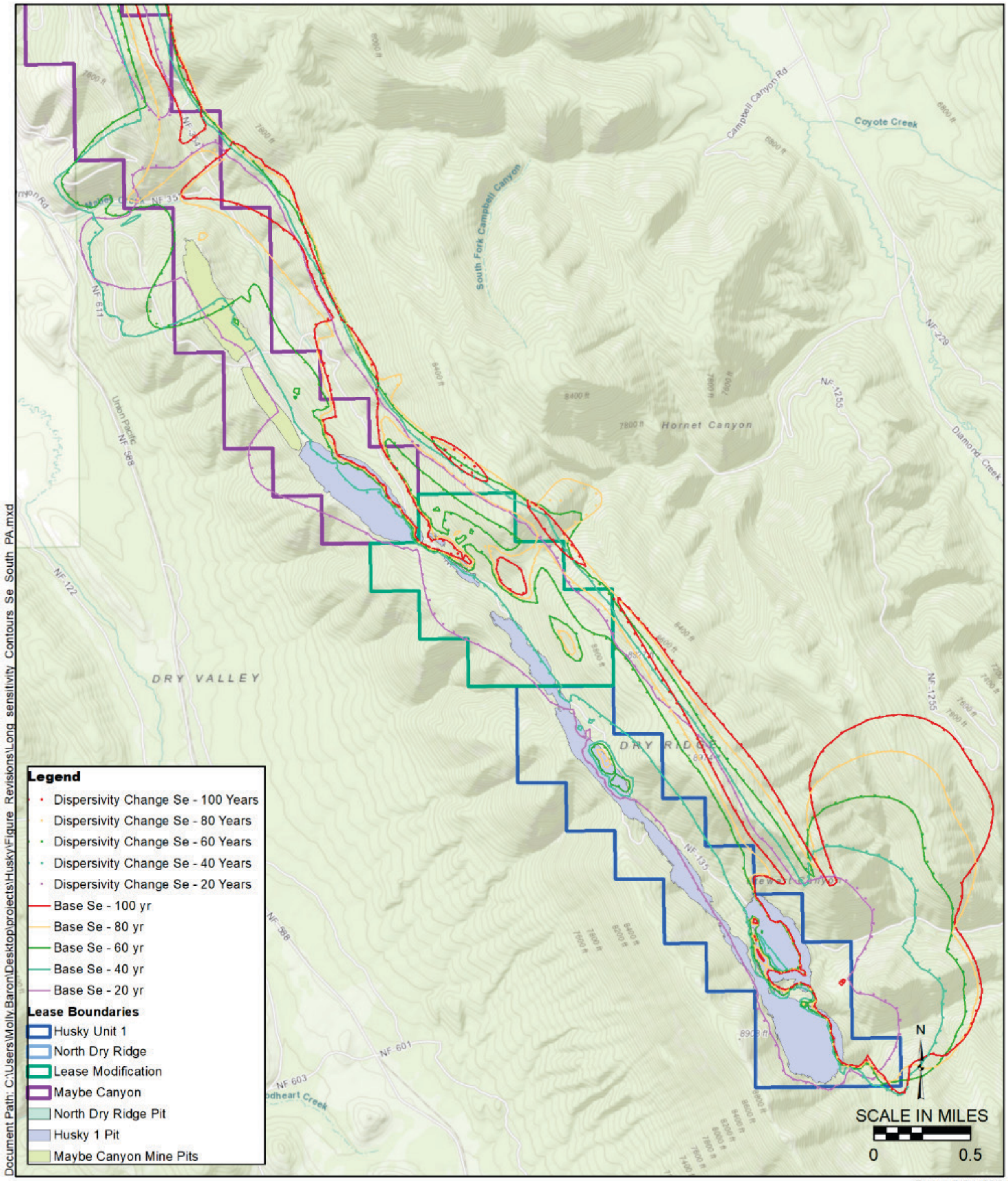


Figure 6-13. Sensitivity Analysis Proposed Action Longitudinal Dispersivity – North Dry Ridge and North Maybe Mine



Date: 5/24/2021

Sensitivity Analysis Proposed Action
Longitudinal Dispersivity
Husky 1 North Dry Ridge
Caribou County, Idaho

Figure 6-14. Sensitivity Analysis Proposed Action Longitudinal Dispersivity – South Maybe Canyon Mine and Husky 1

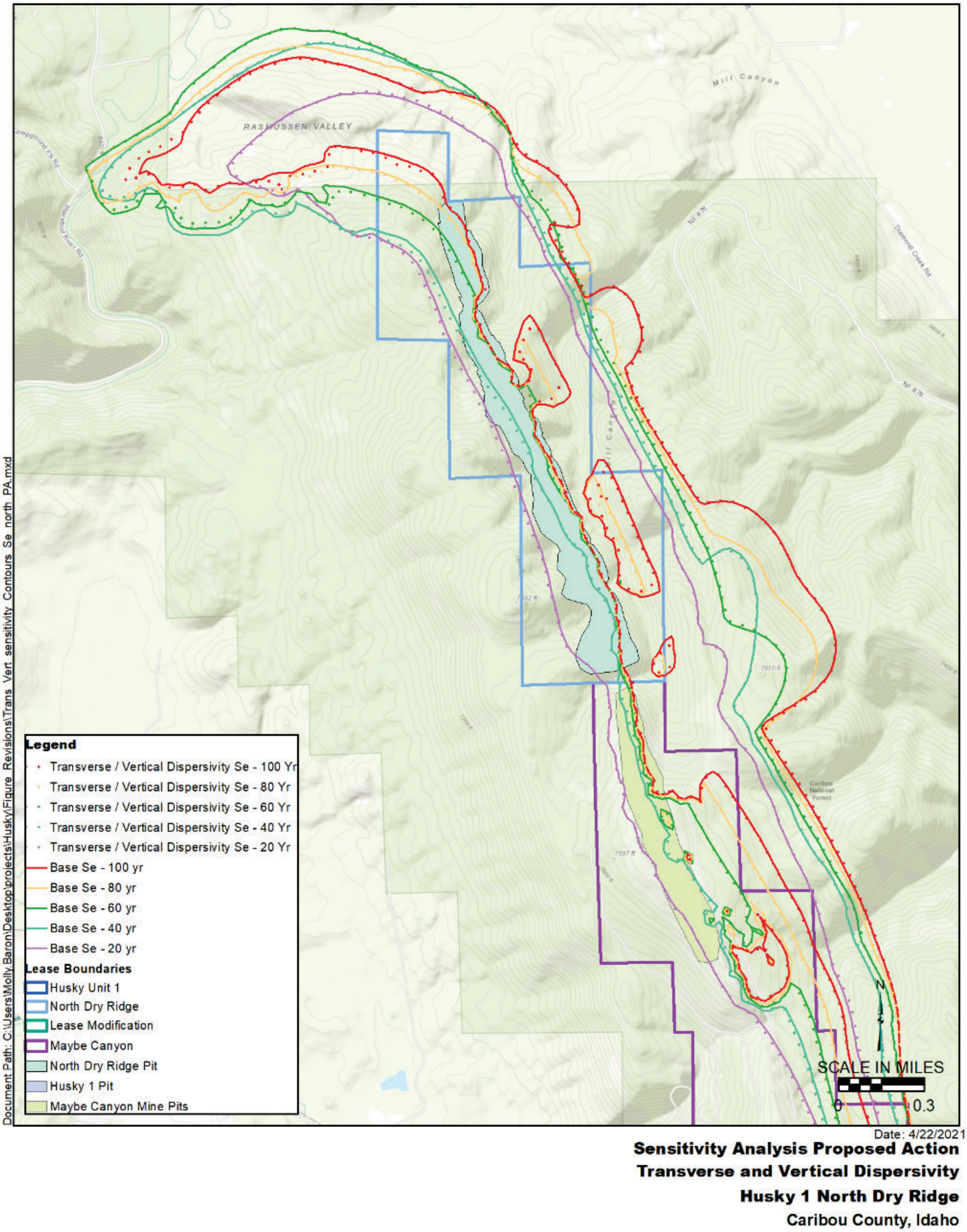


Figure 6-15. Sensitivity Analysis Proposed Action Transverse Dispersivity – North Dry Ridge and North Maybe Mine

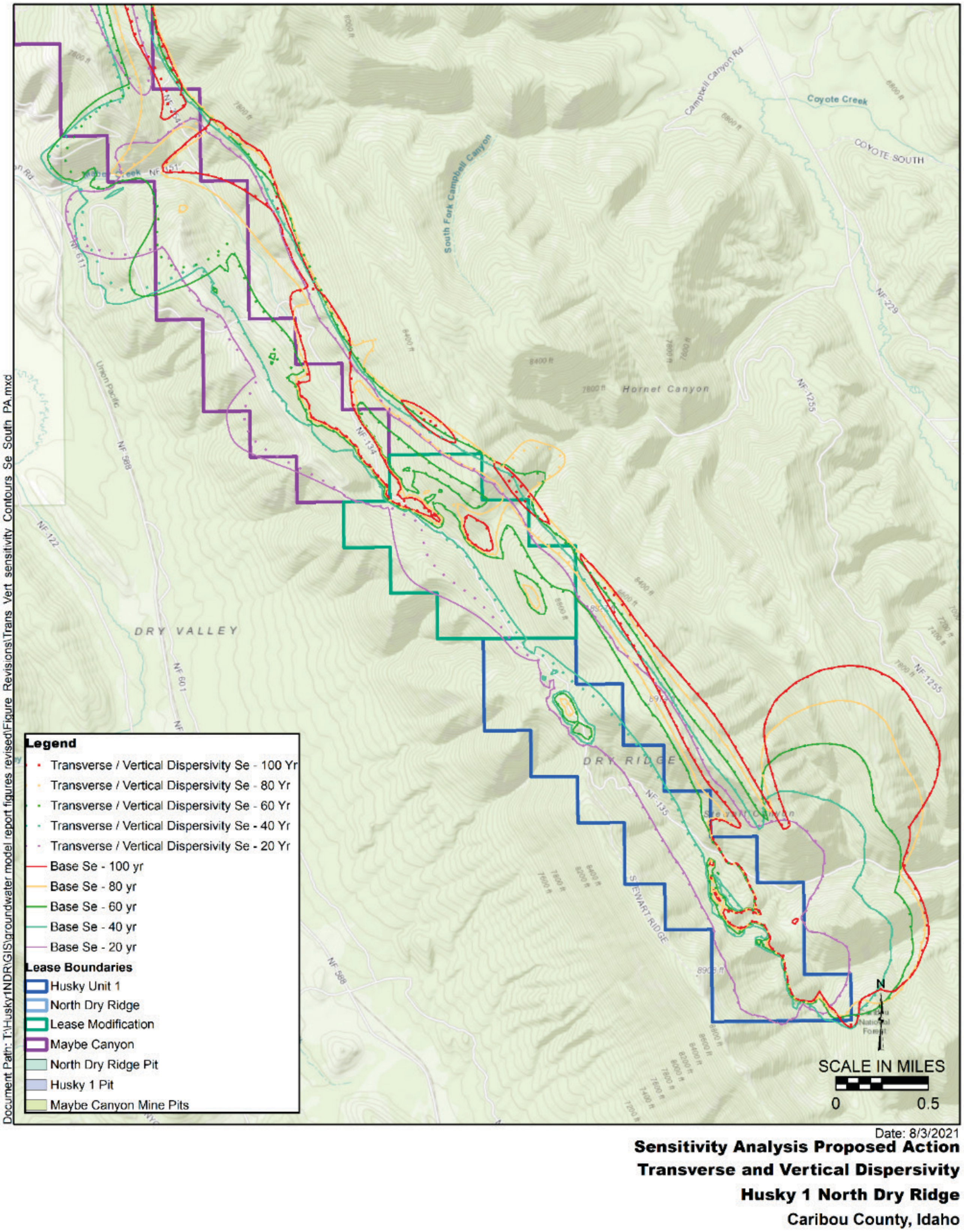


Figure 6-16. Sensitivity Analysis Proposed Action Transverse Dispersivity – South Maybe Canyon Mine and Husky 1

In addition to evaluating the change in selenium plume extent, the sensitivity analysis also assessed the change in peak groundwater discharge into Stewart Creek, Maybe Creek, and East Mill Creek from the Proposed Action. **Table 5-1** shows the change in peak selenium concentration in groundwater discharging into these three creeks by sensitivity model simulation name.

Table 6-2. Groundwater Discharge Peak Concentrations for Proposed Action Sensitivity Analysis

Model Simulation	Stewart Creek (µg/L)	Maybe Creek (µg/L)	East Mill Creek (µg/L)
Base Case	49	18	23
High Infiltration Rate	67	35	52
Low Infiltration Rate	4.9	<0.1	1.0
High Hydraulic Conductivity	37	4.3	17
Low Hydraulic Conductivity	47	19	31
High Effective Porosity	48	18	23
Low Effective Porosity	48	18	23
Longitudinal Dispersivity	48	17	22
Transverse / Vertical Dispersivity	48	17	22

These groundwater discharge concentrations were compared from the same three model cells from each numerical simulation. As expected, higher backfill infiltration rates increased the groundwater selenium concentration entering these three creeks and vice versa for a lower backfill infiltration rate. A higher hydraulic conductivity of the weathered bedrock, Rex Chert Member, and Meade Peak Member caused a reduction in groundwater concentration discharging into these three creeks because as water mounded within the backfill and reached the Rex Chert Member, more selenium was transported downgradient and downdip and the amount of mounding within the backfill was reduced. Changes in effective porosity and dispersivity had minimal effect on groundwater discharge concentrations into these creeks.

6.2 Alternative Cover Model Sensitivity Results

Changes to input parameters for sensitivity analysis of the Alternative Cover scenario model resulted in the following changes to the selenium plume development, migration, and persistence:

- High infiltration rate (**Figure 6-17** and **Figure 6-18**):
  - Increasing backfill infiltration rate for the Alternative Cover increased the selenium plume extent by more than 500 feet downgradient and downdip. In some of the pits, water levels mounded higher in the backfill and allowed transport into the Rex Chert Member (e.g., downgradient and downdip of H1-X).
- Low infiltration rate (**Figure 6-19** and **Figure 6-20**):
  - Decreasing the infiltration or recharge rate into the backfill caused the selenium plume extent to become smaller than in the Alternative Cover simulation. Areas where the plume decreased the most in extent are near the Blackfoot fault in the Grandeur Tongue Member and in the Rex Chert Member downgradient and downdip of the southern portion of North Dry Ridge, H1-S, and H1-E.
- High hydraulic conductivity (**Figure 6-21** and **Figure 6-22**):
  - Increasing horizontal and vertical hydraulic conductivity in weathered bedrock, Meade Peak Member, and Rex Chert Member, resulted in an increase in selenium plume extent in the Rex

Chert Member by hundreds of feet. In particular, increases in plume extent occurred downgradient and downdip of H1-X, H1-S, and H1-E.

- Low hydraulic conductivity (**Figure 6-23** and **Figure 6-24**):
  - Decreasing the horizontal and vertical hydraulic conductivity reduced the selenium plume extent by hundreds of feet. As in the proposed action case, there was a small increase in selenium plume extent east of the OSA at H1-X where the plume encounters the Henry thrust fault and migrates vertically into the Rex Chert Member.

Since the groundwater discharge concentrations of selenium into Stewart Creek, Maybe Creek, and East Mill Creek were more than an order of magnitude below the aquatic standard of 3.1 µg/L and below method detection limits of 0.14 µg/L for the Alternative Cover scenario, the sensitivity analysis did not evaluate changes in groundwater discharge concentrations into these creeks.

6.3 Sensitivity Analysis Conclusions

The conclusions that can be drawn from the sensitivity analysis are:

- Change in backfill infiltration rate has the largest effect on selenium plume migration from the mine pits since this parameter controls the amount of mounding within the pit backfill.
- Horizontal and vertical hydraulic conductivity of the weathered bedrock, Meade Peak Member, and Rex Chert Member along Dry Ridge are also sensitive parameters.
- Increasing or decreasing the backfill infiltration rate also has the largest effect on selenium concentrations in groundwater discharging into East Mill Creek, Maybe Creek, and Stewart Creek.
- Changes in model parameters for the Alternative Cover option produce similar changes in selenium plume extent as in the Proposed Action option.
- Varying the parameters considered in the sensitivity analysis within realistic ranges did not cause the model-predicted COPC concentrations or COPC plume extents to change significantly enough to affect decisions that would be made on that basis.

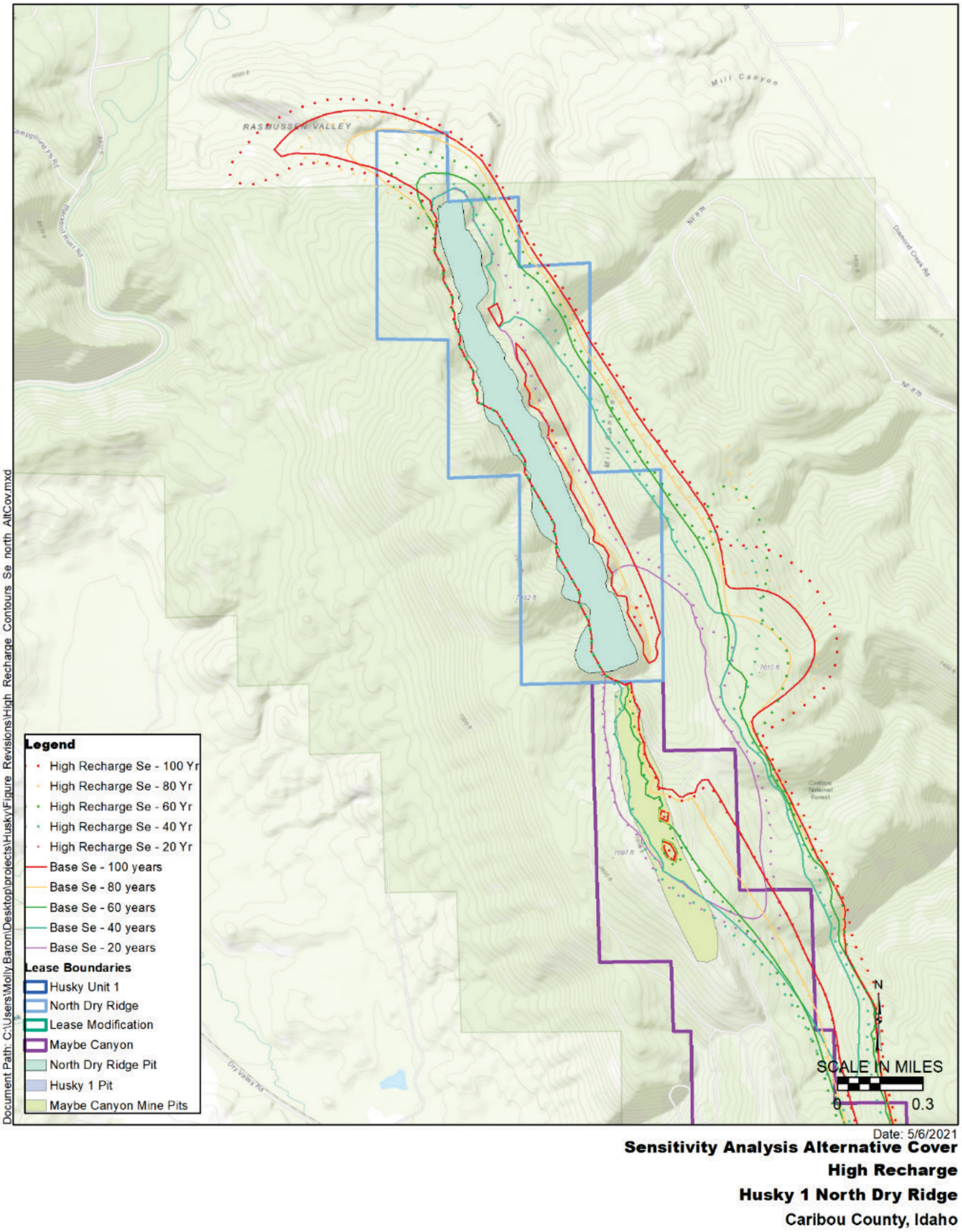
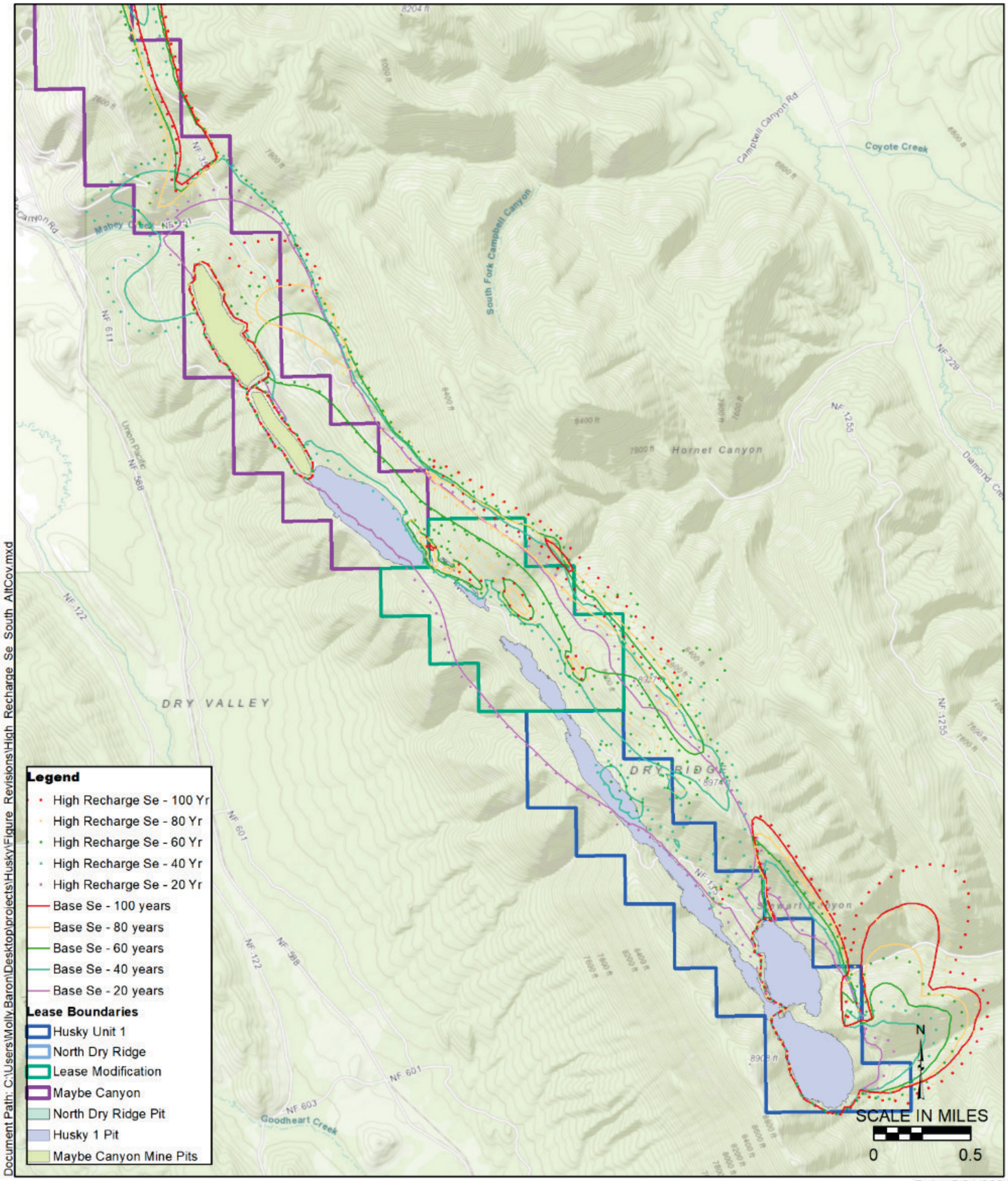


Figure 6-17. Sensitivity Analysis Alternative Cover High Infiltration Rate – North Dry Ridge and North Maybe Mine



Date: 5/24/2021

Sensitivity Analysis Alternative Cover
High Recharge
Husky 1 North Dry Ridge
Caribou County, Idaho

Figure 6-18. Sensitivity Analysis Alternative Cover High Infiltration Rate – South Maybe Canyon Mine and Husky 1

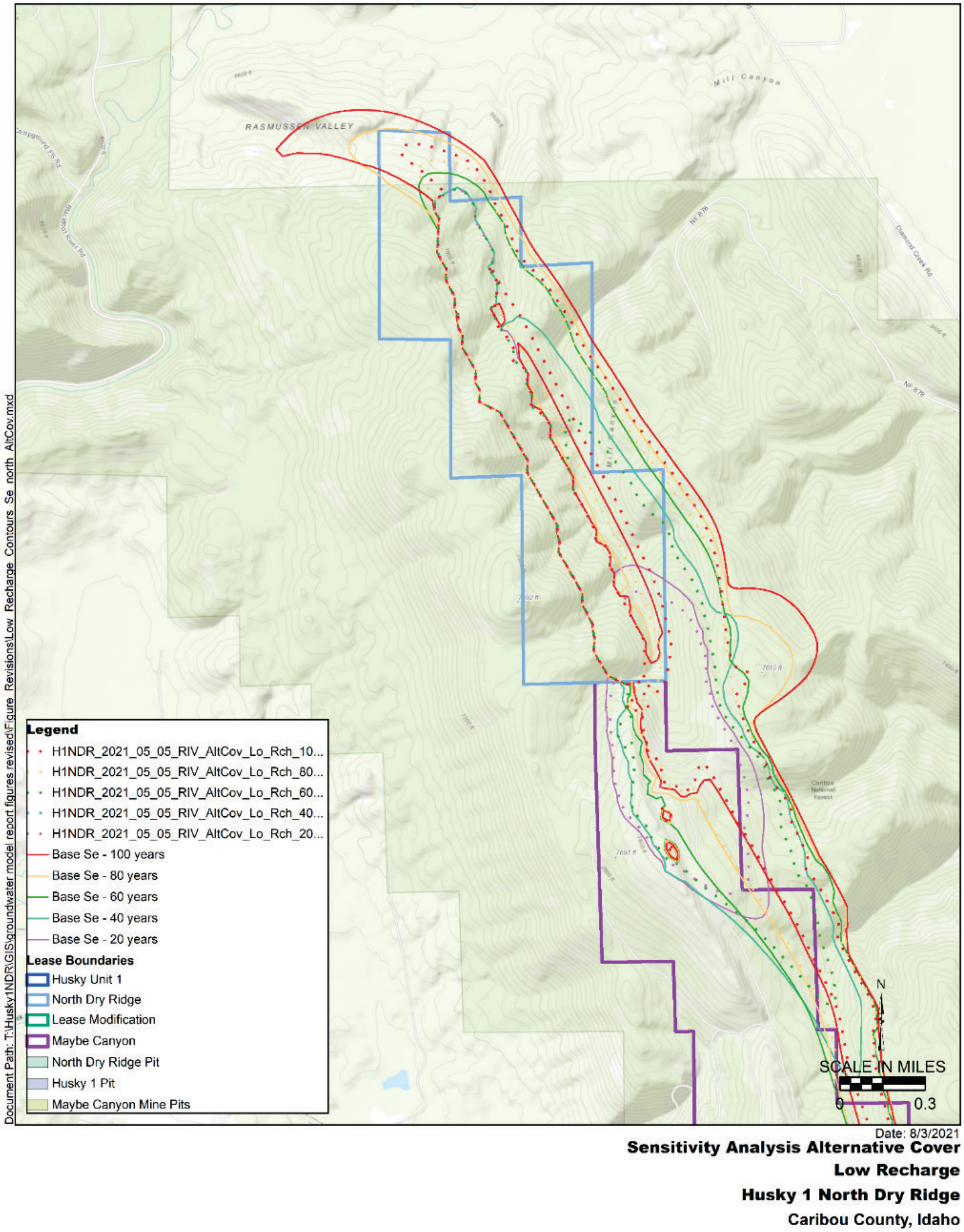


Figure 6-19. Sensitivity Analysis Alternative Cover Low Infiltration Rate – North Dry Ridge and North Maybe Mine

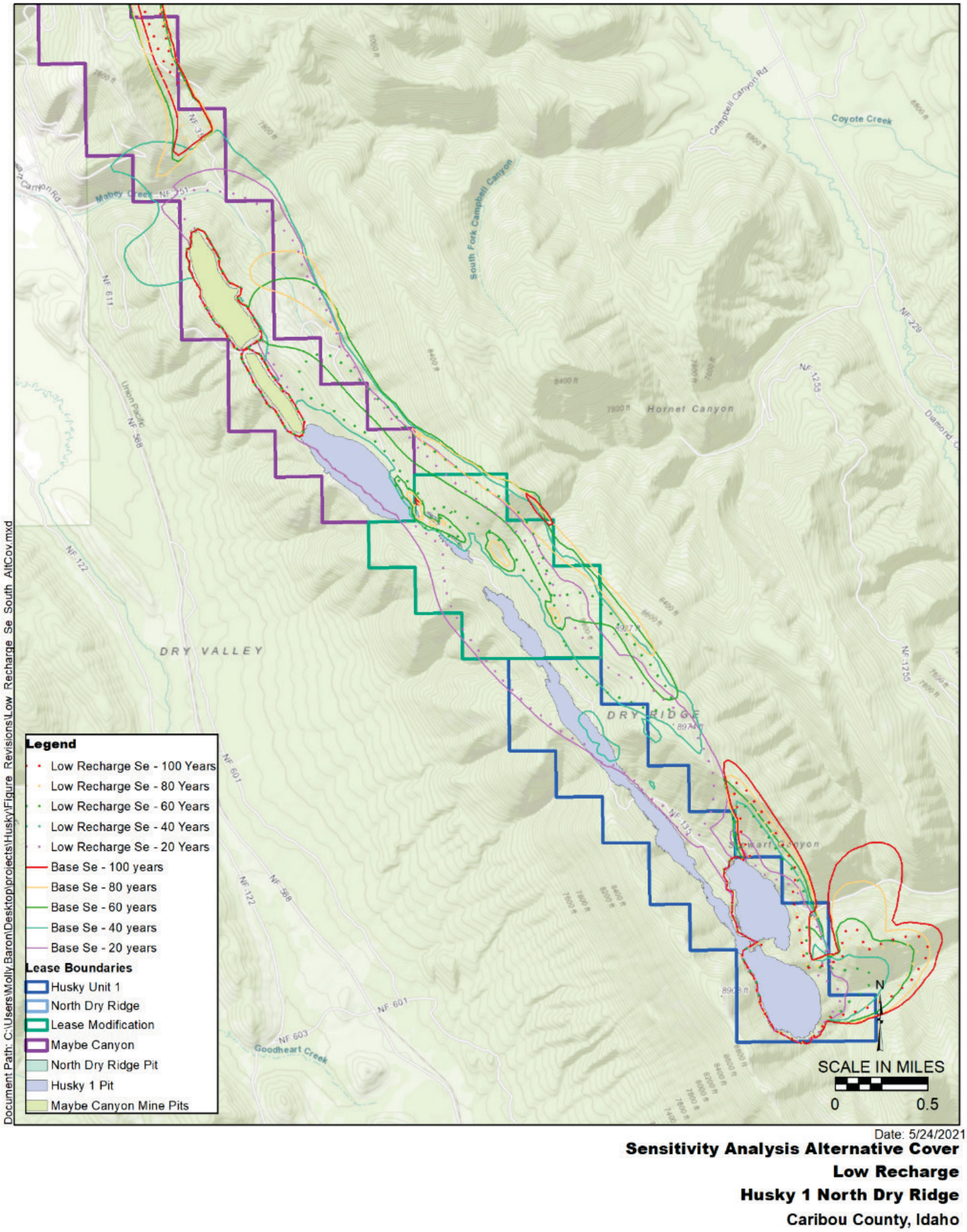


Figure 6-20. Sensitivity Analysis Alternative Cover Low Infiltration Rate – South Maybe Canyon Mine and Husky 1

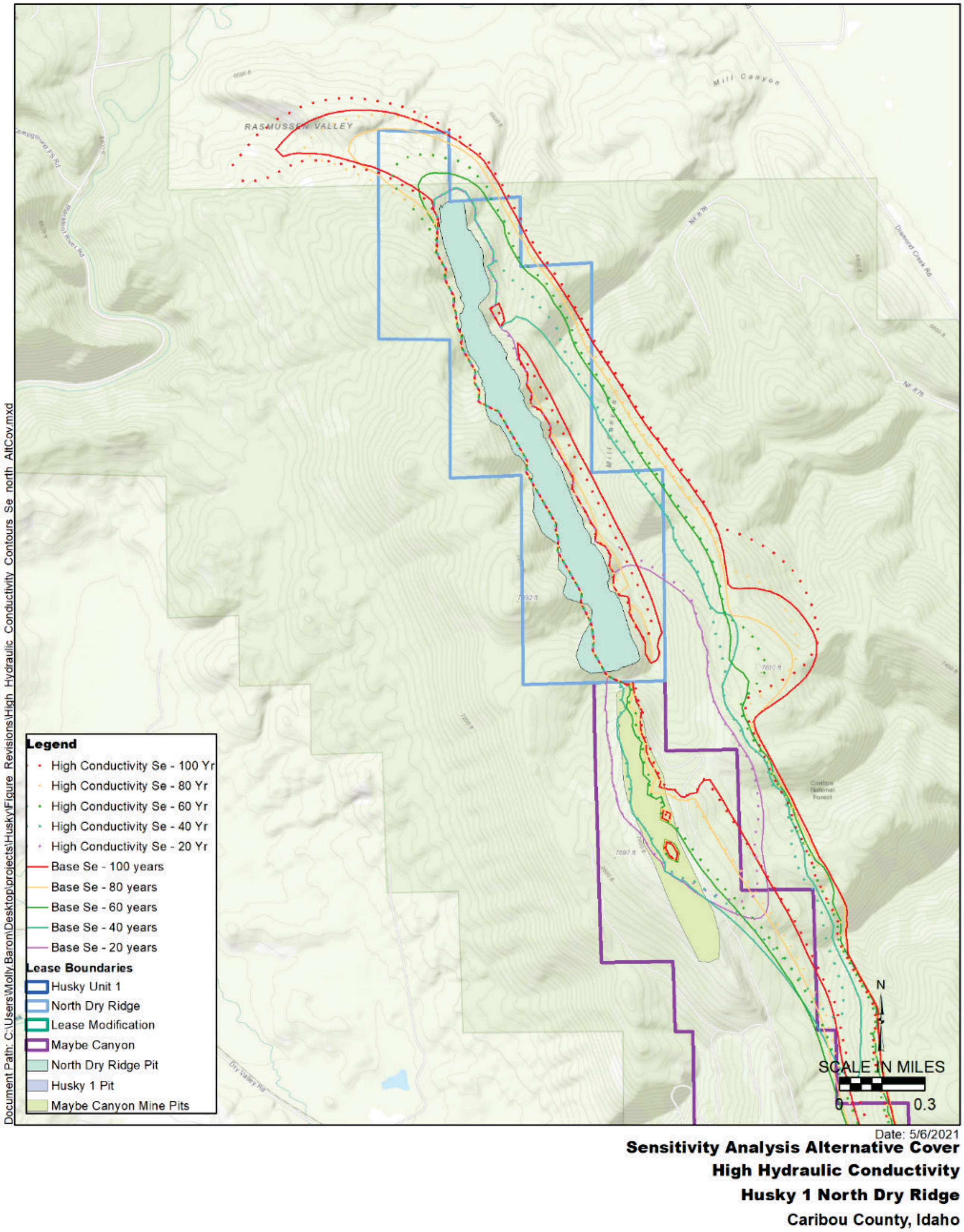


Figure 6-21. Sensitivity Analysis Alternative Cover High Hydraulic Conductivity – North Dry Ridge and North Maybe Mine

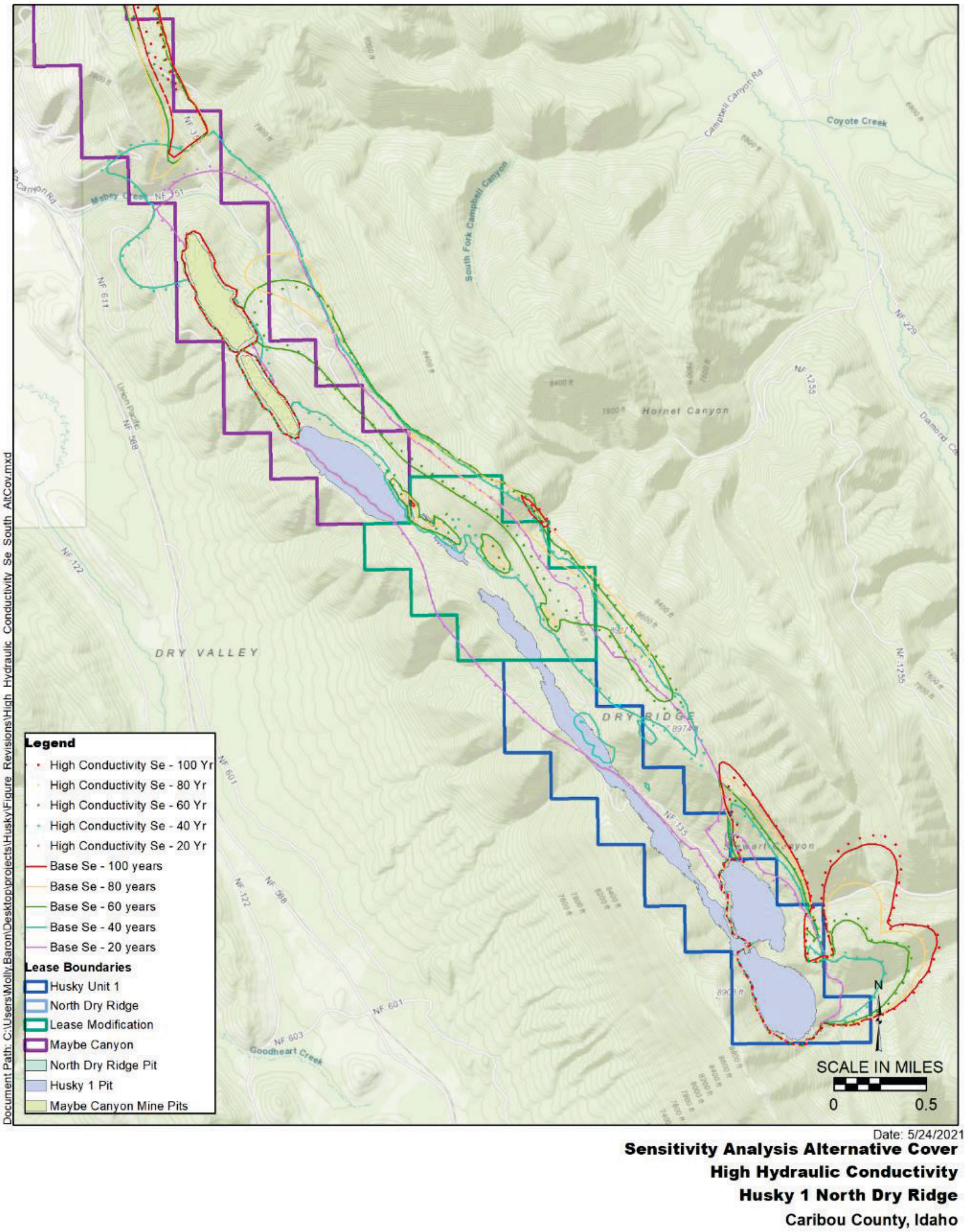


Figure 6-22. Sensitivity Analysis Alternative Cover High Hydraulic Conductivity – South Maybe Canyon Mine and Husky 1

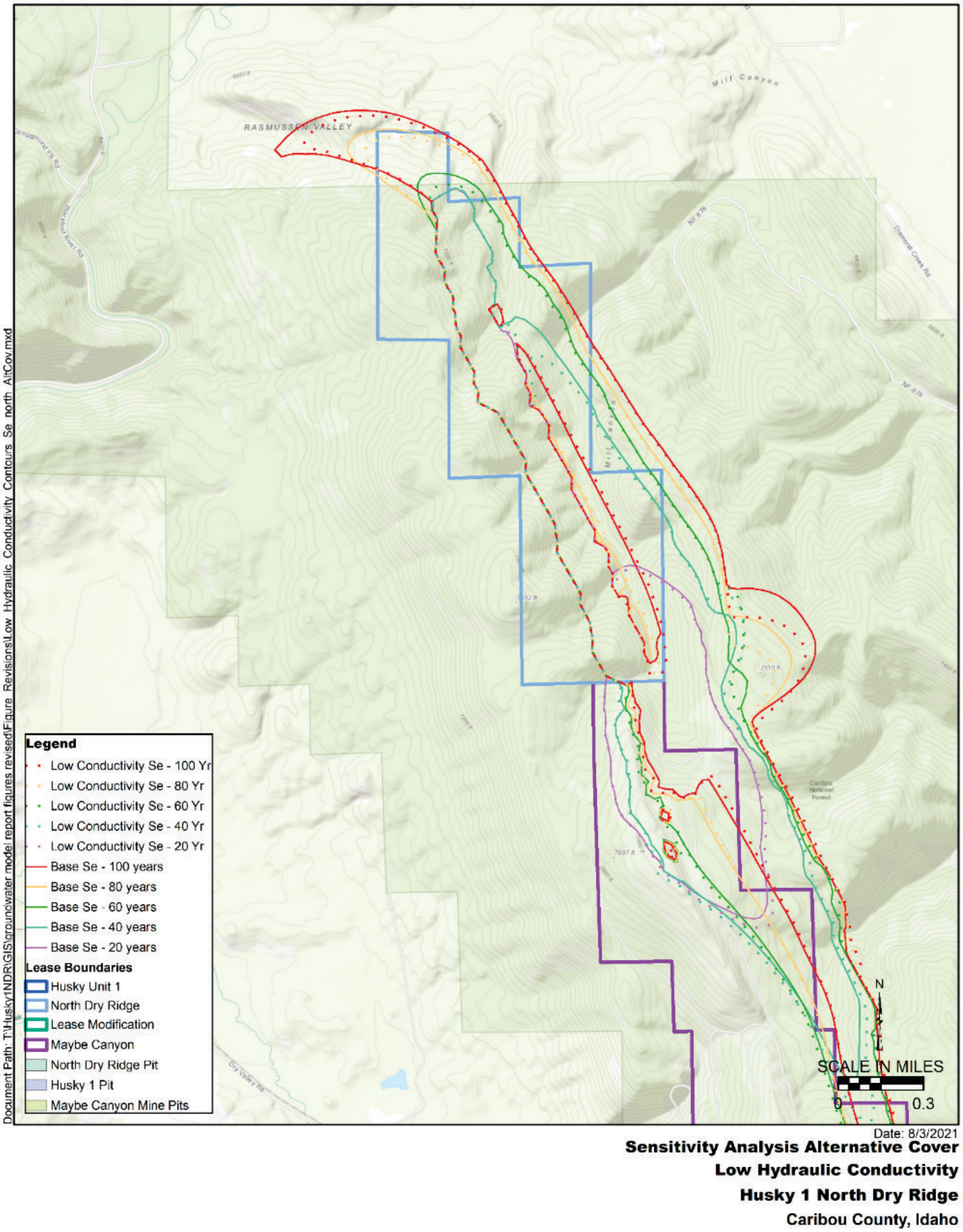


Figure 6-23. Sensitivity Analysis Alternative Cover Low Hydraulic Conductivity – North Dry Ridge and North Maybe Mine

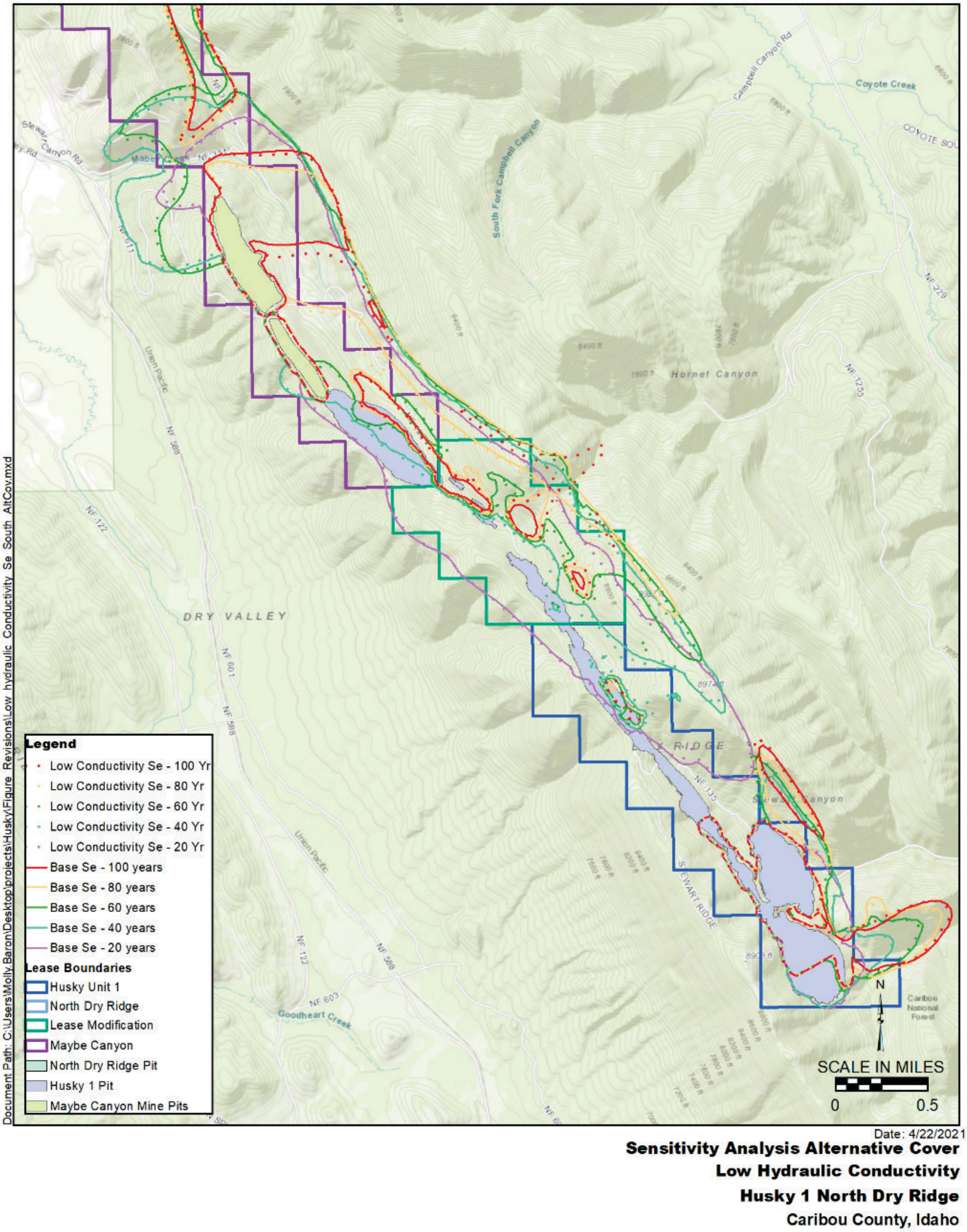


Figure 6-24. Sensitivity Analysis Alternative Cover Low Hydraulic Conductivity – South Maybe Canyon Mine and Husky 1

7.0 GROUNDWATER MODEL UNCERTAINTIES AND LIMITATIONS

The H1NDR numerical groundwater flow and transport model was developed as a tool for quantitative and qualitative prediction of changes in groundwater and surface water quality caused by contaminants leaching and changes in groundwater levels and surface water flows due to mining. The predictions are estimates based on currently available geologic and hydrogeologic data at the time this model was developed.

In some cases, data were either never collected and not feasible to obtain, which caused uncertainty in the site conceptual model and the hydrologic values used in the numerical model. These uncertainties required that assumptions be made in developing both the conceptual and numerical models. Assumptions used were based on published information for the region, basic hydrogeologic principles, and the experience of the modeling team, and the collaborative advisory team (BLM, IDEQ, the project proponent, and their contractors). Examples of data that were unavailable or not feasible to obtain, and related assumptions made to mitigate the lack of data, included:

- The hydrogeologic characteristics of the faults in the area and the roles the faults play in influencing groundwater flow are not well defined, and detailed investigation of the faults is not feasible. Interpretations for the conceptual site model, and subsequently the numerical flow model, were based on the potentiometric surface configuration and hydraulic gradients across faulted areas, and the results of experimentation with fault representations during development and calibration of the numerical model.
- Values for the hydraulic properties for the Thaynes Formation were not available due aquifer testing not being conducted in this formation. Hydraulic conductivity, specific storage, and specific yield values for the Thaynes Formation were therefore assigned based on published qualitative descriptions of its hydrogeologic characteristics (Ralston and Williams, 1979a) and similarities between the Thaynes and Dinwoody Formations.
- Potentiometric data for the Wells Formation east of Dry Ridge (e.g., Diamond Valley) were not available due to monitoring wells not being completed in the Wells Formation. The potentiometric surface configuration in that area was interpreted by extrapolation of data from Smoky Canyon Mine and based on the structural geology.
- The thicknesses of alluvium in the valleys of the Blackfoot River, Diamond Valley, Dry Valley Creek, and their tributaries were available only where borings had been drilled and logged. Assumptions regarding the alluvium thickness were based on extrapolation of the thicknesses to areas without data, generalized reported thicknesses (as by Ralston and Williams, 1979a and 1979b, for example), and application of geologic and hydrogeologic principles.

In addition to the uncertainties, the numerical model is limited due to the simplifications necessary to mathematically represent complex natural systems. Model grid size and available data constrain the resolution and accuracy of the predictions. The model was constructed based on present-day conditions, but changes may occur over the simulation period. No attempt has been made to simulate other possible future natural or anthropogenic changes that could alter the groundwater system. As predictive simulations extend further in time, the potential error and uncertainty associated with the predictions increase.

Conservativism was also built into the numerical model given these uncertainties and limitations. Three key examples of conservativism are as follows:

- Chemical reactions (e.g., selenium attenuation) were not simulated in the predictive modeling. Therefore, COPC concentrations do not decrease over time except after each pore volume flush.
- Infiltration rates into cover systems were not based on additional site-specific cover modeling but were based on measured infiltration rates from lysimeters at neighboring mine sites.

- Pore volume concentrations from unsaturated column tests were specified in the solute transport model, which typically had higher pore volume concentrations of COPCs than COPC concentrations from saturated column testing.

Despite these limitations and uncertainties, the model performs as intended and the model predictions are useful for assessing the range of impacts and the differences between the Proposed Action and the Alternative Cover scenarios. The predictions should be considered in light of the overall objective of the modeling, which was to predict whether the Proposed Action or the Alternative Cover would be likely or unlikely to affect the groundwater system and related surface waters to a degree that would cause exceedances of regulatory standards for water quality or decrease the availability of groundwater or surface water.

8.0 REFERENCES CITED

AECOM. 2009. North Maybe Mine Final Site Investigation Report. June.

AECOM. 2014. Final 2013 Field Season Sampling Data Summary Report, North Maybe Mine, East Mill Operable Unit, Open Pit Sub-Operable Unit. November.

AECOM. 2015. Evaluation of Piezometer/Stilling Well Transect Data at the Blackfoot River, Investigation Area 8, North Maybe Mine, Creeks Sub-Operable Unit. Memorandum dated December 17.

Allen, Richard G. and Clarence W. Robison, 2017. Evapotranspiration and Consumptive Irrigation Water Requirements for Idaho: Supplement updating the Time Series through December 2016, Research Technical Completion Report, Kimberly Research and Extension Center, University of Idaho, Moscow, ID. http://data.kimberly.uidaho.edu/ETIdaho/stninfo.py?station=111

AMEC Geomatrix, 2010. Technical Memorandum: 2010 Monitoring, Aquifer Testing, and Groundwater Modeling Results, South Rasmussen Mine, Caribou County, Idaho. To Bill Volk, BLM. August 5.

ARCADIS. 2015. Final Groundwater Modeling Report Rasmussen Valley Mine Project. September. 170 p.

ARCADIS. 2019. Final 2018 Data Summary Report, North Maybe Mine East Mill Operable Unit Open Pit and East Mill Dump Sub-Operable Units and South Maybe Canyon Mine Open Pits Operable Unit, Caribou County, Idaho. May 7.

ARCADIS. 2020a. Geochemical Baseline Characterization Study Report, Husky 1 North Dry Ridge Mine, Caribou County, Idaho. May 26.

ARCADIS. 2020b. Final Groundwater Baseline Study Report, Husky 1 North Dry Ridge Mine, Caribou County, Idaho. June 12.

ARCADIS. 2020c. Source Term Results for the Husky 1/North Dry Ridge Mine Project, Caribou County, Idaho. July 24.

ARCADIS. 2020d. Cap and Cover Alternatives Evaluation Report, Husky 1 North Dry Ridge, Soda Springs, Idaho. August 6.

ARCADIS. 2020e. H1NDR Mine and Reclamation Plan Addendum. December 16.

ASTM E1739-95(2015), Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites, ASTM International, West Conshohocken, PA, 2015, www.astm.org

Brown and Caldwell. 2013. Final Hydrologic Testing – Slug Test Results. Technical Memorandum prepared for Nu-West Industries, Inc. doing business as Agrium Conda Phosphate Operations. December 20.

Brown and Caldwell. 2014a. Monitoring Well Completion Report for HU-3W Husky 1-North Dry Ridge. Report prepared for Agrium CPO. January 8.

Brown and Caldwell. 2014b. Draft Single-Well Aquifer Test Report. Technical Memorandum prepared for Nu-West Industries, Inc. doing business as Agrium Conda Phosphate Operations. September 26.

Buck B and Mayo A. 2004. Conceptual Groundwater Model, Simplot Panels F/G. Technical Memorandum. January 5.

Cressman EE, and Gulbrandsen RA. 1955. Geology of the Dry Valley Quadrangle Idaho. U.S. Geological Survey Bulletin 1015-I.

Derkey PD, Palmer P, and Wotruba NJ. 1983. Maps Showing Selected Geology and Phosphate Resources of the Upper Valley Quadrangle, Caribou County, Idaho. U.S. Geological Survey Mineral Investigations Resource Map MR-71.

Environmental Simulations Incorporated. 2017. Groundwater Vistas Online User Manual. http://groundwatermodels.com/Groundwater_Vistas/php.

Global Environmental Technologies. 2007. Results of Hydrogeologic Investigation at the North Maybe Mine, Nu-West Mining and Nu-West Industries, Inc. November 30.

Hsieh PA and Freckleton JR. 1993. Documentation of a Computer Program to Simulate Horizontal-Flow Barriers Using the U.S. Geological Survey's Modular Three-Dimensional Finite-Difference Ground-Water Flow Model. U.S. Geological Survey Open-File Report 92-477. 37 p.

HydroGeoLogic, Inc. 2011. MODHMS/MODFLOW-SURFACT, A Comprehensive MODFLOW-Based Hydrologic Modeling System, Software Documentation. Reston.

Idaho Division of Water Resources (IDWR). 2014. Log of Bear Lake Grazing Association well, well tag no. D0051399.

Itafos. 2020a. Mine and Reclamation Plan. Husky 1 North Dry Ridge Mine. Caribou County, Idaho. June 19.

Itafos. 2020b. Draft Cap and Cover Alternatives Evaluation Report. Husky 1 North Dry Ridge Mine. Soda Springs, Idaho. August 6.

J.R. Simplot Company, 2019. Point of Compliance Application Proposed East Smoky Panel Mine Project Smoky Canyon Mine Caribou County, Idaho, April 2019.

Mayo AL, Muller AB, and Ralston DR. 1985. Hydrogeochemistry of Meade Thrust Allochthon, Southeastern Idaho, U.S.A., and its Relevance to Stratigraphic and Structural Groundwater Flow Control. Journal of Hydrology, v. 76, pp. 27-61.

McGregor D. 1993. Hydrologic Evaluation of A and B Pits in Lower Dry Valley, Caribou County, Idaho. MS Thesis, University of Idaho, Moscow, Idaho.

Montgomery KM and Cheney TM. 1967. Geology of the Stewart Flat Quadrangle, Caribou County, Idaho. U.S. Geological Survey Bulletin 1217.

Montgomery Watson, 1998. Letter Report to Mr. Rick Bullis, FMC Dry Valley Mine, Subject: Aquifer Testing at D-Pit. December 10, 1998.

NewFields. 2016. Final Water Resources Baseline Technical Report, Caldwell Canyon Project, Caribou County, Idaho. March 2016 (Revised February 2017).

Oriel SS and Platt LB. 1980. Geologic Map of the Preston 1°X2° Quadrangle, Southeastern Idaho and Western Wyoming. U.S. Geological Survey Miscellaneous Investigations Series Map I-1127.

Pincus WJ. 1985. Dry Valley 1984 Drilling and Hydrology Results, Consultant Geologist Report. January.

PRISM Climate Group. 2019. PRISM Climate Group, Oregon State University. http://prismmap.nasce.org

Ralston DR, and Williams RE. 1979a. Groundwater Flow Systems in the Western Phosphate Field in Idaho. Journal of Hydrology, v. 43, pp. 239-264.

Ralston DR and Williams RE. 1979b. Groundwater Flow Systems in the Western Phosphate Field in Idaho. Idaho Water and Energy Resources Research Institute, University of Idaho, Moscow, 26 p.

Ralston DR, Brooks TD, Cannon MR, Corbet TF Jr, Singh H, and Winter GV. 1980. Interactions of Mining and Water Resource Systems in the Southeastern Idaho Phosphate Field. University of Idaho Water Resources Research Institute Research Technical Completion Report Project C-7651. February.

Ralston DR, Mayo AL, Arrigo JL, Baglio JV, Coleman LM, Hubbell JM, and Souder K. 1981. Geothermal Evaluation of the Thrust Zone in Southeastern Idaho. Idaho Water and Energy Research Institute, University of Idaho, Moscow, 120 p.

Ralston D, Mayo A, Arrigo J, Baglio J, Coleman L, Hubbell J, and Souder K. 1983. Thermal Groundwater Flow Systems in the Thrust Zone in Southeastern Idaho. Idaho Water and Energy Resources Research Institute, University of Idaho, Moscow, 336 p.

Raviv and Patricio Associates, Inc. 1990. Hydrogeologic Evaluation and Dewatering Feasibility for Dry Valley Mine, FMC Corporation. Prepared for FMC Corporation, Soda Springs, Idaho.

Rioux RL, Hite RJ, Dyni JR, and Gere WC. 1975. Geologic Map of the Upper Valley Quadrangle, Caribou County, Idaho. U.S. Geological Survey Geologic Quadrangle Map GQ-1194.

Royse, Frank Jr. 1993. An Overview of the Geologic Structure of the Thrust Belt in Wyoming, Northern Utah, and Eastern Idaho. *In* Snoke AW, Steidtmann JR, and Roberts SM, eds. Geology of Wyoming. Geological Survey of Wyoming Memoir No. 5. pp. 273 – 311.

Shah N, Nachabe M, and Ross M. 2007. Extinction Depth and Evapotranspiration from Ground Water under Selected Land Covers. Ground Water, vol. 45, no. 3, pp. 329-338.

Tetra Tech. 2018. Caldwell Canyon EIS Project Groundwater Modeling Report. July 12.

Tetra Tech. 2019. Hydrogeologic Conceptual Site Model Final, Husky 1 North Dry Ridge Mine, December 2.

United States Bureau of Land Management. 2021. H1/NDR Cap and Cover Alternatives – Percolation Assessment.

United States Fish and Wildlife Service (USFWS). 2019. National Wetlands Inventory Wetlands Mapper. http://www.fws.gov/wetlands/Data/Mapper.html

Whetstone Associates, Inc. 2003. Water Resources Technical Report for the Proposed North Rasmussen Ridge Mine Expansion. Prepared for Bureau of Land Management, Pocatello Field Office. April.

Whetstone Associates, Inc. 2009. Final Source Term Development Report to Support Numerical Modeling of Groundwater Flow and Solute Transport for the Proposed Blackfoot Bridge Mine. Prepared for Bureau of Land Management, Pocatello Field Office. June.

Xu M, Eckstein Y. 1995. Use of Weighted Least-Squares Method in Evaluation of the Relationship Between Dispersivity and Field Scale. Ground Water v. 33 pp 905–908.

APPENDIX A:
Potentiometric Surface Elevations by Model Layer

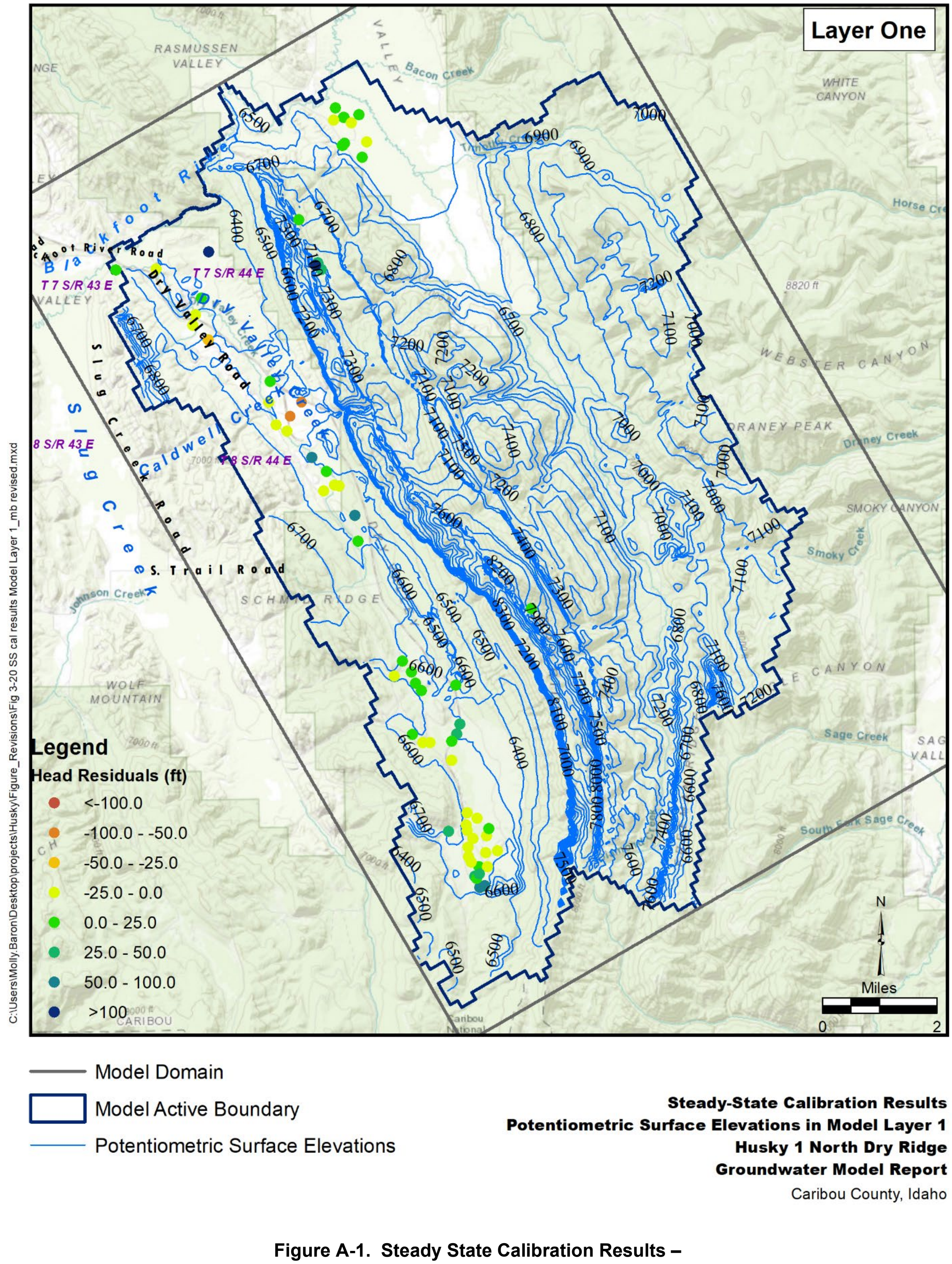


Figure A-1. Steady State Calibration Results – Potentiometric Surface Elevations in Model Layer One

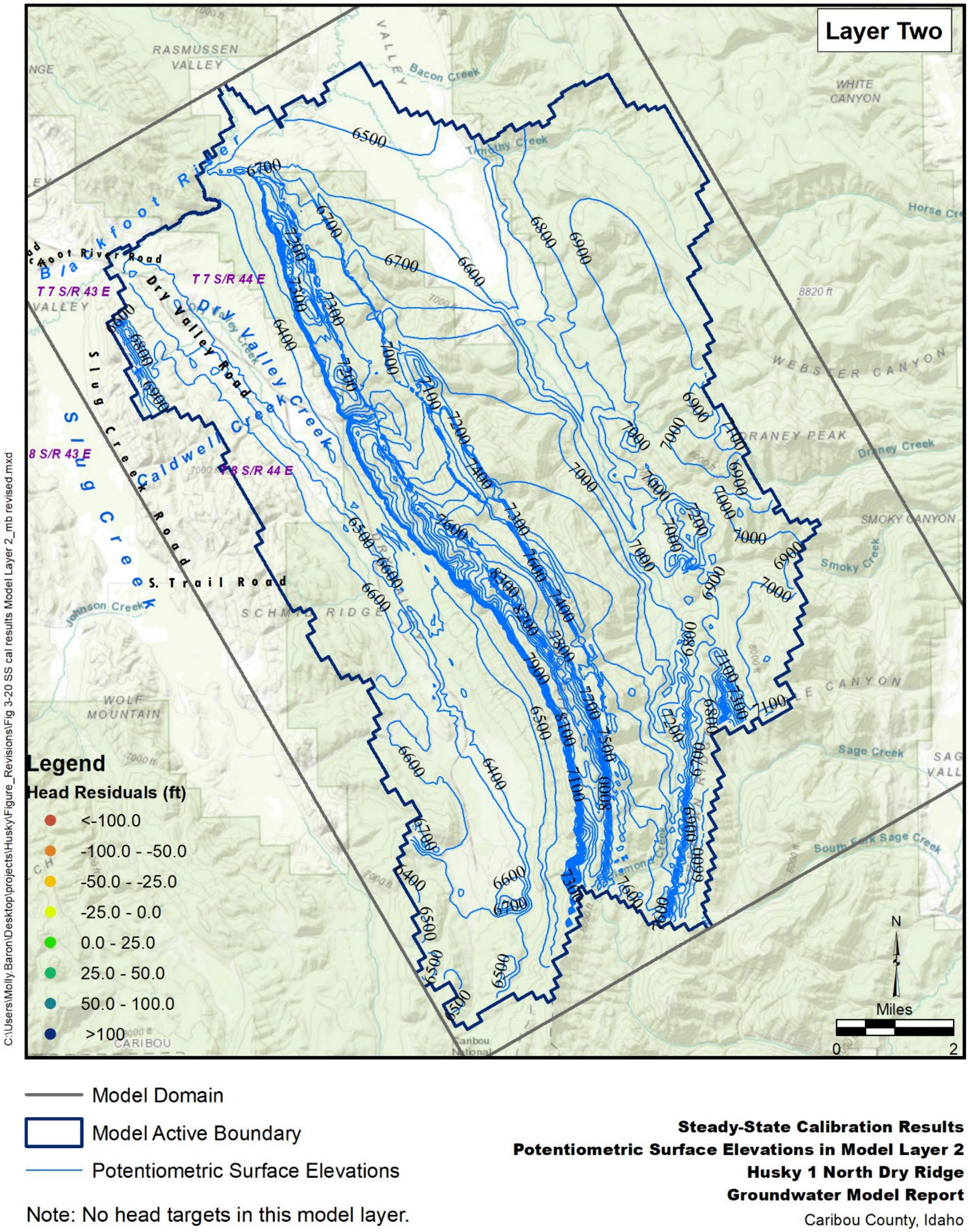


Figure A-2. Steady State Calibration Results – Potentiometric Surface Elevations in Model Layer Two

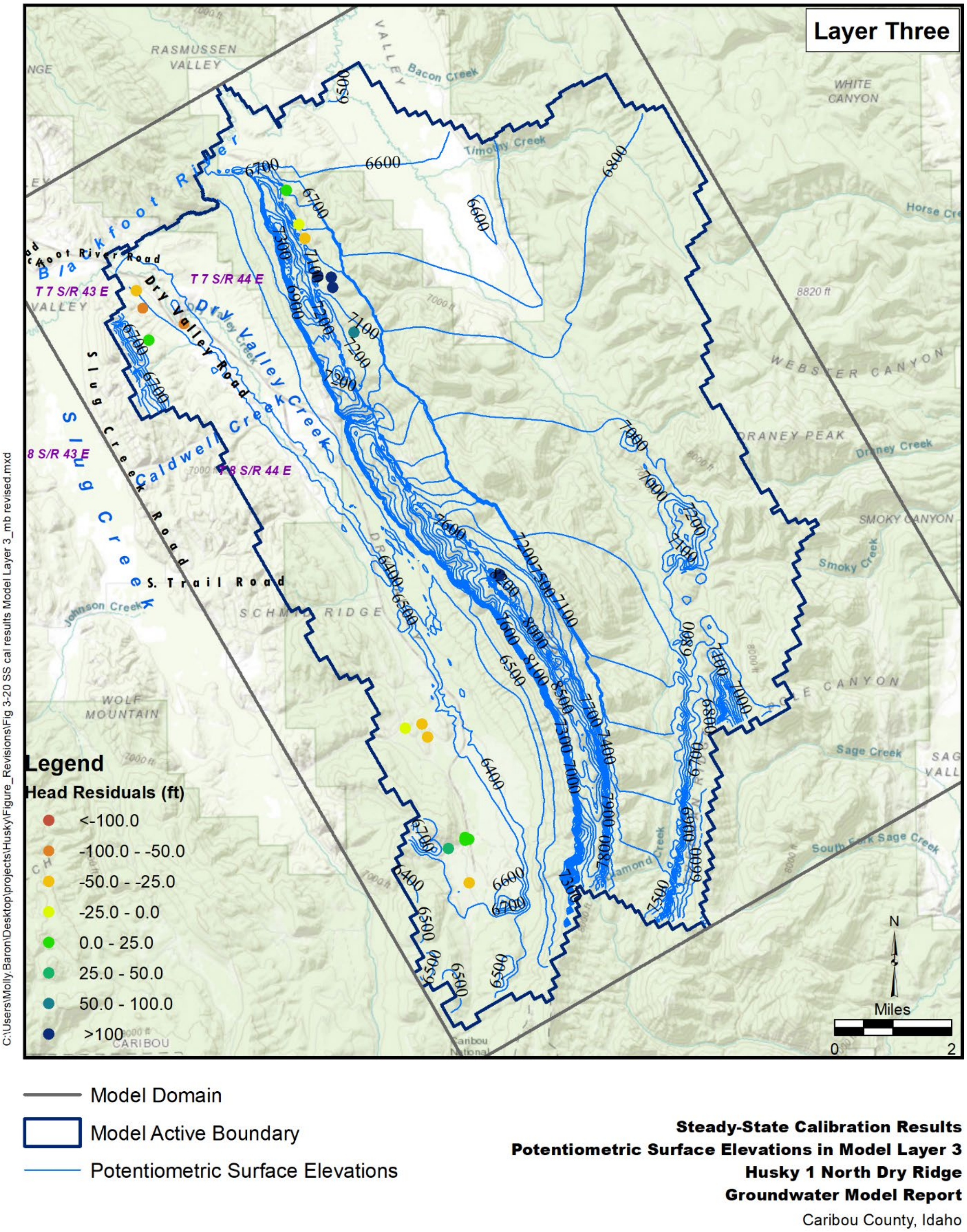
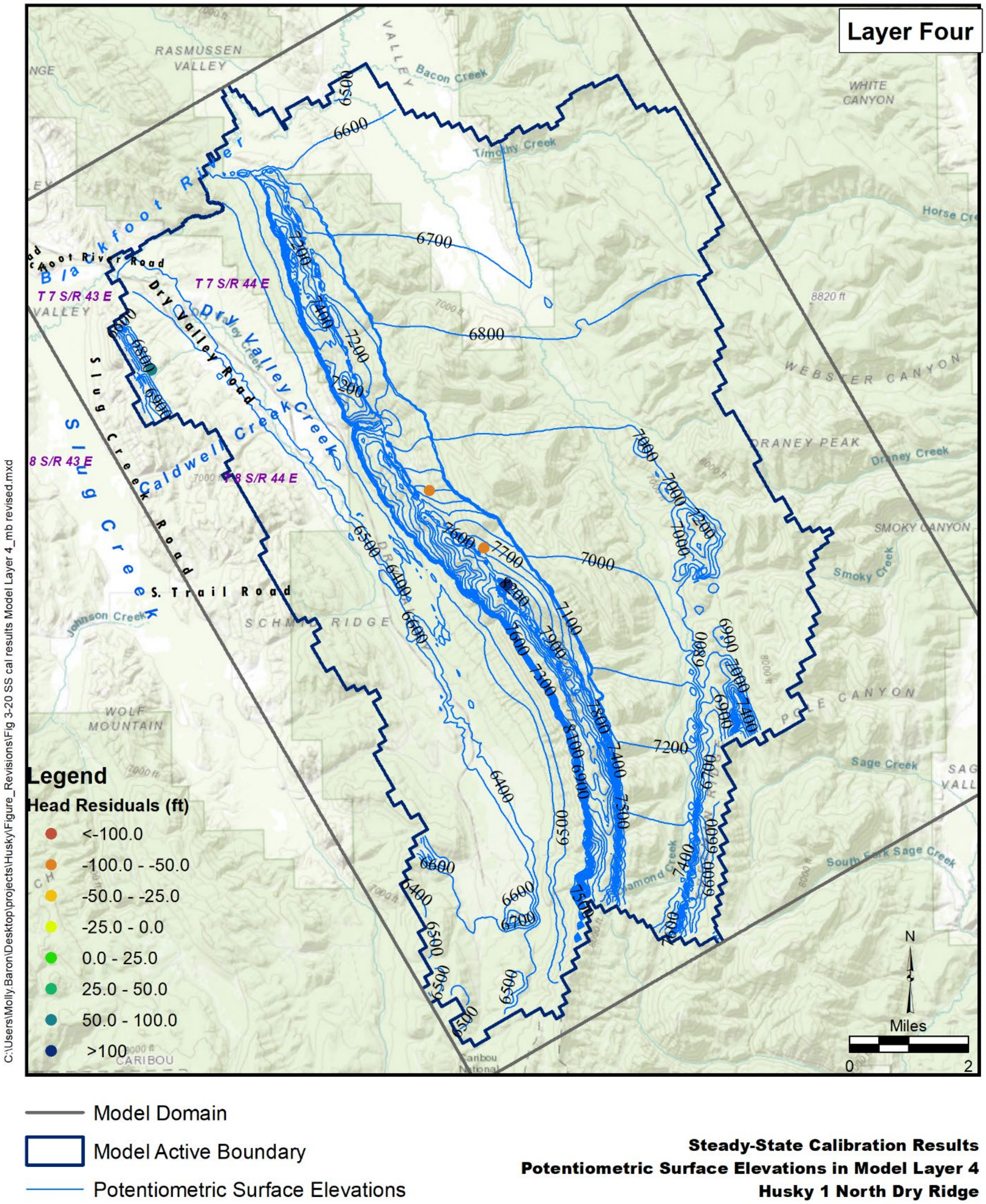


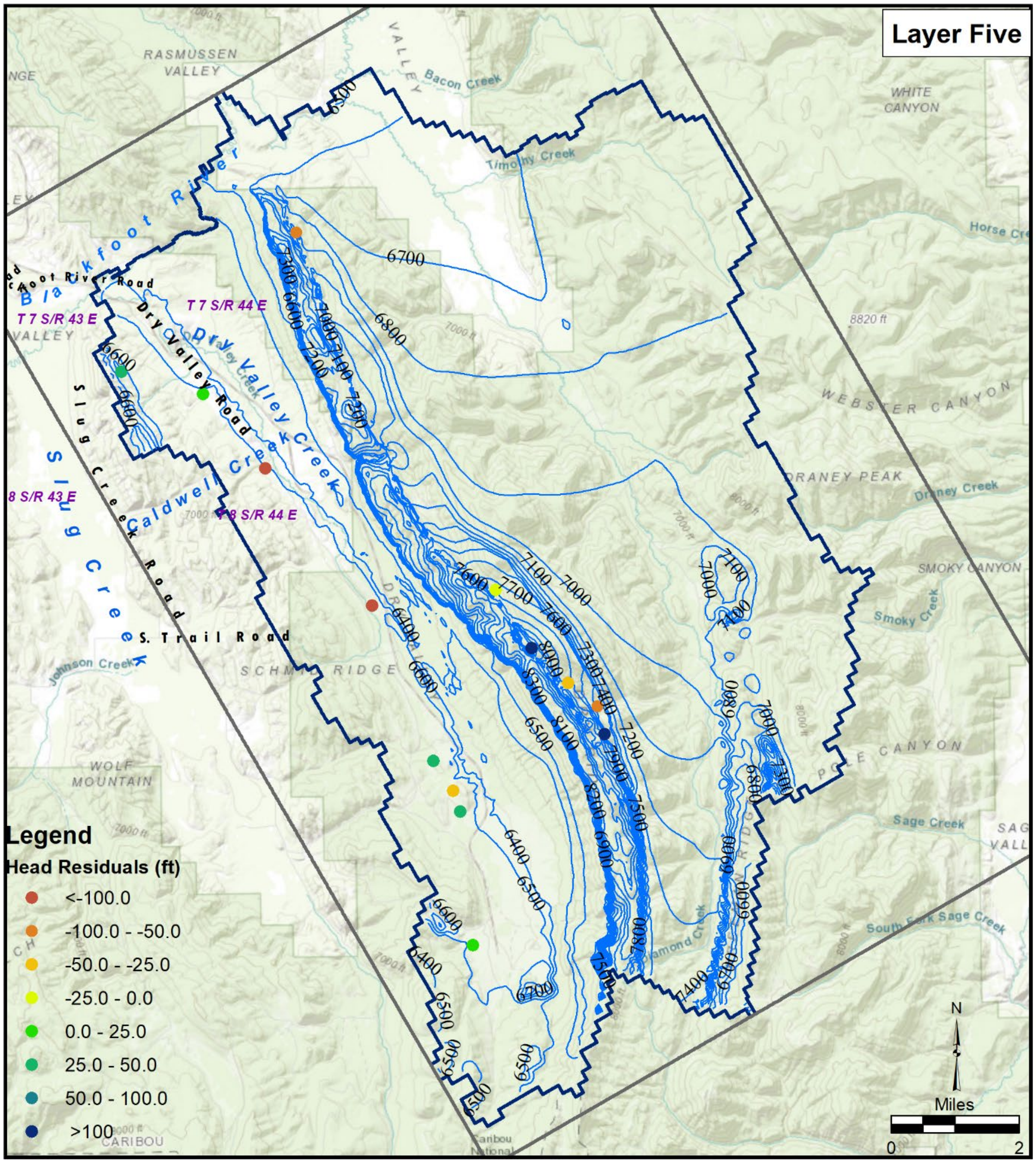
Figure A-3. Steady State Calibration Results – Potentiometric Surface Elevations in Model Layer Three



Steady-State Calibration Results
Potentiometric Surface Elevations in Model Layer 4
Husky 1 North Dry Ridge
Groundwater Model Report
Caribou County, Idaho

Figure A-4. Steady State Calibration Results – Potentiometric Surface Elevations in Model Layer Four

C:\Users\Molly.Baron\Desktop\projects\Husky\Figure_Revisions\Fig 3-20 SS cal results Model Layer 5_mb revised.mxd



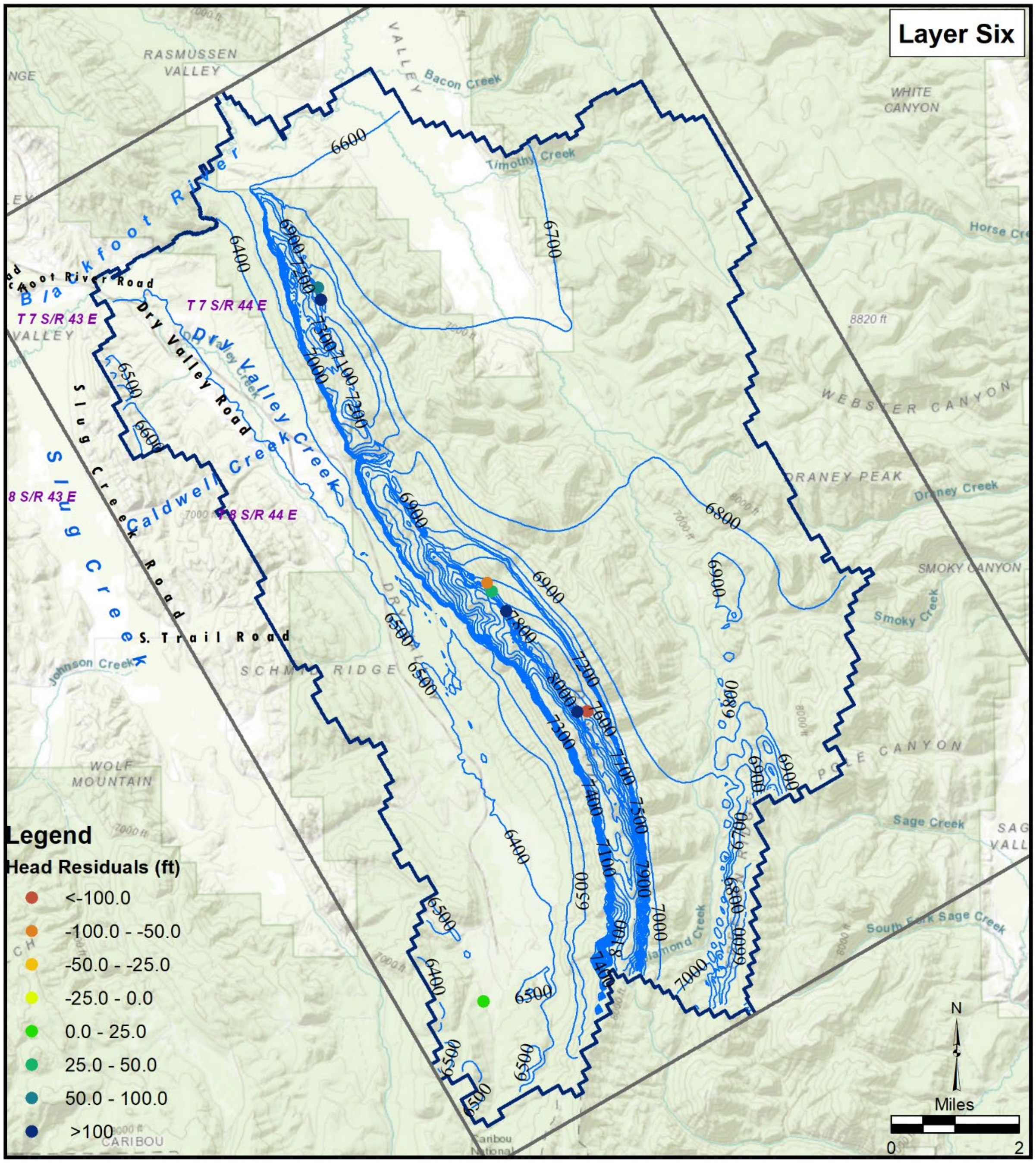
Model Domain

Model Active Boundary

Potentiometric Surface Elevations

Steady-State Calibration Results
Potentiometric Surface Elevations in Model Layer 5
Husky 1 North Dry Ridge
Groundwater Model Report
Caribou County, Idaho

Figure A-5. Steady State Calibration Results – Potentiometric Surface Elevations in Model Layer Five



Steady-State Calibration Results
Potentiometric Surface Elevations in Model Layer 6
Husky 1 North Dry Ridge
Groundwater Model Report
Caribou County, Idaho

Figure A-6. Steady State Calibration Results – Potentiometric Surface Elevations in Model Layer Six

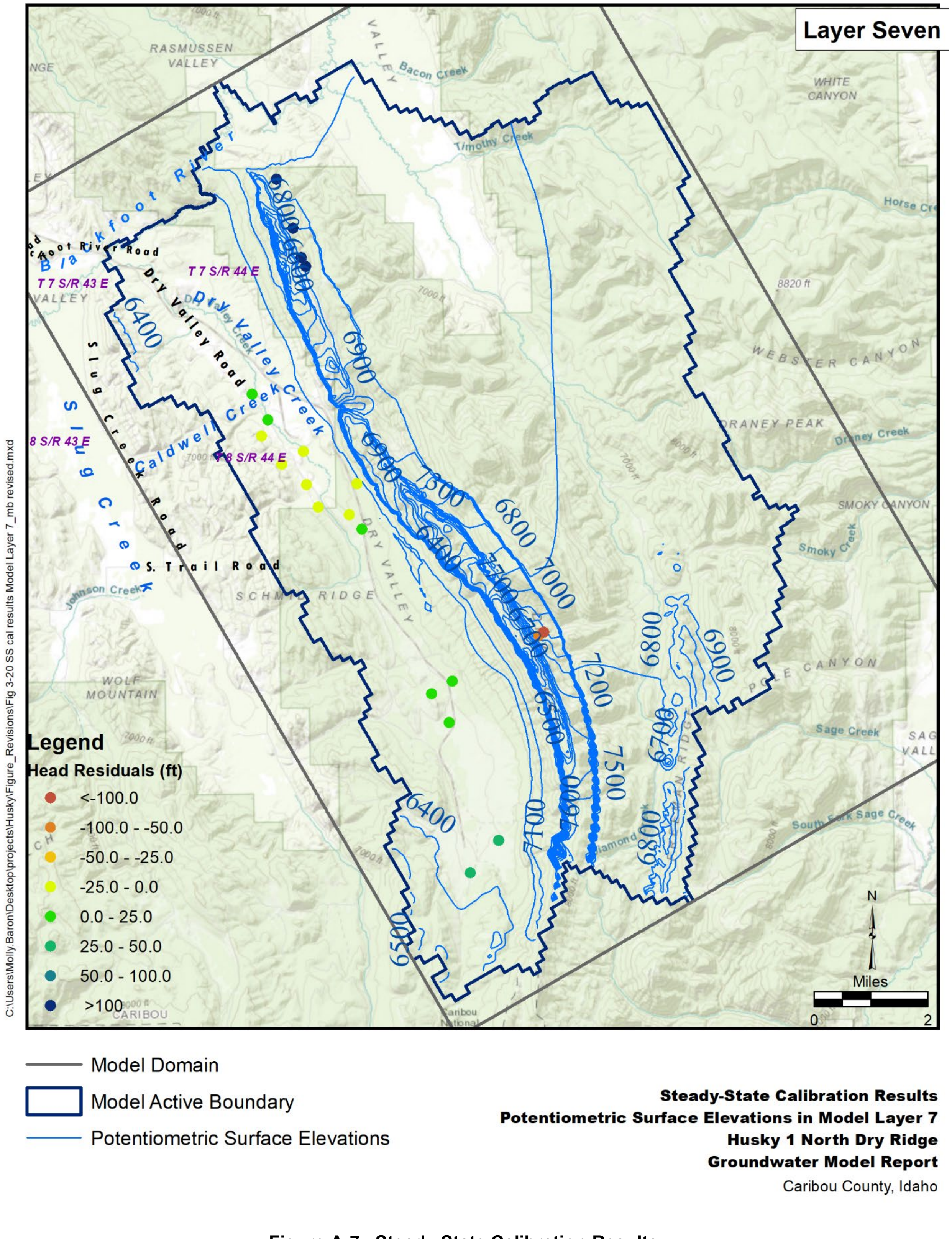
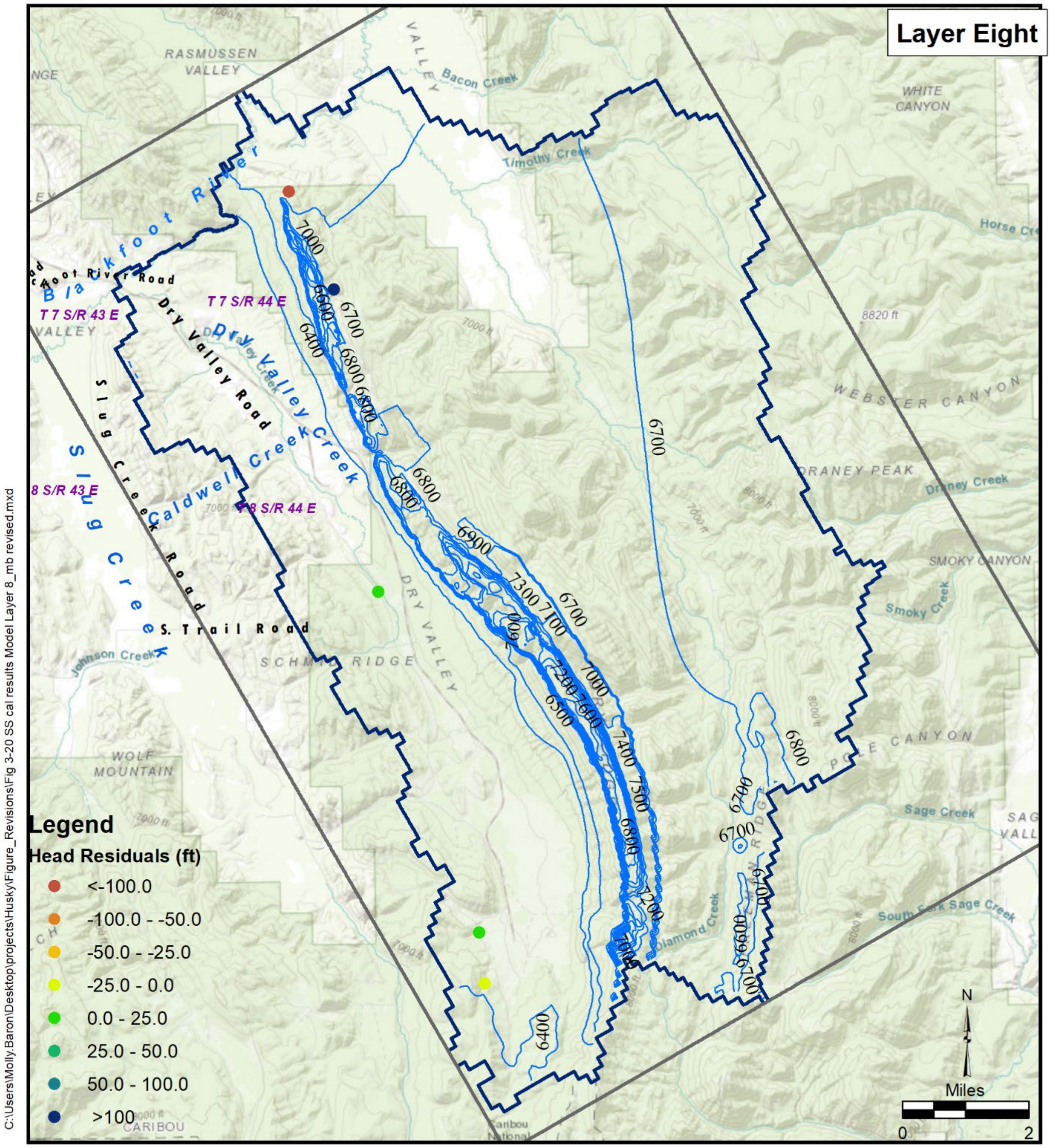


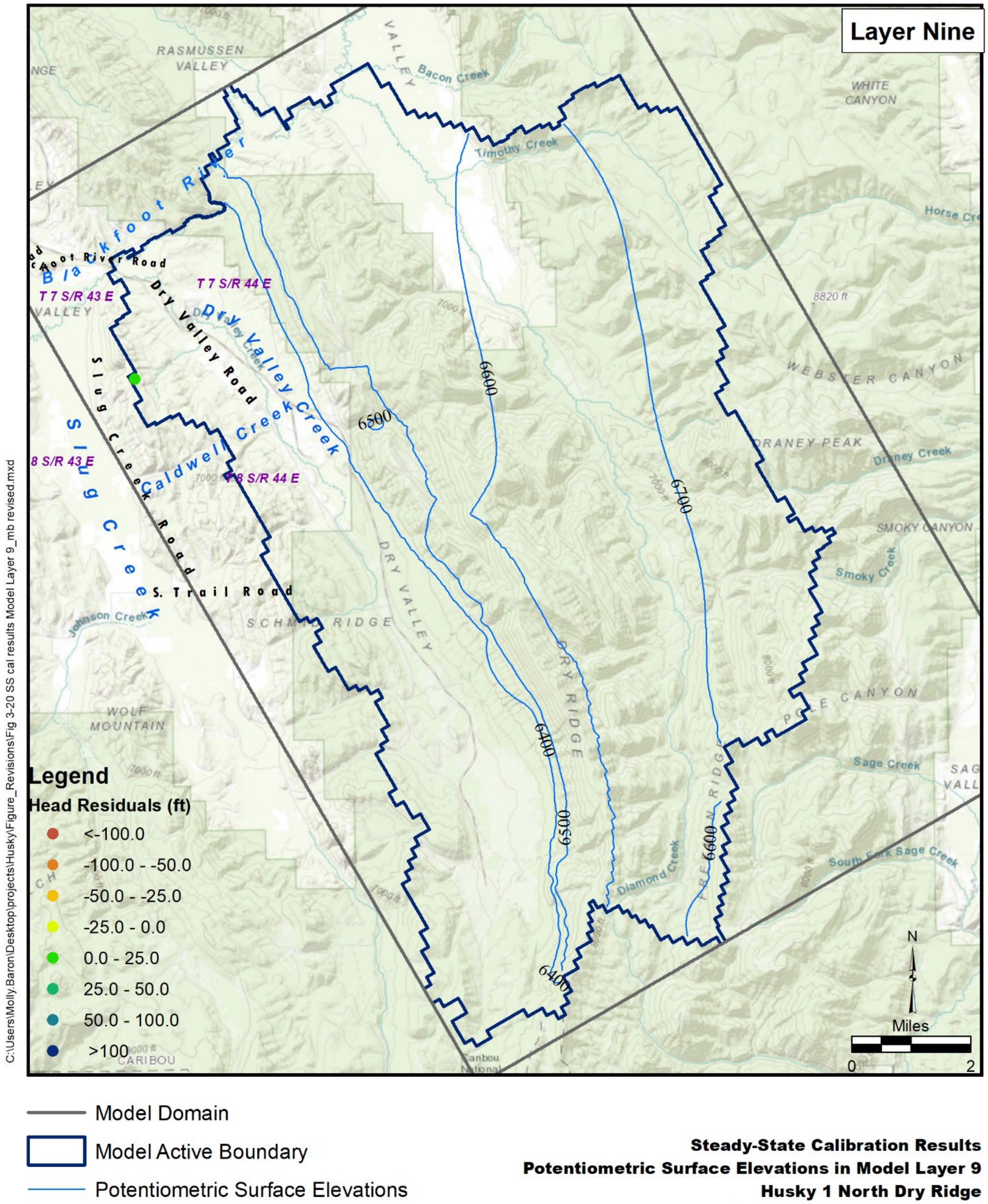
Figure A-7. Steady State Calibration Results – Potentiometric Surface Elevations in Model Layer Seven



Model Domain
Model Active Boundary
Potentiometric Surface Elevations

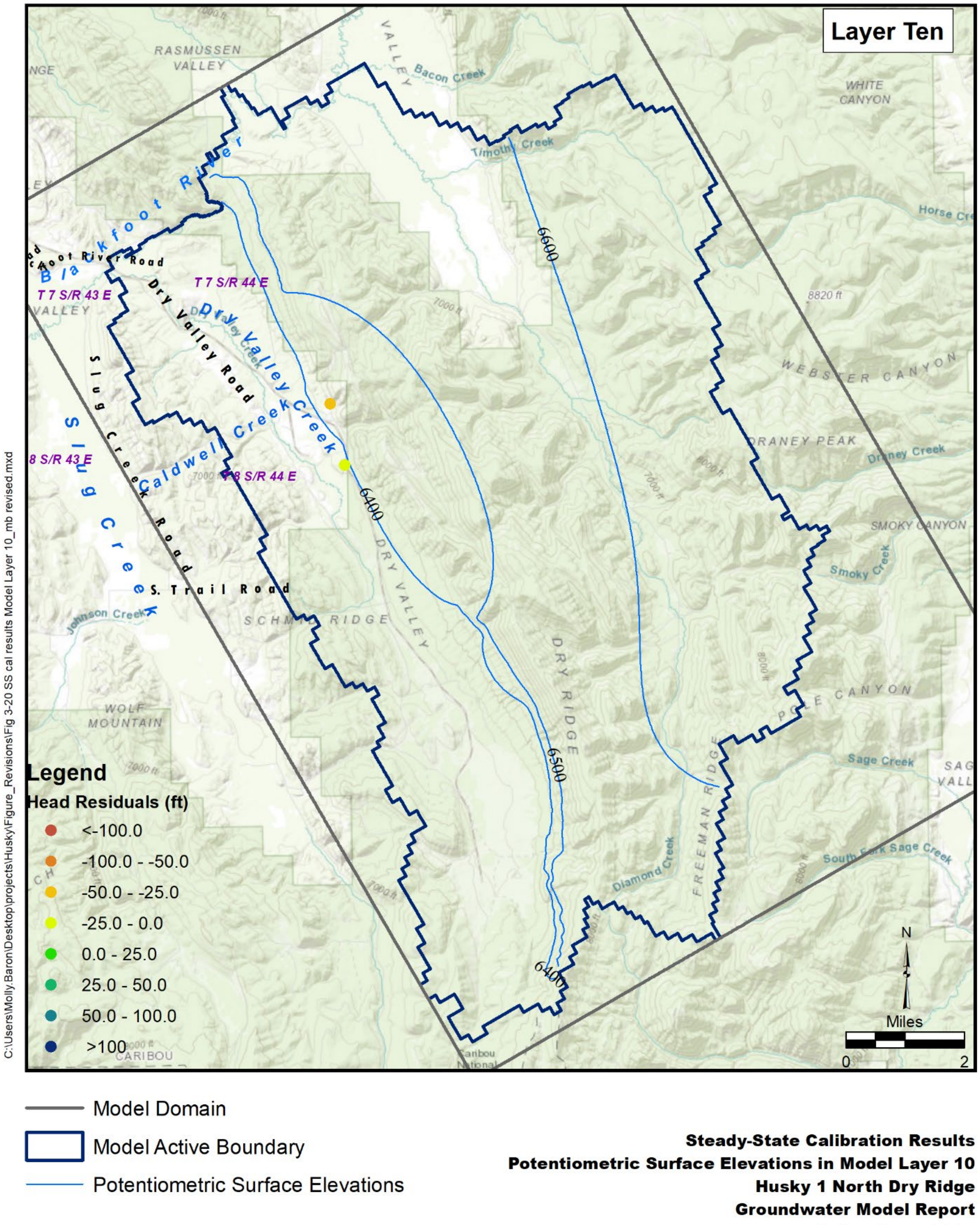
Steady-State Calibration Results
Potentiometric Surface Elevations in Model Layer 8
Husky 1 North Dry Ridge
Groundwater Model Report
Caribou County, Idaho

Figure A-8. Steady State Calibration Results – Potentiometric Surface Elevations in Model Layer Eight



Steady-State Calibration Results
Potentiometric Surface Elevations in Model Layer 9
Husky 1 North Dry Ridge
Groundwater Model Report
Caribou County, Idaho

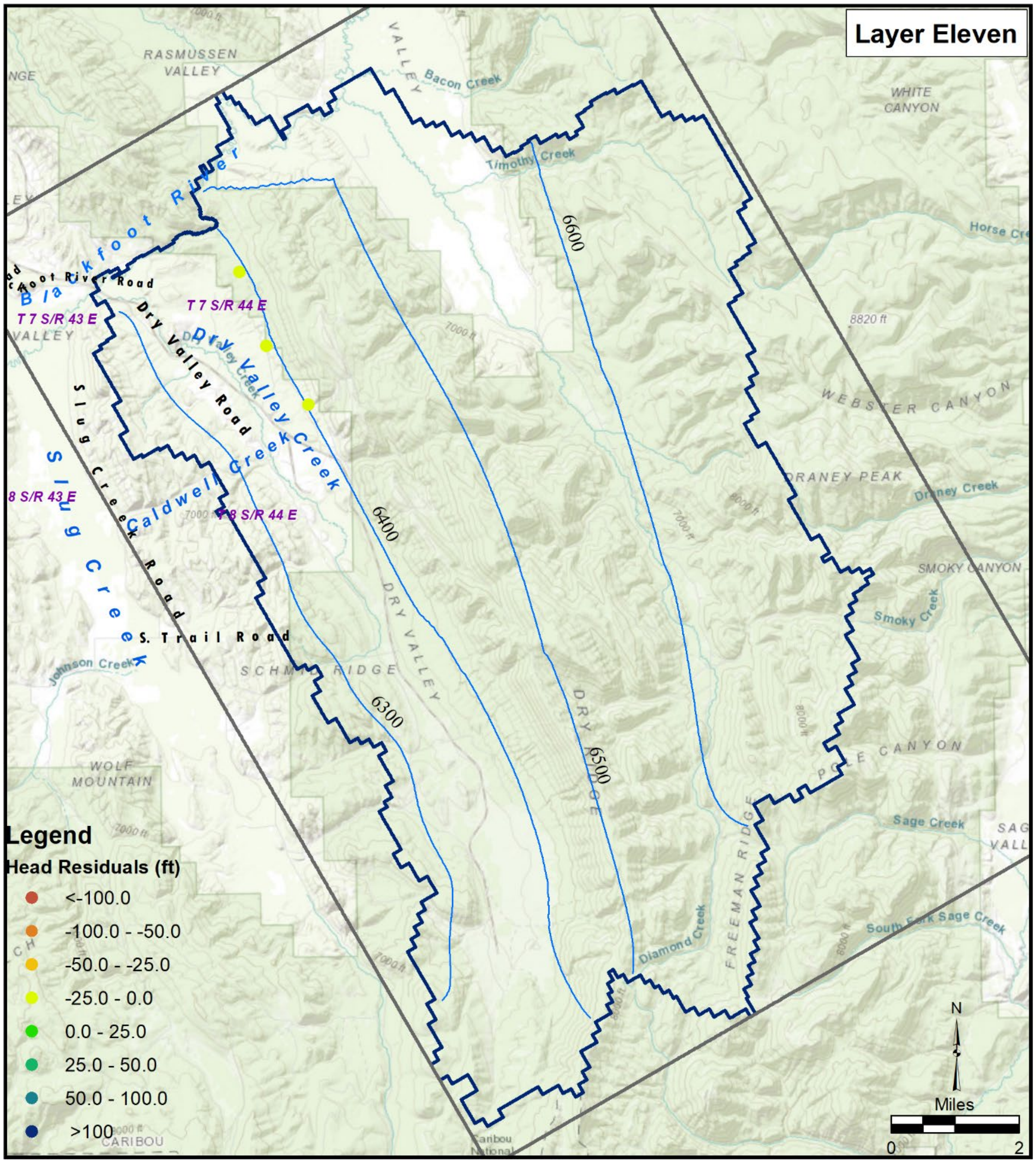
Figure A-9. Steady State Calibration Results – Potentiometric Surface Elevations in Model Layer Nine



Steady-State Calibration Results
Potentiometric Surface Elevations in Model Layer 10
Husky 1 North Dry Ridge
Groundwater Model Report
Caribou County, Idaho

Figure A-10. Steady State Calibration Results – Potentiometric Surface Elevations in Model Layer Ten

C:\Users\Molly.Baron\Desktop\projects\Husky\Figure_Revisions\Fig 3-20 SS cal results Model Layer 11_mb revised.mxd



Model Domain

Model Active Boundary

Potentiometric Surface Elevations

Steady-State Calibration Results
Potentiometric Surface Elevations in Model Layer 11
Husky 1 North Dry Ridge
Groundwater Model Report
Caribou County, Idaho

Figure A-11. Steady State Calibration Results – Potentiometric Surface Elevations in Model Layer Eleven

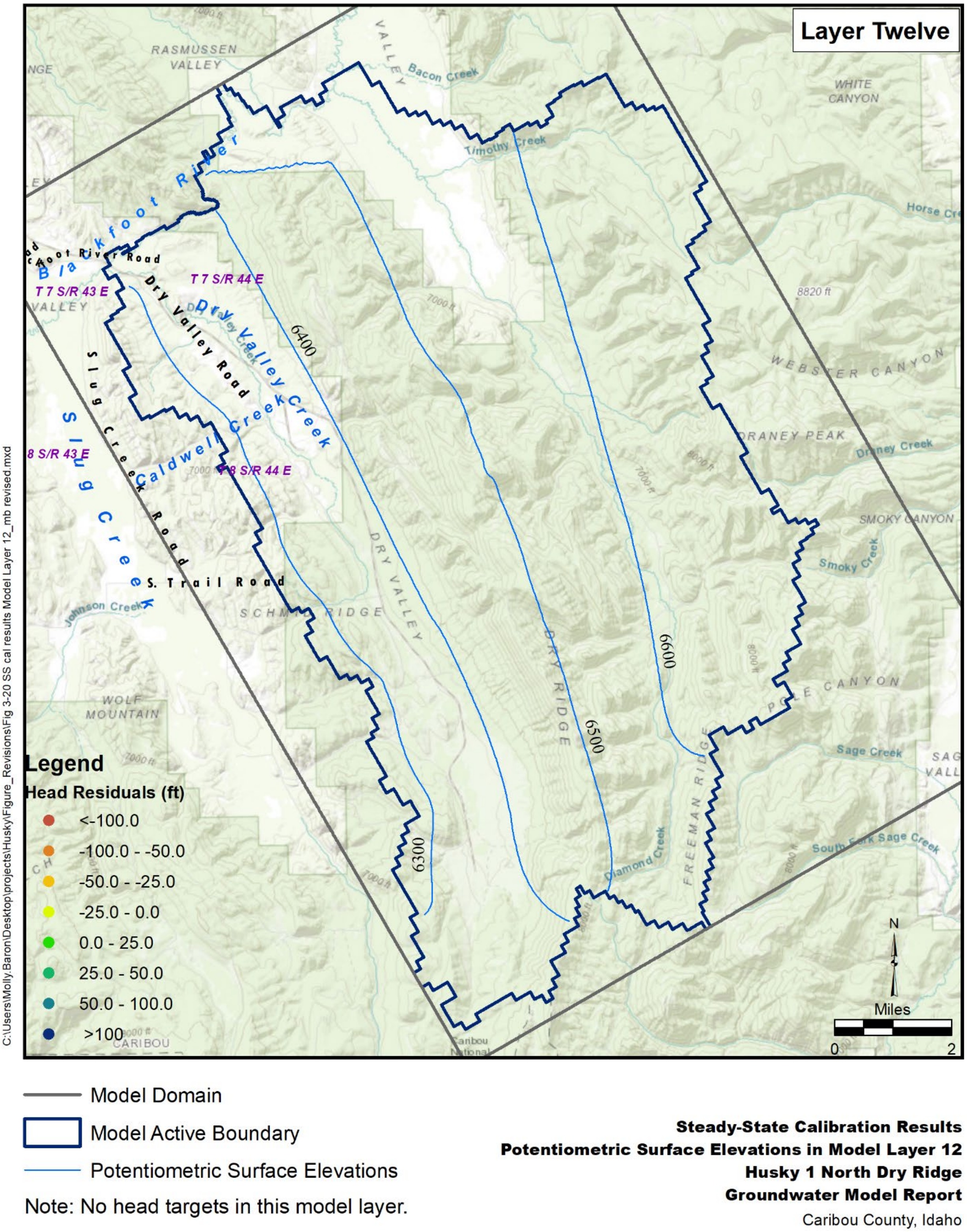
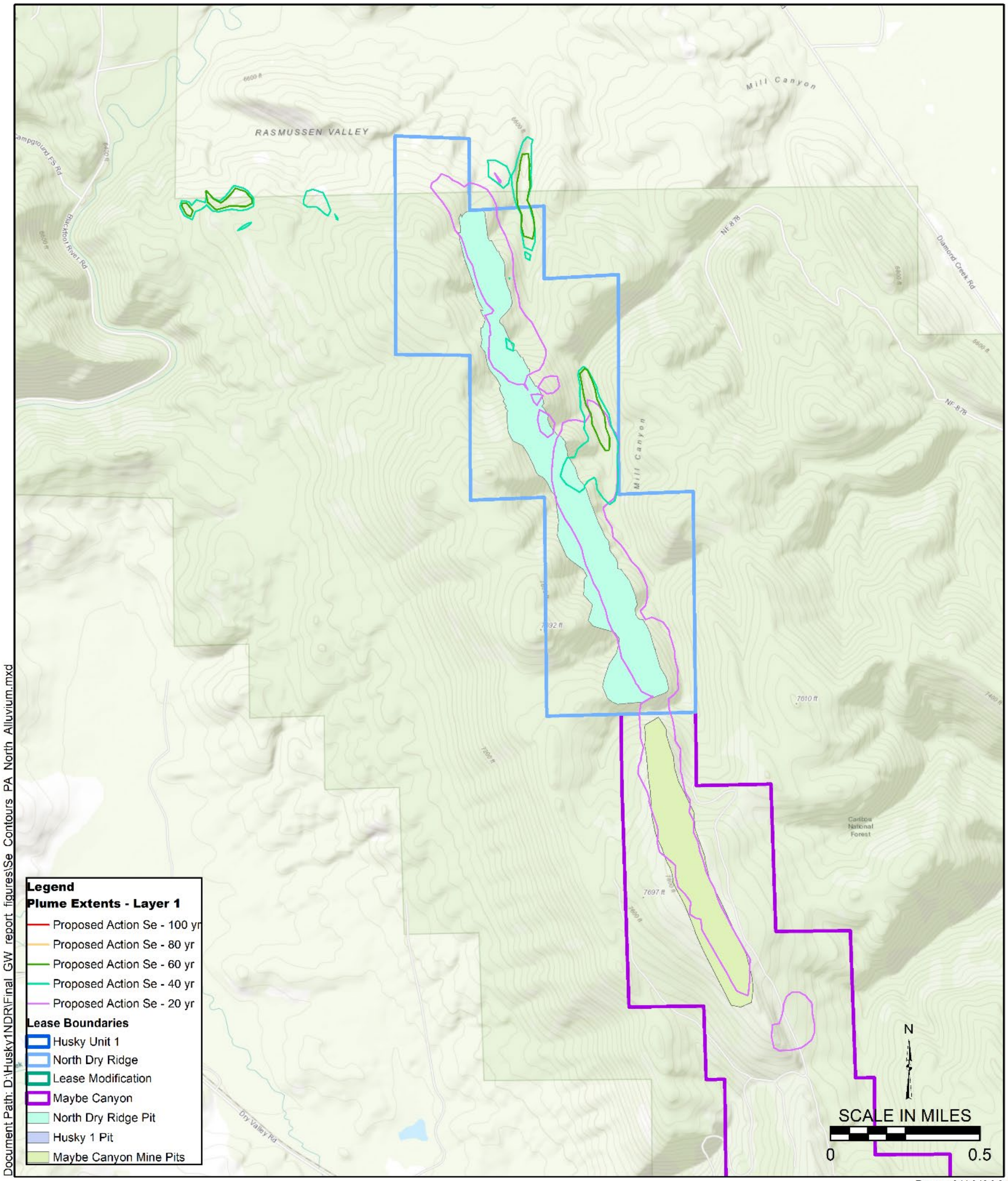


Figure A-12. Steady State Calibration Results – Potentiometric Surface Elevations in Model Layer Twelve

APPENDIX B:
Predicted Extent of COPC Plumes for Proposed Action
Husky 1 / North Dry Ridge



Date: 8/18/2021

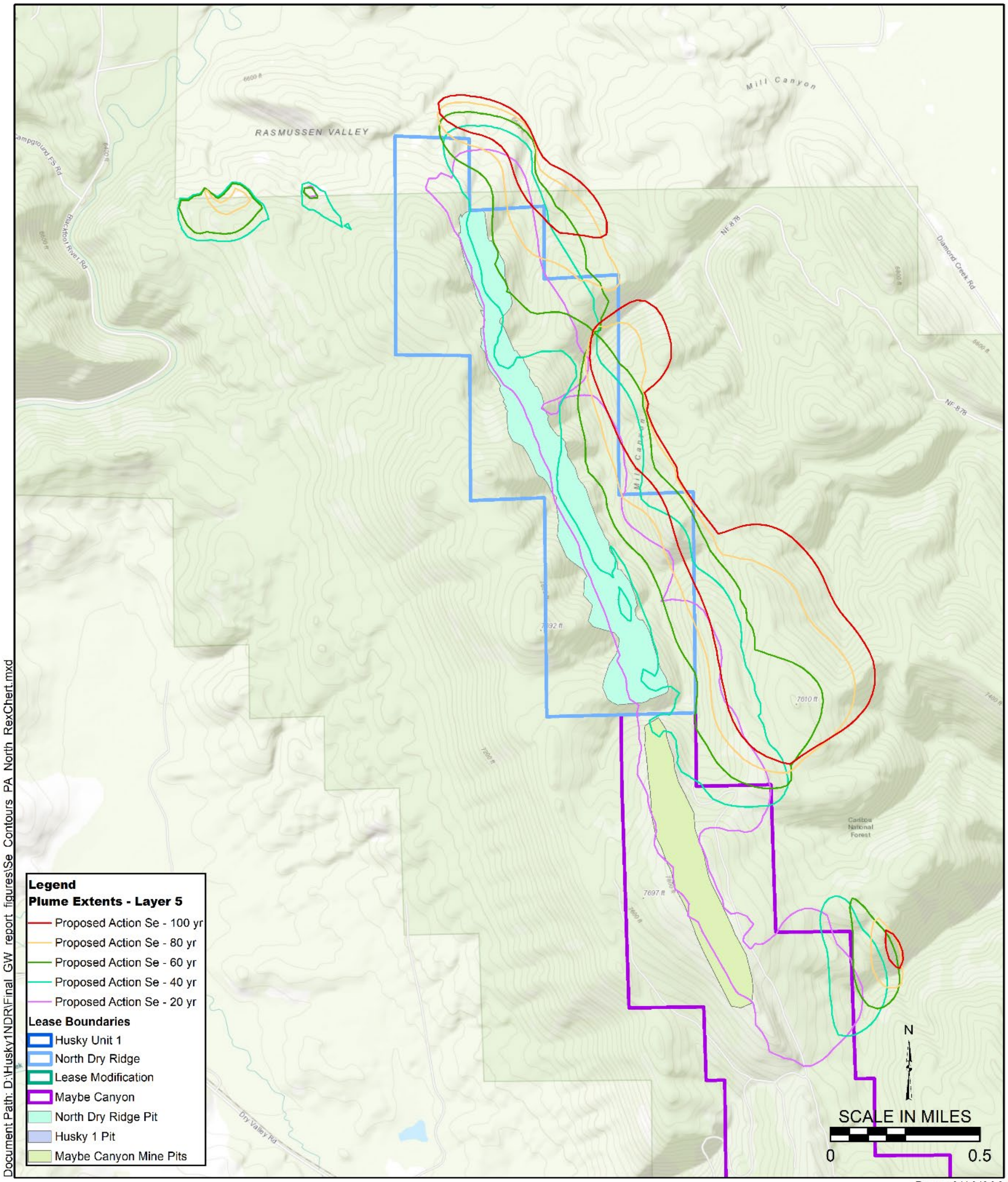
Predicted Extent of Selenium Plumes in Alluvium at 20 - Year Intervals

Proposed Action

Husky 1 North Dry Ridge

Caribou County, Idaho

Figure B-1: Predicted Extent of Selenium Plumes in Alluvium at 20-year Intervals for Proposed Action North Dry Ridge and North Maybe Mine



Document Path: D:\Husky1NDR\Final GW report figures\Se Contours PA North RexChert.mxd

Date: 8/18/2021

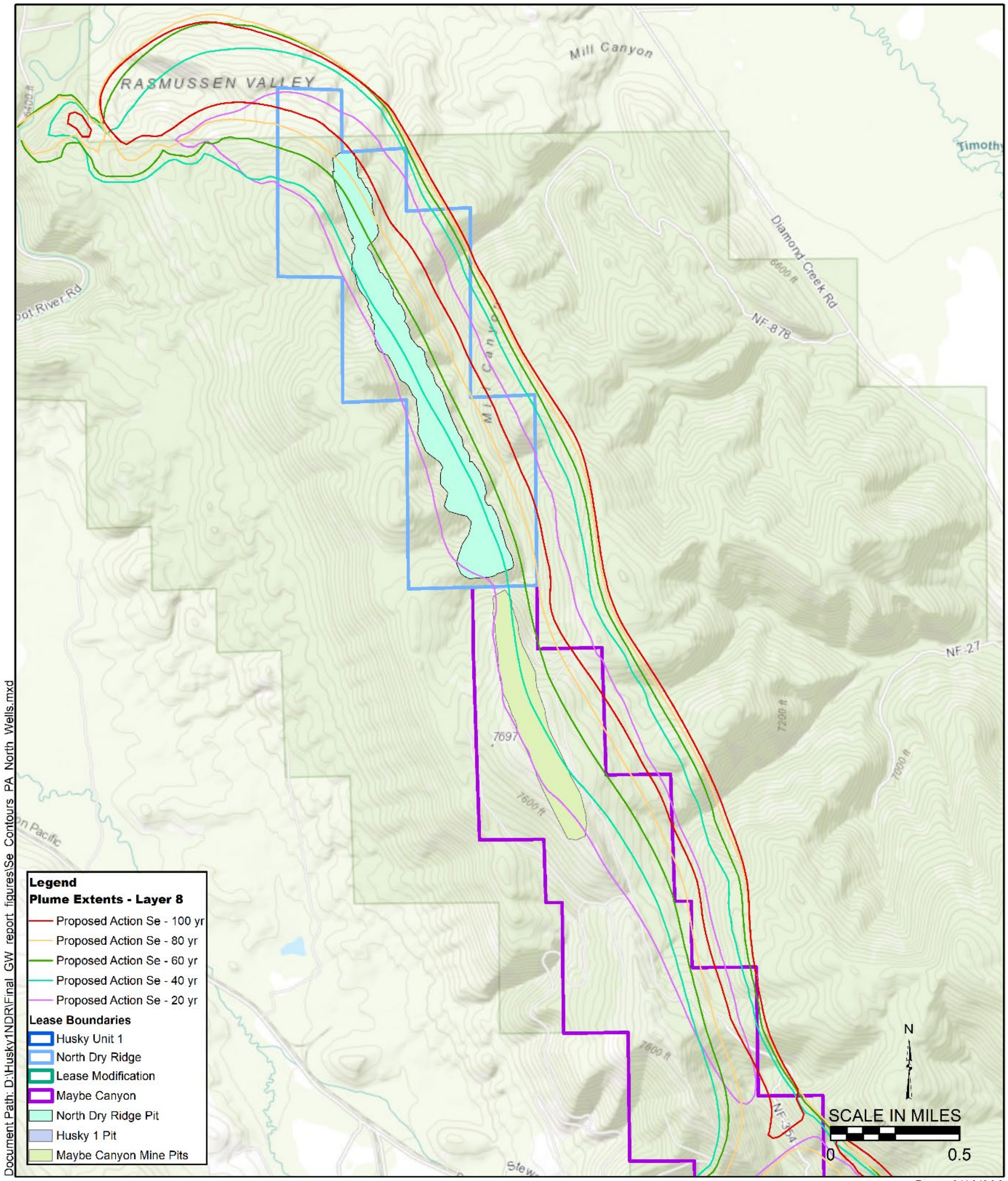
Predicted Extent of Selenium Plumes in Rex Chert at 20 - Year Intervals

Proposed Action

Husky 1 North Dry Ridge

Caribou County, Idaho

Figure B-2: Predicted Extent of Selenium Plumes in Rex Chert at 20-year Intervals for Proposed Action North Dry Ridge and North Maybe Mine



Date: 8/18/2021

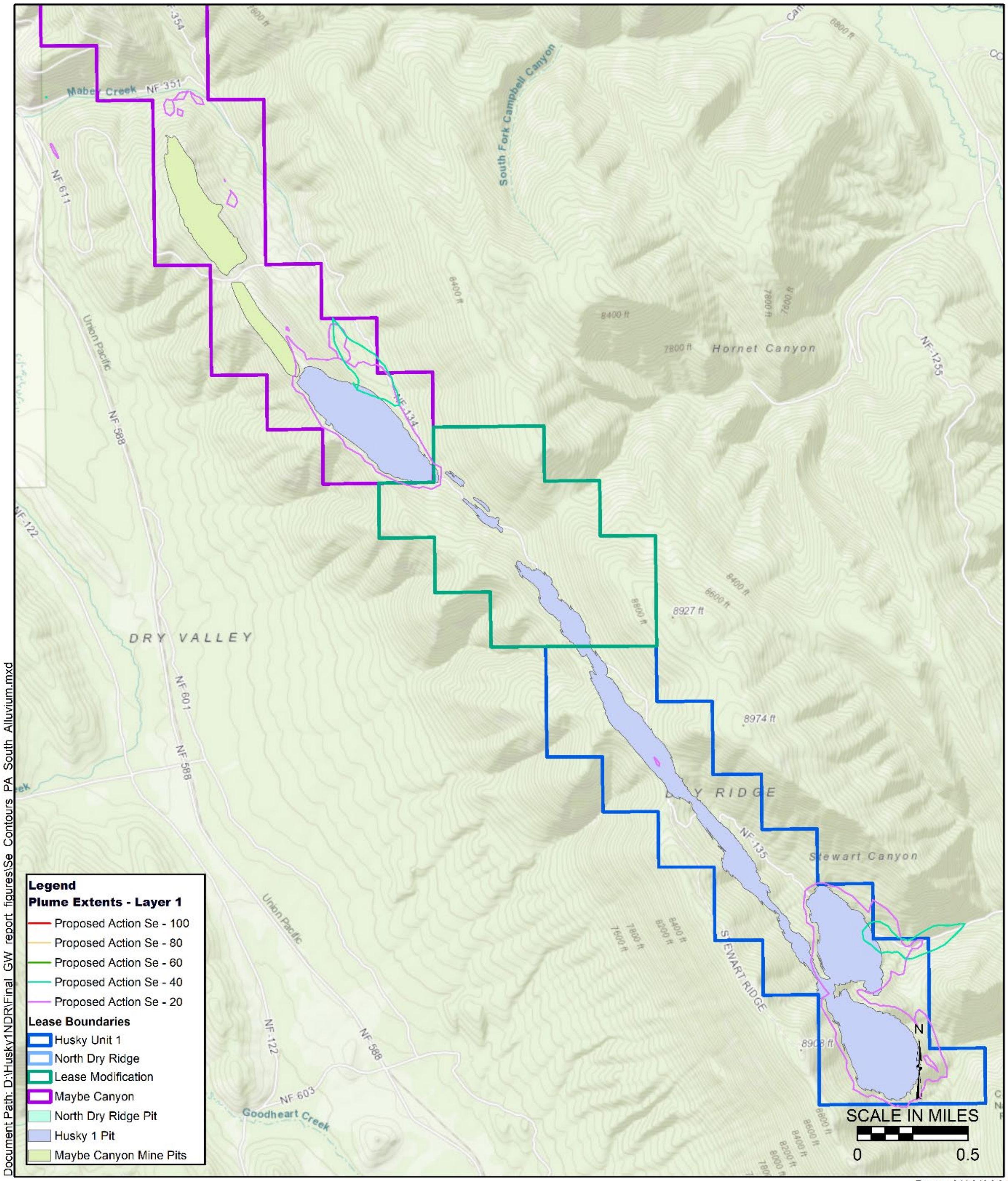
Predicted Extent of Selenium Plumes in Wells Formation at 20 - Year Intervals

Proposed Action

Husky 1 North Dry Ridge

Caribou County, Idaho

Figure B-3: Predicted Extent of Selenium Plumes in Wells Formation at 20-year Intervals for Proposed Action North Dry Ridge and North Maybe Mine



Date: 8/18/2021

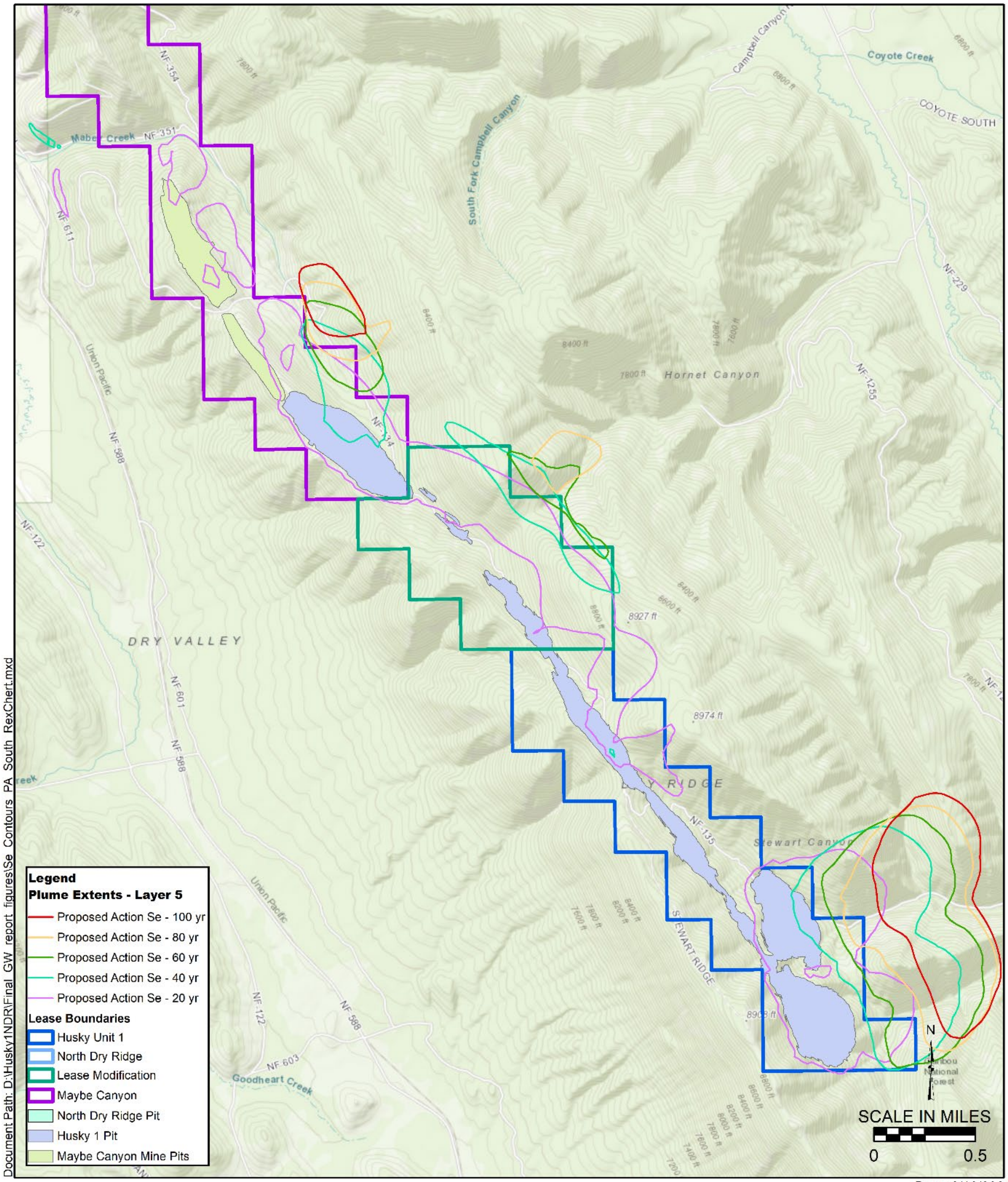
Predicted Extent of Selenium Plumes in Alluvium at 20 - Year Intervals

Proposed Action

Husky 1 North Dry Ridge

Caribou County, Idaho

Figure B-4: Predicted Extent of Selenium Plumes in Alluvium at 20-year Intervals for Proposed Action South Maybe Canyon Mine and Husky 1



Date: 8/18/2021

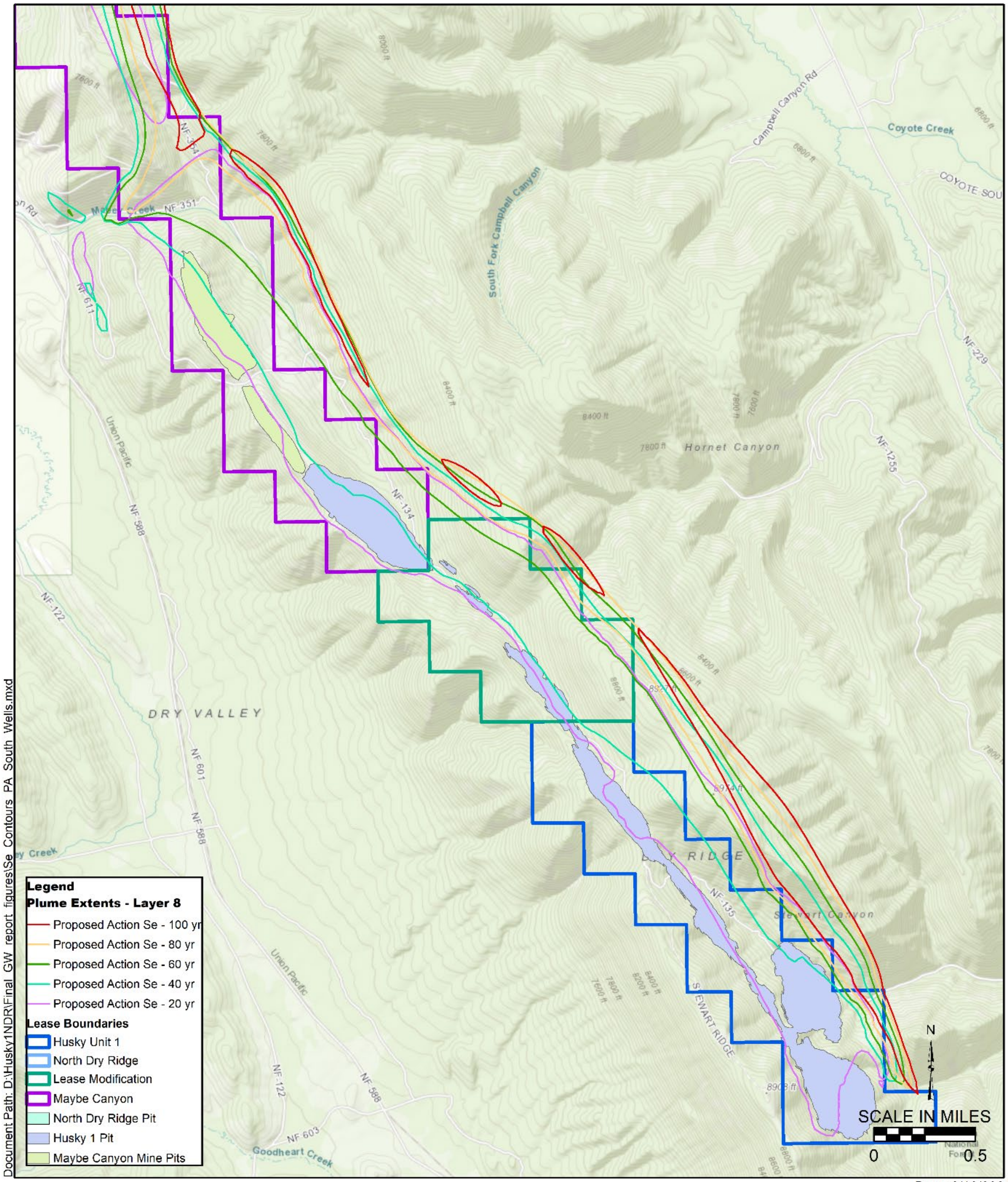
Predicted Extent of Selenium Plumes in Rex Chert at 20 - Year Intervals

Proposed Action

Husky 1 North Dry Ridge

Caribou County, Idaho

Figure B-5: Predicted Extent of Selenium Plumes in Rex Chert at 20-year Intervals for Proposed Action South Maybe Canyon Mine and Husky 1



Predicted Extent of Selenium Plumes in Wells Formation at 20 - Year Intervals
Proposed Action
Husky 1 North Dry Ridge
Caribou County, Idaho

Figure B-6: Predicted Extent of Selenium Plumes in Wells Formation at 20-year Intervals for Proposed Action South Maybe Canyon Mine and Husky 1

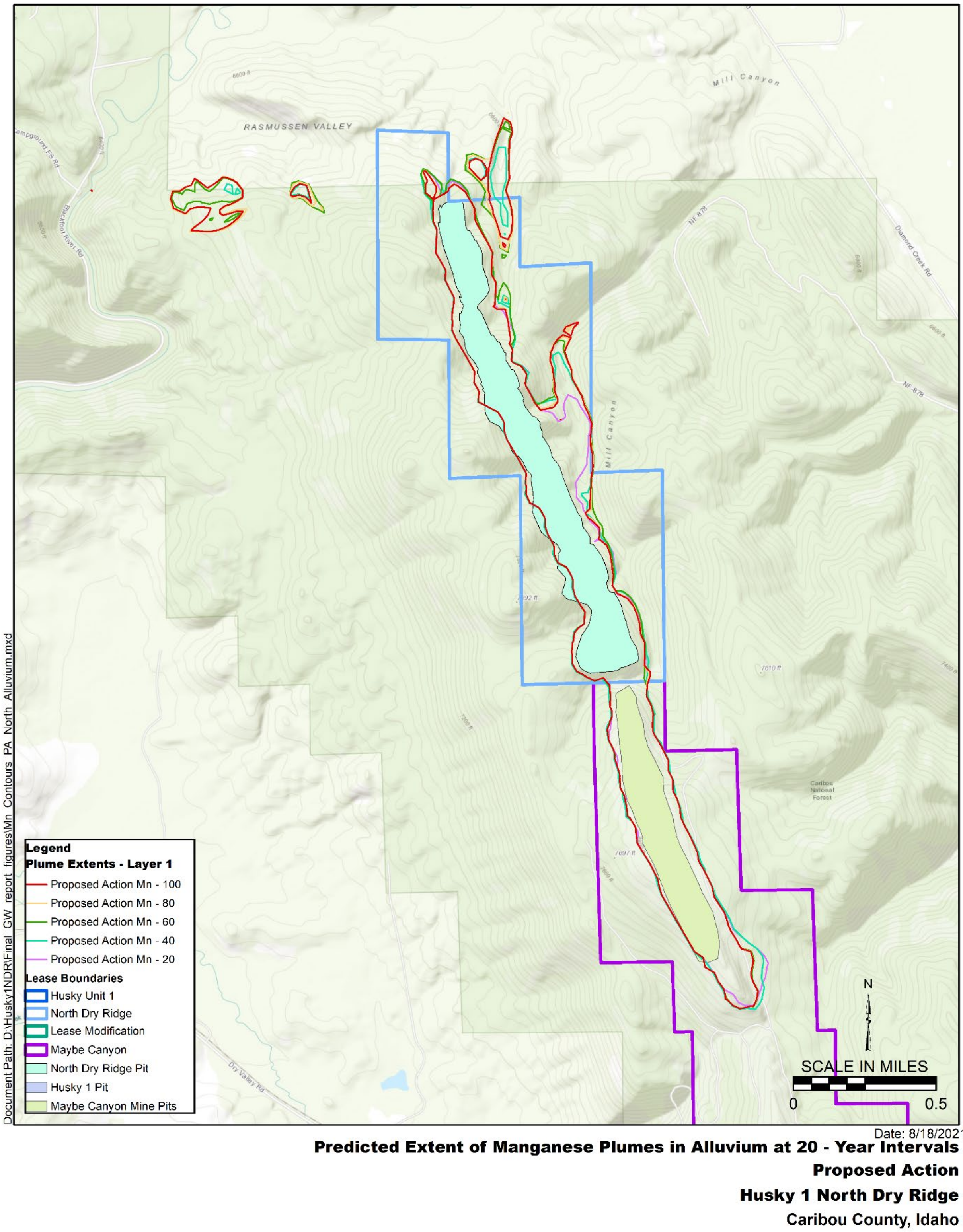
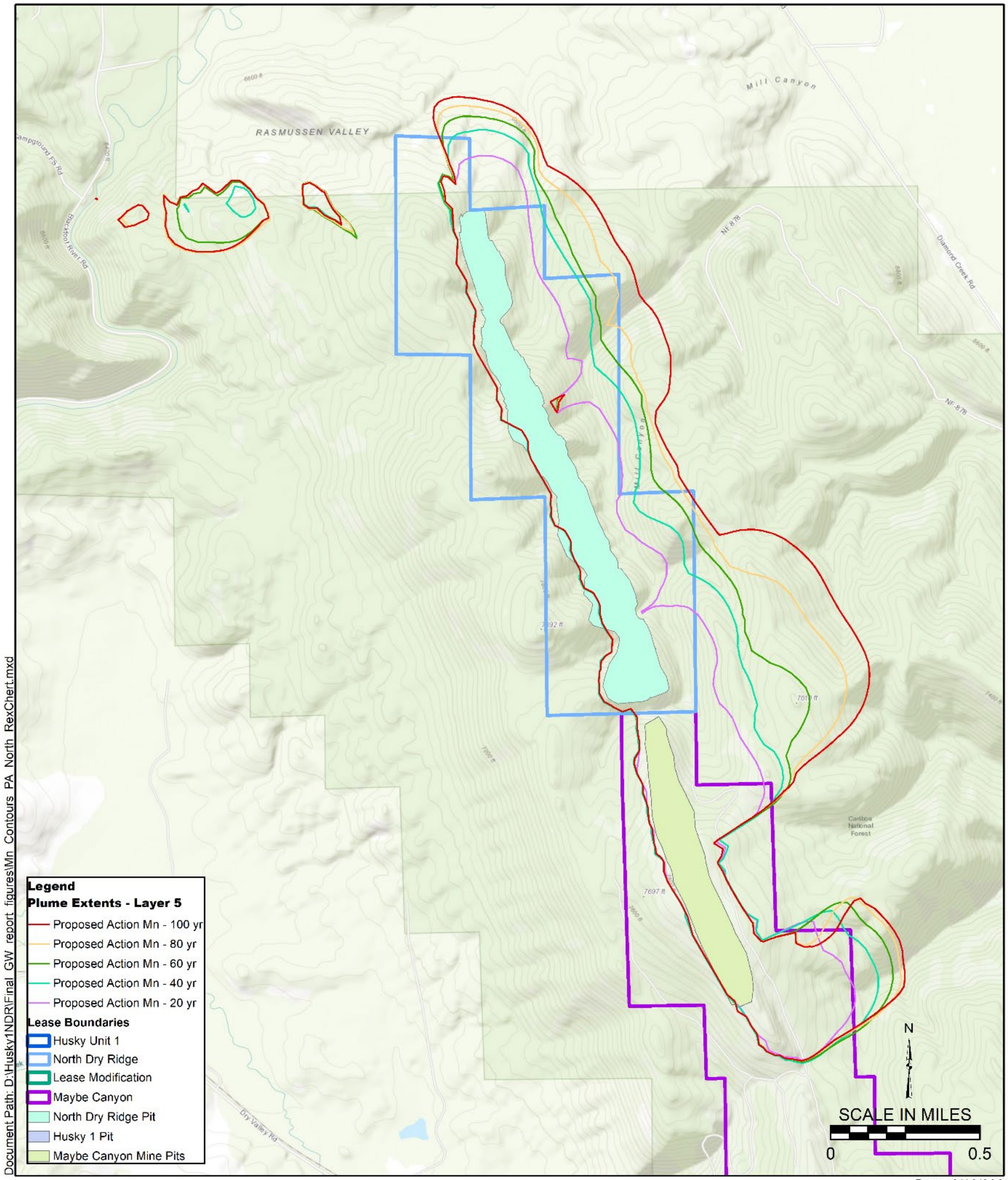


Figure B-7: Predicted Extent of Manganese Plumes in Alluvium at 20-year Intervals for Proposed Action North Dry Ridge and North Maybe Mine



Date: 8/18/2021

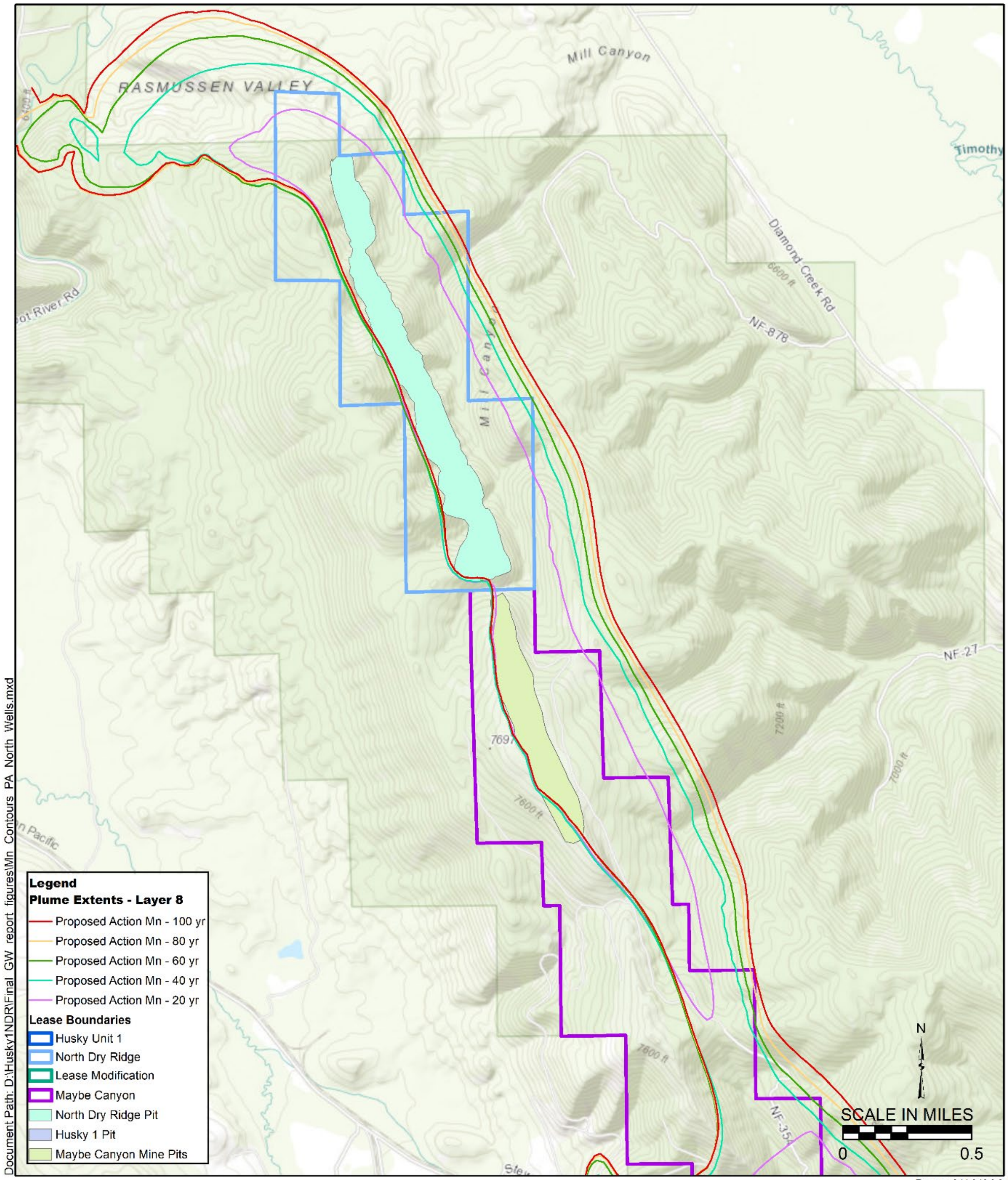
Predicted Extent of Manganese Plumes in Rex Chert at 20 - Year Intervals

Proposed Action

Husky 1 North Dry Ridge

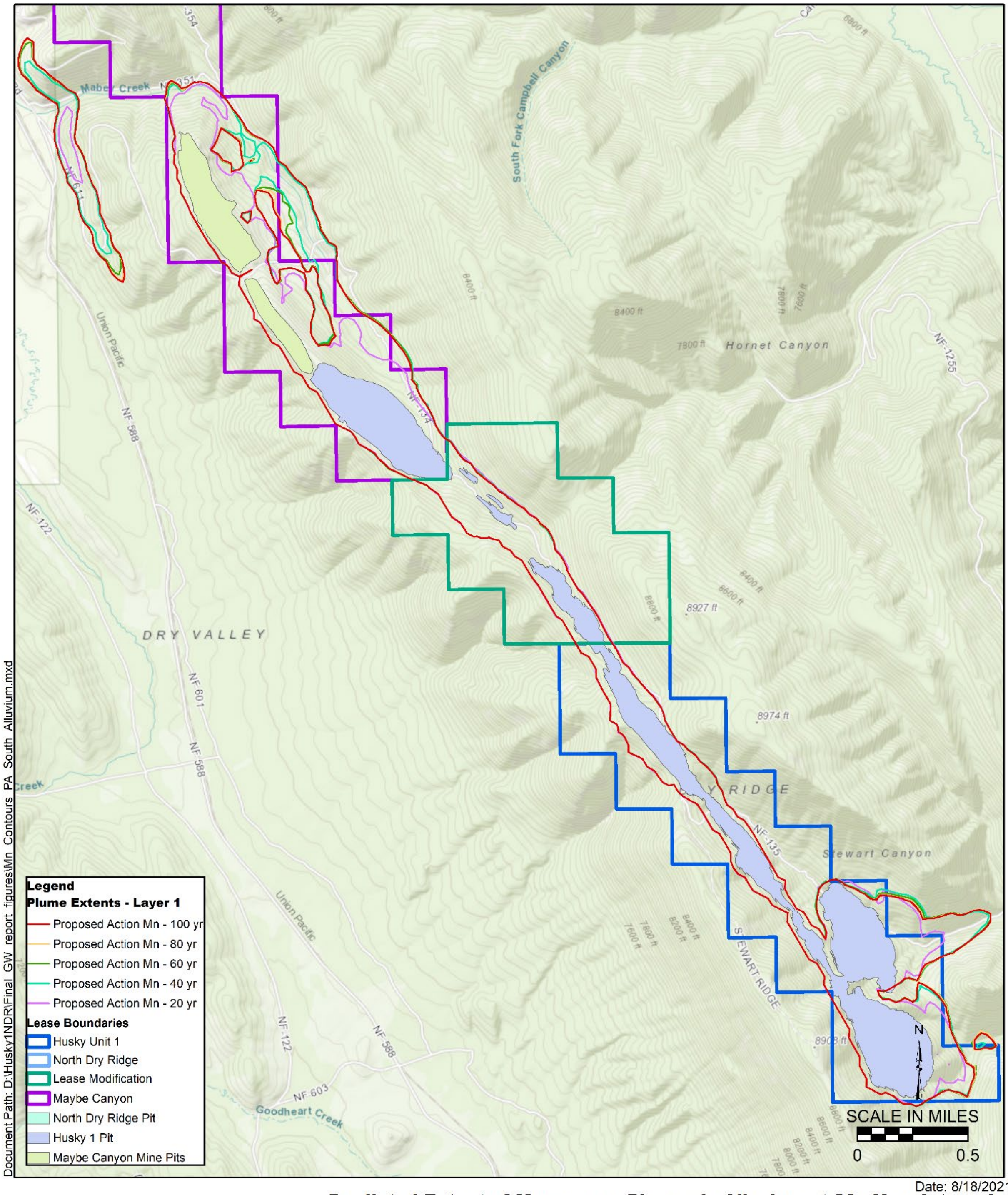
Caribou County, Idaho

Figure B-8: Predicted Extent of Manganese Plumes in Rex Chert at 20-year Intervals for Proposed Action North Dry Ridge and North Maybe Mine



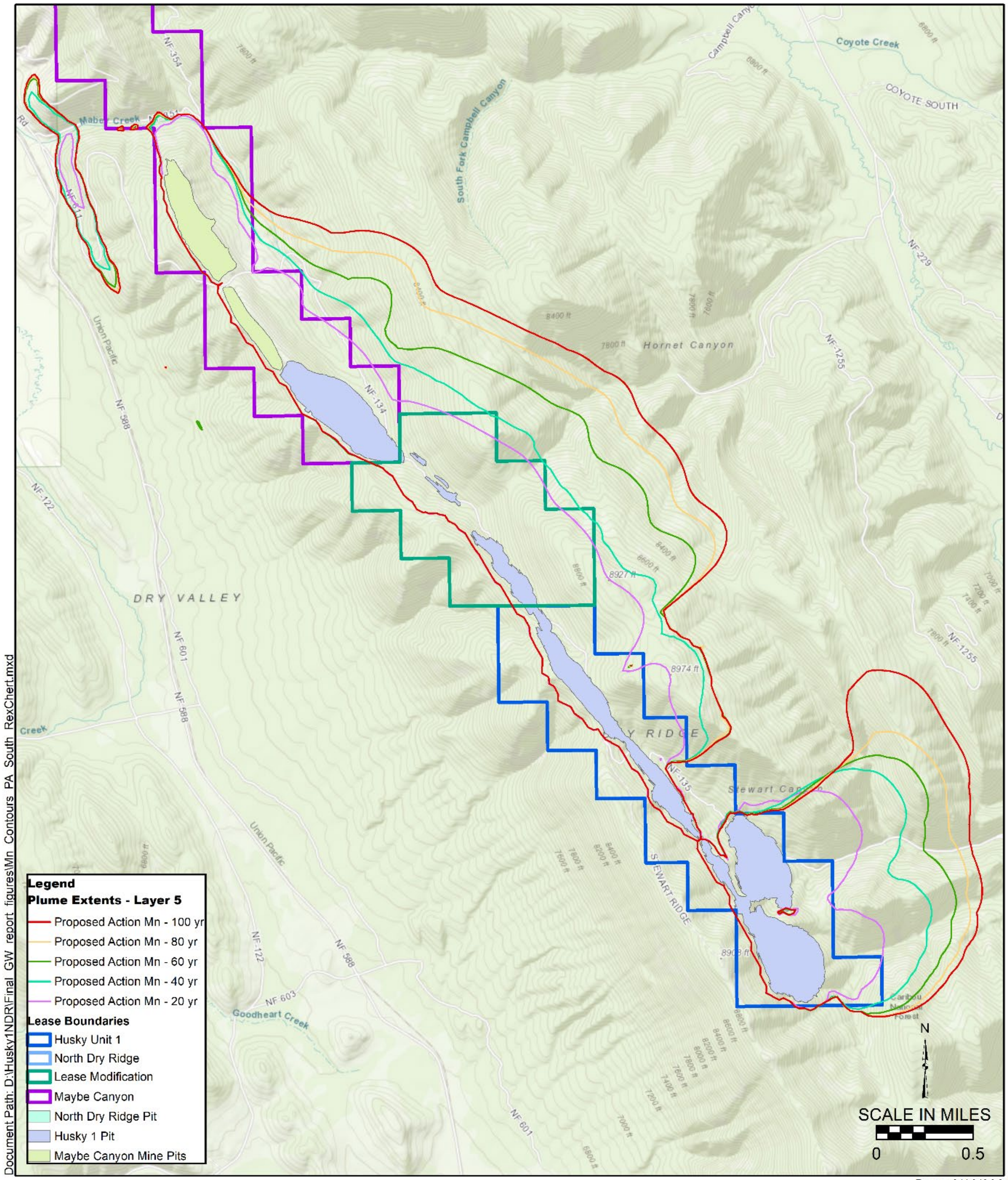
Predicted Extent of Manganese Plumes in Wells Formation at 20 - Year Intervals
Proposed Action
Husky 1 North Dry Ridge
Caribou County, Idaho

Figure B-9: Predicted Extent of Manganese Plumes in Wells Fm at 20-year Intervals for Proposed Action North Dry Ridge and North Maybe Mine



Predicted Extent of Manganese Plumes in Alluvium at 20 - Year Intervals
Proposed Action
Husky 1 North Dry Ridge
Caribou County, Idaho

Figure B-10: Predicted Extent of Manganese Plumes in Alluvium at 20-year Intervals for Proposed Action South Maybe Canyon Mine and Husky 1



Date: 8/18/2021

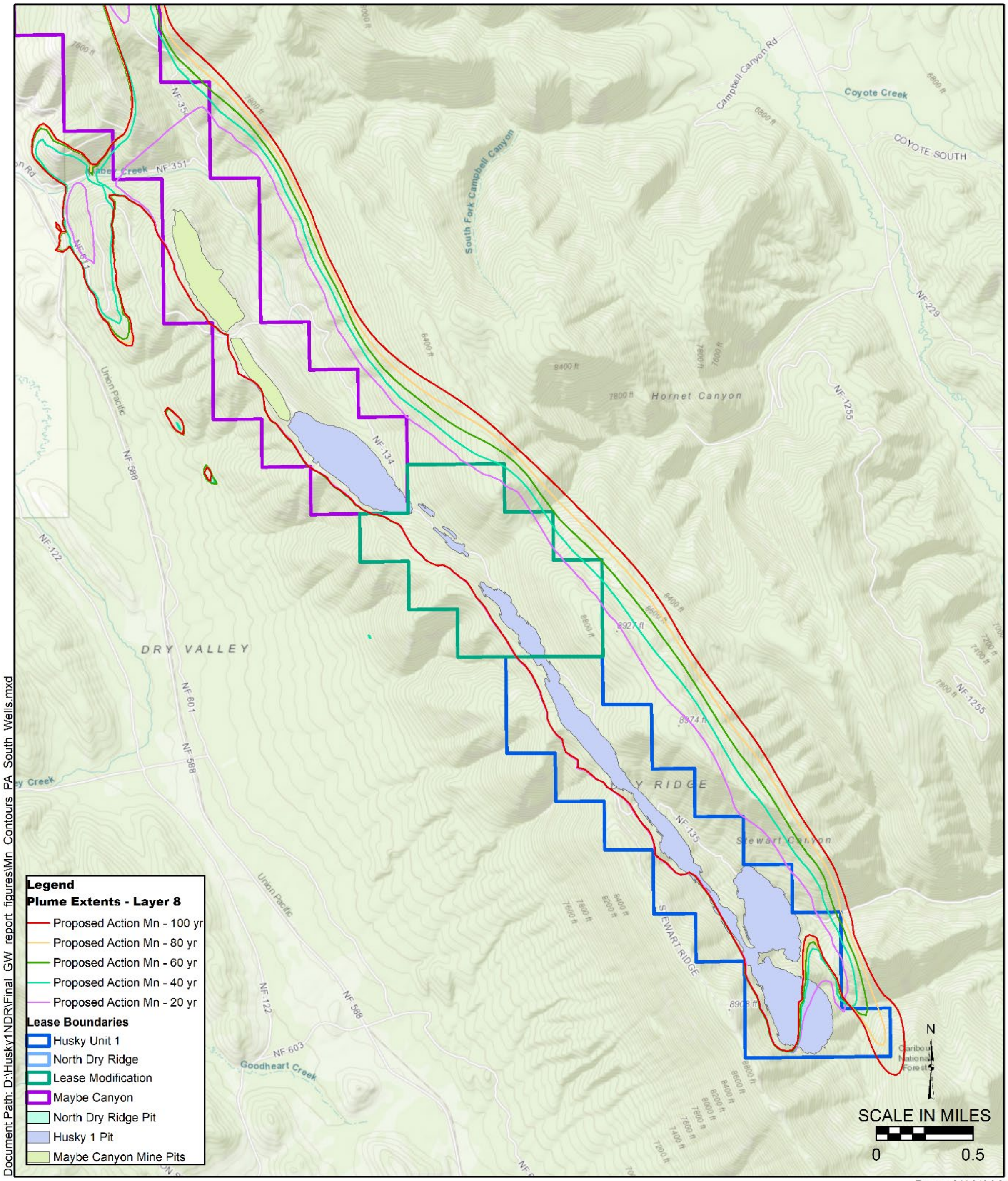
Predicted Extent of Manganese Plumes in Rex Chert at 20 - Year Intervals

Proposed Action

Husky 1 North Dry Ridge

Caribou County, Idaho

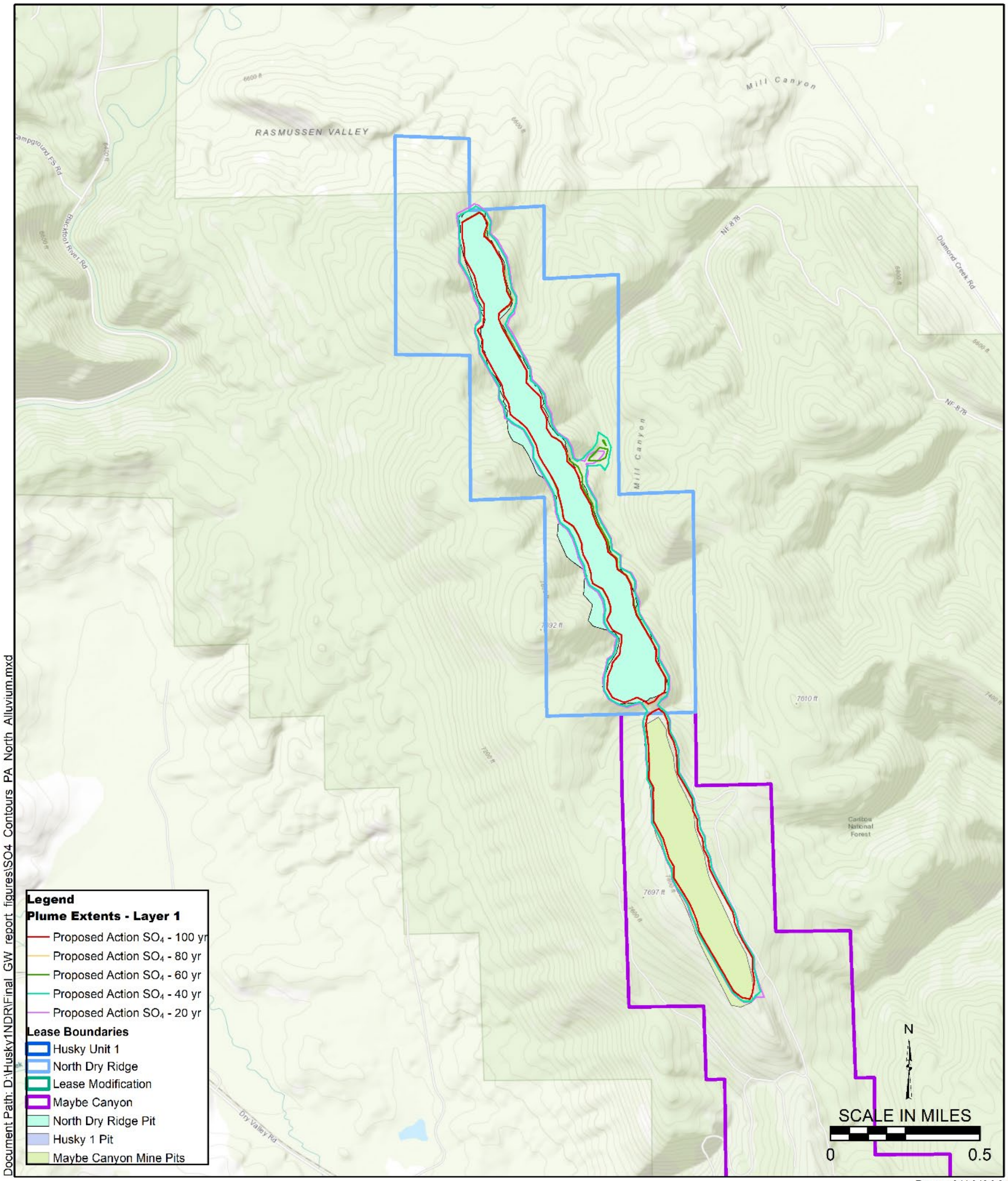
Figure B-11: Predicted Extent of Manganese Plumes in Rex Chert at 20-year Intervals for Proposed Action South Maybe Canyon Mine and Husky 1



Date: 8/18/2021

Predicted Extent of Manganese Plumes in Wells Formation at 20 - Year Intervals
Proposed Action
Husky 1 North Dry Ridge
Caribou County, Idaho

Figure B-12: Predicted Extent of Manganese Plumes in Wells Fm at 20-year Intervals for Proposed Action South Maybe Canyon Mine and Husky 1



Date: 8/18/2021

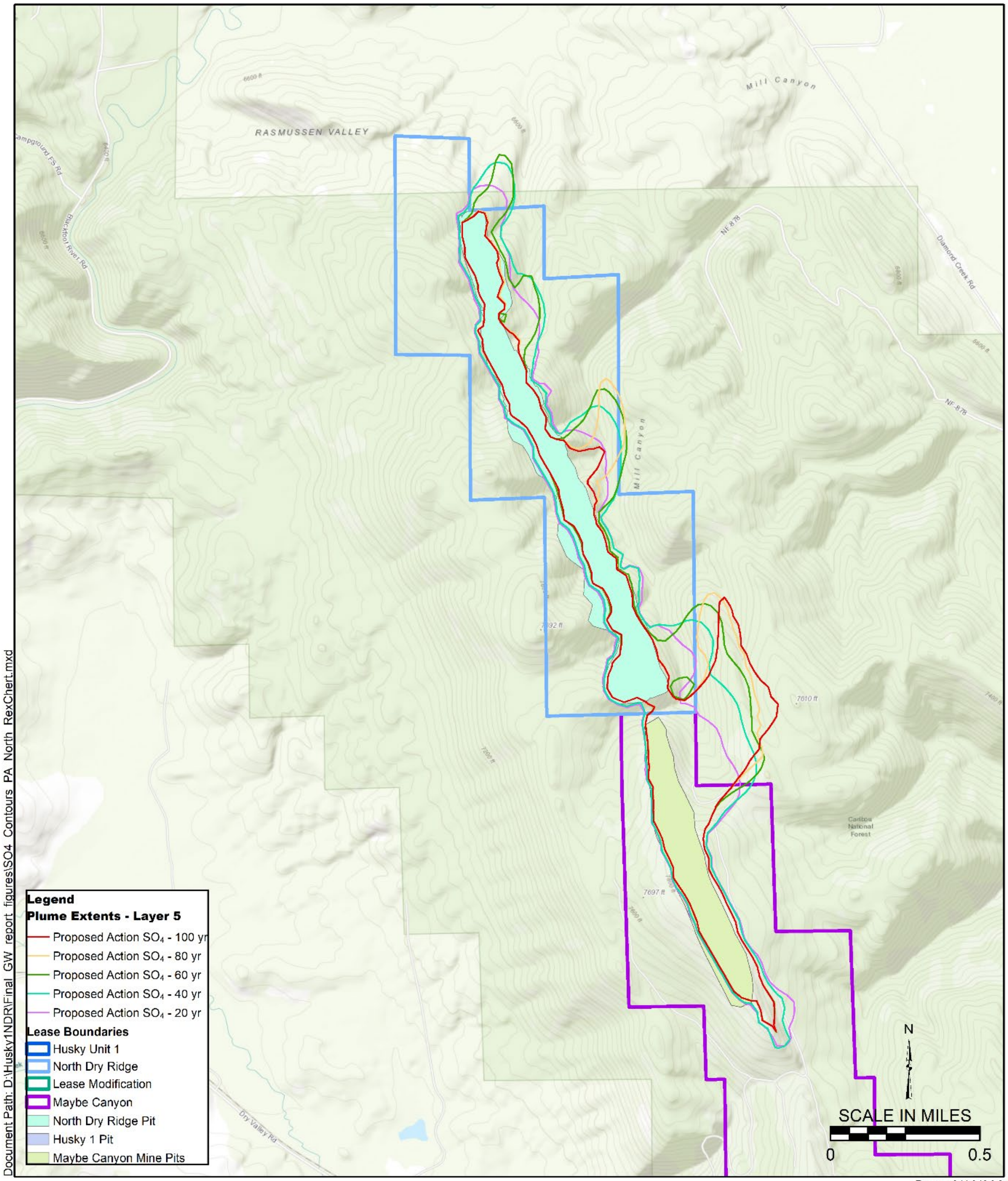
Predicted Extent of Sulfate Plumes in Alluvium at 20 - Year Intervals

Proposed Action

Husky 1 North Dry Ridge

Caribou County, Idaho

Figure B-13: Predicted Extent of Sulfate Plumes in Alluvium at 20-year Intervals for Proposed Action North Dry Ridge and North Maybe Mine



Document Path: D:\Husky1NDR\Final_GW_report_figures\SO4_Contours_PA_North_RexChert.mxd

Date: 8/18/2021

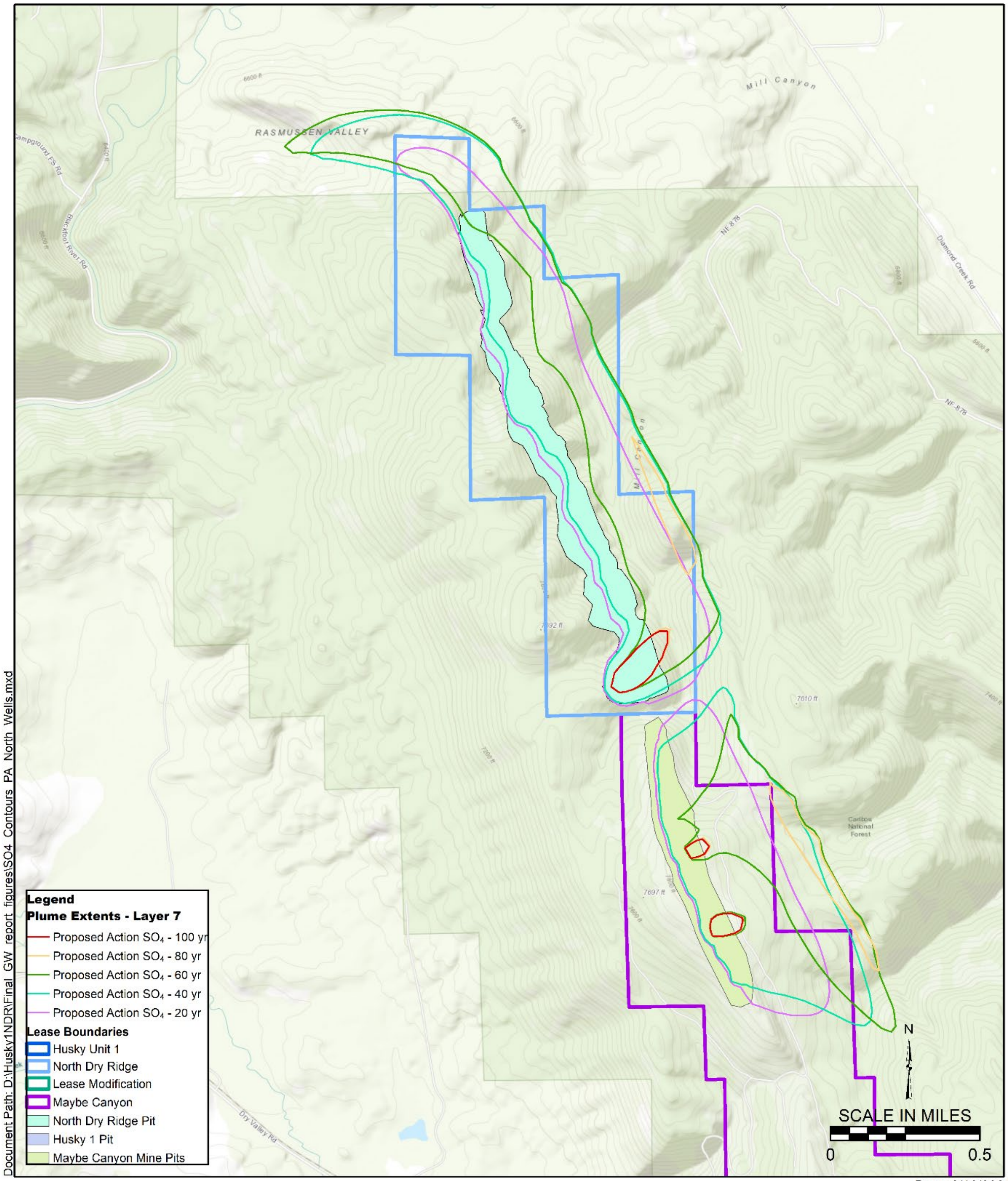
Predicted Extent of Sulfate Plumes in Rex Chert at 20 - Year Intervals

Proposed Action

Husky 1 North Dry Ridge

Caribou County, Idaho

Figure B-14: Predicted Extent of Sulfate Plumes in Rex Chert at 20-year Intervals for Proposed Action North Dry Ridge and North Maybe Mine



Document Path: D:\Husky1NDR\Final_GW_report_figures\SO4_Contours_PA_North_Wells.mxd

Date: 8/18/2021

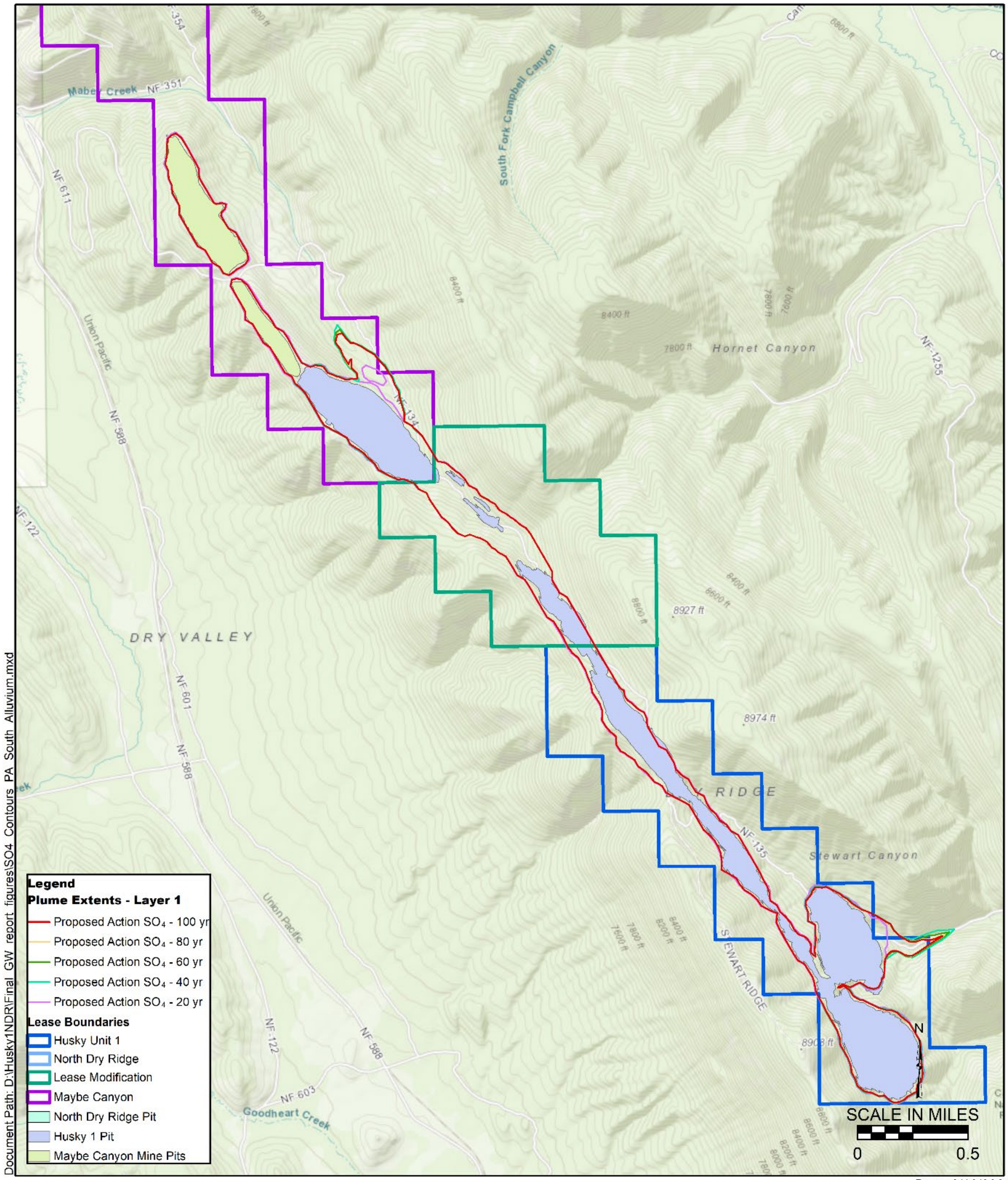
Predicted Extent of Sulfate Plumes in Wells Formation at 20 - Year Intervals

Proposed Action

Husky 1 North Dry Ridge

Caribou County, Idaho

Figure B-15: Predicted Extent of Sulfate Plumes in Wells Formation at 20-year Intervals for Proposed Action North Dry Ridge and North Maybe Mine



Date: 8/18/2021

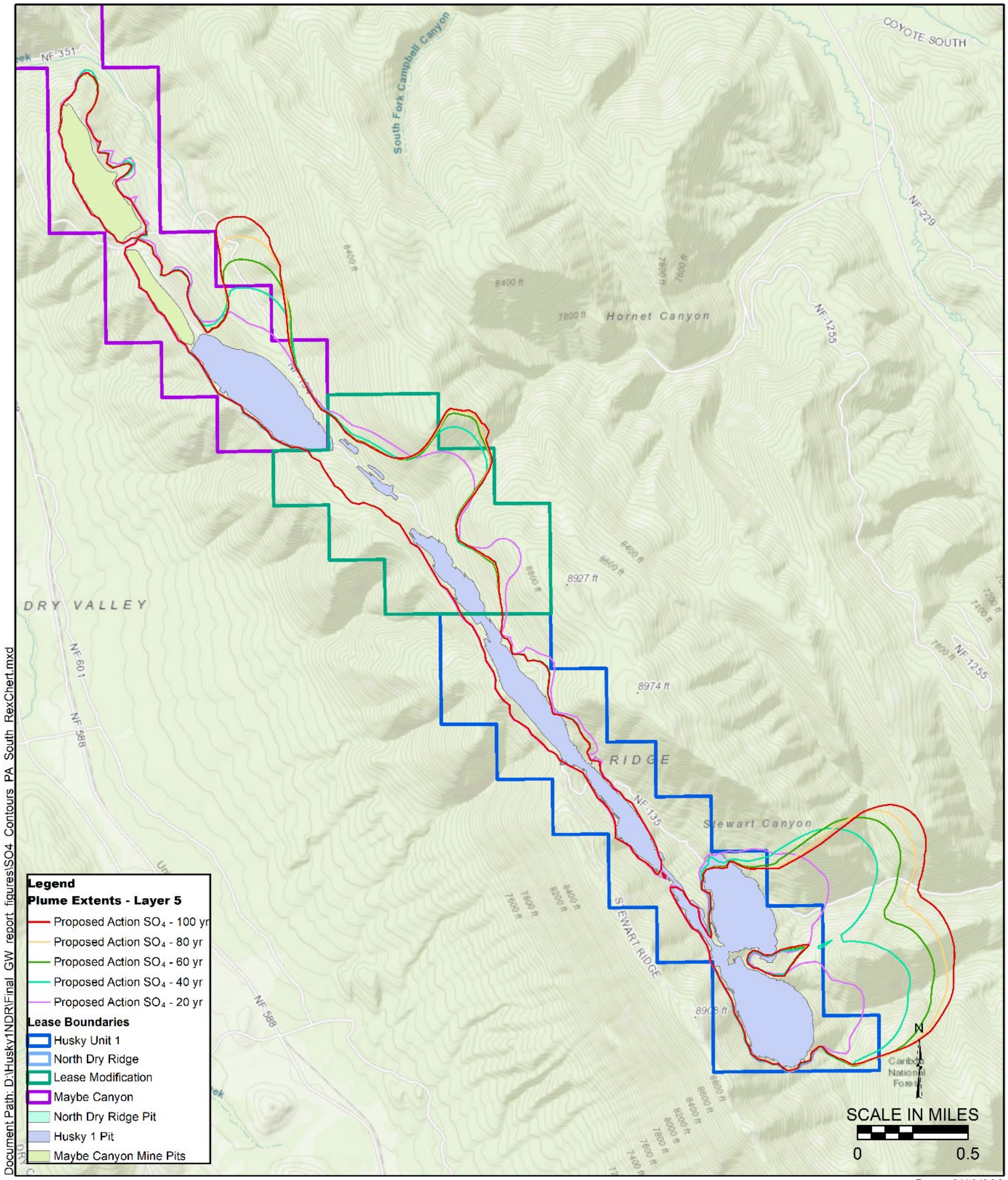
Predicted Extent of Sulfate Plumes in Alluvium at 20 - Year Intervals

Proposed Action

Husky 1 North Dry Ridge

Caribou County, Idaho

Figure B-16: Predicted Extent of Sulfate Plumes in Alluvium at 20-year Intervals for Proposed Action South Maybe Canyon Mine and Husky 1



Date: 8/18/2021

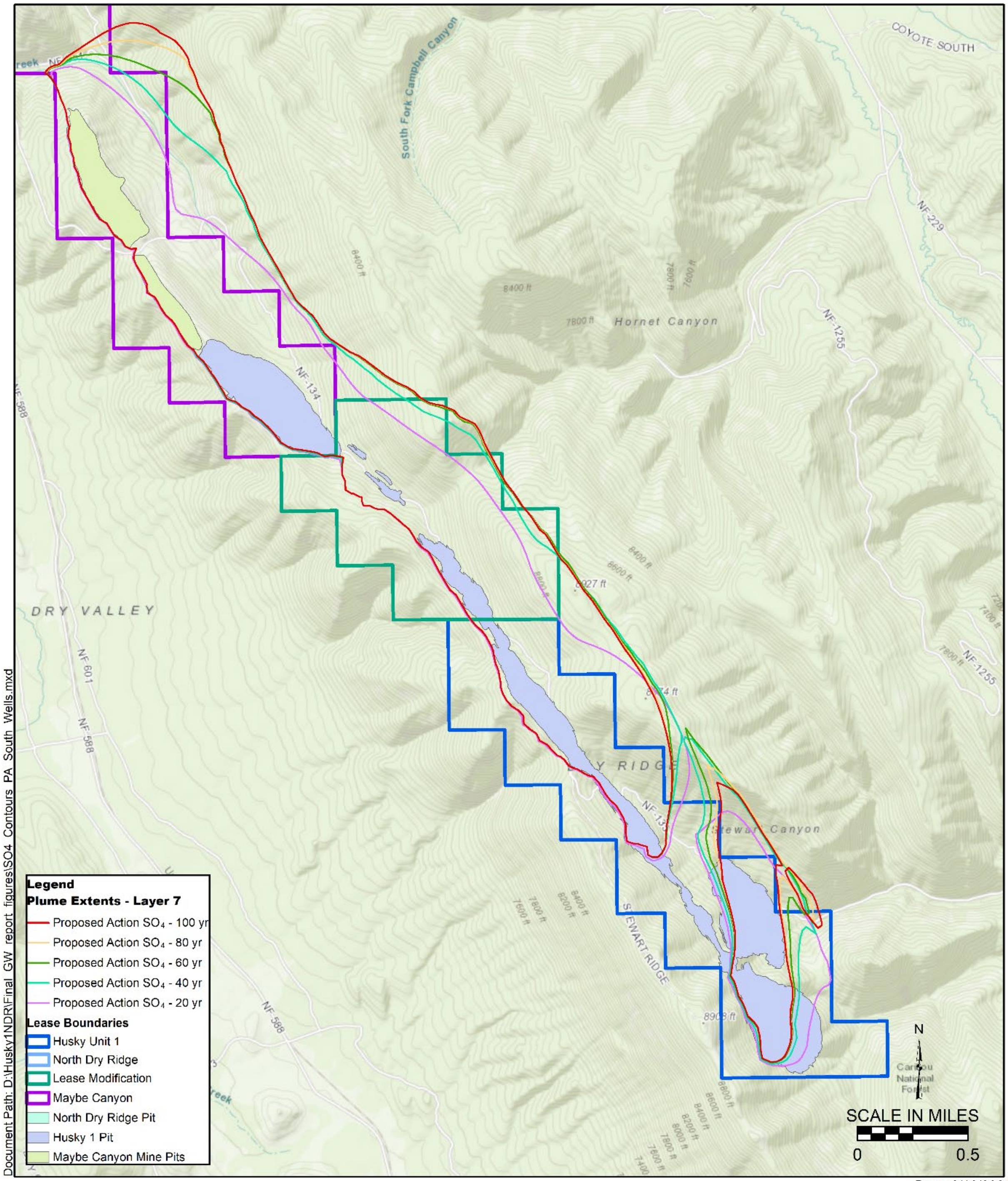
Predicted Extent of Sulfate Plumes in Rex Chert at 20 - Year Intervals

Proposed Action

Husky 1 North Dry Ridge

Caribou County, Idaho

Figure B-17: Predicted Extent of Sulfate Plumes in Rex Chert at 20-year Intervals for Proposed Action South Maybe Canyon Mine and Husky 1



Date: 8/18/2021

Predicted Extent of Sulfate Plumes in Wells Formation at 20 - Year Intervals

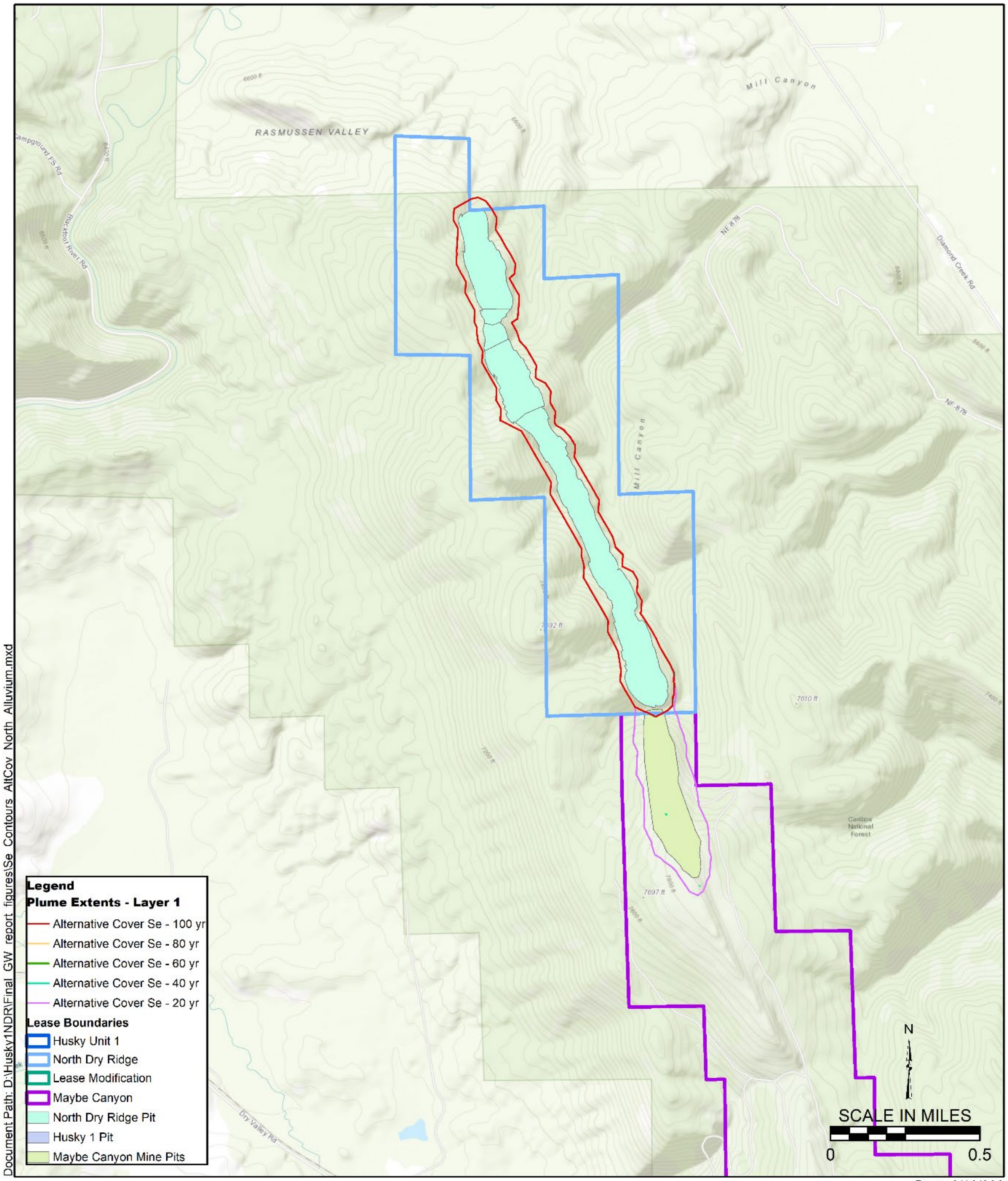
Proposed Action

Husky 1 North Dry Ridge

Caribou County, Idaho

Figure B-18: Predicted Extent of Sulfate Plumes in Wells Formation at 20-year Intervals for Proposed Action South Maybe Canyon Mine and Husky 1

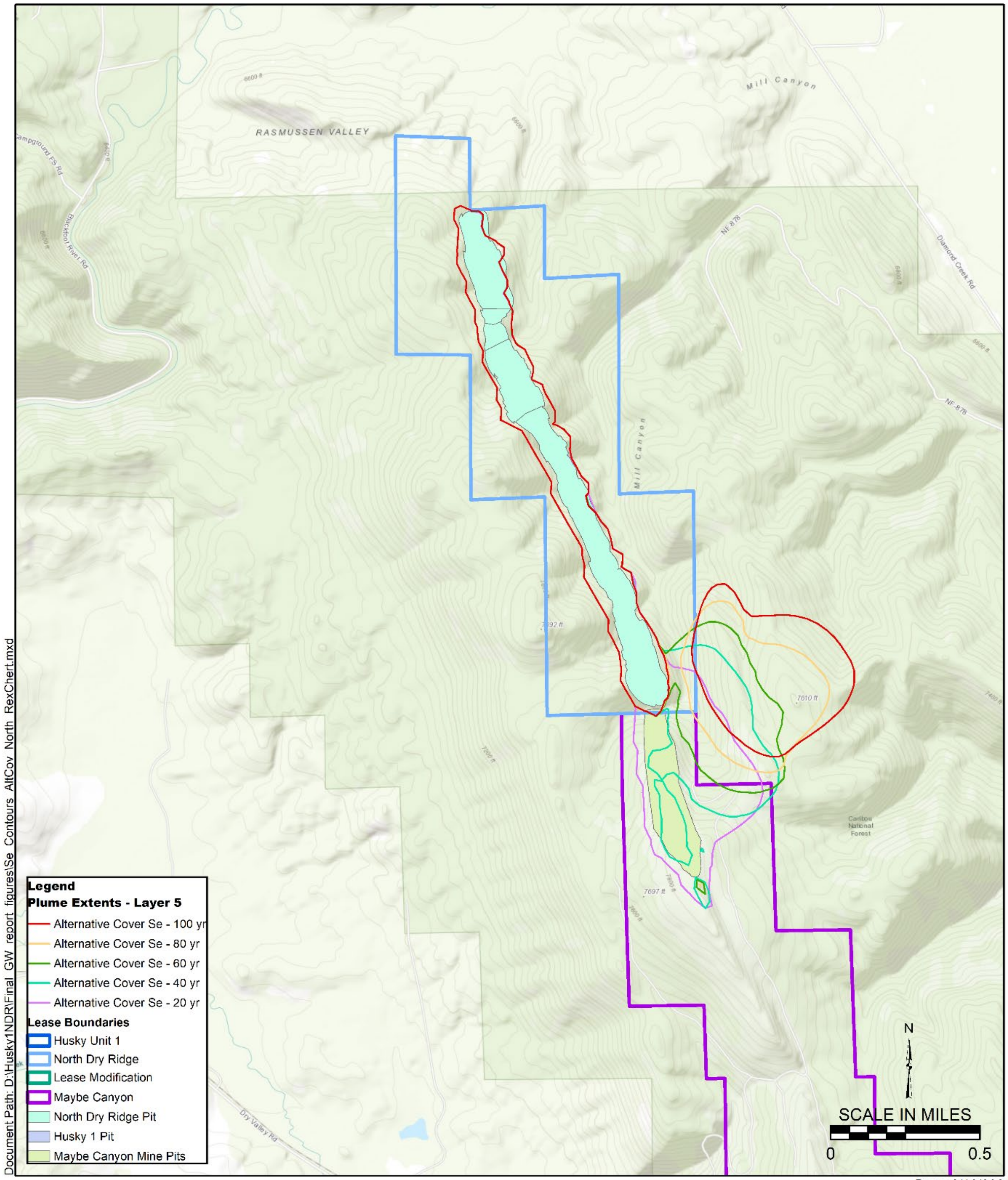
APPENDIX C:
Predicted Extent of COPC Plumes for Alternative Cover
Husky 1 / North Dry Ridge



Date: 8/18/2021

Predicted Extent of Selenium Plumes in Alluvium at 20 - Year Intervals
Alternative Cover
Husky 1 North Dry Ridge
Caribou County, Idaho

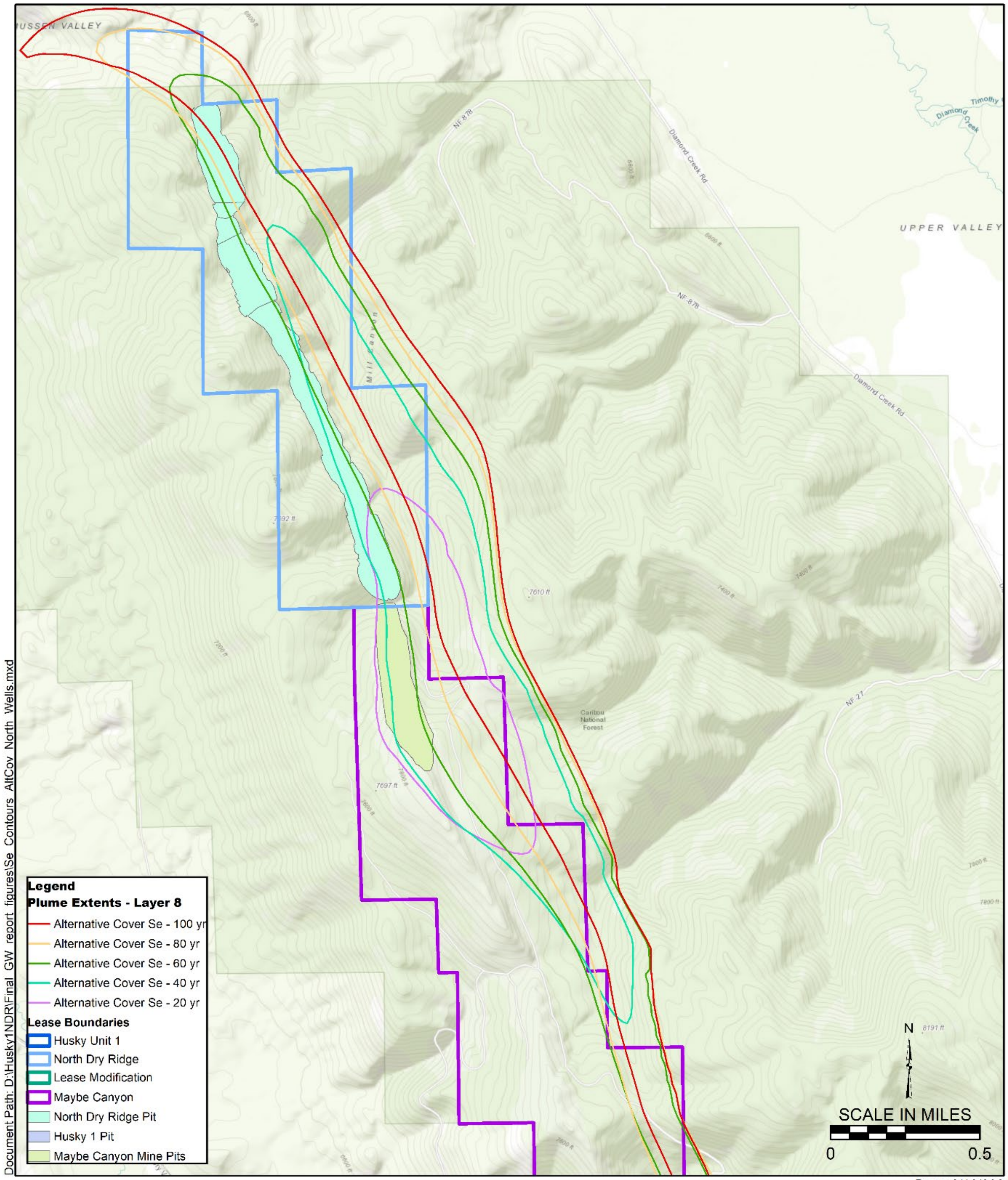
Figure C-1. Predicted Extent of Selenium Plumes in Alluvium at 20-year Intervals for Alternative Cover North Dry Ridge and North Maybe Mine



Date: 8/18/2021

Predicted Extent of Selenium Plumes in Rex Chert at 20 - Year Intervals
Alternative Cover
Husky 1 North Dry Ridge
Caribou County, Idaho

Figure C-2. Predicted Extent of Selenium Plumes in Rex Chert at 20-year Intervals for Alternative Cover North Dry Ridge and North Maybe Mine



Date: 8/18/2021

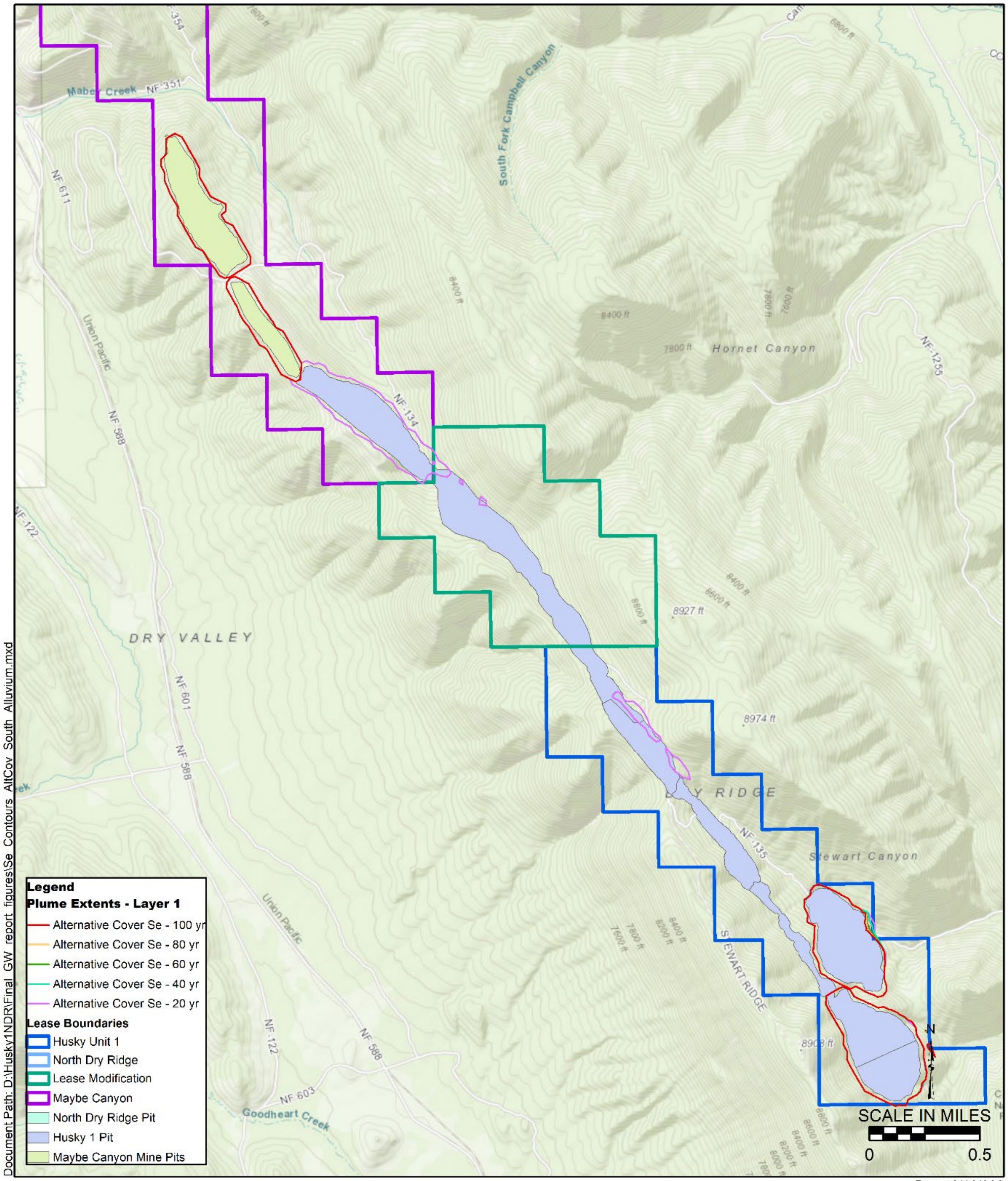
Predicted Extent of Selenium Plumes in Wells Formation at 20 - Year Intervals

Alternative Cover

Husky 1 North Dry Ridge

Caribou County, Idaho

Figure C-3. Predicted Extent of Selenium Plumes in Wells Fm at 20-year Intervals for Alternative Cover North Dry Ridge and North Maybe Mine



Date: 8/18/2021

Predicted Extent of Selenium Plumes in Alluvium at 20 - Year Intervals

Alternative Cover

Husky 1 North Dry Ridge

Caribou County, Idaho

Figure C-4. Predicted Extent of Selenium Plumes in Alluvium at 20-year Intervals for Alternative Cover South Maybe Canyon Mine and Husky 1

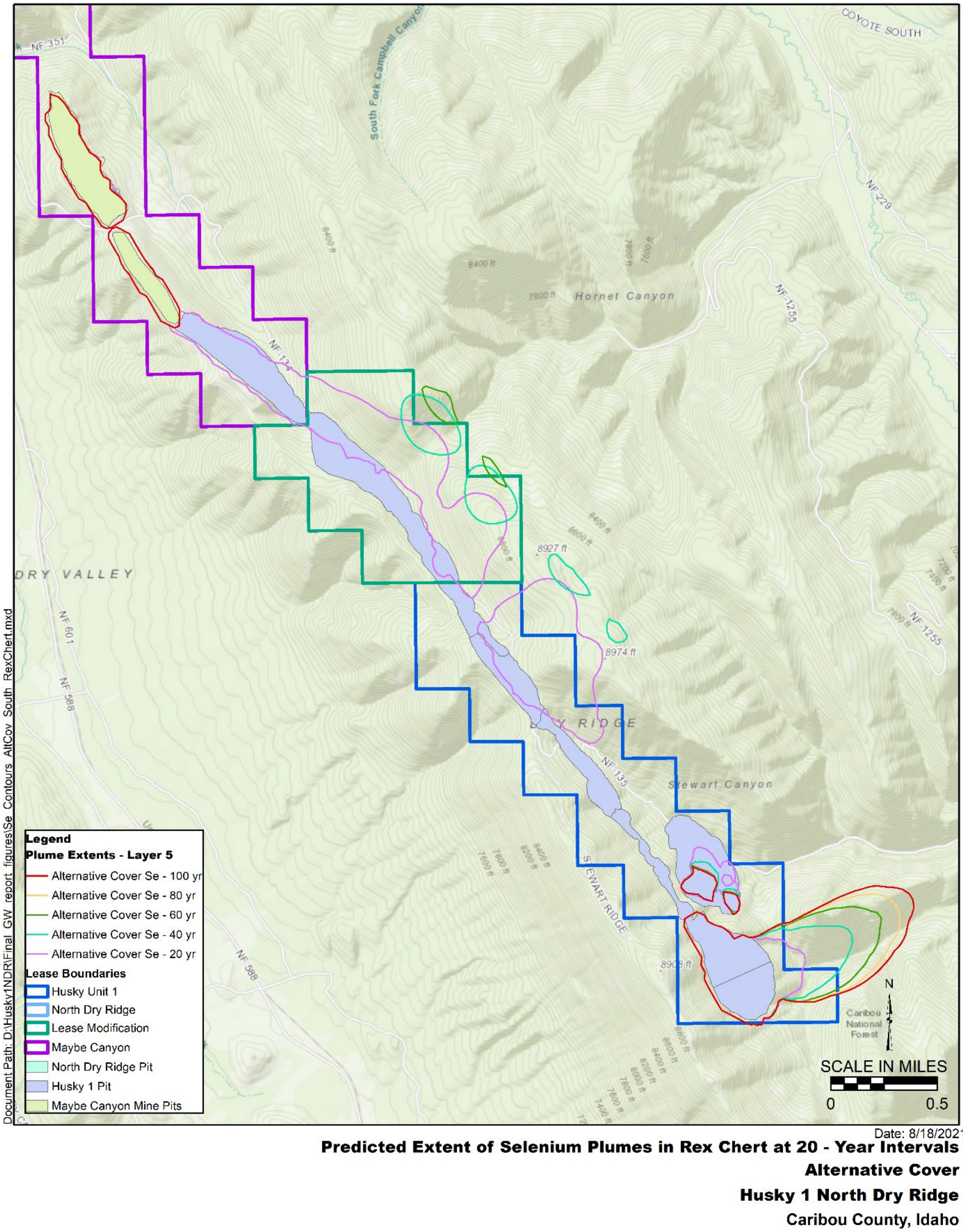
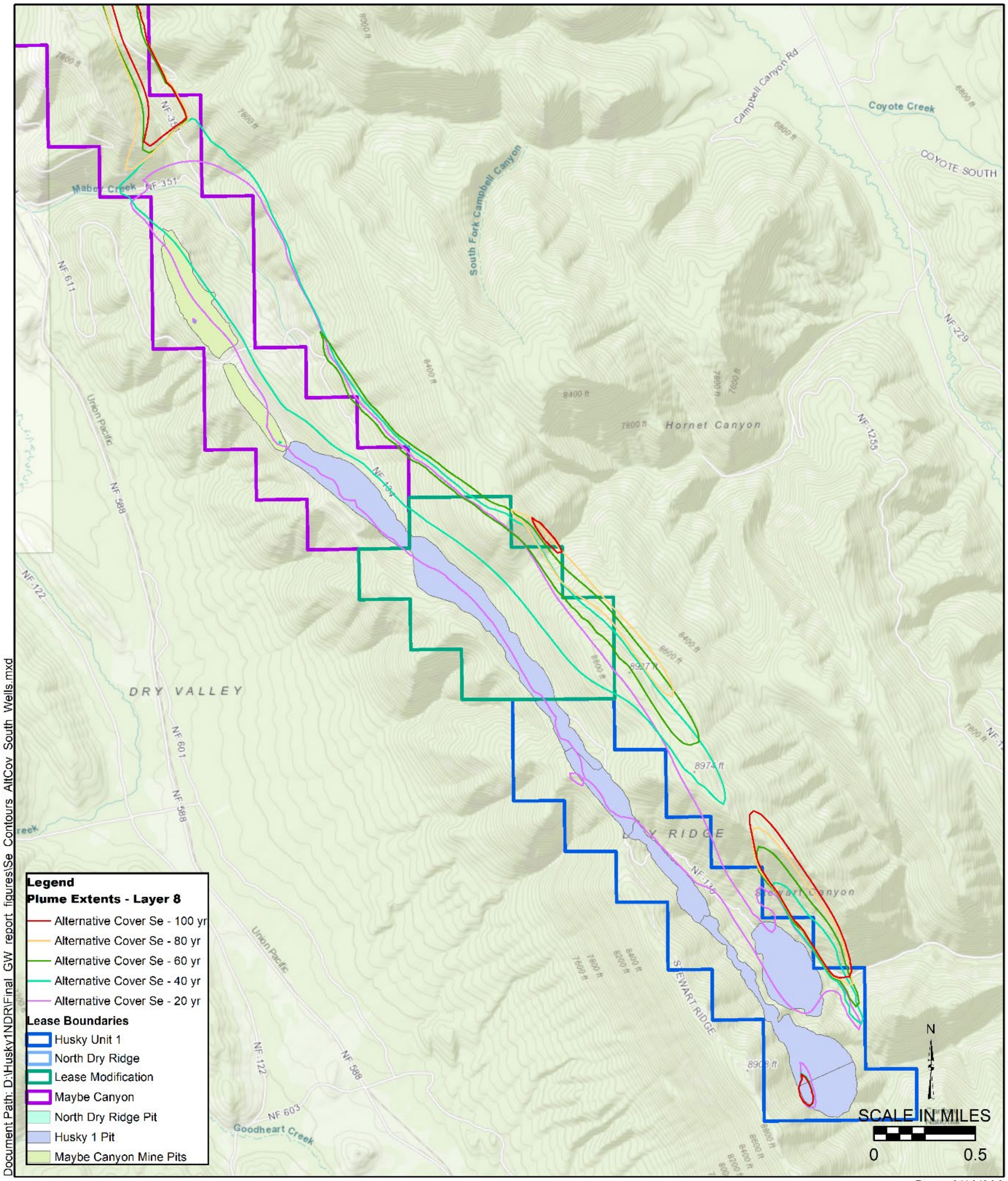


Figure C-5. Predicted Extent of Selenium Plumes in Rex Chert at 20-year Intervals for Alternative Cover South Maybe Canyon Mine and Husky 1

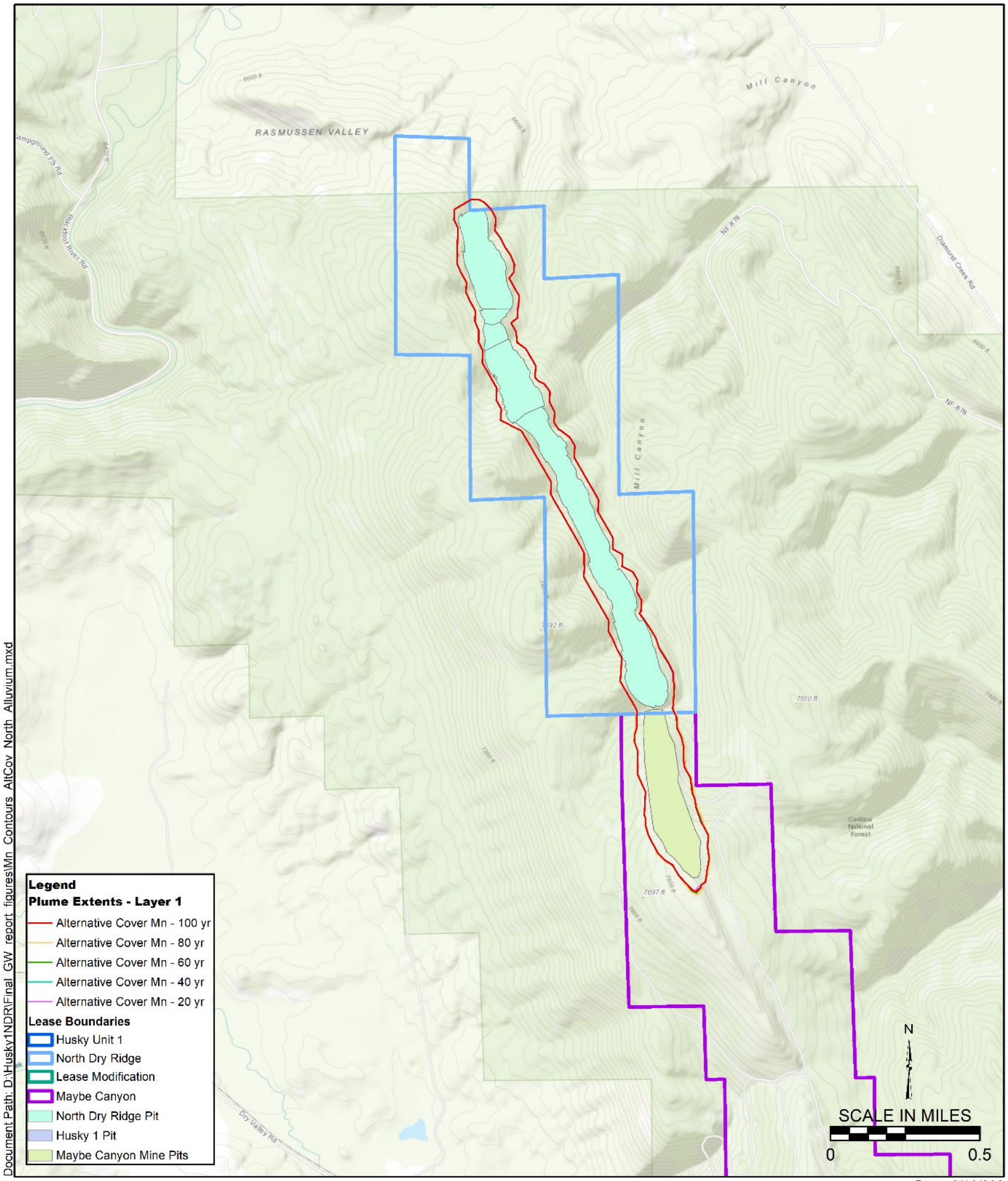


Date: 8/18/2021

Predicted Extent of Selenium Plumes in Wells Formation at 20 - Year Intervals
Alternative Cover
Husky 1 North Dry Ridge
Caribou County, Idaho

Figure C-6. Predicted Extent of Selenium Plumes in Wells Fm at 20-year Intervals for Alternative Cover South Maybe Canyon Mine and Husky 1

Document Path: D:\Husky1NDR\Final GW report figures\Mn Contours AltCov North Alluvium.mxd



Date: 8/18/2021

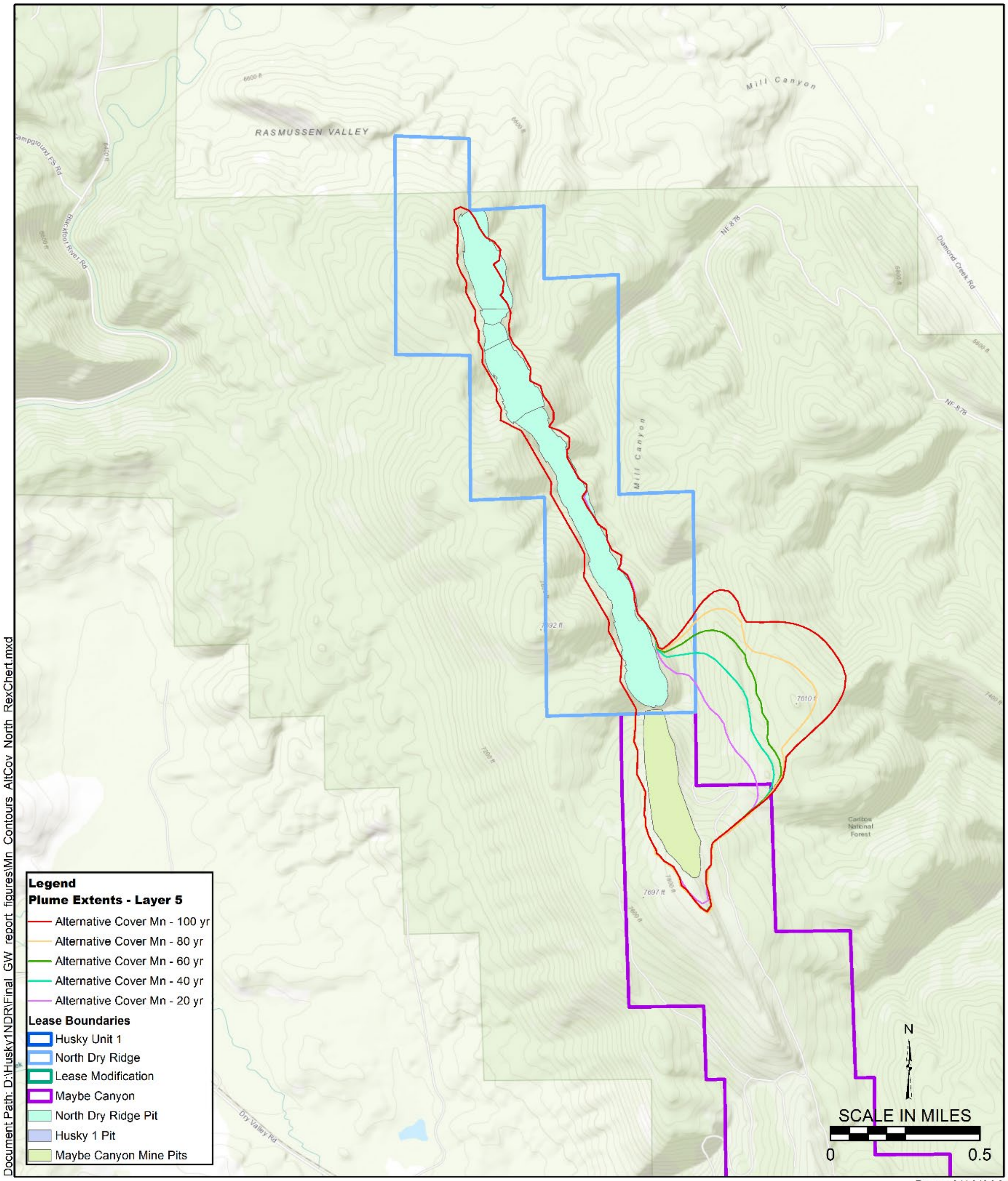
Predicted Extent of Manganese Plumes in Alluvium at 20 - Year Intervals

Alternative Cover

Husky 1 North Dry Ridge

Caribou County, Idaho

Figure C-7. Predicted Extent of Manganese Plumes in Alluvium at 20-year Intervals for Alternative Cover North Dry Ridge and North Maybe Mine



Date: 8/18/2021

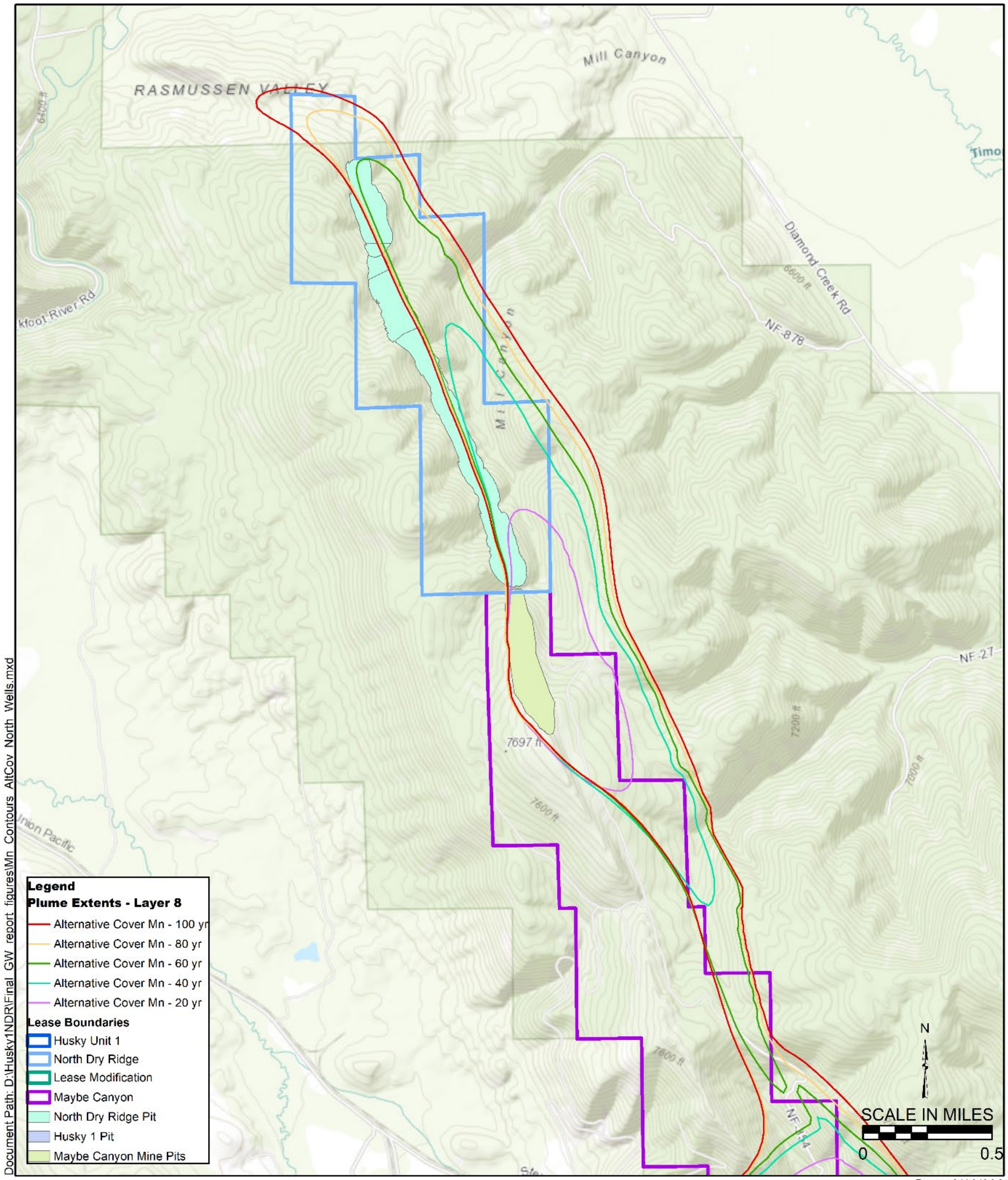
Predicted Extent of Manganese Plumes in Rex Chert at 20 - Year Intervals

Alternative Cover

Husky 1 North Dry Ridge

Caribou County, Idaho

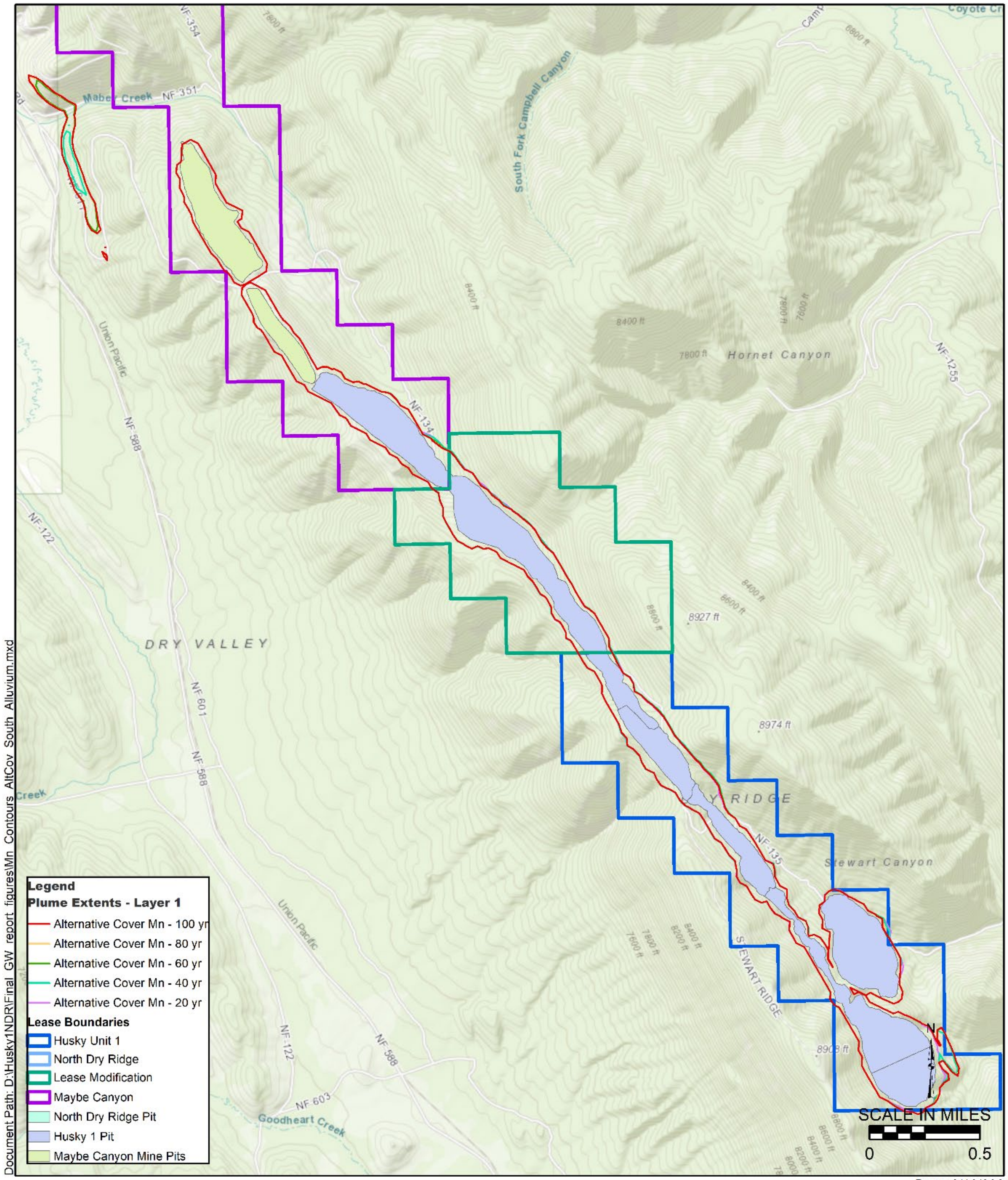
Figure C-8. Predicted Extent of Manganese Plumes in Rex Chert at 20-year Intervals for Alternative Cover North Dry Ridge and North Maybe Mine



Date: 8/18/2021

Predicted Extent of Manganese Plumes in Wells Formation at 20 - Year Intervals
Alternative Cover
Husky 1 North Dry Ridge
Caribou County, Idaho

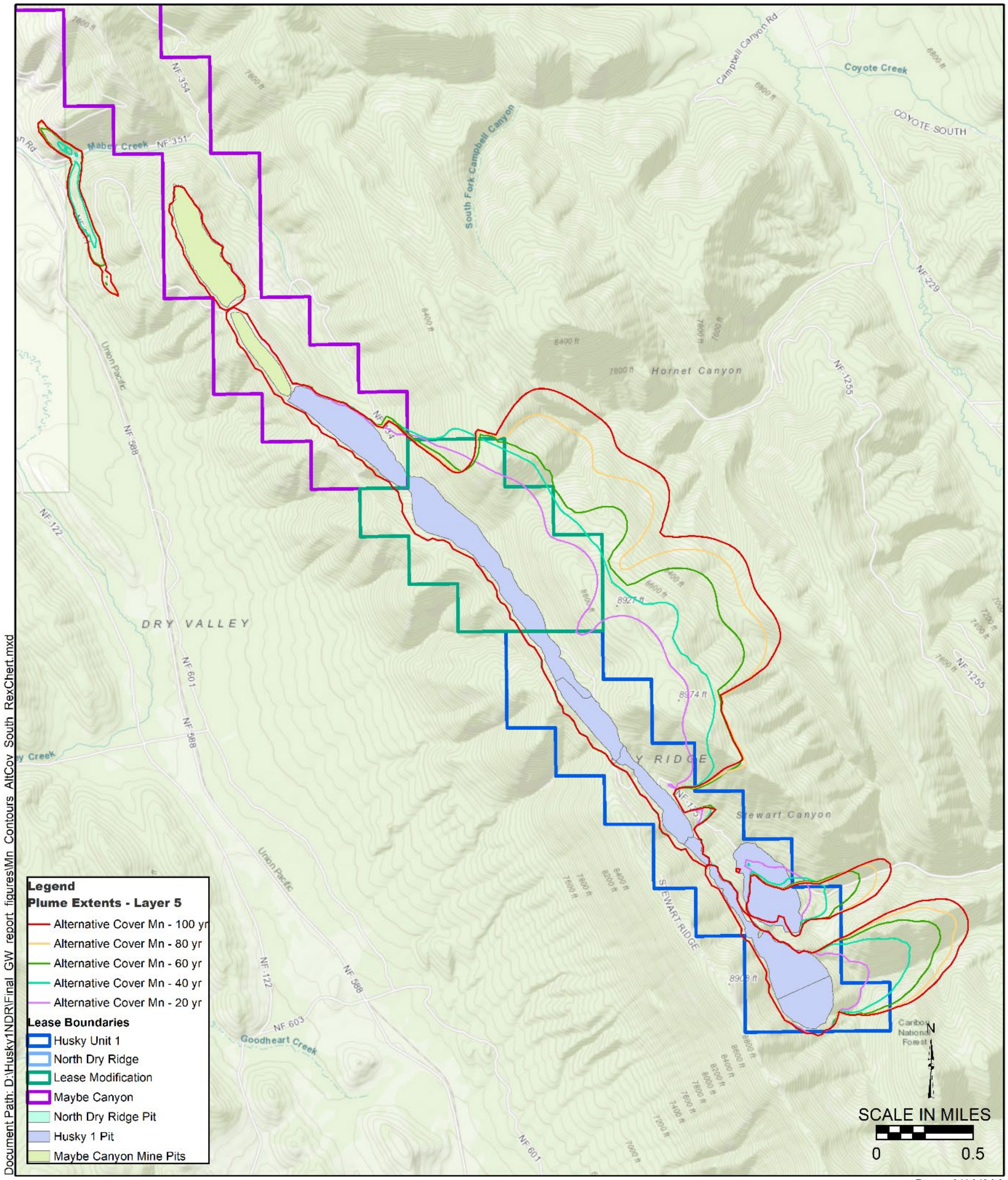
Figure C-9. Predicted Extent of Manganese Plumes in Wells Fm at 20-year Intervals for Alternative Cover North Dry Ridge and North Maybe Mine



Date: 8/18/2021

Predicted Extent of Manganese Plumes in Alluvium at 20 - Year Intervals
Alternative Cover
Husky 1 North Dry Ridge
Caribou County, Idaho

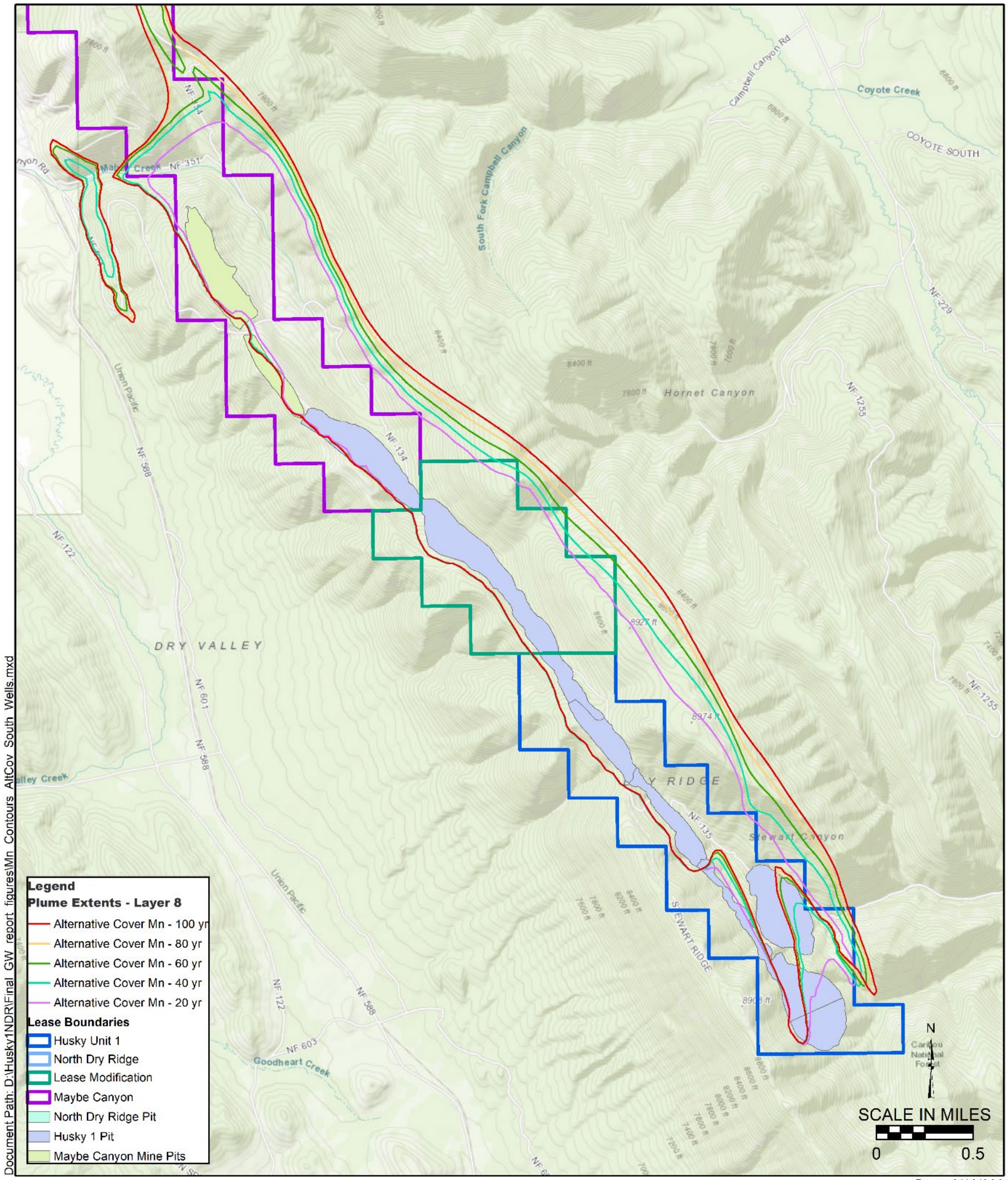
Figure C-10. Predicted Extent of Manganese Plumes in Alluvium at 20-year Intervals for Alternative Cover South Maybe Canyon Mine and Husky 1



Date: 8/18/2021

Predicted Extent of Manganese Plumes in Rex Chert at 20 - Year Intervals
Alternative Cover
Husky 1 North Dry Ridge
Caribou County, Idaho

Figure C-11. Predicted Extent of Manganese Plumes in Rex Chert at 20-year Intervals for Alternative Cover South Maybe Canyon Mine and Husky 1



Date: 8/18/2021

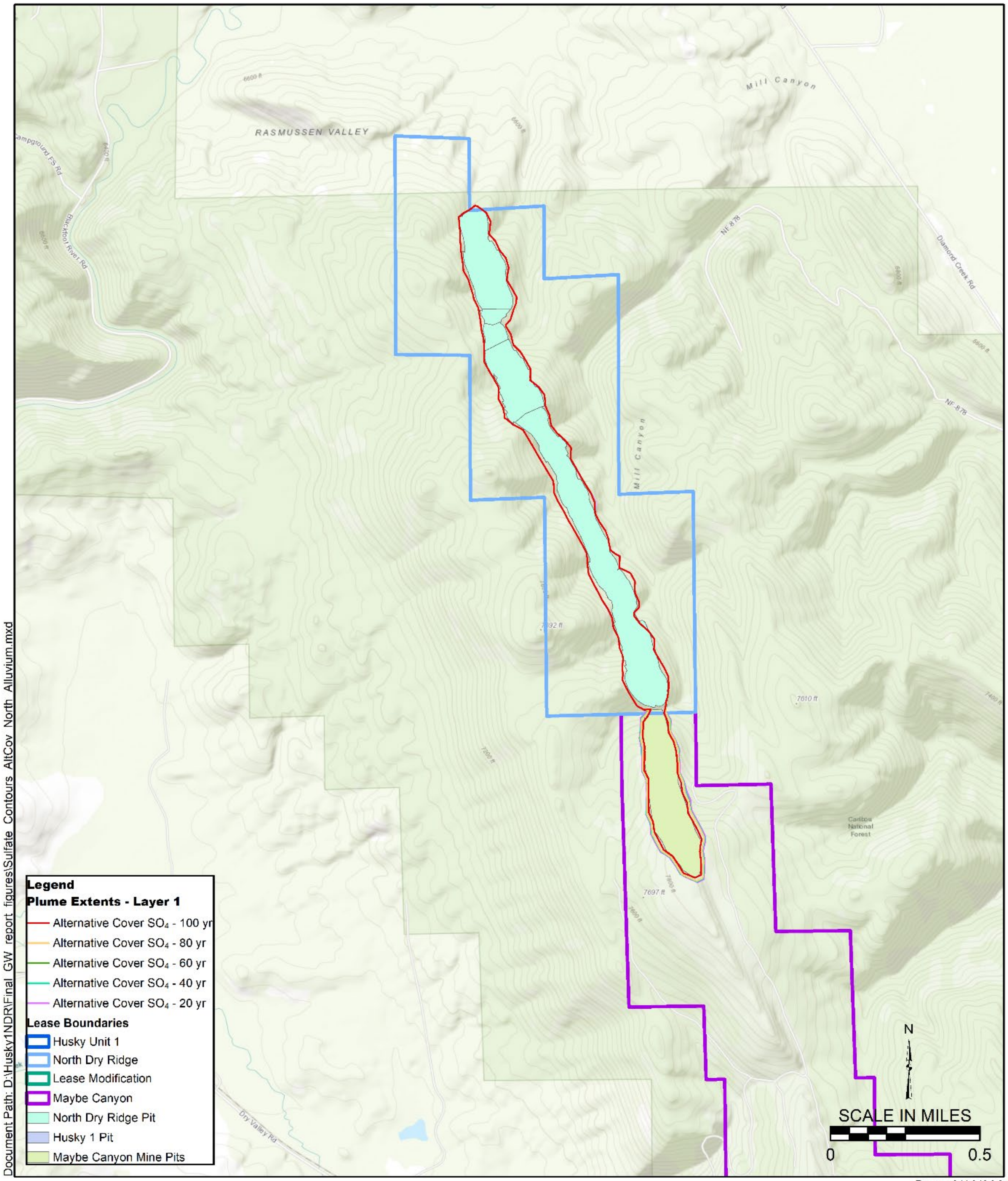
Predicted Extent of Manganese Plumes in Wells Formation at 20 - Year Intervals

Alternative Cover

Husky 1 North Dry Ridge

Caribou County, Idaho

Figure C-12. Predicted Extent of Manganese Plumes in Wells Fm at 20-year Intervals for Alternative Cover South Maybe Canyon Mine and Husky 1



Date: 8/18/2021

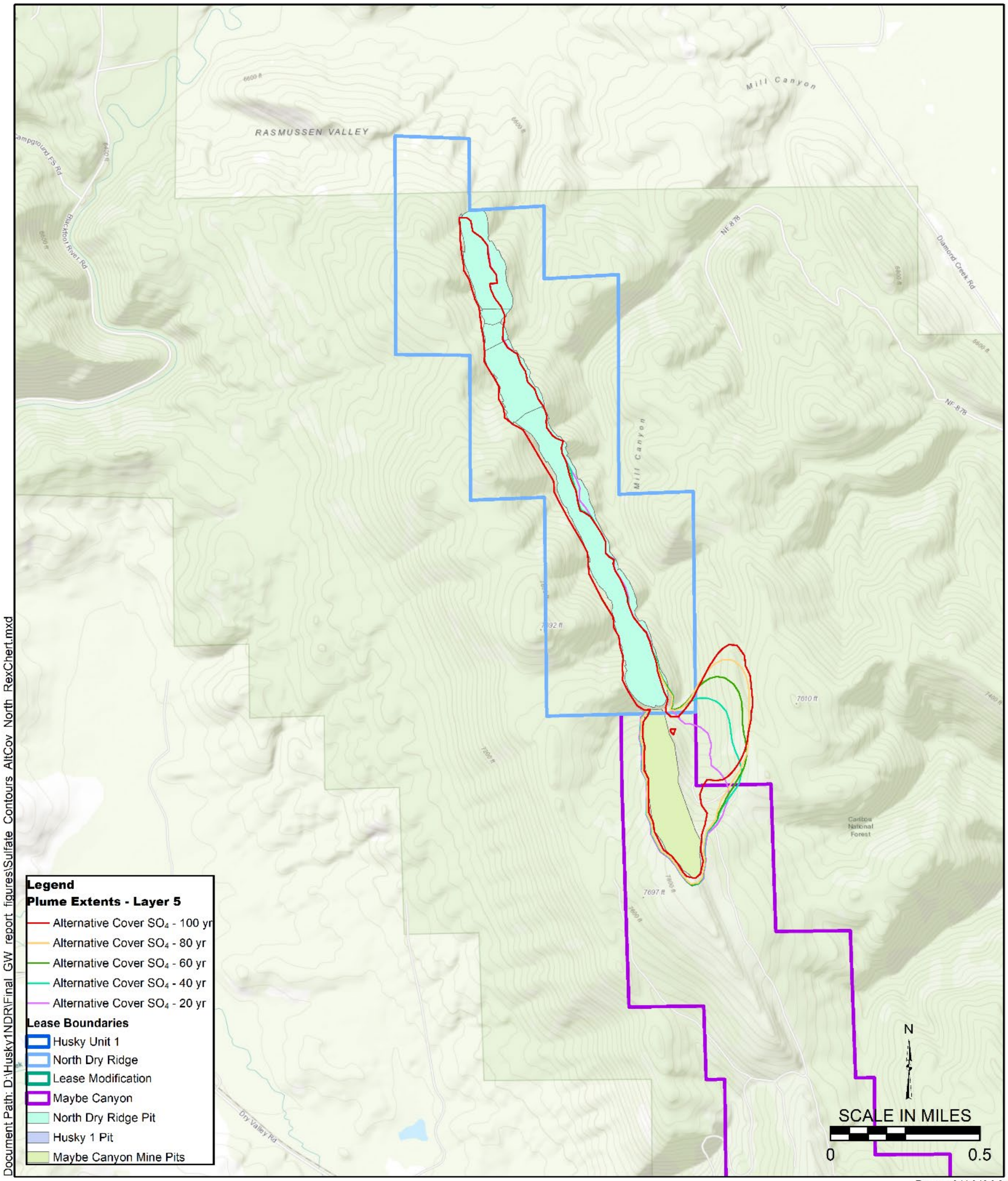
Predicted Extent of Sulfate Plumes in Alluvium at 20 - Year Intervals

Alternative Cover

Husky 1 North Dry Ridge

Caribou County, Idaho

Figure C-13. Predicted Extent of Sulfate Plumes in Alluvium at 20-year Intervals for Alternative Cover North Dry Ridge and North Maybe Mine



Date: 8/18/2021

Predicted Extent of Sulfate Plumes in Rex Chert at 20 - Year Intervals

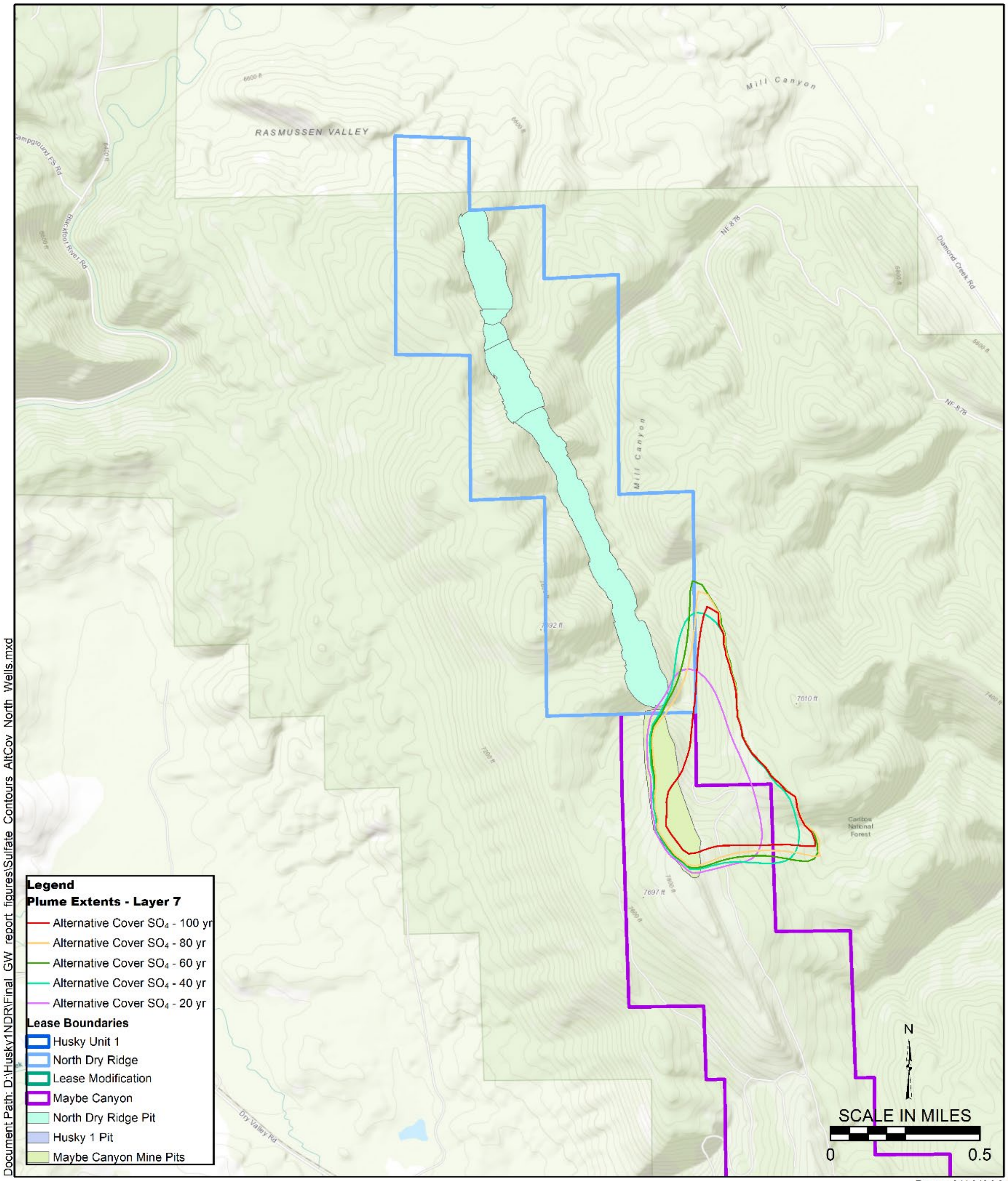
Alternative Cover

Husky 1 North Dry Ridge

Caribou County, Idaho

Figure C-14. Predicted Extent of Sulfate Plumes in Rex Chert at 20-year Intervals for Alternative Cover North Dry Ridge and North Maybe Mine

Document Path: D:\Husky1NDR\Final_GW_report_figures\Sulfate_Contours_AltCov_North_Wells.mxd



Date: 8/18/2021

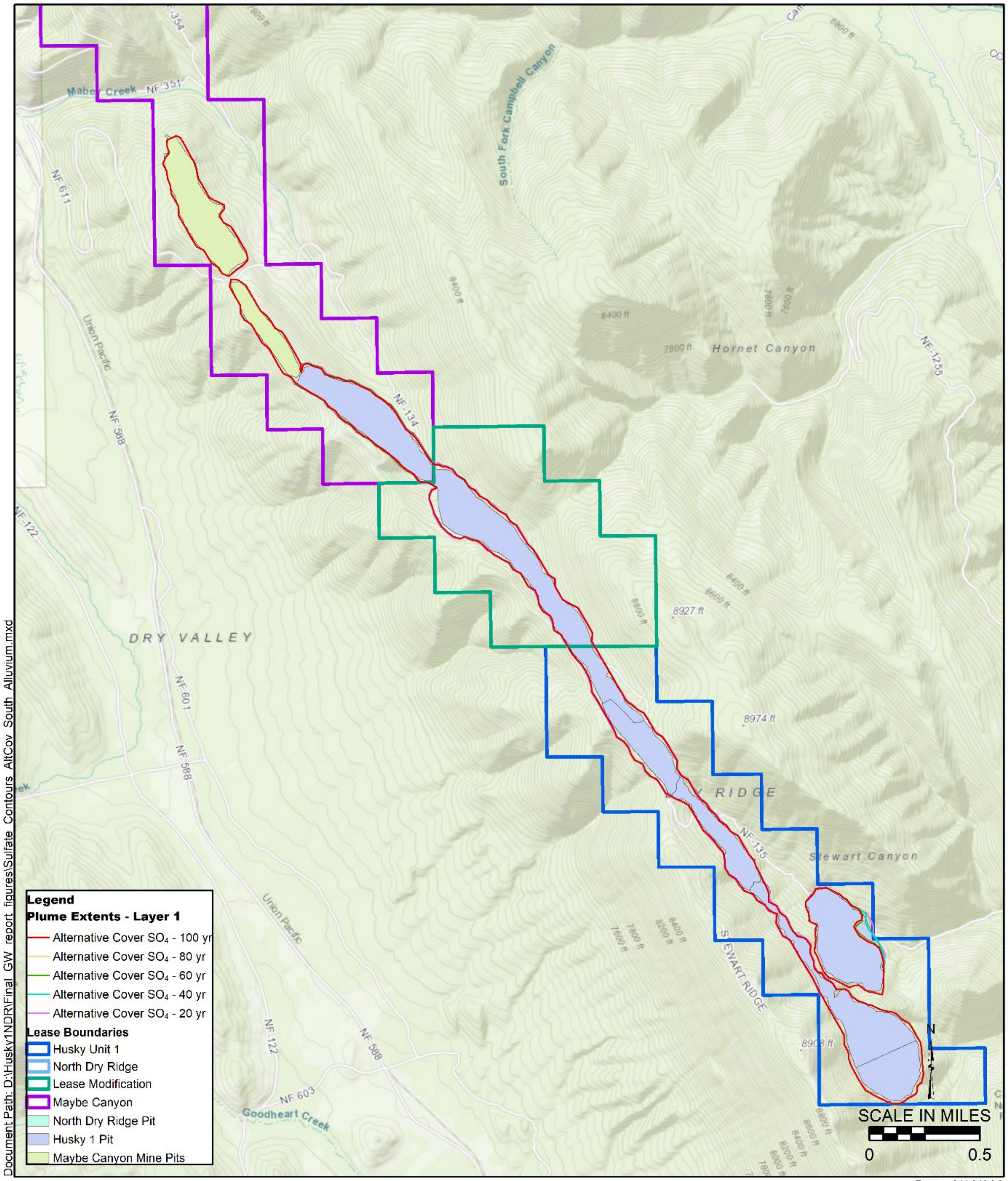
Predicted Extent of Sulfate Plumes in Wells Formation at 20 - Year Intervals

Alternative Cover

Husky 1 North Dry Ridge

Caribou County, Idaho

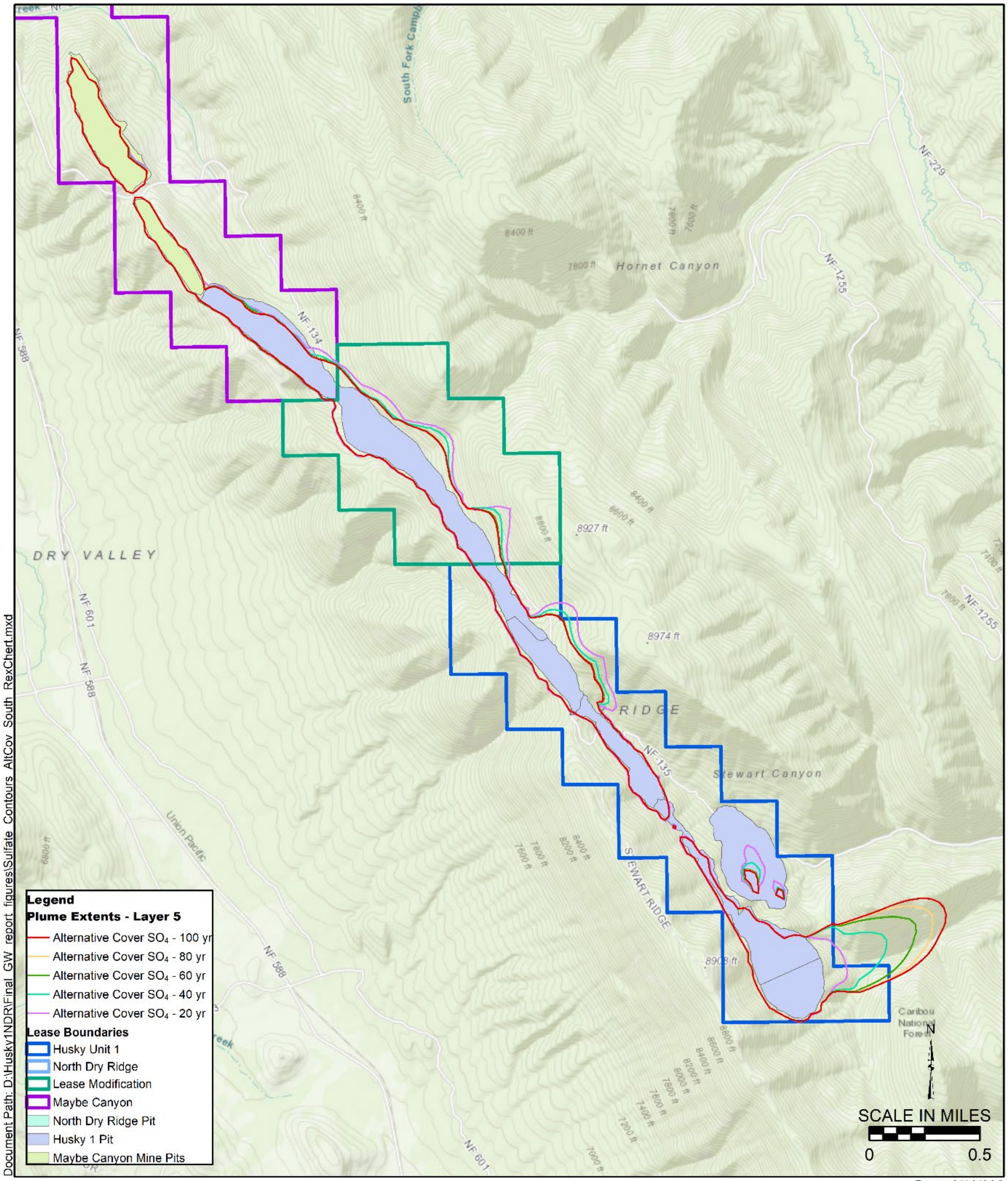
Figure C-15. Predicted Extent of Sulfate Plumes in Wells Formation at 20-year Intervals for Alternative Cover North Dry Ridge and North Maybe Mine



Date: 8/18/2021

Predicted Extent of Sulfate Plumes in Alluvium at 20 - Year Intervals
Alternative Cover
Husky 1 North Dry Ridge
Caribou County, Idaho

Figure C-16. Predicted Extent of Sulfate Plumes in Alluvium at 20-year Intervals for Alternative Cover South Maybe Canyon Mine and Husky 1



Date: 8/18/2021

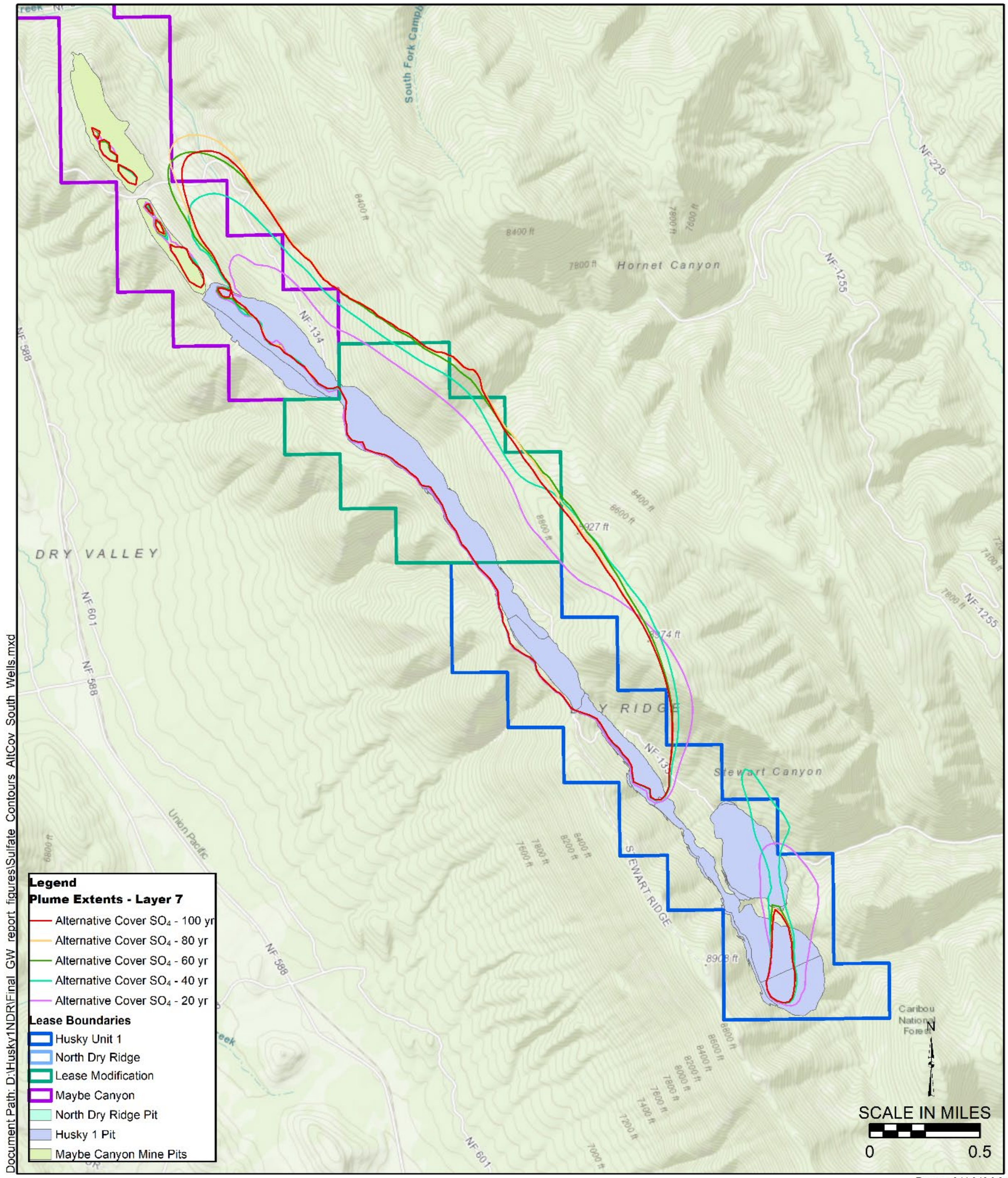
Predicted Extent of Sulfate Plumes in Rex Chert at 20 - Year Intervals

Alternative Cover

Husky 1 North Dry Ridge

Caribou County, Idaho

Figure C-17. Predicted Extent of Sulfate Plumes in Rex Chert at 20-year Intervals for Alternative Cover South Maybe Canyon Mine and Husky 1



Date: 8/18/2021

Predicted Extent of Sulfate Plumes in Wells Formation at 20 - Year Intervals

Alternative Cover

Husky 1 North Dry Ridge

Caribou County, Idaho

Figure C-18. Predicted Extent of Sulfate Plumes in Wells Formation at 20-year Intervals for Alternative Cover South Maybe Canyon Mine and Husky 1