Stibnite Gold Project EIS Appendix E

Geologic Resources and Geotechnical Hazards

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Contents

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E-1: Geohazards Along the Proposed Burntlog Route

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LEGEND

Landslide Features

Landslide or Rock Fall Area

Creek, Seep or Wet Area

Project Components*

Access Roads and Trail System

Burntlog Route 150 ft Corridor

Mile Point

Burntlog Route New

Burntlog Route Upgrade

Burntlog Route Borrow Source

Other Features

U.S. Forest Service

Wilderness

Road

Stream/River

Surface Management Agency

U.S. Forest Service

*Project Components are associated with Alternative 1

0 600 1,200 Feet

1 inch = 1,200 feet when printed at 11x17

N

Plate 3A Proposed Burntlog Access Road Geohazards

Base Layer: World Imagery from Esri
Other Data Sources: State of Idaho Geospatial Gateway (INSIDE Idaho); Boise National Forest; Midas Gold; Payette National Forest

Map Date: 6/24/2020

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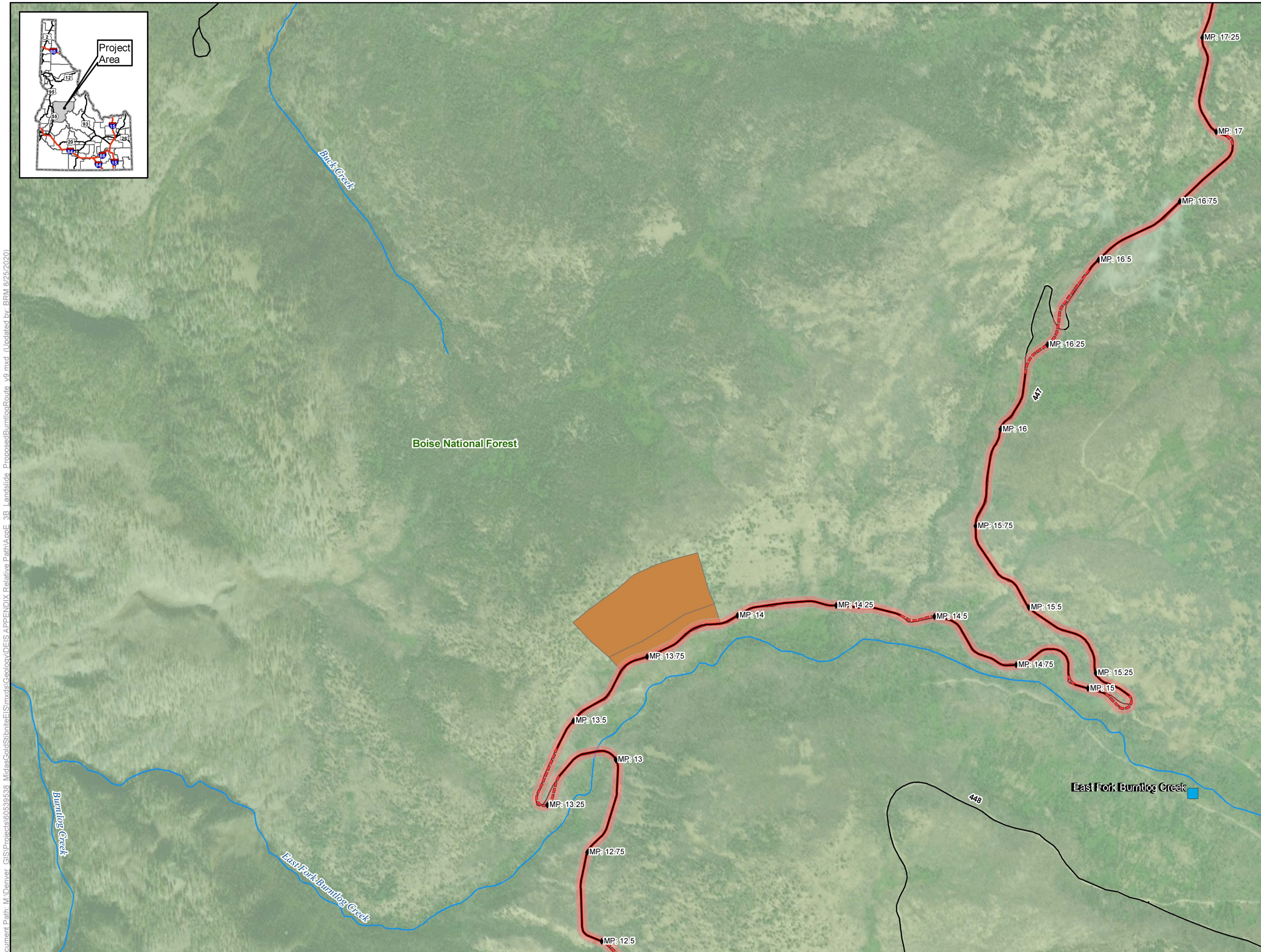

LEGEND

Landslide Features

- Landslide or Rock Fall Area
- Creek, Seep or Wet Area

Project Components*

Access Roads and Trail System

- Burntlog Route 150 ft Corridor
- Mile Point
- Burntlog Route New
- Burntlog Route Upgrade
- Burntlog Route Borrow Source

Other Features

- U.S. Forest Service
- Road
- Stream/River

Surface Management Agency

- U.S. Forest Service

*Project Components are associated with Alternative 1

0 600 1,200 Feet

1 inch = 1,200 feet
when printed at 11x17

Plate 3B Proposed Burntlog Access Road GeoHazards

Base Layer: World Imagery from Esri
Other Data Sources: State of Idaho Geospatial Gateway (INSIDE Idaho); Boise National Forest; Midas Gold; Payette National Forest

Map Date:
6/25/2020

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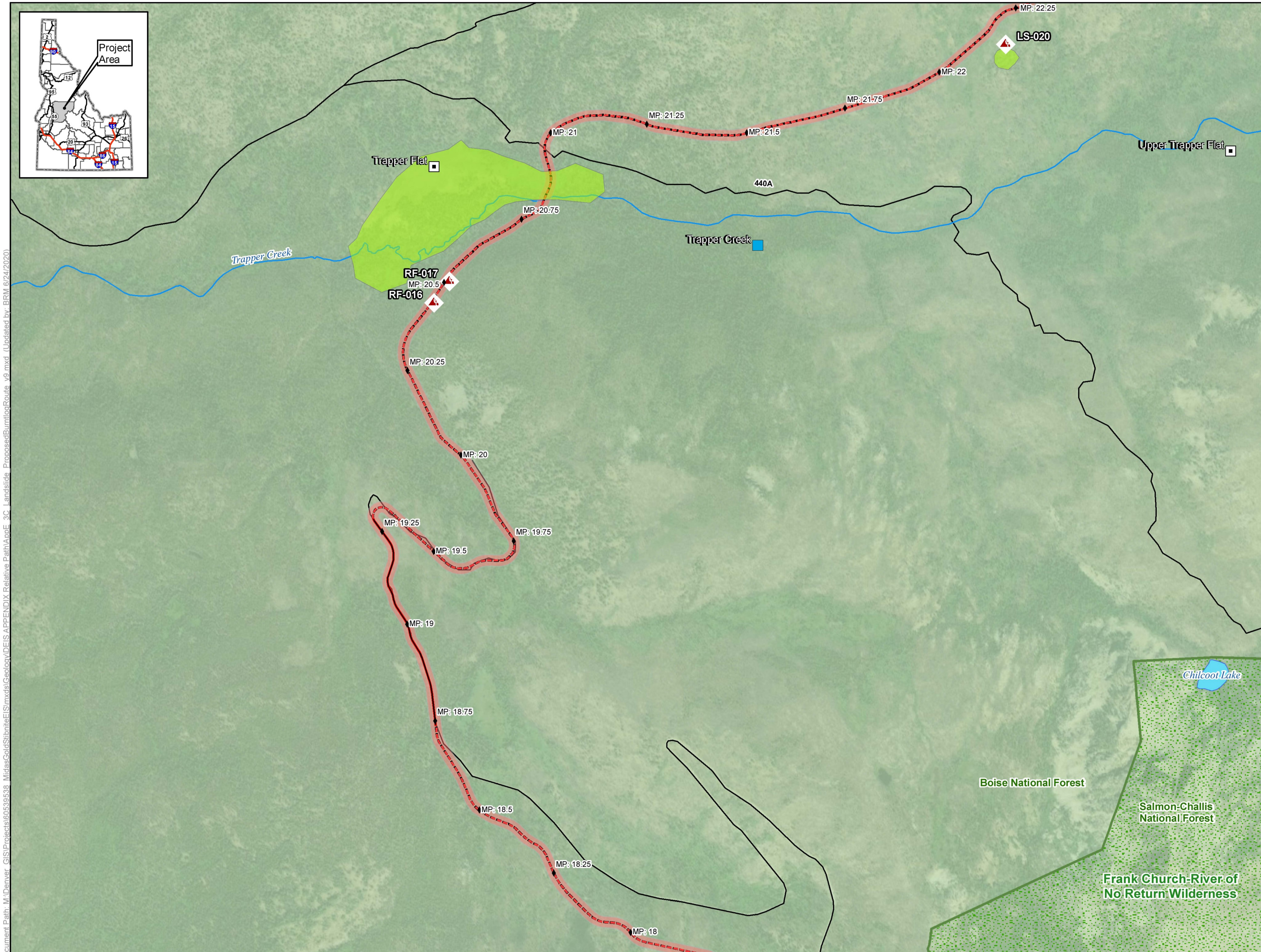

LEGEND

Landslide Features

- Landslide or Rock Fall Area
- Creek, Seep or Wet Area
- Trapper Flats

Project Components*

Access Roads and Trail System

- Burntlog Route 150 ft Corridor
- Mile Point
- Burntlog Route New
- Burntlog Route Upgrade

Other Features

- U.S. Forest Service
- Wilderness
- Road
- Stream/River
- Lake/Reservoir

Surface Management Agency

- U.S. Forest Service

*Project Components are associated with Alternative 1

0 600 1,200 Feet

1 inch = 1,200 feet when printed at 11x17

N

Plate 3C Proposed Burntlog Access Road GeoHazards

Base Layer: World Imagery from Esri
Other Data Sources: State of Idaho Geospatial Gateway (INSIDE Idaho); Boise National Forest; Midas Gold; Payette National Forest

Map Date: 6/24/2020

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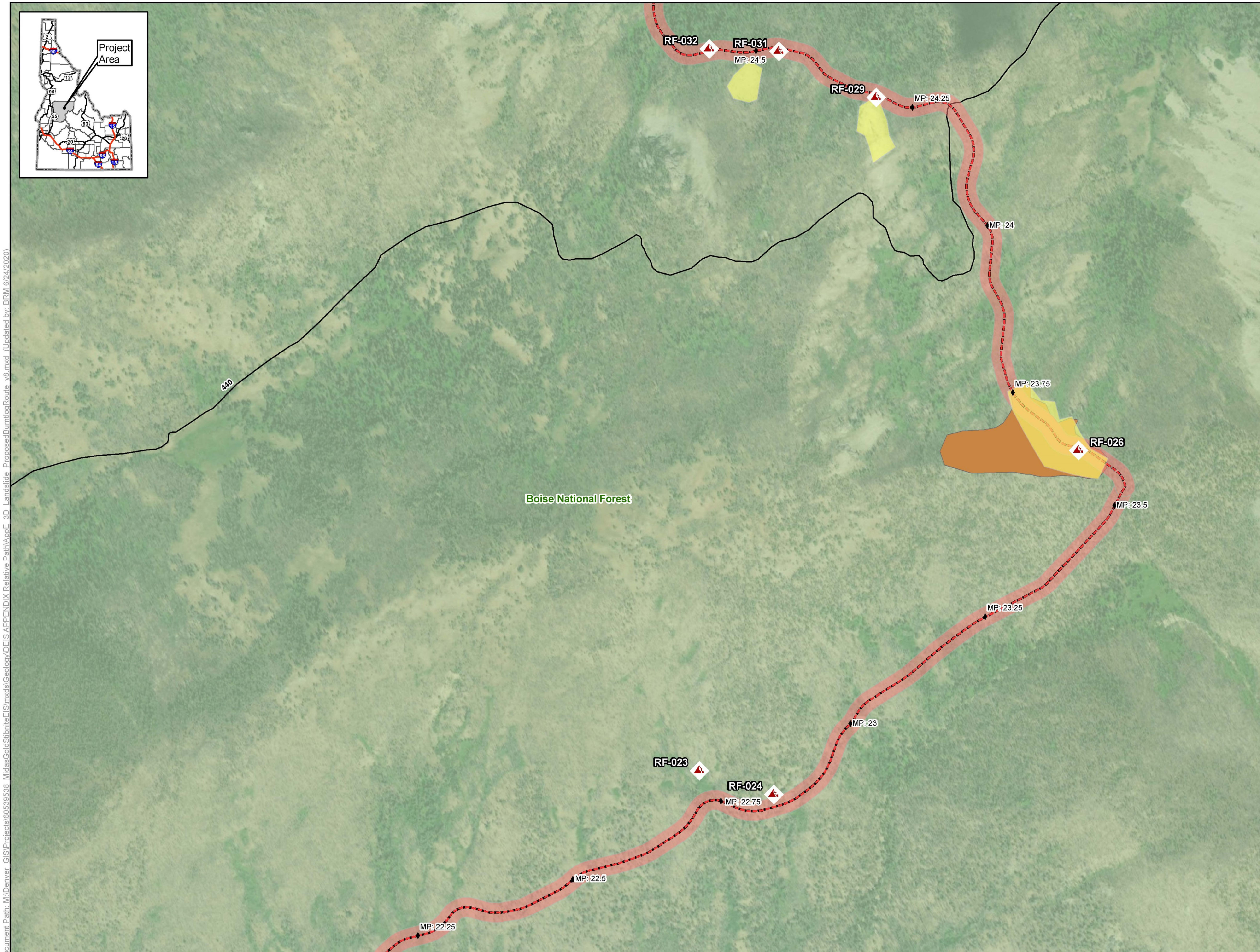

LEGEND

Landslide Features

- Landslide or Rock Fall Area
- Creek, Seep or Wet Area
- Rock Fall Area

Project Components*

Access Roads and Trail System

- Burntlog Route 150 ft Corridor
- Mile Point
- Burntlog Route New
- Burntlog Route Borrow Source

Other Features

- U.S. Forest Service
- Road

Surface Management Agency

- U.S. Forest Service

*Project Components are associated with Alternative 1

0 400 800 Feet

1 inch = 700 feet when printed at 11x17

Plate 3D Proposed Burntlog Access Road GeoHazards

Base Layer: World Imagery from Esri
Other Data Sources: State of Idaho Geospatial Gateway (INSIDE Idaho); Boise National Forest; Midas Gold; Payette National Forest

Map Date: 6/24/2020

LEGEND

Landslide Features

- Landslide or Rock Fall Area
- Creek, Seep or Wet Area
- Wet Area

Project Components*

Access Roads and Trail System

- Burntlog Route 150 ft Corridor
- Mile Point
- Burntlog Route New

Other Features

- U.S. Forest Service
- Road
- Stream/River

Surface Management Agency

- U.S. Forest Service

*Project Components are associated with Alternative 1

0 300 600 Feet

1 inch = 600 feet
when printed at 11x17

N

Plate 3E Proposed Burntlog Access Road GeoHazards

Base Layer: World Imagery from Esri
Other Data Sources: State of Idaho Geospatial Gateway (INSIDE Idaho); Boise National Forest; Midas Gold; Payette National Forest

PAYETTE NATIONAL FOREST

Map Date: 6/24/2020

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LEGEND

Landslide Features

- Landslide or Rock Fall Area
- Creek, Seep or Wet Area
- Wet Area

Project Components*

Access Roads and Trail System

- Burntlog Route 150 ft Corridor
- Mile Point
- Burntlog Route New

Other Features

- U.S. Forest Service
- Wilderness
- Road
- Stream/River

Surface Management Agency

- U.S. Forest Service

*Project Components are associated with Alternative 1

0 300 600 Feet

1 inch = 600 feet when printed at 11x17

N

Plate 3F Proposed Burntlog Access Road GeoHazards

Base Layer: World Imagery from Esri
Other Data Sources: State of Idaho Geospatial Gateway (INSIDE Idaho); Boise National Forest; Midas Gold; Payette National Forest

Map Date: 6/24/2020

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LEGEND

Landslide Features
- Landslide or Rock Fall Area
- Creek, Seep or Wet Area
- Wet Area

Access Roads and Trail System
- Burntlog Route 150 ft Corridor
- Mile Point
- Burntlog Route New

Other Features
- U.S. Forest Service
- Wilderness
- Road
- Stream/River

Surface Management Agency
- U.S. Forest Service

*Project Components are associated with Alternative 1

0 325 650 Feet
1 inch = 650 feet when printed at 11x17

N

Plate 3G Proposed Burntlog Access Road GeoHazards

Base Layer: World Imagery from Esri
Other Data Sources: State of Idaho Geospatial Gateway (INSIDE Idaho); Boise National Forest; Midas Gold; Payette National Forest

Map Date: 6/24/2020

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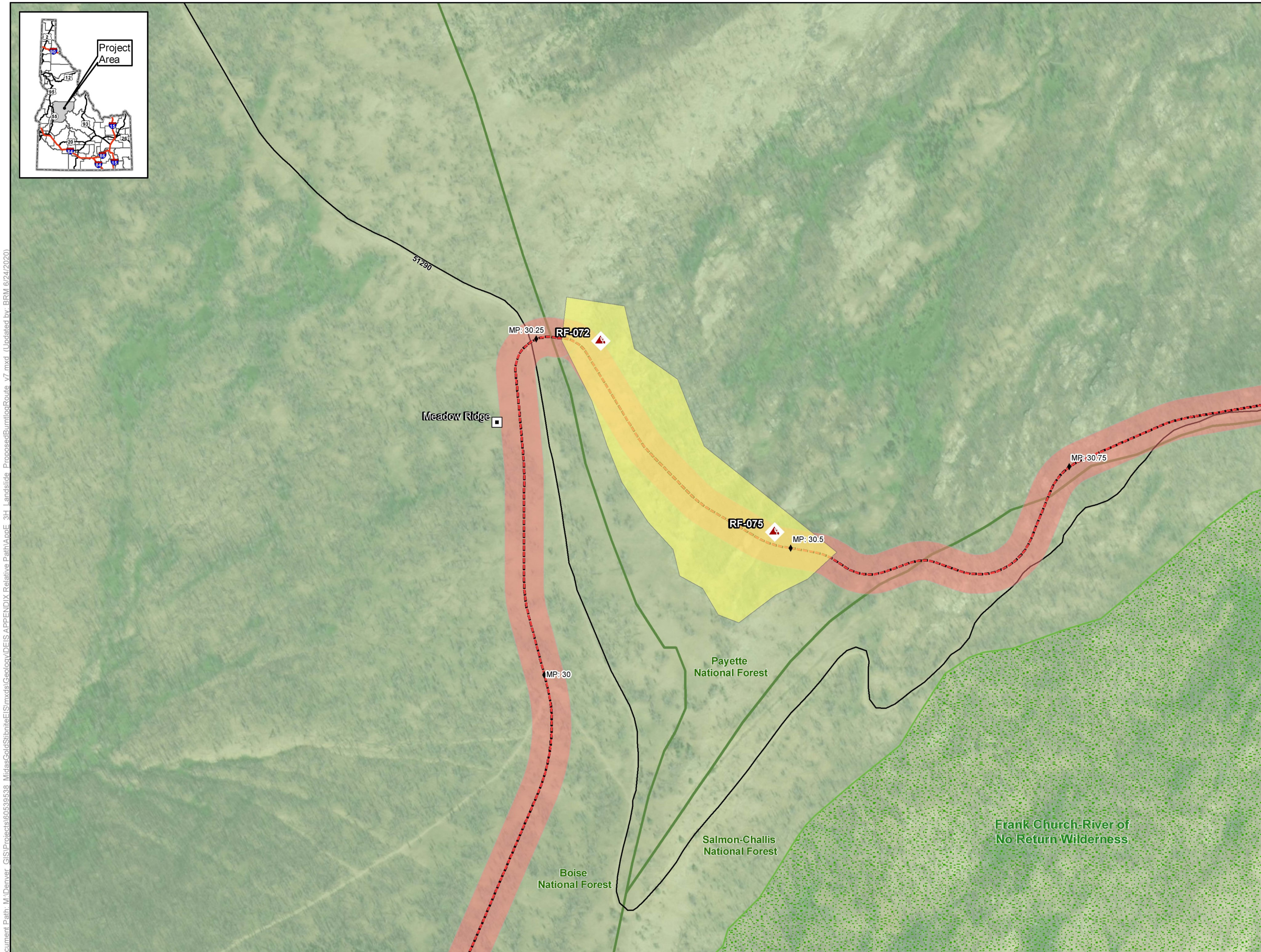


LEGEND

Landslide Features

- Landslide or Rock Fall Area
- Creek, Seep or Wet Area
- Rock Fall Area

Project Components*

Access Roads and Trail System

- Burntlog Route 150 ft Corridor
- Mile Point
- Burntlog Route New

Other Features

- U.S. Forest Service
- Wilderness
- Road

Surface Management Agency

- U.S. Forest Service

*Project Components are associated with Alternative 1

0 200 400 Feet

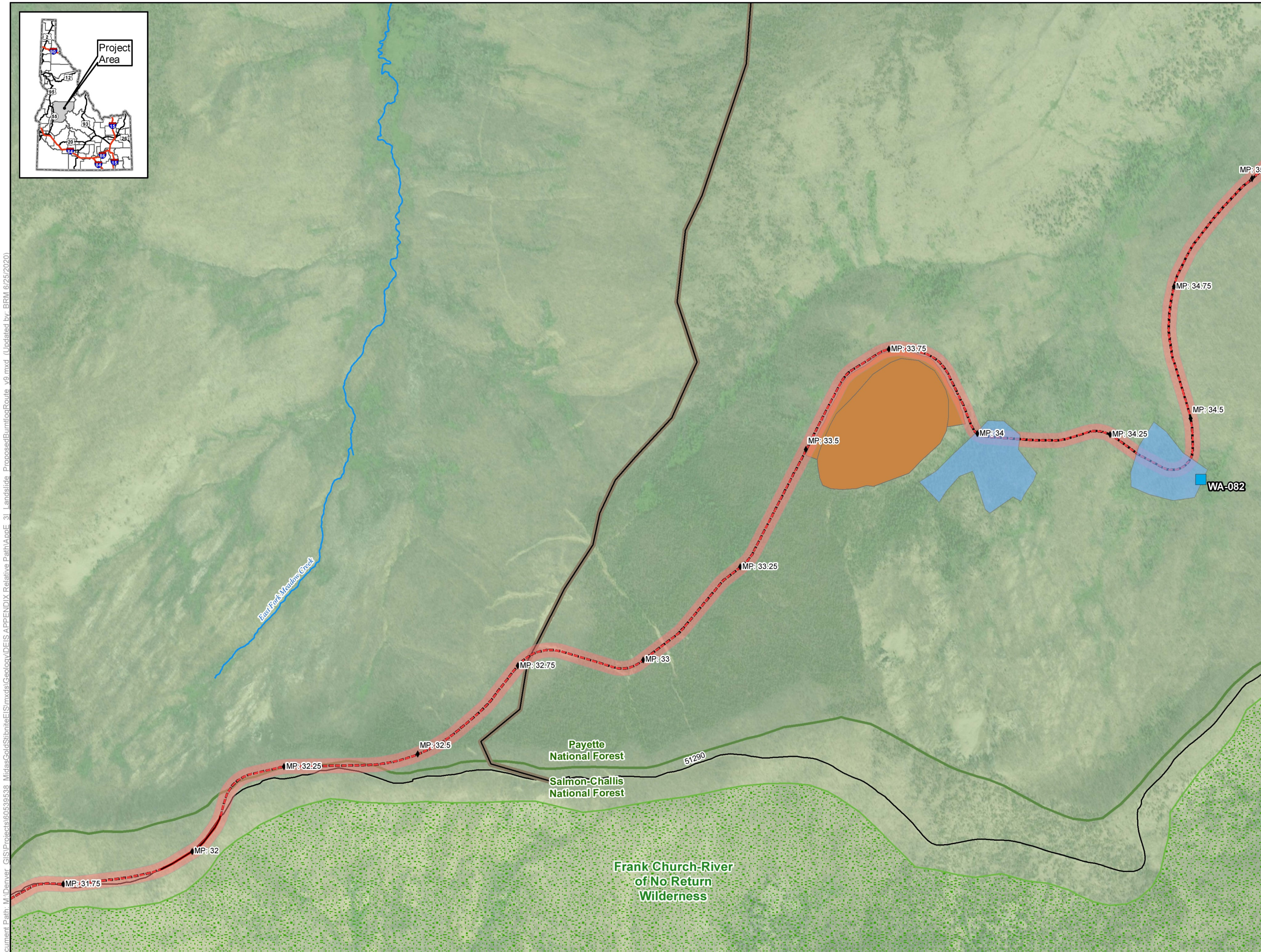
1 inch = 350 feet when printed at 11x17

N

Plate 3H Proposed Burntlog Access Road GeoHazards

Base Layer: World Imagery from Esri
Other Data Sources: State of Idaho Geospatial Gateway (INSIDE Idaho); Boise National Forest; Midas Gold; Payette National Forest

Map Date: 6/24/2020



LEGEND

Landslide Features

- Landslide or Rock Fall Area
- Creek, Seep or Wet Area
- Rock Fall Area

Project Components*

Access Roads and Trail System

- Burntlog Route 150 ft Corridor
- Mile Point
- Burntlog Route New
- Burntlog Route Upgrade
- Cell Tower Access Road
- Burntlog Route Borrow Source

Other Features

- U.S. Forest Service
- Wilderness
- Road
- Stream/River

Surface Management Agency

- U.S. Forest Service

*Project Components are associated with Alternative 1

0 500 1,000 Feet

1 inch = 900 feet when printed at 11x17

Plate 3I Proposed Burntlog Access Road GeoHazards

Base Layer: World Imagery from Esri
Other Data Sources: State of Idaho Geospatial Gateway (INSIDE Idaho); Boise National Forest; Midas Gold; Payette National Forest

Map Date: 6/25/2020

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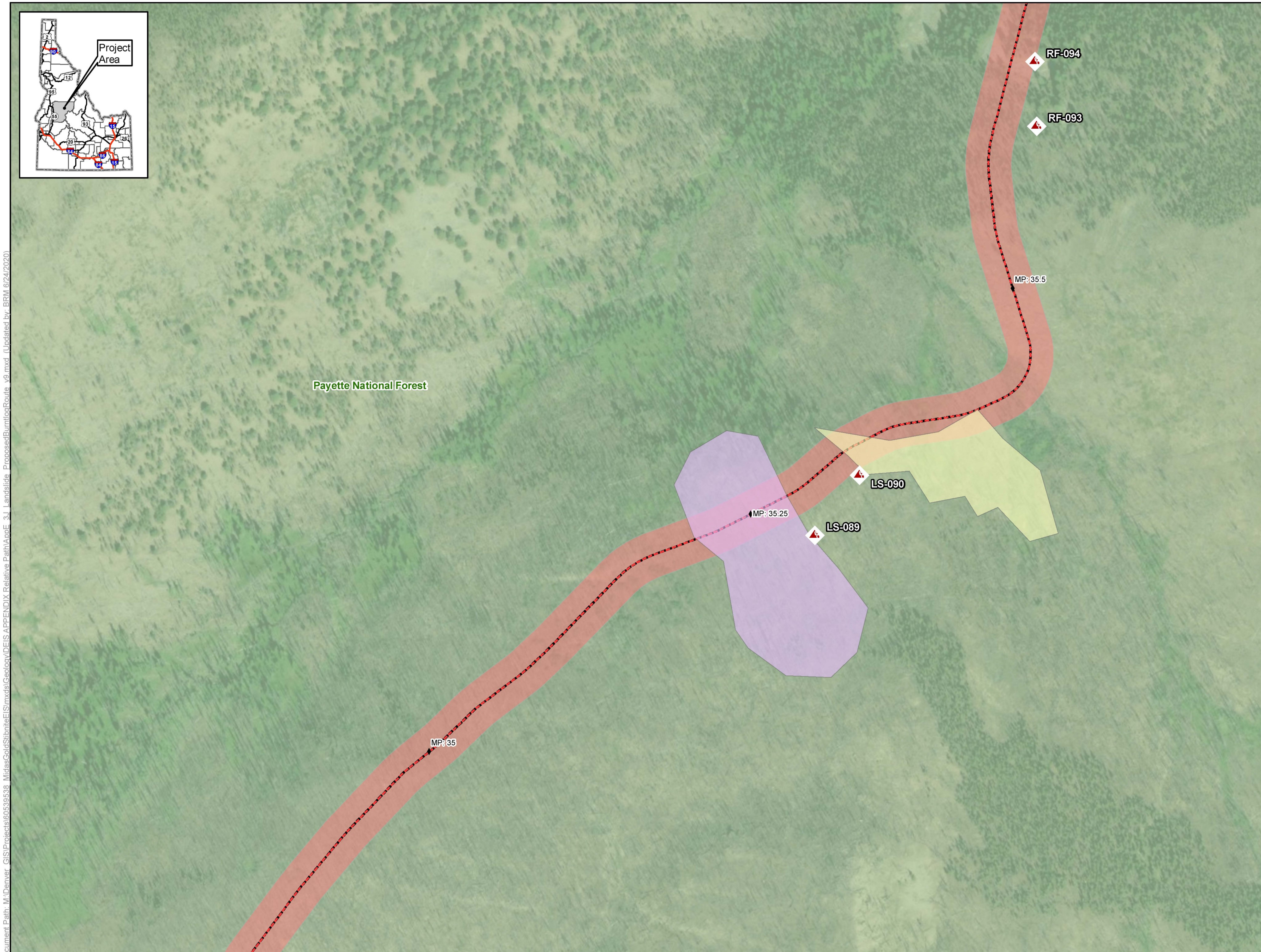


LEGEND

Landslide Features

- Landslide or Rock Fall Area
- Creek, Seep or Wet Area
- LS-089
- LS-090

Project Components*

Access Roads and Trail System

- Burntlog Route 150 ft Corridor
- Mile Point
- Burntlog Route New

Other Features

- U.S. Forest Service

Surface Management Agency

- U.S. Forest Service

*Project Components are associated with Alternative 1

0 150 300 Feet

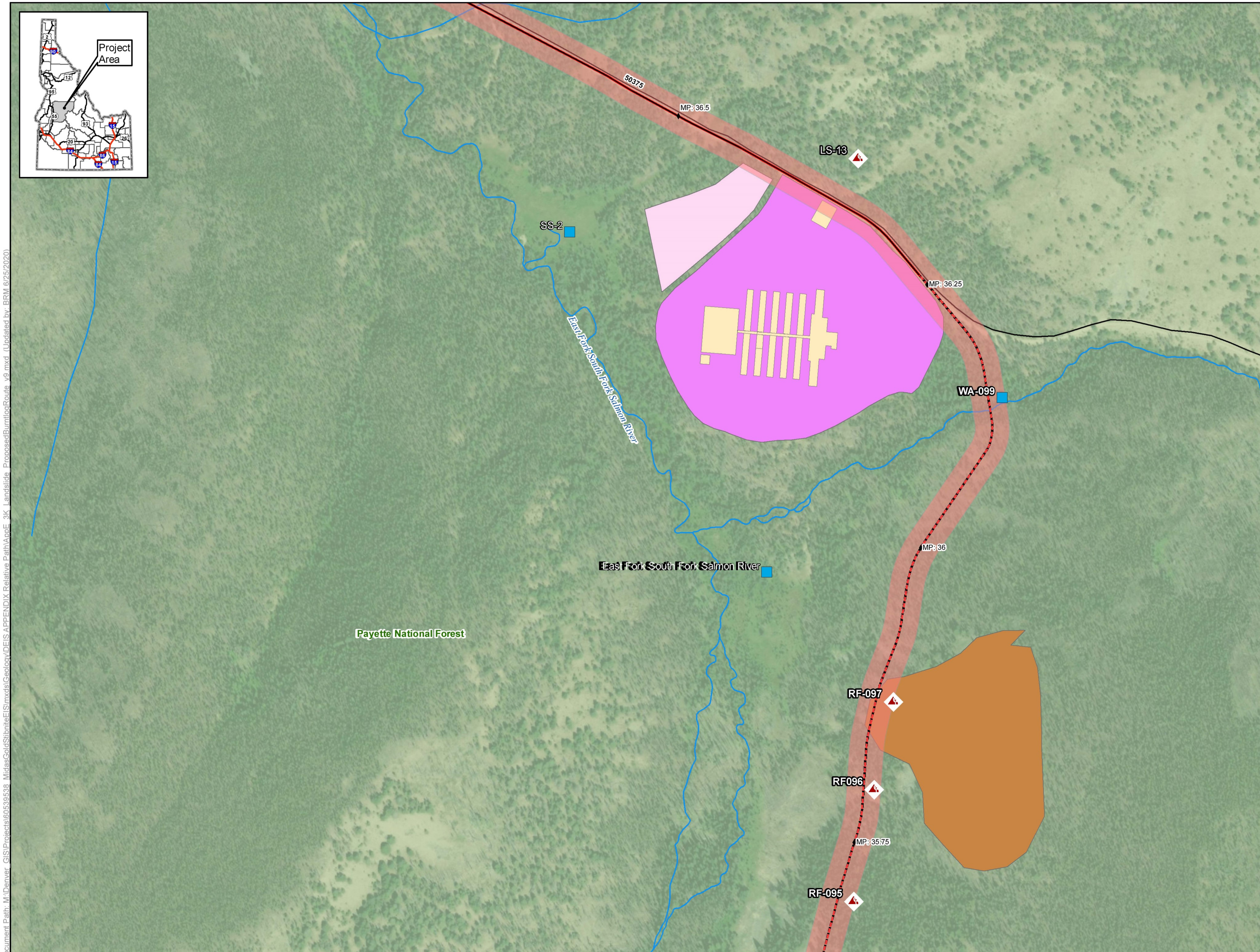
1 inch = 300 feet when printed at 11x17

N

Plate 3J Proposed Burntlog Access Road GeoHazards

Base Layer: World Imagery from Esri
Other Data Sources: State of Idaho Geospatial Gateway (INSIDE Idaho); Boise National Forest; Midas Gold; Payette National Forest

Map Date: 6/24/2020



LEGEND

Landslide Features

- Landslide or Rock Fall Area
- Creek, Seep or Wet Area

Project Components*

Mine Site

- Growth Media Stockpile
- Worker Housing Facility
- Infrastructure

Access Roads and Trail System

- Burntlog Route 150 ft Corridor
- Mile Point
- Burntlog Route New
- Burntlog Route Upgrade
- Burntlog Route Borrow Source

Other Features

- U.S Forest Service
- Road
- Stream/River

Surface Management Agency

- U.S. Forest Service

*Project Components are associated with the Plan

0 200 400 Feet

1 inch = 400 feet when printed at 11x17

N

Plate 3K Proposed Burntlog Access Road GeoHazards

Base Layer: World Imagery from Esri
Other Data Sources: State of Idaho Geospatial Gateway (INSIDE Idaho); Boise National Forest; Midas Gold; Payette National Forest

Map Date: 6/25/2020

LEGEND

Landslide Features

- Landslide or Rock Fall Area
- Creek, Seep or Wet Area

Project Components*

Mine Site

- Open Pit
- Ore Processing Facilities/ Mine Support Infrastructure
- Tailings Storage Facility
- Development Rock Storage Facility
- Growth Media Stockpile
- Worker Housing Facility
- Explosives Storage
- Rapid Infiltration Basin Area
- Infrastructure
- Helicopter Pad
- Haul Road

Access Roads and Trail System

- Burntlog Route 150 ft Corridor
- Mile Point
- Burntlog Route New
- Burntlog Route Upgrade
- Cell Tower Access Road
- Burntlog Route Borrow Source

Utilities

- Cell Tower Option

Other Features

- U.S. Forest Service
- Road
- Stream/River

Surface Management Agency

- Private
- U.S. Forest Service

*Project Components are associated with Alternative 1

0 450 900 Feet

1 inch = 800 feet when printed at 11x17

Plate 3L Proposed Burntlog Access Road GeoHazards

Base Layer: World Imagery from Esri
Other Data Sources: State of Idaho Geospatial Gateway (INSIDE Idaho); Boise National Forest; Midas Gold; Payette National Forest

Map Date: 6/25/2020

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E-2: Geohazards Desktop Study, Access Routes

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Date: **May 20, 2020**

To: **Anne Baldridge, AECOM**

From: **Paul Dworian, AECOM**

Subject: **Stibnite Gold Project EIS – Geohazards Desktop Study, Access Routes**

1.0 Introduction

A desktop study of geohazards was conducted for the Burntlog Route transportation corridor and Yellow Pine Route transportation corridor (which includes Johnson Creek Road [County Road (CR) 10-413] and the Stibnite Road segment of McCall-Stibnite Road [CR 50-412]) to provide a general comparison of identified geohazards along both corridors. This information supports the Stibnite Gold Project Environmental Impact Statement (EIS). The desktop study is based on the following sources of information:

- STRATA. 2016. Geologic Hazard Assessment, Burntlog Access Road Project
- Mears and Wilbur Engineering. 2013. Avalanche Hazard Assessment
- Supplemental Response to Request for Additional Information (RFAI) 83 Regarding Johnson Creek/Stibnite Road (Yellow Pine Route) for Primary SGP Mine Access (2019)
- Mears, A.I. 1992. Snow-Avalanche Hazard Analysis for Land-Use Planning and Engineering
- Google Earth imagery (2020)

2.0 Methods

Imagery from Google Earth (2020) was examined using the following criteria to identify probable landslides, rockfalls, and avalanche paths along the two transportation corridors:

- Landslides – Landslide hazards were identified along existing road cuts based on vegetation signatures and evidence of migrating slope failures up-slope of the road prism. Data from STRATA (2016) was considered along both existing and proposed roads.
- Rockfalls – Rockfall hazards were identified along existing road cuts based on vegetation signatures, substrate color, and evidence of slope erosion upslope of the existing road prism. Information from STRATA (2016) was considered along both existing and proposed roads.
- Avalanche Paths – Avalanche paths were identified based on vegetation signatures and supplemented with slope calculations (30 to 45 degrees) using measurement tools in Google Earth and compared to data from Avalanche Hazard Assessment (Mears and Wilbur Engineering 2013) and Supplemental Response to RFAI 83 regarding the Yellow

Pine Route. Methods for identification of avalanche terrain, as described in Mears 1992, were considered and implemented as appropriate for this desktop study.

Locations of identified hazards along each corridor were assigned a unique identifier with the following information: latitude, longitude, horizontal distance of estimated impact to the road prism, and estimated acreage of the feature. The coordinate identifier locations represent the estimated center of the feature. All calculations and values were derived from mapping and measurement functions included in Google Earth (2020). Values are presented for comparison purposes only. Future field investigations may identify additional geohazards not included in this analysis. Figure 1 depicts identified geohazards based on all sources of information and this desktop study report along both the Burntlog and Yellow Pine routes.

3.0 Burntlog Route Transportation Corridor

The Burntlog Route identified geohazards are listed by road segment in four tables: **Table 1** lists rockfalls along Burntlog Route between Landmark to Burntlog Saddle; **Table 2** lists landslides and rockfalls between Burntlog Saddle and the connection with Thunder Mountain Road (National Forest System Road [FR] 50375); and **Table 3** lists landslides and rockfalls along Thunder Mountain Road to the mine site. In addition, Weppner et al. (2017) describes an area south of the crossing of East Fork of Burntlog Creek that encompasses at least 2 avalanche paths that intersect with the road listed in **Table 4**.

Table 1 Rockfalls, Landmark to Burntlog Saddle

Geohazard Feature Designation	Latitude	Longitude	Length of Road Impacted (feet)	Area (acres)
BLRF005	44°41'14.38"N	115°27'44.07"W	344	<0.1
BLRF006	44°41'36.92"N	115°27'52.89"W	151	<0.1
BLRF001	44°39'45.83"N	115°29'28.51"W	123	<0.1
Total	N/A	N/A	**618**	**<1.0**

Table Source: STRATA 2016

Table Notes:

BLRF = Burntlog Route Rockfall

N/A = not applicable

AECOM

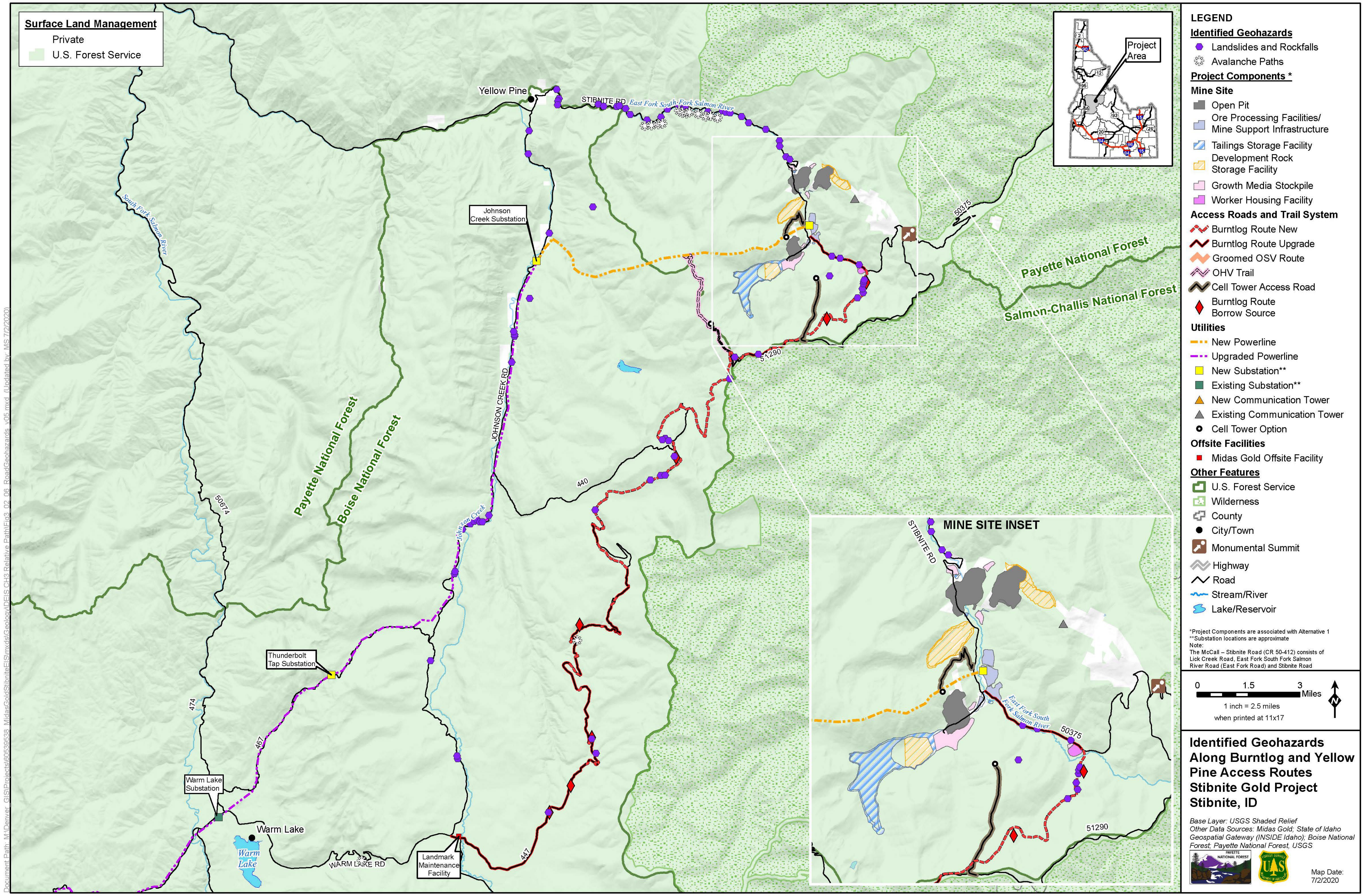

Figure 1 **Identified Geohazards along Burntlog and Yellow Pine Access Routes**

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Table 2 Landslides and Rockfalls, Burntlog Saddle to Connection with Thunder Mountain Road

Geohazard Feature Designation	Latitude	Longitude	Length of Road Impacted (feet)	Area (acres)
LS-002	44°48'9.57"N	115°25'36.62"W	1,062	1.5
RF-016 and RF-017[1]	44°47'25.70"N	115°27'36.10"W	1,800	3.0
RF-023	44°48'16.43"N	115°25'14.39"W	504	0.93
RF-024	44°48'16.82"N	115°25'4.66"W	402	1.1
RF-026	44°48'45.15"N	115°24'44.30"W	1,237	6.0
RF-029	44°49'9.28"N	115°24'55.69"W	468	1.91
RF-031	44°49'12.63"N	115°25'3.14"W	200	1.3
RF-032	44°49'10.74"N	115°25'9.22"W	400	1.01
LS-068A	44°50'41.57"N	115°22'42.68"W	1,100	241
RF-072	44°51'14.80"N	115°22'30.46"W	1,500	5.0
RF-075	44°51'18.16"N	115°21'39.92"W	800	5.0
LS-089 and LS-090[1]	44°52'41.09"N	115°18'4.67"W	650	1.5
RF-093	44°52'48.83"N	115°17'52.27"W	300	3.0 total for RF-093 through RF-097[1]
RF-094	44°52'54.86"N	115°17'53.80"W	242	
RF-095	44°53'2.60"N	115°17'50.82"W	100	
RF-096	44°53'5.74"N	115°17'50.33"W	208	
RF-097	44°53'8.31"N	115°17'49.08"W	100	
Total	N/A	N/A	**11,073**	**272.2**

Table Notes:

1 Presented as per STRATA 2016 (combined geohazard features)

LS = landslide

RF = rockfall

N/A = not applicable

Table 3 Landslides and Rockfalls, Thunder Mountain Road to Mine Site

Geohazard Feature Designation	Latitude	Longitude	Length of Road Impacted (feet)*	Area (acres)*
LS-12	44°53'15.61"N	115°19'3.67"W	2,400	200
LS-13	44°53'31.71"N	115°17'59.20"W	365	9.0
RF-099A	44°53'42.08"N	115°18'39.82"W	291	0.60
RF-100	44°53'45.48"N	115°18'57.82"W	296	0.9
Total	N/A	N/A	**3,352**	**210.5**

Table Notes:

* Estimated from Google Earth 2020

N/A = not applicable

Table 4 Avalanche Paths, Burntlog Route

Geohazard Feature Designation	Latitude	Longitude	Length of Road Impacted (feet)*	Area (acres)+
BL11	44°44'7.25"N	115°28'20.20"W	590	2.4

Table Source: Google Earth 2020; Weppner et al. 2017

Table Notes:

* Estimated from Google Earth 2020

4.0 Yellow Pine Route Transportation Corridor (Johnson Creek Road and Stibnite Road)

Table 5 lists identified landslides and rockfalls along Johnson Creek Road. **Table 6** lists identified landslides and rockfalls along Stibnite Road. **Table 7** lists identified avalanche paths along Stibnite Road. There were no avalanche paths identified along Johnson Creek Road.

Table 5 Landslides and Rockfalls, Johnson Creek Road

Geohazard Feature Designation	Latitude	Longitude	Length of Road Impacted (feet)	Area (acres)
JCL1	44°41'9.91"N	115°32'40.92"W	114	0.04
JCL2	44°41'14.48"N	115°32'41.47"W	186	0.05
JCL3	44°43'40.52"N	115°33'34.72"W	291	0.34
JCL4	44°45'52.14"N	115°32'40.36"W	300	0.06
JCL5	44°45'55.77"N	115°32'39.22"W	102	0.04
JCL6	44°46'59.84"N	115°32'21.71"W	222	0.19
JCL7	44°47'7.94"N	115°32'4.23"W	72	0.02
JCL8	44°47'11.86"N	115°31'56.02"W	114	0.05
JCL9	44°47'14.21"N	115°31'50.18"W	214	1.0
JCL10	44°47'10.67"N	115°31'43.67"W	94	0.10
JCR1	44°47'10.47"N	115°31'38.24"W	92	0.32
JCR2	44°47'20.37"N	115°31'23.96"W	836	1.96
JCR3	44°51'13.22"N	115°30'29.62"W	1,300	6.36
JCR4	44°51'52.67"N	115°30'22.47"W	189	0.19
JCR5	44°51'55.31"N	115°30'22.25"W	459	0.50
JCR6	44°52'0.13"N	115°30'23.99"W	135	0.23
JCL11	44°54'28.99"N	115°29'3.56"W	400	0.91
JCR7	44°56'30.72"N	115°29'45.30"W	6,162	76
JCR8	44°57'5.84"N	115°29'42.62"W	634	21.7
*Slump 1	44°52'50.01"N	115°29'48.54"W	6,300	192
*Slump 2	44°55'8.00"N	115°27'29.04"W	2,600	452
Total	N/A	N/A	**20,816**	**754**

Table Source: Google Earth 2020

Table Notes:

* Hazard not currently impacting road prism and not included in totals in summary table (**Table 8**)

JCL = Johnson Creek Road Landslide

JCR = Johnson Creek Road Rockfall

N/A = not applicable

Table 6 Landslides and Rockfalls, Stibnite Road

Geohazard Feature Designation	Latitude	Longitude	Length of Road Impacted (feet)	Area (acres)
SRL1	44°58'7.89"N	115°28'41.86"W	248	0.68
SRL2	44°57'54.14"N	115°28'37.47"W	411	2.18
SRR1	44°57'50.24"N	115°28'39.86"W	298	1.11
SRR2	44°57'44.64"N	115°28'40.80"W	456	4.6
SRL3	44°57'44.22"N	115°27'12.78"W	300	0.41
SRL4	44°57'41.26"N	115°27'1.29"W	85	0.31
SRL5	44°57'40.46"N	115°26'33.56"W	63	0.22
SRL6	44°57'41.54"N	115°26'27.57"W	306	0.68
SRR3	44°57'37.06"N	115°26'14.21"W	411	1.4
SRR4	44°57'27.78"N	115°26'4.92"W	176	1.36
SRL7	44°57'18.95"N	115°25'28.88"W	362	0.17
SRL8	44°57'22.73"N	115°24'58.97"W	327	0.61
SRL9	44°57'34.86"N	115°24'44.56"W	319	1.37
SRL10	44°57'39.55"N	115°24'20.91"W	302	0.54
SRR5	44°57'37.23"N	115°24'6.34"W	1,033	0.99
SRR6	44°57'29.77"N	115°23'17.29"W	812	2.97
SRR7	44°57'30.42"N	115°22'46.14"W	369	3.30
SRR8	44°57'28.11"N	115°22'39.08"W	207	0.42
SRR9	44°57'27.30"N	115°22'30.01"W	845	2.17
SRR10	44°57'21.41"N	115°22'5.77"W	1,000	3.62
SRR11	44°57'11.62"N	115°21'50.29"W	276	0.73
SRL11	44°57'1.21"N	115°21'13.76"W	227	0.75
SRL12	44°56'43.31"N	115°20'44.98"W	354	0.61
SRL13	44°56'18.83"N	115°20'31.75"W	496	0.21
SRL14	44°56'34.88"N	115°20'44.46"W	222	0.47
SRL15	44°56'14.44"N	115°20'24.16"W	604	3.37
Total	N/A	N/A	**10,509**	**35.3**

Table Source: Google Earth 2020

Table Notes:

SRL = Stibnite Road Landslide

SRR = Stibnite Road Rockfall

Table 7 Avalanche Paths, Stibnite Road

Geohazard Feature Designation	Latitude	Longitude	Length of Road Impacted (feet)*	Area (acres)
AvCh1	44°57'31.71"N	115°24'19.63"W	1,137	1.28
AvCh2	44°57'28.63"N	115°24'12.02"W	1,800	6.50
AvCh3	44°57'27.98"N	115°24'3.41"W	1,300	3.11
AvCh4	44°57'29.41"N	115°23'57.59"W	2,900	8.44
AvCh5	44°57'26.34"N	115°23'38.40"W	3,820	11.43
AvCh6	44°57'22.40"N	115°23'21.93"W	2,440	9.29
AvCh7	44°57'23.18"N	115°23'11.43"W	3,487	16.42
AvCh8	44°57'20.01"N	115°22'57.18"W	3,660	21
AvCh9	44°57'9.72"N	115°25'33.64"W	743	2.4
AvCh10	44°57'10.44"N	115°25'19.23"W	3,204	18.49
AvCh11	44°57'12.22"N	115°25'4.62"W	1,500	6.35
AvCh12	44°57'12.79"N	115°24'55.82"W	1,052	3.43
Total	N/A	N/A	**27,043**	**108.1**

Table Source: Mears and Wilbur Engineering (2013); Supplemental Response to RFAI 83

Table Notes:

* Distance is total length of avalanche path—impacts to road prism are described in Mears and Wilbur Engineering (2013) and Supplemental Response to Request for Additional Information (RFAI) 83 regarding Johnson Creek/Stibnite Road (Yellow Pine Route) for primary SGP Mine Access

N/A = not applicable

5.0 Summary of Geohazards – Transportation Corridors

Table 8 summarizes total geohazards identified along the Burntlog and Yellow Pine Route transportation corridors.

Table 8 Total Identified Geohazards along Burntlog and Yellow Pine Routes

Access Route	Landslides and Rockfalls			Avalanche Paths		
	Total Number	Length of Road Impacted (feet)	Area (acres)	Total Number	Length of Road Impacted (feet)	Area (acres)
Burntlog Route	**26**	15,043	482.5	**2**[2]	590	2.4
Yellow Pine Route: Johnson Creek and Stibnite Road	**45**[1]	22,425[1]	145.3[1]	**12**	27,043	108

Table Notes:

1 Total does not include two slump features listed on **Table 5** for Johnson Creek Road. The slumps are not currently impacting the road prism.

2 Weppner et al. 2017 describes an area with “two or three” avalanche paths south of the road crossing at East Fork Burntlog Creek.

An important difference in types of avalanche hazards between Stibnite Road and Burntlog Route relates to the types of avalanche regimes. Stibnite Road is at the base of large avalanche paths that may have a 5-year return interval with associated impacts. The Burntlog Route is closer to the avalanche starting zone and may contain more frequent, but smaller-size avalanches as compared to Stibnite Road (personal communication, T. Leeds, USFS via email May 5, 2020 [Forest Service 2020]).

In addition to the two corridors described above, the U.S. Forest Service notes an avalanche path along Warm Lake Road (CR 10-579) that would be part of the transportation corridor common to both the Burntlog and Yellow Pine routes. This feature was observed in Google Earth during the desktop study and the location is depicted on Figure 3.2-6 (see Chapter 3.2, Geologic Resources and Geotechnical Hazards).

E-3: Recent Dam Failures and Additional Regulatory Information

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APPENDIX E-3

RECENT DAM FAILURES AND ADDITIONAL REGULATORY INFORMATION

December 2019

INTRODUCTION

In the last five years there have been several notable tailings dam failures. These events warrant discussion because such events can inform regulatory decisions going forward. In addition, the United States Forest Service (Forest Service) has made the decision to regulate the tailings dam in accordance with the State of Idaho regulations. It is important to note that there are other regulatory standards extant, and application would be voluntarily as best practices.

RECENT TAILINGS DAM FAILURES

Post-failure investigations by independent industry experts were conducted in the Mount Polley (2014) and Fundão (2015) tailings dam failures. Both events are discussed here because they provide useful examples of the chain of events that can lead to a catastrophic failure of tailings dams.

Mount Polley Mine, British Columbia, Canada

Mount Polley was a copper/gold open pit mine in British Columbia, Canada. On August 4, 2014, a breach occurred at the Perimeter Embankment of the Tailings Storage Facility (TSF). The breach occurred due to the failure of an underlying glacial lacustrine layer that was not appropriately characterized or accounted for in engineering design (Mining and Mineral Resources Division 2015). The TSF breach released an estimated 10.6 million cubic meters of supernatant fluid, 13.8 cubic meters of tailings slurry. This translates into approximately 17 million cubic meters of water, and 8 million cubic meters of solids (Resource Works 2019). This is the second largest mine waste spill on record (Bryne et al. 2018).

This material flowed into the adjacent Polley Lake, and then down the 9-kilometer Hazeltine Creek channel to Quesnel Lake, causing 236 hectares (ha) of varying degrees of erosion and deposition in the creek valley, as well as deposition of tailings in Polley and Quesnel Lakes (Golder Associates Limited 2015). Only 20 percent of the materials in the tailings pond were released. There was no loss of human life.

Source: Mining and Mineral Resources Division 2015

Figure 1 Mount Polley Before (July 24, 2014)

Source: Mining and Mineral Resources Division 2015

Figure 2 Mount Polley After (August 5, 2014)

At the immediate discharge location, tailings were estimated to be 11 to 12 feet thick. Along Hazeltine Creek, the debris flow scoured some areas to bedrock (estimated 1.2 million cubic meters of material lost) and tailings deposits covered other areas (estimated 1.6 million cubic meters of material deposited). Authorities estimated that Quesnel Lake received almost 19 million cubic meters of tailings, eroded material, and discharged water. The discharge destroyed the aquatic habitat in Hazeltine Creek. It also affected the water quality in Quesnel Lake and Polley Lake through increased turbidity and copper content. Initial assessments within the first year after the release found relatively little permanent or ongoing impact on aquatic life or terrestrial life (Golder Associates Limited 2015).

Overall, water quality impacts are considered low with copper, and to a lesser extent vanadium, being the only elements of concern (Bryne et al. 2018). Although elevated aqueous copper was evident in Hazeltine Creek, this is considered a relatively minor perturbation to a watershed with naturally elevated stream copper concentrations. Hazeltine Creek channel was completely rebuilt by May 2015 to control erosion, and this included removing spilled tailings from the channel. The creek has been running clear since May 2015 (Bryne et al. 2018).

The tailings in Quesnel Lake appear to be physically and chemically stable and are not releasing metals to the lake water (Canadian Press 2019). All water and fish consumption restrictions outside the area of immediate impact (the mouth of Hazeltine Creek) were removed from Quesnel Lake and Quesnel River by Interior Health in August of 2014. The last restrictions were removed from the area of immediate impact in July of 2015, and there have been no restrictions or notices of concern from Interior Health about the water quality of Quesnel Lake related to Mount Polley since that time (Canadian Press 2019).

The causes of the failure were as follows (Lyu et al. 2019):

(1) Insufficient analysis of hydrological and geological conditions: the tailings dam was located on a glaciolacustrine soils. The load applied by the dam exceeded the bearing capacity of the foundation materials, causing shear damage to the dam foundation material. The designer did not account for the fact that the tailings dam would increase the load on the foundation

(2) Inadequate design: the design did not consider the local hydrometeorological conditions, and the embankment slope was too steep for 1.3 H: 1 V.

(**3) Inadequate regulation and regulatory supervision:** faults were found with the regulations and overall supervision of the work.

Fundão Tailings Dam, Minas Gerais, Brazil

On November 5, 2015, the Fundão Tailings Dam in Minas Gerais, Brazil collapsed. Its crest had reached 110 meters. The tailings were from the Germano iron ore mine.

Source: McCrae 2016

Figure 3 The Fundão Tailings Dam in 2015 before its Failure

The Fundão embankment failure released 32 million cubic meters of tailings (Fundão Tailings Dam Review Panel 2016). The tailings release ultimately traveled 620 kilometers downstream, following the Goalbox and Dooce Rivers, to reach the Atlantic Ocean. The town of Bento Rodrigues was immediately downstream of the facility; over a dozen people lost their lives, an estimated 600 families were displaced, and the drinking water supply to over 400,000 people was disrupted. The tailings destroyed an estimated 3,000 to 4,000 acres of riparian forest and destroyed substantial aquatic habitat.

More than three years later, fishing is still forbidden at several locations because of high concentrations of heavy metals in the water (Lima 2019).

The Fundão investigative panel determined that a chain of decisions made during operations ultimately led to the failure of the embankment (Fundão Tailings Dam Review Panel 2016). First, damage to the original starter dam resulted in a change of design that allowed for an increase of saturation in the facility. Second, a series of unplanned deviations during construction resulted in deposition of fine-grained tailings at unintended locations, and the subsequent raising of the embankment above these tailings. This unintended deposition was a result of a design flaw—an inadequate concrete structure below the embankment that prevented the original design from being implemented—but also a deviation in tailings and water management over several years, in which water could encroach much closer to the crest of the embankment than originally planned (Fundão Tailings Dam Review Panel 2016).

The stresses placed on the fine-grained materials underlying the embankment caused them to shift, ultimately weakening the embankment (Fundão Tailings Dam Review Panel 2016). Ninety minutes before the failure a series of small earthquakes occurred, and these seismic shocks triggered the failure. The panel was careful to note that while the seismic event was the trigger mechanism, it was not the ultimate cause of the failure.

Other Failures and Industry Trends

Discussions and analyses of individual mine failure are relevant, it is also important to look at overall failure trends. There have been more than 300 tailings dam failures worldwide between 1928 and 2015 (Lyu et al. 2019), which includes the two failures discussed above. Of these failures:

- **21.6 percent were caused by seepage:** The water stored behind a dam always seeks a means of escape. Therefore, too much seepage can cause piping and erosion of the structures.
- **20.6 percent was by overtopping:** Overtopping is when too much water behind the dam spills over the top of the dam. The flow of water erodes the dam, leading to failure. This is usually caused by large storm events.
- **17 percent were caused by earthquake:** Ground shaking can cause structures to temporarily weaken and fail.
- **17.3 percent by foundation failures:** This is the failure of foundation materials underload and was the cause of the failure at Mount Polley.
- **23.5 percent were from other causes:** In many cases the cause is unknown, likely because the failures were not properly investigated, or no specific cause could be determined.

Failures of tailings dams are closely related to the state of the country's economy (Lyu et al. 2019). Most of the tailings dam breakages in developed countries occurred decades ago. In recent years, the proportion of tailings dam failures in developing countries has been relatively high. For reference, there are approximately 3,500 tailings dams worldwide.

Relevant Regulatory Programs

International Council on Mining and Metals (ICMM)

Both failures involved a combination of design, construction, and operational factors. Industry best practice is evolving to better understand these failure mechanisms and to better prevent such incidents.

An eight-person panel backed by the International Council on Mining and Metals (ICMM), the United Nations Environment Programme (UNEP) released draft standards for tailings dams in November 2019 (Global Tailings Review 2019). The standards are open for public comment until the end of the year and are set to be finalized by 2020. These new design principals include:

- Design, construct, operate and manage the tailings facility on the presumption that the consequence of failure classification is ‘Extreme’, unless this presumption can be rebutted.
- Develop a robust design that integrates the knowledge base and minimizes the risk of failure for all stages of the tailings facility lifecycle.
- Adopt design criteria that minimize risk.
- Build and operate the tailings facility to minimize risk.
- Design, implement and operate monitoring systems.

Mining Association of Canada (MAC)

Following the 2014 tailings failure at the Mount Polley Mine in British Columbia, the Mining Association of Canada (MAC) launched a comprehensive internal and external review of their Tailings Guide. The resulting recommendations included “a risk-based ranking classification system for non-conformances and have corresponding consequences.” The recommendations also asked that guidance on risk assessment methodology be included (Mining Association of Canada 2019).

Of note, the current edition includes a risk-based approach, “managing tailings facilities in a manner commensurate with the physical and chemical risks they may pose.” The revised guidance specifies:

- Regular, rigorous risk assessment;
- Application of most appropriate technology to manage risks on a site-specific basis (best available technology);
- Application of industry best practices to manage risk and achieve performance objective (best available performance); and
- Use of rigorous, transparent decision-making tools to select the most appropriate site-specific combination of best available technology and location for a tailing’s facility.

United States Forest Service (Forest Service)

Regulatory jurisdiction over a tailings embankment and facility depends largely on the location. Tailings facilities located fully or in part on Federal land administered by the Forest Service are analyzed and approved as part of the review process for the mining plan of operations. Additionally, a bond would be required for any reclamation requirements associated with the tailings embankment.

Mineral regulations specifically give the Forest Service the ability to regulate tailings: “All tailings, dumpage, deleterious materials, or substances and other waste produced by operations shall be deployed, arranged, disposed of or treated as to minimize adverse impact upon the environment and forest surface resources” (36 CFR 228.8(c)).

While Forest Service guidance contains prescriptive requirements for how tailings embankments must be constructed, the Federal Emergency Management Agency (FEMA) has developed the National Dam Safety Program, which includes standards that are applicable to structures constructed on federal land which includes tailings embankments. The National Dam Safety Program provides a conceptual framework that includes requirements for site investigation and design, construction oversight, operations and maintenance, and emergency planning.

The Forest Service would require that the tailings storage facility adhere to National Dam Safety Program guidelines. This is included in the "Adherence to National Dam Safety Program Standard" part of the "Mitigation Effectiveness" section as a required mitigation on federal land.

The National Dam Safety Program is a partnership of states, federal agencies and other stakeholders to encourage and promote the establishment and maintenance of effective federal and state dam safety programs to reduce the risk to human life, property, and the environment from dam related hazards, including the following:

- **Federal Guidelines for Dam Safety Risk Management (FEMA P-1025)**
  Guidelines for implementing risk-informed decision making in a dam safety program (FEMA 2015).
- **Emergency Action Planning for Dam Owners (FEMA 64)**
  Guidelines to encourage strict safety standards in the practices and procedures employed by federal agencies or required of dam owners regulated by the federal agencies. Guidelines to encourage emergency action planning for dams to help save lives and reduce property damage (FEMA 2013a).
- **Inundation Mapping of Flood Risks Associated with Dam Incidents and Failures (FEMA P-946)**
  The purpose of this document is to provide dam safety professionals with guidance on how to prepare dam breach inundation modeling studies and conduct mapping that can be used for multiple purposes, including dam safety, hazard mitigation, consequence evaluation and emergency management including developing EAPs. This guidance is intended to provide a consistent approach that can be applied across the country (FEMA 2013b).
- **Selecting and Accommodating Inflow Design Floods for Dams (FEMA P-94)**
  Guidelines that provide procedures for selecting and accommodating inflow design floods (FEMA 2013c).
- **Earthquake Analyses and Design of Dams (FEMA 65)**
  Guidelines that provide the basic framework for the earthquake design and evaluation of dams (FEMA 2005).
- **Federal Guidelines for Dam Safety (FEMA 93)**
  These guidelines encourage strict safety standards in the practices and procedures employed by federal agencies or required of dam owners regulated by the federal agencies (FEMA 2004).

State of Idaho

Tailings dams are regulated by IDWR in the same manner as water storage projects, with an additional provision that a surety bond be secured by the owner payable to IDWR for reclamation of the project works. Design and construction requirements for Mine Tailings Impoundment Structures are described in the Idaho Administrative Procedure Act Rule 37.03.05. The Forest Service has indicated they intend to abide by the State of Idaho Administrative Procedure Act Rules for dam safety. The Forest Service cannot approve a plan of operations that violates an applicable law or regulation.

Industry Best Practices

The mining industry has adopted several industry standards and best practices that are equally or more restrictive than the requirements of the State of Idaho:

- **Risk-based design**. FEMA standards allow for risk-based design as an option (see for example FEMA P-94, Section 2.3.6, Risk— Informed Hydrologic Hazard Analysis [FEMA 2013c]), but do not require it, as these techniques were still evolving and yet to be widely used when FEMA's primary guidance was developed. A risk-based design approach can be used to "fine-tune" design parameters, but only when appropriate and within certain bounds.
- **Design for closure**. FEMA standards are largely silent on the issue of closure and post-closure of tailings facilities, instead focusing primarily on the design, construction, and operation of embankments.
- **Accountability**. FEMA standards require qualified personnel be used, but do not specify a single individual accountable for the design, construction, or management of the tailing's storage facility.
- **Change management**. FEMA includes various requirements for documentation; however, industry best practices include a strong focus on managing and evaluating deviations from the original design, construction, or operation plan.
- **Independent review**. One common feature in many of the industry best practices listed here is the use of independent technical review by an outside expert or panel of experts.

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