Jacobs

Hydraulics Report for the Reds Meadow Road Improvements Project

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DATE:	March 26, 2021
PROJECT NUMBER:	704630

3-26-21

Introduction

The purpose of this report is to document the existing and proposed hydrologic and hydraulic conditions associated with the Reds Meadow Road Improvement Project and to document the drainage design criteria used for final design.

Project Description

The Reds Meadow Road Project consists of improvements to an 8.3-mile corridor of roadway near the community of Mammoth Lakes, California. The road is situated in the southern reaches of the Sierra Nevada mountain range at an elevation that ranges from approximately 8,300' to 9,200' above mean sea level. The road begins at the intersection with Highway 203 at the Minaret Vista Entrance Station and terminates at the Reds Meadow Resort and Pack Station. The road is owned by the U.S. Forest Service and serves as the primary access point for the Reds Meadow Resort and Pack Station and Devil's Postpile National Monument, in addition to providing access to multiple campgrounds, day use parking areas, and trail heads. The roadway is only utilized during the summer tourist season. It is closed in the fall and re-opened in the spring. Winter maintenance activities such as plowing snow are not performed. The roadway has a 15-mph posted speed limit for the first 2.5 miles, then increases to 25 mph for the remainder of the corridor.

For the purposes of this memo, the project is broken into two separate portions: the 4R portion and the 3R portion. The upper 2.5 miles of the project is considered the 4R portion and will involve a complete reconstruction and widening of the roadway to two lanes. The term 4R stands for Resurfacing, Restoration, Rehabilitation and Reconstruction.

The lower 5.8 miles of the project is considered the 3R portion and will involve repair and rehabilitation measures to the existing pavement. Widening, reconstruction, and re-alignment work will not be performed to the 3R portion of the project. The term 3R stands for Resurfacing, Restoration, and Rehabilitation.

There are two additional components to the project: The Devils Postpile re-alignment and the Minaret Vista access road. For the purposes of this memo, the Devils Postpile re-alignment will be considered 4R work and will follow any 4R drainage criteria established for the project. The Minaret Vista access road will be considered 3R work and will follow any 3R drainage criteria established for the project.

See Appendix A for a location map that provides a visual representation of the project components described above. A vicinity map is also included in Appendix A.

Existing Conditions

4R (Upper 2.5 Miles). The existing roadway for the 4R portion consists of a paved surface of variable width; often only wide enough for a single vehicle. The roadway operates as a one-lane, two-way road with pullouts spaced periodically along the alignment that allow for vehicles going in opposite directions to pass each other. This 2.5 miles is on a longitudinal grade that averages approximately 8-9% as the roadway descends along the side of the mountain. The roadway moves down the mountain in a side-hill fashion with roadside cut slopes of approximately 1V:1.5H on the inboard side and roadside fill slopes of approximately 1V:1.5H on the outboard side. The surrounding terrain is mountainous with fair vegetative cover ranging from scattered grasses and brush to large coniferous forests.

The existing drainage facilities include informal roadside ditches coupled with multiple cross culverts along the alignment. Existing cross culvert types, sizes, and locations in the 4R segment are identified in the Culvert Discharge Summary in Appendix C. There are no formal gutters, ditches or catch basins. This roadway receives offsite runoff from the adjacent mountain. The total watershed flowing toward the road is approximately 680 acres. Flow from this watershed is dispersed along the alignment with portions passing under the road via cross culverts and portions passing over the road in a sheet flow manner. Onsite runoff either runs directly off the road or is collected in a roadside ditch and conveyed to a cross culvert where it passes under the road. Roadway cross slope varies along the entire corridor with certain portions super-elevated and certain portions in a normal crown.

3R (Lower 5.8 Miles). The existing roadway for the 3R portion consists of a paved surface that is approximately 22 feet wide. The roadway operates as a two-lane, two-way road with a single centerline stripe and no edge lines or formal shoulders. The surrounding terrain is relatively flat with meadows and forests on either side of the road. The longitudinal grade is relatively flat as the road meanders along the valley floor.

The existing drainage facilities include informal roadside ditches and cross culverts. There are no formal gutters, ditches or catch basins. This roadway receives offsite runoff from the adjacent mountain. Flow from this watershed is dispersed along the alignment with the majority passing under the road via cross culverts. Onsite runoff runs off the road and maintains a sheet flow pattern beyond the edge of pavement. There are no curbs or gutters for the majority of the road.

Proposed Conditions

4R (Upper 2.5 Miles). The proposed project for the upper 2.5 miles involves a complete reconstruction of the roadway. The road will be widened from a one-lane road with turnouts to a two-lane road (11-foot lanes with 1-foot shoulders). A 2-foot wide paved ditch/gutter on the inboard side of the road is being proposed to collect onsite and offsite drainage. Multiple retaining walls are being proposed. All existing cross culverts will be removed and replaced, and additional culverts and inlets will be placed where warranted. The posted speed limit will remain at 15 mph with a design speed of 20 mph.

3R (Lower 5.8 Miles). The proposed project for the 3R portion involves rehabilitating the existing pavement. No widening or re-alignments are proposed. All existing cross culverts were assessed at the 30% field review to determine if they should be replaced, repaired, or left as is. Of the 47 identified culverts, 8 will be kept and the remaining 39 will be replaced. Replaced culverts will be upsized to meet the CFL minimum of 24-inches for cross culverts if adequate cover is available. A summary of the findings from this exercise can be found in Appendix D.

The 30% field review also included an assessment of the overall drainage performance for the 3R corridor. The 30 percent site visit was performed during a rain event. This allowed the team to observe several drainage deficiencies along the corridor. Deficiencies included lack of roadside ditches, roadside berms prohibiting drainage, sags in the roadway that didn't have cross culverts, and concentrated flows traveling across the roadway. Solutions to these situations that have been included in the 95% design included adding new cross culverts, cutting in new ditches, removing roadside berms that block drainage, incorporation of paved ditches, shoulder breaks, and new curb added in select locations. Incorporation of the findings from the site visit into the 95% design package represent the extent of the drainage work for the 3R segment. No hydrologic or hydraulic calculations are being performed for this portion of the project.

Hydrology (4R)

Design Criteria

The Federal Lands Highway Project Development and Design Manual (PDDM) published by the U.S. Department of Transportation Federal Highway Administration is the primary guideline for Hydrologic criteria on the project. The edition dated March 2018 was used.

A Hydrologic analysis was performed to determine flows entering the proposed drainage facilities for the 4R portion of work. Hydrologic calculations were based on the guidelines presented in the document titled Highway Design Series No. 2, Second Edition, Highway Hydrology (HDS-2), published by the U.S. Department of Transportation Federal Highway Administration. The edition dated October 2002 was used. Peak flows were calculated using the Rational Method (Equation 5.28 from HDS-2). See below for Equation 5.28. Use of the rational method is dependent on the maximum size of watershed. Per Section 5.3.1 of HDS-2 the maximum drainage area should be smaller than 200 acres for the rational method to work properly. All watersheds within the project are below 200 acres in size. An evaluation of the topography revealed the largest drainage basin to be approximately 120 acres in size.

$$Q = \frac{1}{\alpha} C\, i\, A \qquad (5.28)$$

where,

- Q = the peak flow, m^3/s (ft^3/s)
- i = the rainfall intensity for the design storm, mm/h (in/h)
- A = the drainage area, ha (acres)
- C = dimensionless runoff coefficient assumed to be a function of the cover of the watershed and often the frequency of the flood being estimated
- α = unit conversion constant equal to 360 in SI units and 1 in CU units.

Rational Formula, Equation 5.28

Below is a summary of the components of the rational method as they relate to this project.

- Runoff Coefficient (C): Runoff coefficients were based on Table 5.7 of HDS-2. A value of **0.3** for the offsite runoff coefficient was used due to the steep un-improved nature of the existing terrain. A value of 0.90 was used for the onsite runoff coefficient, which is typical for paved surfaces such as the proposed roadway. Table 5.7 from HDS-2 is included in Appendix B.
- Rainfall Intensity (i): Values from NOAA Atlas 14 were used for rainfall intensity. A listing of the NOAA Atlas 14 rainfall data specific to this project's location is included in Appendix B. Rainfall intensity values were selected based on the time of concentration calculated. Time of concentrations for each basin were calculated simultaneous to the flow calculation using the Hydraulic Toolbox.
- Drainage Area (A): The watershed boundaries were determined from the following sources:
  - The projects topographic survey (1' contour interval), limited to within 50'+/- of roadway CL

- USGS Topographic Mapping (10-foot contour interval)
- Site walk performed in fall of 2018
- Google Earth imagery, last updated June 2016

The existing culverts in the 4R portion of work determined the locations of basins within the watershed. Analysis of the contours in the survey and mapping led to the conclusion that some of the collected water within each basin will flow directly to the culvert by bypassing the gutter. To address this the basins with very limited gutter capacity were separated into a culvert basin and a gutter basin to provide a more accurate representation of the drainage conditions for hydrologic analysis. Each culvert basin and gutter basin was named based on the station of the culvert it drains to.

The culvert basin boundaries were developed by using both the 1' contours from the topographic survey and the 10' contours from the USGS maps beyond the topographic survey. Due to the imprecise nature of the 10' contour mapping, the site walk photos and Google Earth were referenced to help adjust the boundaries to better reflect the behavior of water on the slope. The interior boundary of each gutter basin was developed by following the 1' contours to the limits of the topographic survey. The 10' contour mapping, site visit photos, and Google Earth imagery were then used to help develop the remaining portion of the interior boundary to intersect with the gutter basin. Portions of the roadway which drain toward the inboard side were included in the basins. The basin maps are included in Appendix B. Note, gutter basins were only delineated, and the subsequent hydrologic analysis were only performed for the gutters that did not have enough capacity to pass the entire culvert flow.

- Time of Concentration: The time of concentration was calculated in a manner consistent with Section 2.6, Travel Time, of HDS-2. The total time of concentration used for each basin was a summation of the Sheet Flow travel time (derived from HDS-2, Equation 2.6), Shallow Concentrated Flow travel time (derived from HDS-2, Equation 2.7), and Channel Flow (derived from HDS-2, Equation 2.8). Key values to be used in time of concentration calculations are listed below.
  - Maximum Sheet Flow Distance: **300 feet** (HDS-2, Section 2.6.2.1)
  - Mannings Roughness Coefficient (n) for Sheet Flow: **0.40** (HDS-2, Table 2.1, Woods, Light underbrush). Table 2.1 included in Appendix B.
  - Intercept Coefficient (k) for Shallow Concentrated Flow: **0.076** (HDS-2, Table 2.2, Forest with heavy ground litter). Table 2.2 included in Appendix B.
  - Mannings Roughness Coefficient (n) for Channels and Pipes: To be based on Table 3-4 of Hydraulic Engineering Circular No. 22 (HEC-22), Third Edition, Urban Drainage Design Manual, published by the U.S. Department of Transportation Federal Highway Administration. Table 3.4 included in Appendix B.
  - Minimum time of concentration: **5 minutes** (HEC-22, Section 7.2.2)

Calculations

Hydrologic calculations were performed using the FHWA Hydraulic Toolbox software, Version 4.2. A summary of the hydrologic calculations for both the culvert and gutter basins can be found in Appendix B. The Hydraulic Toolbox reports for each basin analyzed are included in Appendix F.

Hydraulics (4R)

Design Criteria

The Federal Lands Highway Project Development and Design Manual (PDDM) published by the U.S. Department of Transportation Federal Highway Administration is the primary guideline for Hydraulic criteria on the project. The edition dated March 2018 was used.

Drainage facilities in the 4R portion of the project were analyzed in a manner consistent with the guidelines in the PDDM. For the purposes of hydraulic analysis, the roadway is considered a Low-Standard Road consistent with the guidelines established in Section 7.1.6.1 of the PDDM. Low standard roads have a design speed less than 45 mph or an ADT less than 1,500 or are not designated a critical access road. The Reds Meadow Road has a design speed of 20 mph, an ADT of 450, and is not considered a critical access road, therefore it is classified as a Low-Standard Road.

Exhibit 7.1A in the PDDM provides a quick reference guide to the key pieces of hydraulic criteria associated with commonly encountered drainage facilities. Exhibit 7.1A is included in Appendix C. Key hydraulic criteria that were employed on this project are summarized below.

- Pavement Drainage
  - Design Storm: 10-year, 50-year in sumps
  - Spread: Shoulder and half of one travel lane
  - Inlet Clogging: 50% in sag or sump, 0% on grade

- Cross Culverts
  - Design Storm: 25-year
  - Minimum Size: 24-inches

- Inlets
  - Design Storm: 10-year, 50-year in sumps

Gutters. Gutters were analyzed using the Hydraulic Toolbox. An initial analysis of all gutters was performed using the entire flow going to the culvert. Based on this analysis several gutters did not have adequate capacity. A secondary analysis was performed for the gutters that didn't meet capacity. The secondary analysis used the capacity based on the gutter basin flow. See the hydrology section for an explanation of the gutter basin. Upon completion of the secondary analysis it was determined that all gutters adequately passed the design flows. A summary of the gutter calculations can be found in Appendix C. The Hydraulic Toolbox reports can be found in Appendix F.

Inlets. Multiple inlet types and configurations were evaluated to determine what types best meet the context of the project. Where the terrain allowed, CFL standard flared culvert ends were selected as the preferred entrance condition. When a flared end section was not feasible, a Caltrans Standard GMP inlet was selected to operate as a sump inlet beyond the edge of pavement. There are several locations where there is not enough space to accommodate a flared end section or a sump inlet. CFL on-grade inlets were utilized in these cases. Any bypass flow from the on-grade inlets was included in the evaluation of the downstream inlet. A CFL Standard 6A-6 inlet is being used for all on grade inlets. On grade inlets were analyzed using the FHWA Hydraulic Toolbox software, Version 4.2. The Caltrans GMP inlet was analyzed using equations 4-26 and 4-27 of HEC-22 for weir and orifice operation respectively. See Appendix C for a summary of the inlet calculations.

Culverts

The minimum proposed culvert diameter is 24 inches. All culverts were analyzed using the culvert Hydraulic Analysis Program HY-8 version 7.5 published by the Federal Highway Administration. According to the HDS-5, as noted in the FHWA HY-8 User Manual, "flared end sections made of either metal or concrete, are the section commonly available from manufacturers. From limited hydraulic tests they are equivalent in operation to a headwall in both inlet and outlet control." Based on this equivalency, headwalls were used as the inlet condition for the purposes of the HY-8 cross culvert analysis. Actual headwalls will not be utilized.

A summary of the culvert analysis can be found in Appendix C. All proposed culverts in the 4R segment adequately pass the design flows.

Existing culverts in the 3R portion of the project that are less the 24 inches in diameter will be removed and replaced with a standard sized culvert (24-inch minimum) if there is adequate cover between the crown of the culvert pipe and the roadway surface. If there is not adequate cover to accommodate a 24-inch culvert, the largest feasible culvert will be installed. In most situations this is an 18-inch culvert. Channel grading and roadway re-profiling will not be performed to accommodate larger culverts. A summary of the 3R culverts can be found in Appendix D.

Riprap/Energy Dissipators. All new culverts in the 4R portion of the project will have an energy dissipator installed at the outlet. If the culvert has a gentle slope (<10%) and is discharging on native ground a standard energy dissipator per CFL Standard Drawing C251-50 was utilized. If the culvert was discharging on a fill slope, a modified version of Standard Drawing C251-50 was used. In the modified version, the riprap class, width, and depth remain the same, but the length of dissipator is extended to the toe of fill slope. If the culvert was discharging on a steep slope (>1:1.5) gabion baskets were used to dissipate the energy. The baskets extend from the culvert outlet to the toe of slope. A detail showing the gabion basket configuration can be found in the G series of the drawing set.

Floodplain

The floodplain relative to this project was reviewed. Published FEMA maps (National Flood Hazard Layer FIRMette, dated June 29, 2018) show this project to be entirely in Zone D, which is classified as Area of Undetermined Flood Hazard. No impacts to the floodplain are anticipated as part of this project. The relevant FEMA Flood Maps are attached in Appendix E.

Environmental Impacts

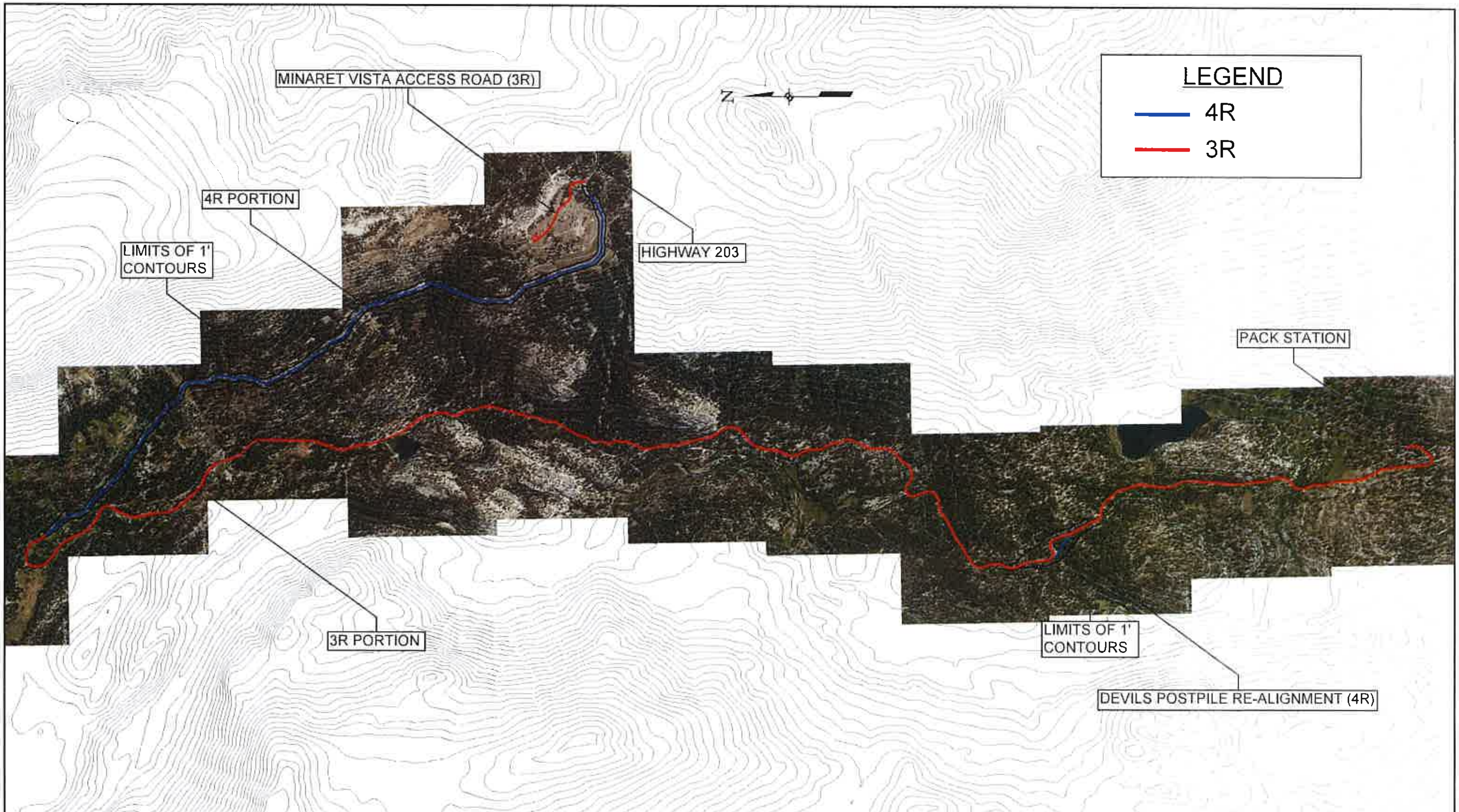
The California Construction General Permit requires best management practices (BMPs) for mitigating hydromodification associated with increases in the impervious area. The 3R segment will not increase the impervious area as the existing pavement is being replaced to the same roadway width. The 4R segment descends from the crest of the mountain to the valley floor and bisects a 1,300 acre drainage basin with steep forested terrain. The 4R segment includes 40 cross culverts that have drainage sub-basins that range in size from 2 acres to 120 acres and convey flows along the steep drainage courses which are accustom to high velocities. The 4R segment will increase the existing impervious area from 5.7 acres to 7.9 acres (+2.2 acres), which represents 0.17% of the overall drainage basin area. The increased impervious area is distributed across the 40 sub-basins resulting in negligible increases to their peak flows; therefore, the project is not anticipated to cause hydromodification impacts.

Conclusions

This document provides a summary of the existing and proposed hydrologic and hydraulic conditions associated with the Reds Meadow Road Improvement Project. All proposed drainage facilities adequately comply with the established project criteria. There are no adverse effects to surrounding properties anticipated as a part of this project.

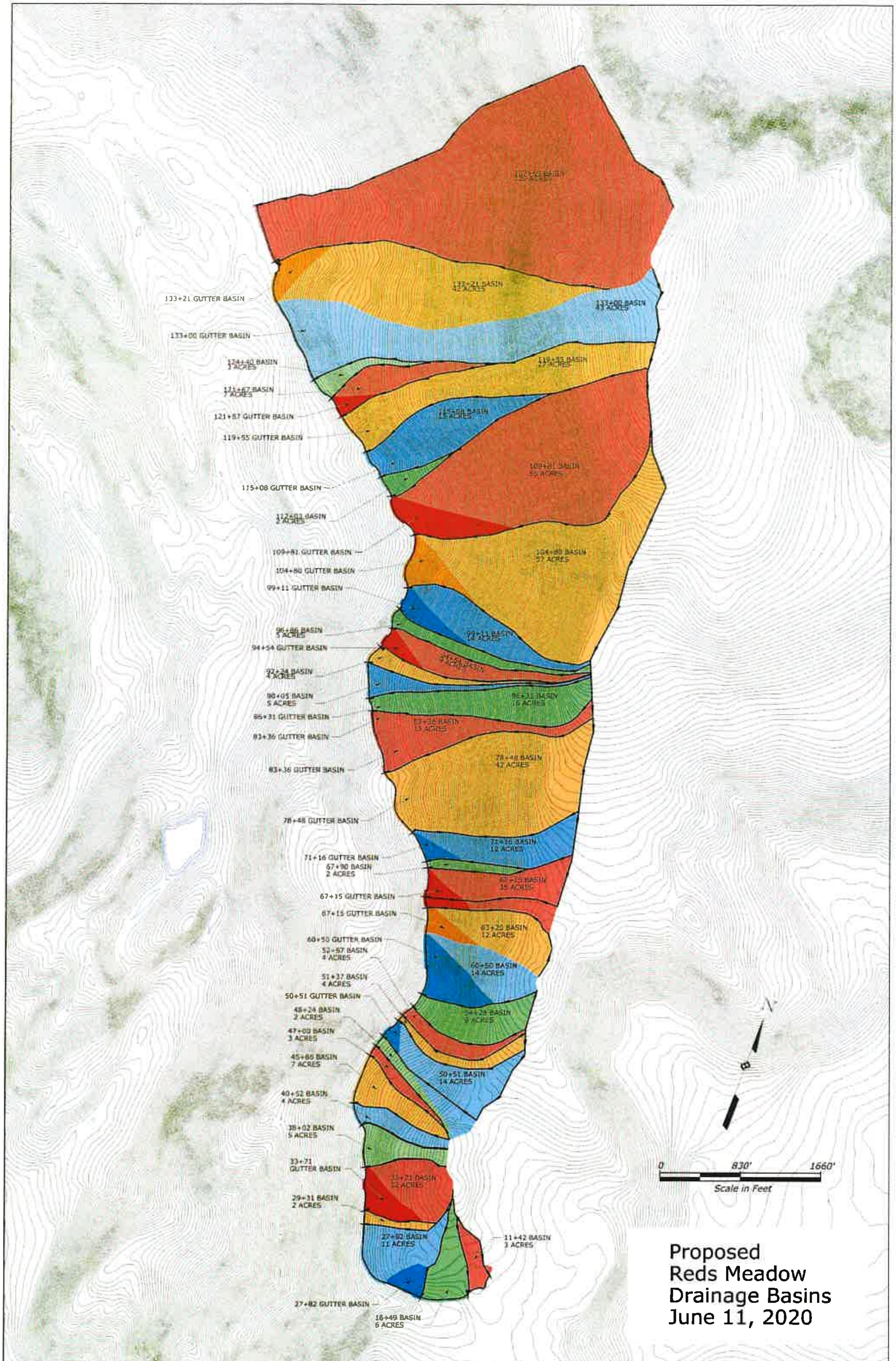
Appendix A – Location and Vicinity Maps

VICINITY MAP



REDS MEADOW IMPROVEMENTS
LOCATION MAP
JULY 2, 2018

Appendix B – Hydrology


133+21 GUTTER BASIN
133+21 BASIN
42 ACRES
133+00 GUTTER BASIN
133+00 BASIN
124+40 BASIN
121+67 BASIN
7 ACRES
121+67 GUTTER BASIN
119+55 BASIN
119+55 GUTTER BASIN
115+08 GUTTER BASIN
109+81 BASIN
112+03 BASIN
109+81 GUTTER BASIN
104+80 BASIN
57 ACRES
104+80 GUTTER BASIN
99+11 GUTTER BASIN
96+86 BASIN
99+11 BASIN
94+54 GUTTER BASIN
92+24 BASIN
90+05 BASIN
5 ACRES
86+31 GUTTER BASIN
86+31 BASIN
16 ACRES
83+36 GUTTER BASIN
83+36 BASIN
83+36 GUTTER BASIN
78+48 BASIN
42 ACRES
78+48 GUTTER BASIN
71+16 BASIN
12 ACRES
71+16 GUTTER BASIN
67+90 BASIN
2 ACRES
67+15 BASIN
15 ACRES
67+15 GUTTER BASIN
67+15 GUTTER BASIN
63+20 BASIN
12 ACRES
60+50 GUTTER BASIN
52+57 BASIN
4 ACRES
60+50 BASIN
14 ACRES
51+37 BASIN
4 ACRES
50+51 GUTTER BASIN
54+28 BASIN
9 ACRES
48+24 BASIN
2 ACRES
47+00 BASIN
3 ACRES
45+66 BASIN
7 ACRES
50+51 BASIN
14 ACRES
40+52 BASIN
4 ACRES
38+02 BASIN
5 ACRES
33+71
GUTTER BASIN
33+71 BASIN
22 ACRES
29+31 BASIN
2 ACRES
27+82 BASIN
11 ACRES
11+42 BASIN
3 ACRES
27+82 GUTTER BASIN
16+49 BASIN
6 ACRES
0
830'
1660'
Scale in Feet
Proposed
Reds Meadow
Drainage Basins
June 11, 2020

Culvert Basin Hydrology Summary

	C	A (acres)	t_c (min)			i (in/h)			Basin Q (cfs)		
			10yr	25 yr	50 yr	10 yr	25 yr	50 yr	10 yr	25 yr	50 yr
11+42	0.3	3.00	43	42	42	1.08	1.38	1.62	1.00	1.20	1.50
16+49	0.3	6.00	45	45	45	1.04	1.33	1.56	1.90	2.40	2.80
27+82	0.3	11.00	45	45	45	1.04	1.33	1.55	3.50	4.40	5.20
29+31	0.3	2.00	33	33	33	1.24	1.59	1.86	0.80	1.00	1.10
33+71	0.3	12.00	42	43	43	1.08	1.37	1.60	3.90	5.00	5.80
38+02	0.3	5.00	29	29	29	1.33	1.71	1.99	2.00	2.60	3.00
40+52	0.3	4.00	29	29	29	1.34	1.71	2.01	1.60	2.10	2.40
45+86	0.3	7.00	31	31	31	1.29	1.65	1.93	2.70	3.50	4.10
47+00	0.3	3.00	30	29	29	1.33	1.70	1.99	1.20	1.50	1.80
48+24	0.3	2.00	33	33	33	1.25	1.60	1.87	0.80	1.00	1.10
50+51	0.3	14.00	58	59	59	0.90	1.13	1.32	3.80	4.80	5.60
51+37	0.3	4.00	48	48	48	1.01	1.29	1.50	1.20	1.60	1.80
52+67	0.3	4.00	44	43	43	1.06	1.35	1.59	1.30	1.60	1.90
54+28	0.3	9.00	48	49	49	1.00	1.27	1.48	2.70	3.50	4.00
60+50	0.3	14.00	38	38	38	1.15	1.46	1.70	4.90	6.20	7.20
63+20	0.3	12.00	120	120	120	0.58	0.74	0.87	2.10	2.70	3.20
67+15	0.3	15.00	24	54	54	0.94	1.19	1.40	4.30	5.40	6.30
67+90	0.3	2.00	26	26	26	1.42	1.82	2.12	0.90	1.10	1.30
71+16	0.3	12.00	54	54	54	0.94	1.19	1.39	3.40	4.30	5.10
78+48	0.3	42.00	61	61	61	0.87	1.11	1.30	11.10	14.10	16.50
83+36	0.3	13.00	53	53	53	0.94	1.20	1.41	3.70	4.70	5.50
86+31	0.3	16.00	51	51	51	0.97	1.23	1.44	4.70	6.00	7.00
90+05	0.3	5.00	45	45	45	1.05	1.33	1.56	1.60	2.00	2.40
92+24	0.3	4.00	37	37	37	1.17	1.49	1.74	1.40	1.80	2.10
94+54	0.3	9.00	45	46	46	1.04	1.32	1.54	2.80	3.60	4.20
96+86	0.3	5.00	47	47	47	1.02	1.30	1.52	1.50	2.00	2.30
99+11	0.3	14.00	43	43	43	1.07	1.37	1.60	4.50	5.80	6.80
104+80	0.3	57.00	104	104	104	0.63	0.80	0.94	10.90	13.90	16.30
109+81	0.3	65.00	78	78	78	0.75	0.96	1.13	14.80	18.90	22.10
112+03	0.3	2.00	25	25	25	1.45	1.86	2.18	0.90	1.10	1.30
115+08	0.3	15.00	35	35	35	1.21	1.54	1.81	5.50	7.00	8.20
119+55	0.3	27.00	90	90	90	0.69	0.88	1.03	5.60	7.20	8.40
121+67	0.3	7.00	33	33	34	1.25	1.58	1.84	2.60	3.30	3.90
124+40	0.3	3.00	28	28	28	1.37	1.75	2.05	1.20	1.60	1.90
133+00	0.3	43.00	104	103	103	0.63	0.81	0.95	8.30	10.50	12.30
133+21	0.3	42.00	69	69	69	0.81	1.03	1.21	10.20	13.10	15.30
137+69	0.3	120.00	105	105	105	0.63	0.80	0.94	22.90	29.10	34.20

NOAA Atlas 14, Volume 6, Version 2
Location name: Oakhurst, California, USA*
Latitude: 37.6736°, Longitude: -119.0644°
Elevation: 9328.04 ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Sarah Dietz, Sarah Heim, Lillian Hiner, Kazungu Maitaria, Deborah Martin, Sandra Pavlovic, Ishani Roy, Carl Trypaluk, Dale Unruh, Fenglin Yan, Michael Yekta, Tan Zhao, Geoffrey Bonnin, Daniel Brewer, Li-Chuan Chen, Tye Parzybok, John Yarchoan

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches/hour)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	1.32 (1.16-1.52)	1.91 (1.68-2.21)	2.70 (2.36-3.13)	3.36 (2.90-3.94)	4.28 (3.53-5.24)	5.00 (4.01-6.31)	5.76 (4.46-7.50)	6.55 (4.90-8.87)	7.68 (5.42-11.0)	8.58 (5.80-12.8)
10-min	0.948 (0.834-1.09)	1.37 (1.20-1.58)	1.94 (1.69-2.24)	2.41 (2.08-2.82)	3.07 (2.53-3.76)	3.59 (2.87-4.52)	4.13 (3.20-5.38)	4.70 (3.51-6.35)	5.50 (3.89-7.85)	6.14 (4.16-9.18)
15-min	0.764 (0.672-0.876)	1.10 (0.968-1.27)	1.56 (1.36-1.81)	1.94 (1.68-2.28)	2.48 (2.04-3.03)	2.89 (2.32-3.64)	3.33 (2.58-4.33)	3.79 (2.83-5.12)	4.44 (3.14-6.33)	4.96 (3.35-7.40)
30-min	0.518 (0.456-0.596)	0.752 (0.658-0.866)	1.06 (0.928-1.23)	1.32 (1.14-1.55)	1.68 (1.39-2.06)	1.97 (1.58-2.48)	2.26 (1.76-2.95)	2.58 (1.93-3.48)	3.01 (2.13-4.30)	3.37 (2.28-5.03)
60-min	0.345 (0.303-0.396)	0.499 (0.438-0.575)	0.706 (0.616-0.816)	0.878 (0.758-1.03)	1.12 (0.922-1.37)	1.31 (1.05-1.65)	1.50 (1.17-1.96)	1.71 (1.28-2.31)	2.00 (1.42-2.86)	2.24 (1.51-3.34)
2-hr	0.258 (0.226-0.296)	0.352 (0.309-0.406)	0.481 (0.420-0.556)	0.588 (0.508-0.688)	0.740 (0.610-0.906)	0.859 (0.689-1.08)	0.984 (0.764-1.28)	1.12 (0.835-1.51)	1.30 (0.922-1.86)	1.45 (0.984-2.17)
3-hr	0.215 (0.189-0.248)	0.289 (0.253-0.333)	0.388 (0.339-0.449)	0.472 (0.407-0.551)	0.588 (0.485-0.720)	0.681 (0.546-0.857)	0.777 (0.603-1.01)	0.880 (0.658-1.19)	1.02 (0.725-1.46)	1.14 (0.772-1.70)
6-hr	0.159 (0.140-0.183)	0.209 (0.184-0.241)	0.277 (0.241-0.320)	0.333 (0.287-0.389)	0.411 (0.340-0.504)	0.474 (0.380-0.597)	0.539 (0.418-0.702)	0.608 (0.454-0.821)	0.704 (0.498-1.00)	0.781 (0.529-1.17)
12-hr	0.112 (0.099-0.129)	0.152 (0.133-0.175)	0.205 (0.179-0.237)	0.249 (0.215-0.291)	0.310 (0.255-0.379)	0.357 (0.286-0.450)	0.406 (0.315-0.528)	0.457 (0.341-0.618)	0.528 (0.373-0.753)	0.584 (0.395-0.872)
24-hr	0.079 (0.070-0.091)	0.110 (0.098-0.126)	0.151 (0.134-0.174)	0.184 (0.162-0.214)	0.230 (0.195-0.276)	0.266 (0.221-0.326)	0.302 (0.245-0.380)	0.340 (0.268-0.439)	0.391 (0.296-0.528)	0.432 (0.316-0.603)
2-day	0.056 (0.049-0.064)	0.074 (0.066-0.086)	0.099 (0.088-0.115)	0.120 (0.105-0.139)	0.148 (0.126-0.178)	0.170 (0.142-0.209)	0.193 (0.156-0.242)	0.216 (0.171-0.280)	0.249 (0.188-0.335)	0.274 (0.200-0.383)
3-day	0.044 (0.039-0.050)	0.057 (0.051-0.066)	0.075 (0.067-0.087)	0.090 (0.079-0.105)	0.111 (0.094-0.133)	0.127 (0.106-0.156)	0.144 (0.117-0.181)	0.161 (0.127-0.208)	0.185 (0.140-0.249)	0.203 (0.149-0.284)
4-day	0.037 (0.033-0.042)	0.048 (0.042-0.055)	0.062 (0.055-0.072)	0.075 (0.066-0.087)	0.091 (0.078-0.110)	0.104 (0.087-0.128)	0.118 (0.096-0.148)	0.132 (0.104-0.170)	0.151 (0.114-0.203)	0.166 (0.121-0.232)
7-day	0.025 (0.023-0.029)	0.033 (0.030-0.038)	0.044 (0.039-0.050)	0.052 (0.046-0.061)	0.064 (0.054-0.077)	0.073 (0.061-0.089)	0.082 (0.067-0.103)	0.092 (0.072-0.119)	0.105 (0.079-0.141)	0.115 (0.084-0.161)
10-day	0.020 (0.018-0.023)	0.026 (0.023-0.030)	0.035 (0.031-0.040)	0.042 (0.037-0.048)	0.051 (0.043-0.061)	0.058 (0.048-0.071)	0.065 (0.053-0.082)	0.073 (0.057-0.094)	0.083 (0.063-0.112)	0.091 (0.066-0.127)
20-day	0.013 (0.011-0.015)	0.017 (0.015-0.020)	0.023 (0.020-0.026)	0.027 (0.024-0.032)	0.033 (0.028-0.040)	0.038 (0.031-0.046)	0.042 (0.034-0.053)	0.046 (0.037-0.060)	0.052 (0.040-0.071)	0.057 (0.042-0.079)
30-day	0.010 (0.009-0.012)	0.014 (0.012-0.016)	0.018 (0.016-0.021)	0.022 (0.019-0.025)	0.026 (0.022-0.032)	0.030 (0.025-0.036)	0.033 (0.027-0.041)	0.036 (0.029-0.047)	0.040 (0.031-0.055)	0.044 (0.032-0.061)
45-day	0.009 (0.008-0.010)	0.011 (0.010-0.013)	0.015 (0.013-0.017)	0.018 (0.016-0.021)	0.021 (0.018-0.025)	0.024 (0.020-0.029)	0.026 (0.021-0.033)	0.029 (0.023-0.037)	0.032 (0.024-0.043)	0.034 (0.025-0.047)
60-day	0.008 (0.007-0.009)	0.010 (0.009-0.012)	0.013 (0.012-0.015)	0.015 (0.014-0.018)	0.018 (0.016-0.022)	0.020 (0.017-0.025)	0.022 (0.018-0.028)	0.024 (0.019-0.031)	0.027 (0.020-0.036)	0.028 (0.021-0.040)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

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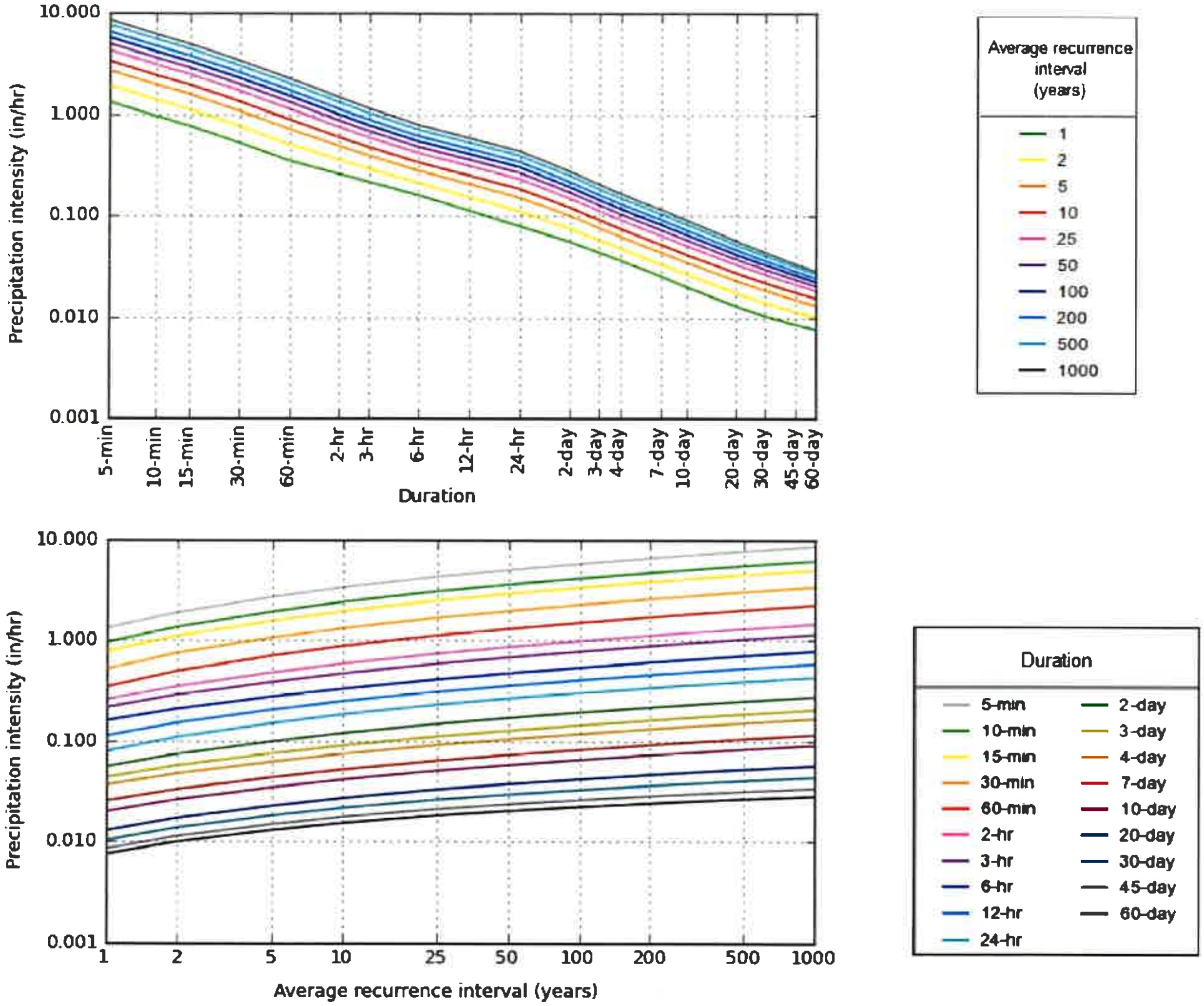
PF graphical

PDS-based intensity-duration-frequency (IDF) curves
Latitude: 37.6736°, Longitude: -119.0644°



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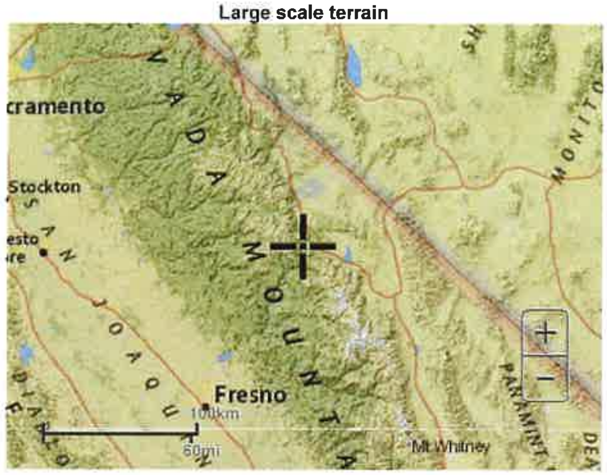
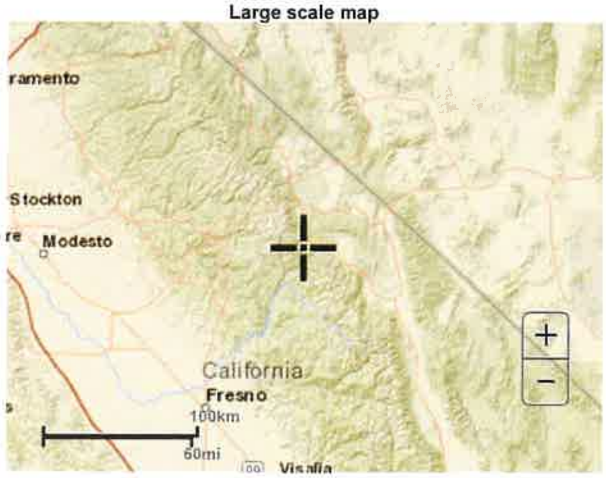
Maps & aerials

Small scale terrain

Large scale terrain



Large scale map



Large scale aerial

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National Oceanic and Atmospheric Administration
National Weather Service
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Gutter Basin Hydrology Summary

2-foot gutter	C	A (acres)	t_c (min)			i (in/h)			Q (cfs)		
			10yr	25 yr	50 yr	10 yr	25 yr	50 yr	10 yr	25 yr	50 yr
33+71 Gutter	0.3	4.00	29.07	28.82	28.69	1.34	1.72	2.02	1.60	2.10	2.40
50+51 Gutter	0.3	1.00	19.83	19.41	19.19	1.67	2.15	2.53	0.50	0.70	0.80
60+50 Gutter	0.3	6.00	21.71	22.49	22.95	1.58	1.98	2.29	2.90	3.60	4.20
63+20 Gutter	0.3	2.00	16.37	16.12	15.99	1.85	2.38	2.80	1.10	1.40	1.70
67+15 Gutter	0.3	2.00	18.41	18.03	17.84	1.74	2.24	2.63	1.10	1.40	1.60
71+16 Gutter	0.3	1.00	19.04	18.41	18.09	1.70	2.22	2.61	0.50	0.70	0.80
94+54 Gutter	0.3	2.00	21.27	21.05	20.94	1.60	2.06	2.41	1.00	1.20	1.50
99+11 Gutter	0.3	3.00	23.11	22.95	22.87	1.53	1.96	2.29	1.40	1.80	2.10
104+80 Gutter	0.3	4.00	22.87	22.59	23.83	1.54	1.98	2.24	1.90	2.40	2.70
109+81 Gutter1	0.3	7.00	25.68	25.39	25.24	1.44	1.85	2.17	3.10	3.90	4.60
109+81 Gutter2	0.3	3.00	25.00	24.87	24.80	1.46	1.87	2.19	1.30	1.70	2.00
121+67 Gutter	0.3	1.00	19.86	19.45	19.24	1.67	2.15	2.53	0.50	0.60	0.80
133+21 Gutter	0.3	3.00	26.84	26.51	26.34	1.40	1.80	2.12	1.30	1.60	1.90

HDS-2, TABLE 2.1

from Equation 2.5 and used to check the initial value of i. If they are not the same, the process is repeated until two successive t_c estimates are the same.

Table 2.1. Manning's Roughness Coefficient (n) for Overland and Sheet Flow

(SCS, 1986; McCuen, 1989)

n	**Surface Description**
0.011	Smooth asphalt
0.012	Smooth concrete
0.013	Concrete lining
0.014	Good wood
0.014	Brick with cement mortar
0.015	Vitrified clay
0.015	Cast iron
0.024	Corrugated metal pipe
0.024	Cement rubble surface
0.050	Fallow (no residue)
	Cultivated soils
0.060	Residue cover ≤ 20%
0.170	Residue cover > 20%
0.130	Range (natural)
	Grass
0.150	Short grass prairie
0.240	Dense grasses
0.410	Bermuda grass
	Woods*
0.400	Light underbrush
0.800	Dense underbrush

*When selecting n for woody underbrush, consider cover to a height of about 30 mm (0.1 ft). This is the only part of the plant cover that will obstruct sheet flow.

To avoid the necessity to solve for t_c iteratively, the SCS TR-55 (1986) uses the following variation of the kinematic wave equation:

$$t_c = \frac{\alpha}{P_2^{0.5}} \left(\frac{nL}{\sqrt{S}} \right)^{0.8} \qquad (2.6)$$

where,

P_2 = 2-year, 24-hour rainfall depth, mm (in)

α = unit conversion constant equal to 5.5 in SI units and 0.42 in CU units.

The other variables are as previously defined. Equation 2.6 is based on an assumed IDF relationship. SCS TR-55 (1986) recommends an upper limit of L = 90 m (300 ft) for using this equation.

HDS-2, TABLE 2.2

2.6.2.2 Shallow Concentrated Flow

After short distances, sheet flow tends to concentrate in rills and then gullies of increasing proportions. Such flow is usually referred to as shallow concentrated flow. The velocity of such flow can be estimated using an empirical relationship between the velocity and the slope:

$$V = \alpha k S^{0.5} \tag{2.7}$$

where,

V = velocity, m/s (ft/s)
S = slope, m/m (ft/ft)
k = dimensionless function of land cover (see Table 2.2)
α = unit conversion constant equal to 10 in SI and 33 in CU units.

Table 2.2. Intercept Coefficients for Velocity vs. Slope Relationship (McCuen, 1989)

k	Land Cover/Flow Regime
0.076	Forest with heavy ground litter; hay meadow (overland flow)
0.152	Trash fallow or minimum tillage cultivation; contour or strip cropped; woodland (overland flow)
0.213	Short grass pasture (overland flow)
0.274	Cultivated straight row (overland flow)
0.305	Nearly bare and untilled (overland flow); alluvial fans in western mountain regions
0.457	Grassed waterway (shallow concentrated flow)
0.491	Unpaved (shallow concentrated flow)
0.619	Paved area (shallow concentrated flow); small upland gullies

2.6.2.3 Pipe and Channel Flow

Flow in gullies empties into channels or pipes. In many cases, the transition between shallow concentrated flow and open channels may be assumed to occur where either the blue-line stream is depicted on USGS quadrangle sheets (scale equals 1:24000) or when the channel is visible on aerial photographs. Channel lengths may be measured directly from the map or scale photograph. However, depending on the scale of the map and the sinuosity of the channel, a map-derived channel length may be an underestimate. Pipe lengths should be taken from as-built drawings for existing systems and design plans for future systems.

Cross-section information (i.e., depth-area and roughness) can be obtained for any channel reach in the watershed. Manning's equation can be used to estimate average flow velocities in pipes and open channels:

$$V = \frac{\alpha}{n} R^{2/3} S^{1/2} \tag{2.8}$$

where,

V = velocity, m/s (ft/s)
n = Manning's roughness coefficient
R = hydraulic radius, m (ft)

HEC-22, TABLE 3-4

Table 3-4. Typical Range of Manning's Coefficient (n) for Channels and Pipes.	
Conduit Material	Manning's n*
Closed Conduits	
Concrete pipe	0.010 - 0.015
CMP	0.011 - 0.037
Plastic pipe (smooth)	0.009 - 0.015
Plastic pipe (corrugated)	0.018 - 0.025
Pavement/gutter sections	0.012 - 0.016
Small Open Channels	
Concrete	0.011 - 0.015
Rubble or riprap	0.020 - 0.035
Vegetation	0.020 - 0.150
Bare Soil	0.016 - 0.025
Rock Cut	0.025 - 0.045
Natural channels (minor streams, top width at flood stage <30 m (100 ft))	
Fairly regular section	0.025 - 0.050
Irregular section with pools	0.040 - 0.150
*Lower values are usually for well-constructed and maintained (smoother) pipes and channels	

HDS-2, TABLE 5.7

Table 5.7. Runoff Coefficients for Rational Formula (ASCE, 1960)

Type of Drainage Area	Runoff Coefficient
Business:	
Downtown area	0.70-0.95
Neighborhood areas	0.50-0.70
Residential:	
Single-family areas	0.30-0.50
Multi-units, detached	0.40-0.60
Multi-units, attached	0.60-0.75
Suburban	0.25-0.40
Apartment dwelling areas	0.50-0.70
Industrial:	
Light areas	0.50-0.80
Heavy areas	0.60-0.90
Parks, cemeteries	0.10-0.25
Playgrounds	0.20-0.40
Railroad yard areas	0.20-0.40
Unimproved areas	0.10-0.30
Lawns:	
Sandy soil, flat, < 2%	0.05-0.10
Sandy soil, average, 2 to 7%	0.10-0.15
Sandy soil, steep, > 7%	0.15-0.20
Heavy soil, flat, < 2%	0.13-0.17
Heavy soil, average 2 to 7%	0.18-0.22
Heavy soil, steep, > 7%	0.25-0.35
Streets:	
Asphalt	0.70-0.95
Concrete	0.80-0.95
Brick	0.70-0.85
Drives and walks	0.75-0.85
Roofs	0.75-0.95

Appendix C – Hydraulics

Exhibit 7.1-A PDDM

Exhibit 7.1-A QUICK REFERENCE GUIDE

Topic	Standard	Criteria	Method Reference
HYDROLOGY			
Peak Flow Methods			HDS 2, HEC 22, NEH Part 630, TR-55, TM 4-A6, Bulletin 17B
Hydrograph Methods			HDS 2, WinTR-55
ROADWAY HYDRAULICS			
Culverts	Capacity Design and Stability Design: High-Standard road: 50-year flood Low-Standard road: 25-year flood Roadside ditch: 10-year flood Capacity Check Flood: Evaluate potential for adverse impacts for the overtopping flood Exception: See Floodplain Encroachments	Headwater New: WSEL ≤ bottom of aggregate base layer Existing: WSEL ≤ shoulder hinge point. HW/D ratio: 48" [1200 mm] or smaller = 1.5 Larger than 48" [1200 mm] = 1.2 Other: WSEL limited by unacceptable hazards to human life or property. Minimum Size: Cross-road culvert = 24" [600 mm] Parallel culvert = 18" [450 mm] Slope: Stream Crossings: Match streambed Ditch Relief: Min. = 2%, Max. = 10% Cover Pipe Anchors: Concrete > 10% slope, Metal > 25% slope	HDS 5, HEC 14

Exhibit 7.1-A QUICK REFERENCE GUIDE *(Continued)*

Topic	Standard	Criteria	Method Reference
Ditches	Capacity Design: 10-year flood Stability Design: Permanent Linings 10-year flood Temporary Linings: 2-year flood	Depth: New: WSEL ≤ bottom of aggregate base layer Existing: WSEL ≤ shoulder hinge point Slope: Min. = 0.5% Stability: Permissible shear stress	HDS 3, HEC 15
Pavement Drainage	Capacity Design: 10-year flood, 50-year in sumps	Spread: High-Standard road: 3 ft [900 mm] into one travel lane, Low-Standard road: Half of one travel lane Depth: On-grade and Sags: Allowable spread, not to exceed curb height, Sumps and Parking Areas: 6" [150 mm]. Inlet Clogging Factor: Grate Inlets in sag or sump, 50%	HEC 21, HEC 22
Storm Drains	Capacity Design: 10-year flood, 50-year in sumps	Minimum Size: 15" [375 mm]. Minimum Slope: Pipe-full velocity ≥ 3 ft/sec [0.9 m/s]	HEC 22
Outlet Protection			HEC 14
Alternative Pipe Materials	Service Life: 50-years Minimum Pipe Classification: RCP: Class II Metal: 0.064" [1.63 mm]		FHWA-RD-97-140, Caltrans Chapter 850

Exhibit 7.1-A QUICK REFERENCE GUIDE *(Continued)*

Topic	Standard	Criteria	Method Reference
RIVER HYDRAULICS			
Floodplain Encroachment	Design Flood: 100-year Check Flood: Overtopping flood, not to exceed 500-year	FEMA Regulated Base Floodplain with Detailed Study: With floodway defined, no floodway encroachment With no defined floodway or no detailed study, rise ≤ 1.0 ft [0.3 m] Unregulated Base Floodplain: Rise ≤ 1.0 ft [0.3 m]	HEC-RAS
Scour and Stream Stability			HDS 6, HEC 18, HEC 20,HEC 23
Bridged Waterways	Capacity Design: Design Flood: 50-year Check Flood: Greater of overtopping flood or 100-year, not to exceed 500-year Stability Design: Design Flood: 100-year Check Flood: 500-year	Freeboard: 2.0 ft [0.6 m], greater where potential for debris or ice Stability Design: Design Flood: Normal geotechnical and structural safety factors Check Flood: Safety Factor ≥ 1.0	HEC-RAS, HEC 18, HEC 20, HEC 23
Longitudinal Embankments	Capacity Design: High-Standard road: 50-year flood Low-Standard road: 25-year flood Check Flood: Greater of overtopping or 100-year Stability Design: High-Standard road: 50-year flood Low-Standard road: 25-year flood	Capacity Design: Freeboard: 2.0 ft [0.6 m]	HEC 14, HEC 23

Exhibit 7.1-A QUICK REFERENCE GUIDE *(Continued)*

Topic	Standard	Criteria	Method Reference
Retaining Walls	Longitudinal Flow Scour: Wall height > 6.5 ft [2 m]: 100-year Wall height ≤ 6.5 ft [2 m] on High-Standard road: 50-year Wall height ≤ 6.5 ft [2 m] on Low-Standard road: 25-year Pipe Penetrations: High-Standard road: 50-year Low-Standard road: 25-year	Stability Design: Normal geotechnical and structural safety factors	HEC 14, HEC 23
Low-Water Crossings	Allowable Uses: ADT ≤ 200 or existing feature Capacity Design: Vented: 10-year Stability Design: 25-year flood	Capacity Design: Vented: No overtopping Stability Design	Low Volume Roads Engineering, HDS 5, HEC 20, HEC 23
Channel Changes	Capacity Design: Duplicate existing stream characteristics Stability Design: High-Standard road: 50-year Low-Standard road: 25-year	Capacity Design Stability Design	HDS 6, HEC 20, HEC 23
Scour and Stream Instability Counter-measures			HDS 6, HEC 11, HEC 14, HEC 23
Energy Dissipators	Design Standard: Range of discharges	Design Guidance: Natural or stable channel velocity	HEC 14

Exhibit 7.1-A QUICK REFERENCE GUIDE *(Continued)*

Topic	Standard	Criteria	Method Reference
COASTAL HYDRAULICS			
General			HEC 25
Hydrology			HEC 25, EM 1110-2-1100
Scour and Stream Stability			HDS 6, HEC 18, HEC 20, HEC 23, HEC 25
Bridged Waterways	Capacity Design: 50-year storm tide plus wave height Stability Design: Design Flood: 100-year Check Flood: 500-year	Design Criteria Same as riverine except freeboard measurement reference datum	HDS 6, HEC 11, HEC 23, HEC 25
Roadway Embankments	Capacity Design: High-Standard road: 50-year storm tide plus wave height Low-Standard road: Highest astronomic tide plus 25-year wave height Stability Design: High-Standard road: 50-year storm tide plus wave height Low-Standard road: 25-year wave	Capacity Design: High Standard road Freeboard: 2.0 ft [0.6 m] Stability Design	HEC 14, HEC 23
Scour and Stream Instability Counter-measures			HDS 6, HEC 11, HEC 14, HEC 23

Gutter Summary - Based on Culvert Basins

Design Storm: 10-year (50-year for sumps)

	Road Longitudinal Slope	Road Cross slope	Gutter Cross-slope	Road Width (ft)	Gutter Width (ft)	Allowable Spread (ft)	Basin Q (cfs)			Bypass Q From Upstream (cfs)			Total Q (cfs)			Spread Width (ft)			Depth at Curb (in)			
							10 yr	25 yr	50 yr	10 yr	25 yr	50 yr	10 yr	25 yr	50 yr	10 yr	25 yr	50 yr	10 yr	25 yr	50 yr	Compliant?
11+42	4.13%	-2.30%	12.5%	26	2	2	1.0	1.2	1.5							1.51	1.66	1.76	3.00	3.00	3.00	Yes
16+49	7.71%	3.40%	12.5%	26	2	8.5	1.9	2.4	2.8							1.72	1.89	2.02	2.89	2.96	3.01	Yes
27+82	7.51%	2.00%	12.5%	26	2	8.5	3.5	4.4	5.2							3.11	4.19	4.97	3.27	3.53	3.71	Yes
29+31	7.84%	2.00%	12.5%	26	2	8.5	0.8	1.0	1.1	1.3	1.7	2.2	2.1	2.7	3.3	1.79	1.97	2.73	2.95	2.99	3.18	Yes
33+71	7.83%	-2.43%	12.5%	26	2	2	3.9	5.0	5.8	0.2	0.8	1.2	4.1	5.8	7.0	Infinite	Infinite	Infinite	3.14	3.20	3.23	No, see gutter basin analysis
38+02	7.84%	-0.16%	12.5%	26	2	2	2.0	2.6	3.0	0.0	0.9	1.0	2.0	3.5	4.0	1.76	Infinite	Infinite	3.00	3.10	3.13	Yes
40+52	6.30%	3.50%	12.5%	26	2	8.5	1.6	2.1	2.4				1.6	2.1	2.4	1.68	1.84	1.95	2.86	2.93	2.98	Yes
45+86	8.99%	2.40%	12.5%	26	2	8.5	2.7	3.5	4.1	0.0	0.1	0.5	2.7	3.6	4.6	1.92	2.82	3.98	2.98	3.20	3.48	Yes
47+00	8.62%	2.40%	12.5%	26	2	8.5	1.2	1.5	1.8				1.2	1.5	1.8	1.43	1.56	1.66	2.86	2.90	2.92	Yes
48+24	8.03%	2.00%	12.5%	26	2	8.5	0.8	1.0	1.1							1.21	1.33	1.41	2.81	2.84	2.86	Yes
50+51	9.37%	-0.05%	12.5%	26	2	2	3.8	4.8	5.6							Infinite	Infinite	Infinite	3.02	3.03	3.03	No, see gutter basin analysis
51+37	9.84%	3.80%	12.5%	26	2	8.5	1.2	1.6	1.8							1.40	1.53	1.62	2.97	2.97	2.98	Yes
52+67	8.85%	-3.80%	12.5%	26	2	2	1.3	1.6	1.9							1.45	1.59	1.69	3.00	3.00	3.00	Yes
54+28	9.36%	-2.27%	12.5%	26	2	2	2.7	3.5	4.0							1.91	Infinite	Infinite	3.00	3.02	3.02	Yes
60+50	8.63%	-2.00%	12.5%	26	2	2	4.6	6.2	7.2							Infinite	Infinite	Infinite	3.16	3.20	3.22	No, see gutter basin analysis
63+20	6.80%	-2.00%	12.5%	26	2	2	2.1	2.7	3.2	0.0	1.1	1.0	2.1	3.8	4.2	Infinite	Infinite	Infinite	3.17	3.26	3.28	No, see gutter basin analysis
67+15	6.58%	-3.60%	12.5%	26	2	2	4.3	5.4	6.3	0.8	2.5	2.9	5.1	7.9	9.2	Infinite	Infinite	Infinite	3.19	3.26	3.28	No, see gutter basin analysis
67+90	7.60%	-3.60%	12.5%	26	2	2	0.9	1.1	1.3	0.4	2.4	3.6	1.3	3.5	4.9	1.50	Infinite	Infinite	3.00	3.10	3.17	Yes
71+16	8.01%	-3.60%	12.5%	26	2	2	3.4	4.3	5.1	0.0	0.6	2.0	3.4	4.9	7.1	Infinite	Infinite	Infinite	3.09	3.16	3.22	No, see gutter basin analysis
78+48	9.34%	5.00%	12.5%	26	2	8.5	11.1	14.1	16.5	0.0	0.0	0.9	11.1	14.1	17.4	4.80	5.43	6.01	4.68	5.06	5.40	Yes
83+36	8.47%	3.00%	12.5%	26	2	8.5	3.6	4.7	5.5							2.75	3.55	4.07	3.27	3.56	3.75	Yes
86+31	1.30%	3.57%	12.5%	26	2	8.5	4.7	6.0	7.0							6.15	6.98	7.55	4.78	5.13	5.38	Yes
90+05	2.52%	5.20%	12.5%	26	2	8.5	1.6	2.0	2.4				1.6	2.0	2.4	1.99	2.43	2.74	2.99	3.27	3.46	Yes
92+24	3.50%	-2.62%	12.5%	26	2	2	1.4	1.8	2.1	0.00	0.05	0.10	1.4	1.8	2.2	1.79	1.98	Infinite	3.00	3.00	3.08	Yes
94+54	3.73%	-4.80%	12.5%	26	2	2	2.8	3.6	4.2				2.8	3.6	4.2	Infinite	Infinite	Infinite	3.14	3.18	3.20	No, see gutter basin analysis
96+86	5.33%	-2.40%	12.5%	26	2	2	1.5	2.0	2.3	0.8	1.5	2.1	2.3	3.5	4.4	1.99	Infinite	Infinite	3.00	3.14	3.18	Yes
99+11	5.55%	-3.20%	12.5%	26	2	2	4.5	5.8	6.8	0.3	1.0	1.9	4.8	6.8	8.7	Infinite	Infinite	Infinite	3.19	3.25	3.29	No, see gutter basin analysis
104+80	6.60%	-4.80%	12.5%	26	2	2	10.9	13.9	16.3				10.9	13.9	16.3	Infinite	Infinite	Infinite	3.06	3.06	3.07	No, see gutter basin analysis
109+81	8.13%	-4.80%	12.5%	26	2	2	14.8	18.9	22.1				14.8	18.9	22.1	Infinite	Infinite	Infinite	3.34	3.38	3.41	No, see gutter basin analysis
112+03	7.30%	2.00%	12.5%	26	2	2	0.9	1.1	1.3				0.9	1.1	1.3	1.30	1.43	1.52	3.00	2.99	3.00	Yes
115+08	8.51%	2.00%	12.5%	26	2	8.5	5.5	7.0	8.2				5.5	7.0	8.2	4.94	6.06	6.79	3.70	3.97	4.15	Yes
119+55	7.56%	2.00%	12.5%	26	2	8.5	5.6	7.2	8.4							5.33	6.46	7.20	3.80	4.07	4.25	Yes
119+55 inlet 1	7.47%	2.00%	12.5%	26	2	8.5	2.6	3.2	3.8							5.36	6.48	7.26	3.81	4.08	4.26	Yes
121+67	5.32%	-3.80%	12.5%	26	2	2	2.6	3.3	3.9	0.6	1.3	1.8	3.2	4.6	5.7	Infinite	Infinite	Infinite	3.12	3.19	3.22	No, see gutter basin analysis
124+40	8.33%	2.00%	12.5%	26	2	8.5	1.2	1.6	1.9				1.2	1.6	1.9	1.48	1.62	1.72	2.88	2.91	2.93	Yes
133+00	4.65%	3.50%	12.5%	26	2	8.5	8.3	10.5	12.3	0.4	0.6	0.8	8.7	11.1	13.1	6.15	6.99	7.59	4.74	5.10	5.35	Yes
133+21	5.43%	-4.54%	12.5%	26	2	2	10.2	13.1	15.3				10.2	13.1	15.3	Infinite	Infinite	Infinite	3.06	3.06	3.07	No, see gutter basin analysis
137+69	2.90%	0.34%	12.5%	26	2	8.5	22.9	29.1	34.2							4.23	4.63	4.91	12.68	13.88	14.75	Yes

NOTE: Where spread width is infinite, a secondary analysis was performed with just the gutter basin flow.

Gutter Summary - Based on Gutter Basins

Design Storm: 10-year (50-year for sumps)

	Road Longitudinal Slope	Road Cross-slope	Gutter Cross-slope	Road Width (ft)	Gutter Width (ft)	Allowable Spread (ft)*	Basin Q (cfs)			Bypass Q From Upstream (cfs)			Total Q (cfs)			Spread Width (ft)			Depth at Curb (in)			Flow Overtopping Road	Compliant?
							10 yr	25 yr	50 yr	10 yr	25 yr	50 yr	10 yr	25 yr	50 yr	10 yr	25 yr	50 yr	10 yr	25 yr	50 yr		
33+71	7.83%	-2.43%	12.5%	26	2	2	1.60	2.10	2.40	0.21	0.80	1.24	1.81	2.90	3.64	1.69	Infinite	Infinite	3.00	3.02	3.11	No	Yes
50+51	9.37%	-0.05%	12.5%	26	2	2	0.50	0.70	0.80				0.50	0.70	0.80	1.01	1.11	1.18	3.00	3.00	3.00	No	Yes
60+50	8.63%	-2.00%	12.5%	26	2	2	2.90	3.60	4.20				2.90	3.60	4.20	1.98	Infinite	Infinite	3.00	3.09	3.13	No	Yes
63+20	9.61%	-2.00%	12.5%	26	2	2	1.10	1.40	1.70	0.00	1.14	0.98	1.10	2.54	2.68	1.36	1.85	1.89	3.00	3.00	3.00	No	Yes
67+15	6.58%	-3.60%	12.5%	26	2	2	1.10	1.40	1.60	0.82	2.49	2.88	1.92	3.89	4.48	1.78	Infinite	Infinite	3.00	3.14	3.17	No	Yes
71+16	6.58%	-3.60%	12.5%	26	2	2	0.50	0.70	0.80	0.00	0.58	1.96	0.50	1.28	2.76	1.04	1.47	1.96	3.00	3.00	3.00	No	Yes
94+54	3.73%	-4.80%	12.5%	26	2	2	1.00	1.20	1.50				1.00	1.20	1.50	1.54	1.69	1.79	3.00	3.00	3.00	No	Yes
99+11	5.50%	-4.80%	12.5%	26	2	2	1.40	1.80	2.10	0.34	1.04	1.93	1.74	2.84	4.03	1.78	Infinite	Infinite	3.00	3.09	3.16	No	Yes
104+80	6.60%	-4.80%	12.5%	26	2	2	1.90	2.40	2.70				1.90	2.40	2.70	1.77	1.94	Infinite	3.00	3.00	3.01	No	Yes
109+81 (1)	8.19%	-4.80%	12.5%	26	2.7	2.7	3.10	3.90	4.60				3.10	3.90	4.60	2.04	2.24	2.38	4.05	4.05	4.05	No	Yes
109+81 (2)	7.22%	0.00%	12.5%	26	2	2	1.30	1.70	2.00				1.30	1.70	2.00	1.53	1.68	1.78	3.00	3.00	3.00	No	Yes
121+67	5.30%	-3.80%	12.5%	26	2	2	0.50	0.60	0.80	0.57	1.29	1.80	1.07	1.89	2.60	1.48	1.84	Infinite	3.00	3.00	3.06	No	Yes
129+60	4.80%	1.00%	12.5%	26	2	8.5	2.60	3.30	3.90	0.00	0.00	0.03	2.60	3.30	3.93	3.45	5.55	6.93	3.17	3.43	3.59	No	Yes
133+21	5.43%	-4.54%	12.5%	26	2	2	1.30	1.60	1.90				1.30	1.60	1.90	1.59	1.75	1.85	3.00	3.00	3.00	No	Yes

*Allowable spread per the PDDM is shoulder plus 1/2 travel lane. Due to super elevation of roadway actual spread will be infinite once it exceeds capacity of gutter. In these situations allowable spread is defined as gutter width.

GMP Inlet Summary - 4R Section

Design Storm: 50-year

Culvert STA	Inlet Type	d (ft) @ inlet	High (min) Elev	Inlet Elev	d min (ft)	Basin Q (cfs)			Additional Q (cfs) From Bypass			Total Q (cfs)			Inlet capacity (cfs)	Capacity > Flow?
						10 yr	25 yr	50 yr	10 yr	25 yr	50 yr	10 yr	25 yr	50 yr		
11+42	GMP	1.43	9162.08	9161.50	0.58	1.0	1.2	1.5				1.0	1.2	1.5	7.6	Yes
16+49	GMP	1.12	9124.69	9124.13	0.56	1.9	2.4	2.8				1.9	2.4	2.8	7.2	Yes
27+82	On-grade															See on grade inlet summary
29+31	On-grade															See on grade inlet summary
33+71	On-grade 1st															See on grade inlet summary
33+71	On-grade 2nd															See on grade inlet summary
38+02	GMP	0.88	8959.88	8959.33	0.55	2.0	2.6	3.0	0.0	0.9	1.0	2.0	3.5	4.0	7.1	Yes
40+52	GMP	1.53	8945.16	8943.63	1.53	1.6	2.1	2.4				1.6	2.1	2.4	17.6	Yes
45+86	GMP	1.09	8897.48	8896.39	1.09	2.7	3.5	4.1	0.0	0.1	0.5	2.7	3.6	4.6	14.8	Yes
47+00	GMP	0.27	8887.27	8887.00	0.27	1.2	1.5	1.8				1.2	1.5	1.8	2.4	Yes
48+24	On-grade															See on grade inlet summary
50+51	GMP	1.87	8857.99	8856.12	1.87	3.8	4.8	5.6				3.8	4.8	5.6	19.4	Yes
51+37	On-grade															See on grade inlet summary
52+67	GMP	0.90	8839.04	8838.21	0.83	1.3	1.6	1.9				1.3	1.6	1.9	13.0	Yes
54+28	GMP	1.34	8825.30	8823.96	1.34	2.7	3.5	4.0				2.7	3.5	4	16.5	Yes
60+50	On-grade 1st															See on grade inlet summary
60+50	On-grade 2nd															See on grade inlet summary
63+20	On-grade															See on grade inlet summary
67+15	On-grade 1st															See on grade inlet summary
67+15	On-grade 2nd															See on grade inlet summary
67+90	On-grade															See on grade inlet summary
71+16	On-grade 1st															See on grade inlet summary
71+16	On-grade 2nd															See on grade inlet summary
78+48	GMP	1.69	8622.94	8621.25	1.69	11.1	14.1	16.5	0.0	0.0	0.6	11.1	14.1	17.1	18.5	Yes
83+36	GMP	1.97	8584.29	8582.32	1.97	3.7	4.7	5.5				3.7	4.7	5.5	20.0	Yes
86+31	GMP	1.89	8583.35	8582.80	0.55	4.7	6.0	7.0				4.7	6	7	7.1	Yes
90+05	On-grade															See on grade inlet summary
92+24	GMP	0.98	8567.90	8566.92	0.98	1.4	1.8	2.1	0.0	0.0	0.1	1.4	1.8	2.2	14.1	Yes
94+54	On-grade															See on grade inlet summary
96+86	On-grade															See on grade inlet summary
99+11	GMP	1.11	8535.50	8534.39	1.11	4.5	5.8	6.8	0.3	1.0	1.9	4.8	6.8	8.73	15.0	Yes
104+80	GMP	0.93	8500.55	8497.86	2.69	10.9	13.9	16.3				10.9	13.9	16.3	23.1	Yes
109+81	Flaired End															See culvert summary
112+03	On-grade															See on grade inlet summary
115+08	GMP	1.73	8420.73	8419.00	1.73	5.5	7.0	8.2				5.5	7.0	8.2	18.7	Yes
119+55	On-grade 1st															See on grade inlet summary
119+55	On-grade 2nd															See on grade inlet summary
121+67	GMP	0.91	8376.00	8375.09	0.91	2.6	3.3	3.9	0.6	1.3	1.8	3.2	4.6	5.68	13.6	Yes
124+40	On-grade															See on grade inlet summary
129+60	On-grade															See on grade inlet summary
133+00	GMP	2.23	8317.20	8316.31	0.89	8.3	10.5	12.3	0.4	0.6	0.8	8.7	11.1	13.1	13.4	Yes
133+21	GMP	2.68	8317.20	8316.00	1.20	10.2	13.1	15.3				10.2	13.1	15.3	15.6	Yes
137+69	Flaired End															See culvert summary

On-grade Inlet Summary - 4R Section

Design Storm: 10-year
Grate Type: Curved Vane

Culvert STA	Inlet Type	Grate Length (ft)	Grate Width (ft)	Inlet Length (ft)	Gutter Width (ft)	Basin Q (cfs)			Bypass Q From Upstream (cfs)			Total Q (cfs)			Intercepted Flow (cfs)			Bypass Flow (cfs)			Efficiency		
						10 yr	25 yr	50 yr	10 yr	25 yr	50 yr	10 yr	25 yr	50 yr	10 yr	25 yr	50 yr	10 yr	25 yr	50 yr	10 yr	25 yr	50 yr
27+82	On-grade	3	1.833	3	2	3.5	4.4	5.2				3.5	4.4	5.2	2.2	2.7	3.0	1.3	1.7	2.2	63%	60%	58%
29+31	On-grade	3	1.833	3	2	0.8	1.0	1.1	1.3	1.7	2.2	2.1	2.7	3.3	1.9	1.9	2.1	0.2	0.8	1.2	90%	70%	63%
33+71	On-grade 1st	3	1.833	3	2	3.9	5.0	5.8	0.2	0.8	1.2	4.1	5.8	7.0	3.0	3.0	3.0	1.1	2.8	4.0	73%	52%	43%
33+71	On-grade 2nd	3	1.833	3	2	0.0	0.0	0.0	1.1	2.8	4.0	1.1	2.8	4.0	1.1	1.9	3.0	0.0	0.9	1.0	100%	67%	75%
48+24	On-grade	3	1.833	3	2	0.8	1.0	1.1				0.8	1.0	1.1	0.8	1.0	1.1	0.0	0.0	0.0	100%	100%	100%
51+37	On-grade	3	1.833	3	2	1.2	1.6	1.8				1.2	1.6	1.8	1.2	1.6	1.8	0.0	0.0	0.0	100%	100%	100%
60+50	On-grade 1st	3	1.833	3	2	4.9	6.2	7.2				4.9	6.2	7.2	3.1	3.1	3.2	1.7	3.0	4.1	64%	51%	44%
60+50	On-grade 2nd	3	1.833	3	2	0.0	0.0	0.0	1.7	3.0	4.1	1.7	3.0	4.1	1.7	2.0	3.1	0.0	1.0	0.9	100%	67%	77%
63+20	On-grade	3	1.833	3	2	2.1	2.7	3.2	0.0	1.0	0.9	2.1	3.7	4.1	1.9	2.8	2.8	0.2	1.1	1.3	92%	75%	67%
67+15	On-grade 1st	3	1.833	3	2	4.3	5.4	6.3	0.2	1.1	1.3	4.5	6.5	7.6	2.7	2.8	2.8	1.7	3.7	4.9	61%	43%	36%
67+15	On-grade 2nd	3	1.833	3	2	0.0	0.0	0.0	1.7	3.7	4.9	1.7	3.7	4.9	1.7	2.7	2.7	0.0	1.0	2.1	100%	74%	56%
67+90	On-grade	3	1.833	3	2	0.9	1.1	1.3	0.0	1.0	2.1	0.9	2.1	3.4	0.9	1.9	2.9	0.0	0.1	0.5	100%	94%	86%
71+16	On-grade 1st	3	1.833	3	2	3.4	4.3	5.1	0.0	0.1	0.5	3.4	4.4	5.6	3.0	3.1	3.1	0.4	1.3	2.5	89%	69%	55%
71+16	On-grade 2nd	3	1.833	3	2	0.0	0.0	0.0	0.4	1.3	2.5	0.4	1.3	2.5	0.4	1.3	2.0	0.0	0.0	0.6	100%	100%	78%
90+05	On-grade	3	1.833	3	2	1.6	2.0	2.4				1.6	2.0	2.4	1.6	2.0	2.3	0.0	0.0	0.1	100%	98%	96%
94+54	On-grade	3	1.833	3	2	2.8	3.6	4.2				2.8	3.6	4.2	2.1	2.1	2.1	0.8	1.5	2.1	73%	58%	49%
96+86	On-grade	3	1.833	3	2	1.5	2.0	2.3	0.8	1.5	2.1	2.3	3.5	4.4	2.0	2.5	2.5	0.3	1.0	1.9	85%	70%	56%
112+03	On-grade	3	1.833	3	2	0.9	1.1	1.3				0.9	1.1	1.3	0.9	1.1	1.3	0.0	0.0	0.0	100%	100%	100%
119+55	On-grade 1st	3	1.833	3	2	5.6	7.2	8.4				5.6	7.2	8.4	3.2	3.7	4.0	2.5	3.5	4.4	56%	51%	47%
119+55	On-grade 2nd	3	1.833	3	9	0.0	0.0	0.0	2.5	3.5	4.4	2.5	3.5	4.5	1.9	2.2	2.7	0.6	1.3	1.8	78%	63%	60%
124+40	On-grade	3	1.833	3	2	1.2	1.6	1.9				1.2	1.6	1.9	1.2	1.6	1.8	0.0	0.0	0.0	100%	100%	98%
129+60	On-grade	3	1.833	3	2	2.6	3.3	3.9	0.00	0.00	0.03	2.6	3.3	3.9	2.2	2.7	3.1	0.4	0.6	0.8	85%	83%	80%

Culvert Discharge Summary - 4R Section

Design Storm: 25-year

Culvert STA	Culvert Type	Existing Culvert Diameter (in) (for information only)	Proposed Culvert Diameter (in)	Manning's n	Culvert Slope*	Length (ft)	Basin Q (cfs) - 25 yr	Bypass From Upstream (cfs) 25 yr	Total Flow (cfs) 25 yr	Culvert Discharge(cfs)	Roadway Discharge (cfs)	Inlet Invert Elevation	Outlet Invert Elevation	Headwater Elevation	Headwater Depth (ft)	Allowable HW Elevation	Outlet Velocity (ft/s)**	Overtopping
11+42	Corrugated Steel, Circular, Straight	18	24	0.024	1.00%	48.20	1.2		1.2	1.2	0.0	9157.20	9156.72	9157.76	0.51	9162.08	2.95	No
16+49	Corrugated Steel, Circular, Straight	NA	24	0.024	1.00%	34.18	2.4		2.4	2.4	0.0	9120.63	9120.28	9121.44	0.74	9124.69	3.56	No
27+82	Corrugated Steel, Circular, Straight	18	24	0.024	5.87%	32.22	2.7		2.7	2.7	0.0	9036.91	9035.03	9037.65	0.74	9040.83	5.91	No
29+31	Corrugated Steel, Circular, Straight	18	24	0.024	9.59%	36.30	1.9		1.9	1.9	0.0	9025.98	9022.24	9026.58	0.60	9029.90	6.42	No
33+71 (up sta)	Corrugated Steel, Circular, Straight	-	24	0.024	1.00%	5.00	3.0		3.0	3.0	0.0	8990.26	8990.21	8991.18	0.83	8995.55	3.77	No
33+71	Corrugated Steel, Circular, Straight	18	24	0.024	1.00%	31.27	1.9	3.0	4.9	4.9	0.0	8990.18	8989.87	8991.38	1.08	8994.86	4.36	No
37+75	Corrugated Steel, Circular, Straight	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
38+02	Corrugated Steel, Circular, Straight	12	24	0.024	5.34%	41.04	3.5		3.5	3.5	0.0	8955.55	8953.37	8956.41	0.86	8959.88	6.14	No
40+52	Corrugated Steel, Circular, Straight	NA	24	0.024	4.84%	49.24	1.9		1.9	1.9	0.0	8939.94	8937.56	8940.57	0.63	8944.98	5.02	No
45+86	Corrugated Steel, Circular, Straight	18	24	0.024	1.00%	35.07	3.5	0.1	3.6	3.6	0.0	8892.89	8892.54	8893.91	0.92	8897.48	4.00	No
47+00	Corrugated Steel, Circular, Straight	NA	24	0.024	1.00%	34.59	1.5		1.5	1.5	0.0	8883.50	8883.15	8884.14	0.58	8888.27	3.12	No
48+24	Corrugated Steel, Circular, Straight	18	24	0.024	1.00%	29.98	1.0		1.0	1.0	0.0	8873.82	8873.52	8874.34	0.47	8878.18	2.83	No
50+51	Corrugated Steel, Circular, Straight	15	24	0.024	6.01%	39.56	4.8		4.8	4.8	0.0	8852.27	8851.84	8853.45	1.07	8857.99	4.34	No
51+37	Corrugated Steel, Circular, Straight	18	24	0.024	1.00%	35.45	1.6		1.6	1.6	0.0	8846.98	8846.59	8847.64	0.60	8850.91	3.17	No
52+67	Corrugated Steel, Circular, Straight	15	24	0.024	1.00%	33.64	1.6		1.6	1.6	0.0	8834.71	8834.34	8835.37	0.60	8839.11	3.17	No
54+28	Corrugated Steel, Circular, Straight	18	24	0.024	6.96%	43.13	3.5		3.5	3.5	0.0	8819.98	8816.77	8820.83	0.85	8825.30	6.78	No
60+50 (up sta)	Corrugated Steel, Circular, Straight	-	24	0.024	1.60%	5.00	3.1		3.1	3.1	0.0	8766.51	8766.43	8767.35	0.84	8771.26	3.74	No
60+50	Corrugated Steel, Circular, Straight	18	24	0.024	1.65%	29.97	1.9	3.1	5.0	5.0	0.0	8766.37	8765.82	8767.46	1.09	8770.29	4.46	No
63+20	Corrugated Steel, Circular, Straight	18	24	0.024	1.00%	29.71	1.3		1.3	1.3	0.0	8741.84	8741.55	8742.43	0.54	8745.77	3.02	No
67+15 (up sta)	Corrugated Steel, Circular, Straight	-	24	0.024	1.00%	5.00	2.8		2.8	2.8	0.0	8716.40	8716.07	8717.35	0.80	8720.68	3.70	No
67+15	Corrugated Steel, Circular, Straight	18	24	0.024	1.00%	32.07	2.7	2.8	5.5	5.5	0.0	8716.40	8716.07	8717.67	1.16	8720.68	4.50	No
67+90	Corrugated Steel, Circular, Straight	15	24	0.024	1.00%	31.67	2.9		2.9	2.9	0.0	8710.60	8710.28	8711.50	0.82	8715.57	3.75	No
71+16 (up sta)	Corrugated Steel, Circular, Straight	-	24	0.024	1.00%	5.00	3.1		3.1	3.1	0.0	8683.60	8683.55	8684.53	0.84	8688.20	3.80	No
71+16	Corrugated Steel, Circular, Straight	15	24	0.024	1.00%	32.80	1.8	3.1	4.9	4.9	0.0	8683.53	8683.20	8684.73	1.08	8687.45	4.36	No
78+48	Corrugated Steel, Circular, Straight	15	24	0.024	1.16%	51.89	14.1		14.1	14.1	0.0	8617.75	8617.15	8620.02	2.12	8622.94	6.26	No
83+36	Corrugated Steel, Circular, Straight	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Culvert Discharge Summary - 4R Section

Design Storm: 25-year

Culvert STA	Culvert Type	Existing Culvert Diameter (In) (for information only)	Proposed Culvert Diameter (in)	Manning's n	Culvert Slope*	Length (ft)	Basin Q (cfs) - 25 yr	Bypass From Upstream (cfs) 25 yr	Total Flow (cfs) 25 yr	Culvert Discharge(cfs)	Roadway Discharge (cfs)	Inlet Invert Elevation	Outlet Invert Elevation	Headwater Elevation	Headwater Depth (ft)	Allowable HW Elevation	Outlet Velocity (ft/s)**	Overtopping
83+36	Corrugated Steel, Circular, Straight	NA	24	0.024	7.58%	39.81	4.7		4.7	4.7	0.0	8578.76	8575.75	8579.75	0.99	8584.29	7.60	No
86+31	Corrugated Steel, Circular, Straight	12	24	0.024	2.47%	37.87	6.0		6.0	6.0	0.0	8579.30	8578.28	8580.50	1.20	8583.35	5.43	No
90+05	Corrugated Steel, Circular, Straight	NA	24	0.024	1.00%	34.66	2.0		2.0	2.0	0.0	8570.78	8570.44	8571.52	0.67	8574.44	3.40	No
92+24	Corrugated Steel, Circular, Straight	15	24	0.024	1.00%	37.55	1.8		1.8	1.8	0.0	8563.42	8563.05	8564.12	0.63	8533.92	3.27	No
94+54	Corrugated Steel, Circular, Straight	18	24	0.024	5.27%	32.09	2.1		2.1	2.1	0.0	8555.55	8553.86	8556.20	0.65	8559.23	5.30	No
96+86	Corrugated Steel, Circular, Straight	15	24	0.024	3.51%	34.79	2.5		2.5	2.5	0.0	8543.72	8542.50	8544.45	0.73	8547.40	4.79	No
99+11	Corrugated Steel, Circular, Straight	18	24	0.024	1.00%	37.39	6.8		6.8	6.8	0.0	8530.89	8530.52	8532.33	1.32	8534.39	4.80	No
104+80	Corrugated Steel, Circular, Straight	NA	24	0.024	7.09%	37.64	13.9		13.9	13.9	0.0	8494.20	8491.54	8496.24	2.04	8497.86	9.29	No
109+81	Corrugated Steel, Circular, Straight	24	24	0.024	8.68%	46.05	18.9		18.9	18.9	0.0	8458.23	8454.25	8460.90	2.67	8462.23	10.95	No
112+03	Corrugated Steel, Circular, Straight	18	24	0.024	1.00%	37.03	1.1		1.1	1.1	0.0	8441.99	8441.62	8442.53	0.49	8445.82	2.89	No
115+08	Corrugated Steel, Circular, Straight	18	24	0.024	1.00%	43.88	7.0		7.0	7.0	0.0	8414.89	8414.39	8416.35	1.33	8420.73	4.83	No
119+55 (up sta)	Corrugated Steel, Circular, Straight	NA	24	0.024	2.20%	5.00	3.7		3.7	3.7	0.0	8383.33	8383.22	8384.24	0.91	8387.40	4.33	No
119+55	Corrugated Steel, Circular, Straight	18	24	0.024	1.00%	31.78	2.21	3.7	5.9	5.9	0.0	8383.16	8382.82	8384.47	1.20	8387.00	3.76	No
121+67	Corrugated Steel, Circular, Straight	15	24	0.024	1.00%	37.00	4.6		4.6	4.6	0.0	8371.27	8370.87	8372.42	1.04	8376.00	4.26	No
124+40	Corrugated Steel, Circular, Straight	12	24	0.024	1.00%	33.07	1.6		1.6	1.6	0.0	8352.86	8352.49	8353.52	0.60	8356.59	3.17	No
129+60	Corrugated Steel, Circular, Straight	NA	24	0.24	4.97%	31.65	2.7		2.7	2.7	0.0	8327.58	8326.01	8328.33	0.75	8331.25	5.55	No
132+18	Corrugated Steel, Circular, Straight	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
133+00	Corrugated Steel, Circular, Straight	NA	24	0.024	4.77%	39.90	11.1		11.1	11.1	0.0	8312.81	8310.91	8314.56	1.75	8316.31	8.13	No
133+21	Corrugated Steel, Circular, Straight	18	24	0.024	5.33%	37.19	13.1		13.1	13.1	0.0	8312.50	8310.52	8314.46	1.96	8317.14	8.46	No
137+69	Corrugated Steel, Circular, Straight	36	36	0.024	8.59%	45.55	29.1		29.1	29.1	0.0	8338.32	8333.86	8340.79	2.47	8341.36	12.82	No

*Value is highlighed when the slope is greater than 10.00%.

**Value is highlA2:O47ighted when the velocity is less than 3.00 ft/s or greater than 6.00 ft/s.

Appendix D – 3R Culvert Assessments

REDS MEADOW ROADWAY IMPROVEMENTS - 3R CULVERTS - ASSESSMENT WORKSHEET

Date: 10-2-18 Notes By: Travis Howard

No.	STA	DIA (IN)	TYPE	LENGTH (FT)	Min COVER (IN)	SLOPE (Mild or Steep)	FLOW DIRECTION (L or R)	UPSTREAM END TREATMENT	DOWNSTREAM END TREATMENT	CONDITION good/fair/poor/crit/unk	PHOTOS Roadway (ahead)	Roadway (back)	Inlet	View up-stream	Outlet	View down-stream	NOTES:	RECOMMENDATION
34	137+50	36"	CMP	38	24"	MILD	R to L	Stone HW	Projecting	POOR	X	X	X	X	X	X	Rusted invert, rocks in barrel	Replace with 36" with FES at inlet and outlet
35	506+00	24"	CMP	36	24"	MILD	R to L	Projecting	Projecting	FAIR	X	X	X	X	X	X	Silt and rocks in invert, rusted barrel	Replace with 24" with FES at inlet and outlet
36	512+00	24"	CMP	36	12"	MILD	L to R	Projecting	Projecting	FAIR	X	X	X	X	X	X	Minor rust in invert, functioning system, flowing water	KEEP
37	515+50	18"	CMP	41	12"	MILD	L to R	Projecting	Projecting	POOR	X	X	X	X	X	X	Rusted, silted in barrel	Replace with 24", add FES at inlet and outlet
38	517+50	15"	CMP	37	12"	MILD	L to R	Projecting	Projecting	POOR	X	X	X	X	X	X	Rusted, silted in barrel	Replace with 18", add FES at inlet and outlet
39	518+00	36"	CMP	43	12"	MILD	L to R	Projecting	Projecting	FAIR	X	X	X	X	X	X	Functioning System, appears to be year round flow, minor rust on invert, slight drop at outlet	KEEP
40	521+30	18"	CMP	48	8"	MILD	L to R	Projecting	Projecting	POOR	X	X	X	X	X	X	Silted, rusted invert, mis-aligned barrel	Replace with 18", add FES at inlet and outlet
41	524+00	15"	CMP	40	12"	MILD	L to R	Projecting	Projecting	FAIR	X	X	X	X	X	X	Rusted barrel	Replace with 18", add FES at inlet and outlet
42	534+50	15"	CMP	35	20"	MILD	L to R	Projecting	Projecting	FAIR	X	X	X	X	X	X	Mis-aligned, rusted barrel, flowing water, appears to receive year round flow	Replace with 24", add FES at inlet and outlet
43	536+00	15"	CMP	46	8"	MILD	L to R	Stone HW	Projecting	FAIR	X	X	X	X	X	X	Silted in, rusted invert, mis-aligned barrel	Replace with 18", add FES at inlet and outlet
44	539+50	15"	CMP	39	12"	MILD	L to R	Stone HW	Projecting	FAIR	X	X	X	X	X	X	Rusted, damaged barrel	Replace with 18", add FES at inlet and outlet
45	545+00	15"	CMP	41	12"	MILD	L to R	Stone HW	Projecting	POOR	X	X	X	X	X	X	Rusted barrel	Replace with 18", add FES at inlet and outlet
46	550+00	15"	CMP	44	4"	MILD	L to R	Projecting	Projecting	POOR	X	X	X	X	X	X	Crushed inlet, rusted barrel	Replace with 15", add FES at inlet and outlet
47	551+00	15"	CMP	41	12"	MILD	L to R	Stone HW	Projecting	POOR	X	X	X	X	X	X	Silted in outlet	Replace with 18", add FES at inlet and outlet
48	552+00	24"	CMP	38	12"	MILD	L to R	Stone HW	Projecting	FAIR	X	X	X	X	X	X	Minor rust on invert, flowing water, slight drop at outlet, functionining system, appears to receive year round flow	KEEP
49	555+40	26"x34" squash pipe	CMP	40	12"	MILD	L to R	Projecting	Projecting	FAIR	X	X	X	X	X	X	Minor rust invert, flowing water, functioning system, appears to receive year round flow	KEEP
50	556+00	18"	CMP	39	20"	MILD	L to R	Projecting	Projecting	POOR	X	X	X	X	X	X	Rusted invert, crushed inlet	Replace with 24", add FES at inlet and outlet
51	563+00	18"	CMP	40	12"	MILD	L to R	Projecting	Projecting	POOR	X	X	X	X	X	X	Mis-aligned barrel, rusted invert, concrete placed as energy dissipater at outlet	Replace with 24", add FES at inlet and outlet, add riprap at outlet
52	564+50	36"	CMP	40	12"	MILD	L to R	Projecting	Projecting	POOR	X	X	X	X	X	X	Rusted, detioriated invert, flowing water, appears to have year round flow	Replace with 36", add FES at inlet and outlet
53	576+00	18"	CMP	35	12"	MILD	L to R	Projecting	Projecting	FAIR	X	X	X	X	X	X	Mis-aligned barrel, minor rust on invert	Replace with 24", add FES at inlet and outlet

REDS MEADOW ROADWAY IMPROVEMENTS - 3R CULVERTS - ASSESSMENT WORKSHEET

Date: 10-2-18 Notes By: Travis Howard

No.	STA	DIA (IN)	TYPE	LENGTH (FT)	Min COVER (IN)	SLOPE (Mild or Steep)	FLOW DIRECTION (L or R)	UPSTREAM END TREATMENT	DOWNSTREAM END TREATMENT	CONDITION good/fair/poor/crit/unk	PHOTOS: Roadway (ahead)	PHOTOS: Roadway (back)	PHOTOS: Inlet	PHOTOS: View up-stream	PHOTOS: Outlet	PHOTOS: View down stream	NOTES:	RECOMMENDATION
54	590+00	Double 18"	CMP	60	8"	MILD	L to R	Projecting	Projecting, FES	POOR	X	X	X	X	X	X	Rusted, detioriated barrels	Replace with double 18", add FES at inlet and outlet
55	595+50	15"	CMP	35	18"	MILD	L to R	Projecting	Projecting	POOR	X	X	X	X	X	X	Mis-aligned barrel, silted outlet, rusted invert	Replace with 24", add FES at inlet and outlet
56	595+80	15"	CMP	38	6"	MILD	L to R	Projecting	Projecting	POOR	X	X	X	X	X	X	Crown of barrel punctured, fully silted in outlet	Replace with 18", add FES at inlet and outlet
57	599+00	32" x 26" squash pipe	CMP	41	8"	MILD	L to R	Projecting	Projecting	FAIR	X	X	X	X	X	X	Barrel in fair condition, significant erosion at outlet, 4' vertical drop at outlet	Replace with 24", add FES at inlet and outlet, extend outlet 10' and add riprap at outlet
58	603+00	24"	CMP	44	6"	MILD	L to R	Projecting	Projecting	POOR	X	X	X	X	X	X	Mis-aligned barrel, significant erosion at outlet, 2.5' vertical drop at outlet	Replace with 24", add FES at inlet and outlet, extend outlet 10' and add riprap at outlet
59	608+00	Double, 18" and 24"	CMP	42	12"	MILD	L to R	Projecting	Projecting	FAIR	X	X	X	X	X	X	Rusted barrel, silted invert	Replace with dual 24" and new FES at inlet and outlet
60	617+00	18"	CMP	34	6"	MILD	L to R	Projecting	Projecting	POOR	X	X	X	X	X	X	Ruested, silted in, deformed barrel	Replace with 18", add FES at inlet and outlet
61	620+50	15"	CMP	34	8"	MILD	L to R	Projecting	Projecting	POOR	X	X	X	X	X	X	Silted in, rusted barrel	Replace with 18", add FES at inlet and outlet
62	627+00	42" x 30" squash pipe	CMP	42	12"	MILD	L to R	Projecting	Projecting	POOR	X	X	X	X	X	X	Deformed crown, erosion at outlet	Replace with 36", add FES at inlet and outlet, add riprap at outlet
63	636+00	18"	CMP	46	12"	MILD	L to R	Projecting	Projecting	POOR	X	X	X	X	X	X	Silted Outlet, rusted barrel	Replace with 24", add FES at inlet and outlet
64	650+00	48" x 70" Arch	CMP	51	12"	MILD	L to R	HW	HW	FAIR	X	X	X	X	X	X	Summers Creek, culvert functional, flowing water, appears to be year round flow	KEEP
65	652+00	15"	CMP	52	12"	MILD	L to R	FES	FES	POOR	X	X	X	X	X	X	Culvert silted in, rusted	Replace with 18", new FES at inlet and outlet
66	658+00	24"	CMP	59	36"	MILD	L to R	FES	FES	FAIR	X	X	X	X	X	X	Culvert has slight rust and silt along invert, functional, in fair condition	KEEP
67	662+00	41" wide elipse	CMP	41	12"	MILD	L to R	FES	FES	POOR	X	X	X	X	X	X	Culvert flowing water, silted in, wood block proping up crown	Replace with double 24" culverts with FES at inlet and outlet
68	668+30	24"	CMP	44	12"	MILD	L to R	FES	FES	FAIR	X	X	X	X	X	X	Culvert in fair condition, functioning, flowing water	KEEP
69	669+30	36"	CMP	50	6"	MILD	L to R	FES	FES	FAIR	X	X	X	X	X	X	Culvert in good fair to good condition, recommend leaving in place.	KEEP
70	680+00	24"	CMP	53	6"	MILD	L to R	FES	FES	POOR	X	X	X	X	X	X	Barrel crown is crushed, culvert is functional	Replace with 24", new FES at inlet and outlet
71	685+00	18"	CMP	56	18"	MILD	L to R	FES	FES	FAIR	X	X	X	X	X	X	Culvert in fair condition, invert slightly rusted, culvert is functional	Replace with 24", new FES at inlet and outlet

REDS MEADOW ROADWAY IMPROVEMENTS - 3R CULVERTS - ASSESSMENT WORKSHEET

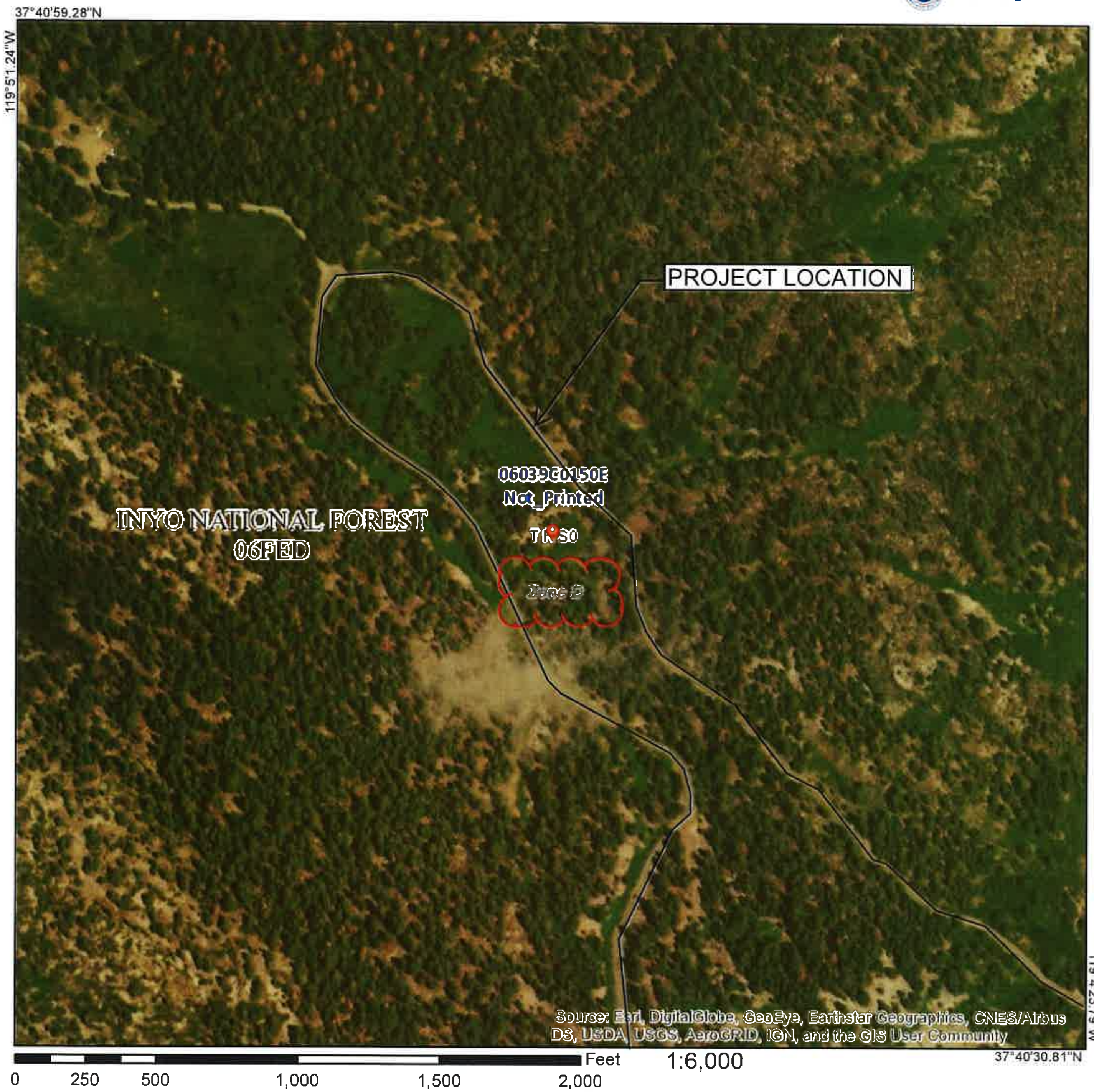
Date: 10-2-18 Notes By: Travis Howard

No.	STA	DIA (IN)	TYPE	LENGTH (FT)	Min COVER (IN)	SLOPE (Mild or Steep)	FLOW DIRECTION (L or R)	UPSTREAM END TREATMENT	DOWNSTREAM END TREATMENT	CONDITION good/fair/poor/crit/unk	PHOTOS Roadway (ahead)	Roadway (back)	Inlet	View up-stream	Outlet	View down-stream	NOTES:	RECOMMENDATION
72	693+00	10" inside a 15"	CMP	33	6"	MILD	L to R	Projecting	Projecting	POOR	X	X	X	X	X	X	15" lined with a 10", concrete grout in annular space	Replace with 18" add FES at inlet and outlet, room to lower pipe
73	724+00	24"	CMP	40	8"	MILD	L to R	Projecting	Projecting	POOR	X	X	X	X	X	X	Silted Outlet, deformed barrel, rusted invert	Replace with 24", add FES at inlet and outlet
74	727+73	18"	CMP	34	18"	MILD	L to R	Projecting	Projecting	POOR	X	X	X	X	X	X	Silted in bottom 1/3, rusted invert	Replace with 24", add FES at inlet and outlet
75	735+00	12"	CMP	29	16"	MILD	R to L	Projecting	Stone HW	POOR	X	X	X	X	X	X	Culvert rusted, bottom 1/3 silted in, two 1" flexible pipes from water line blow off discharge to culvert inlet	Replace with 18" add FES at inlet and outlet
76	772+00	36" (2)	CMP	30	12"	MILD	L to R	Stone HW	Conc HW	FAIR	X	X	X	X	X	X	Culvert functioning, flowing water, appears to be significant year round flow.	Replace with dual 36", extend inlet 6', HW at inlet and outlet
77	784+00	24"	CMP	38	12"	MILD	R to L	FES (Detached)	FES	POOR	X	X	X	X	X	X	Rusted invert, sediment filled, detached FES at inlet	Replace with 24", extend outlet 4', add FES at inlet and outlet

Appendix E – Floodplain Maps

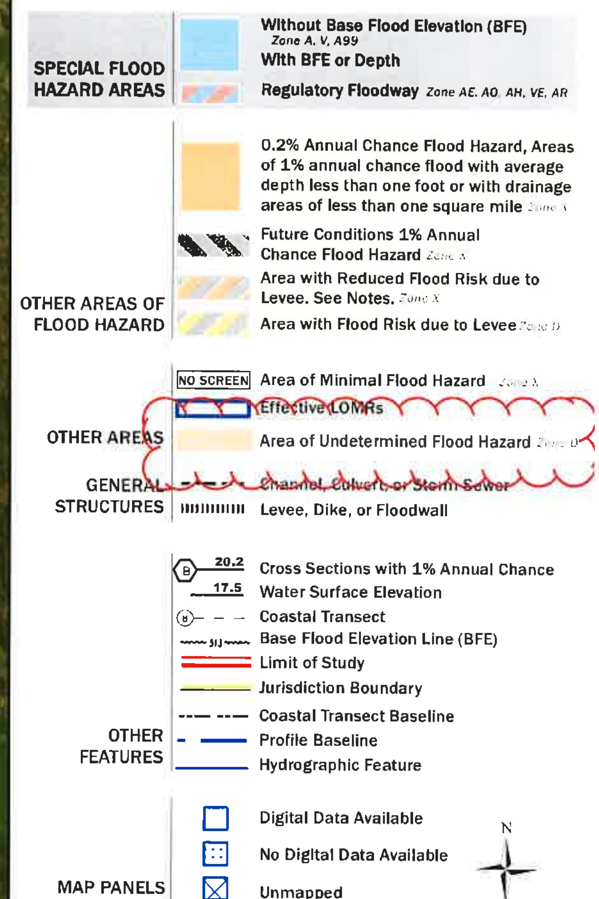
National Flood Hazard Layer FIRMette

FEMA



Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT



This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The base map shown complies with FEMA's base map accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 6/29/2018 at 6:16:11 PM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

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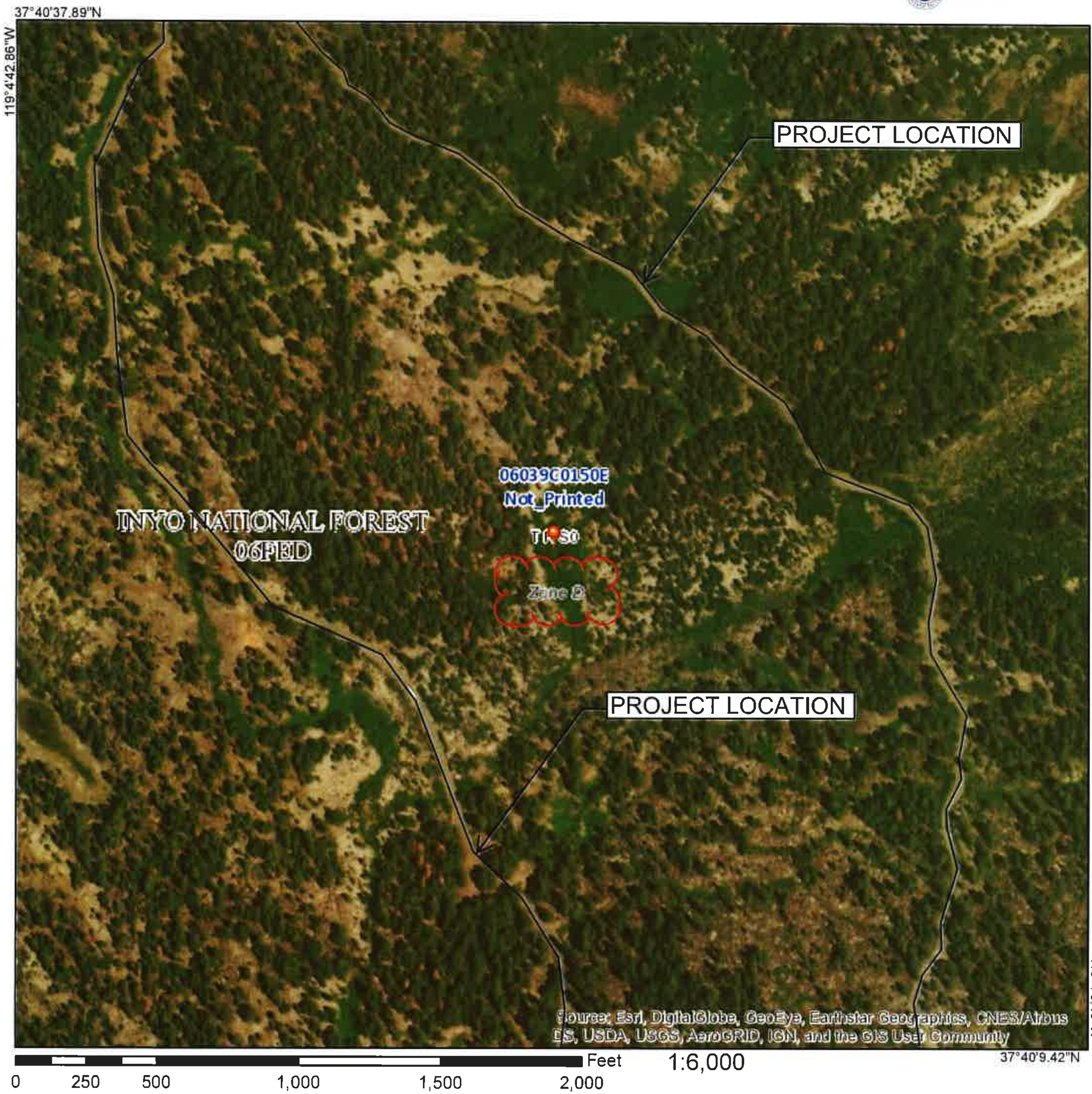
National Flood Hazard Layer FIRMette

FEMA



Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS		Without Base Flood Elevation (BFE) Zone A, V, A99
		With BFE or Depth
		Regulatory Floodway Zone AE, AO, AH, VE, AR
OTHER AREAS OF FLOOD HAZARD		0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile
		Future Conditions 1% Annual Chance Flood Hazard
		Area with Reduced Flood Risk due to Levee. See Notes.
		Area with Flood Risk due to Levee
OTHER AREAS	NO SCREEN	Area of Minimal Flood Hazard
		Effective LOMRs
		Area of Undetermined Flood Hazard
GENERAL STRUCTURES		Channel, Culvert, or Storm Sewer
		Levee, Dike, or Floodwall
OTHER FEATURES	20.2 / 17.5	Cross Sections with 1% Annual Chance Water Surface Elevation
		Coastal Transect
	513	Base Flood Elevation Line (BFE)
		Limit of Study
		Jurisdiction Boundary
		Coastal Transect Baseline
		Profile Baseline
		Hydrographic Feature
MAP PANELS		Digital Data Available
		No Digital Data Available
		Unmapped

N

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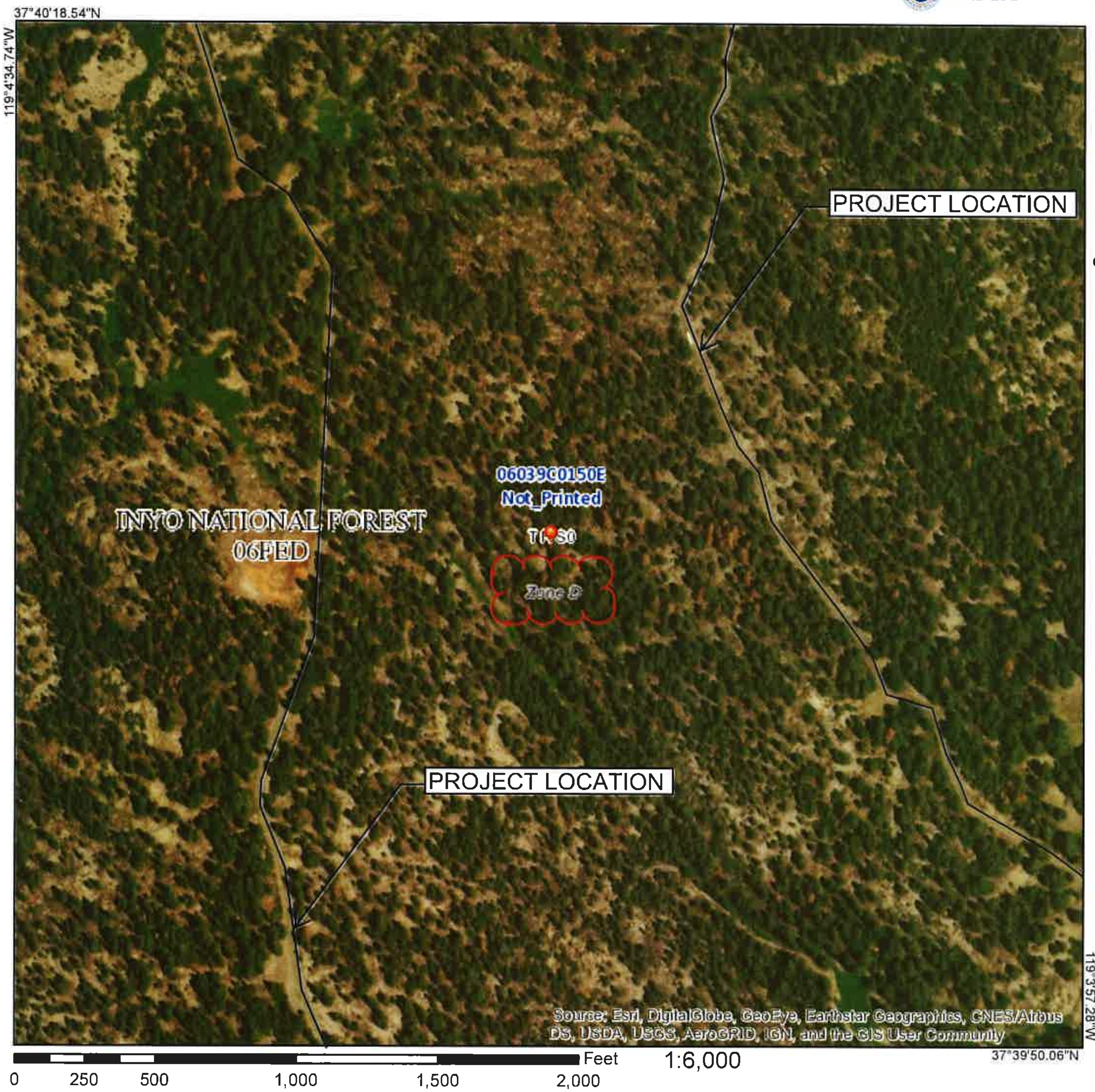
National Flood Hazard Layer FIRMette

FEMA



Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS
- Without Base Flood Elevation (BFE) *Zone A, V, A99*
- With BFE or Depth
- Regulatory Floodway *Zone AE, AO, AH, VE, AR*

OTHER AREAS OF FLOOD HAZARD
- 0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile *Zone X*
- Future Conditions 1% Annual Chance Flood Hazard *Zone X*
- Area with Reduced Flood Risk due to Levee. See Notes. *Zone X*
- Area with Flood Risk due to Levee *Zone D*

OTHER AREAS
- NO SCREEN Area of Minimal Flood Hazard *Zone X*
- Effective LOMRs
- Area of Undetermined Flood Hazard *Zone D*

GENERAL STRUCTURES
- Channel, Culvert, or Storm Sewer
- Levee, Dike, or Floodwall

OTHER FEATURES
- 20.2 / 17.5 Cross Sections with 1% Annual Chance Water Surface Elevation
- Coastal Transect
- Base Flood Elevation Line (BFE)
- Limit of Study
- Jurisdiction Boundary
- Coastal Transect Baseline
- Profile Baseline
- Hydrographic Feature

MAP PANELS
- Digital Data Available
- No Digital Data Available
- Unmapped

N

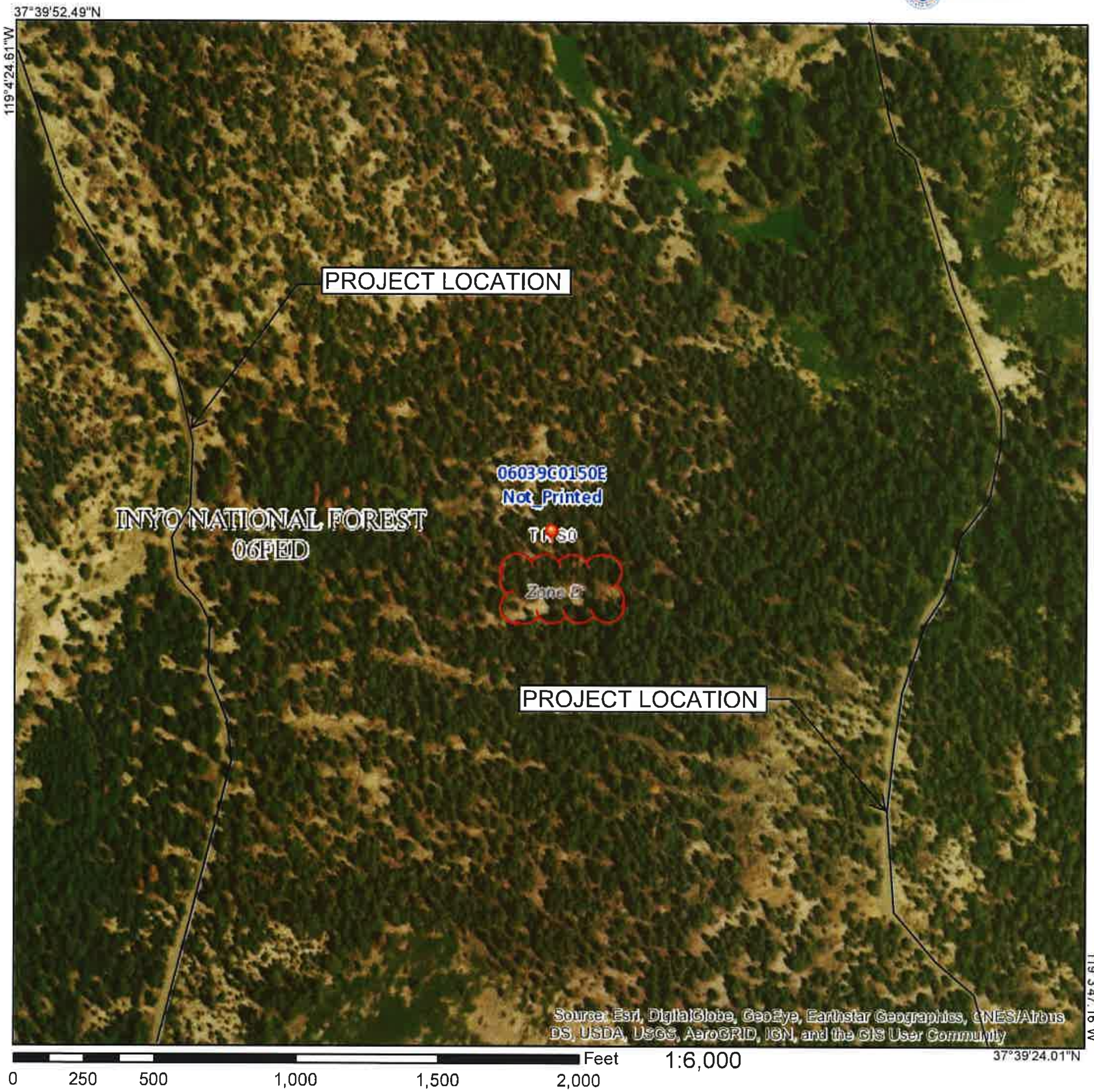
This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The base map shown complies with FEMA's base map accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 6/29/2018 at 6:20:00 PM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

This map image is void if the one or more of the following map elements do not appear: base map imagery, flood zone labels, legend, scale bar, map creation date, community identifiers, FIRM panel number, and FIRM effective date. Map images for unmapped and unmodernized areas cannot be used for regulatory purposes.

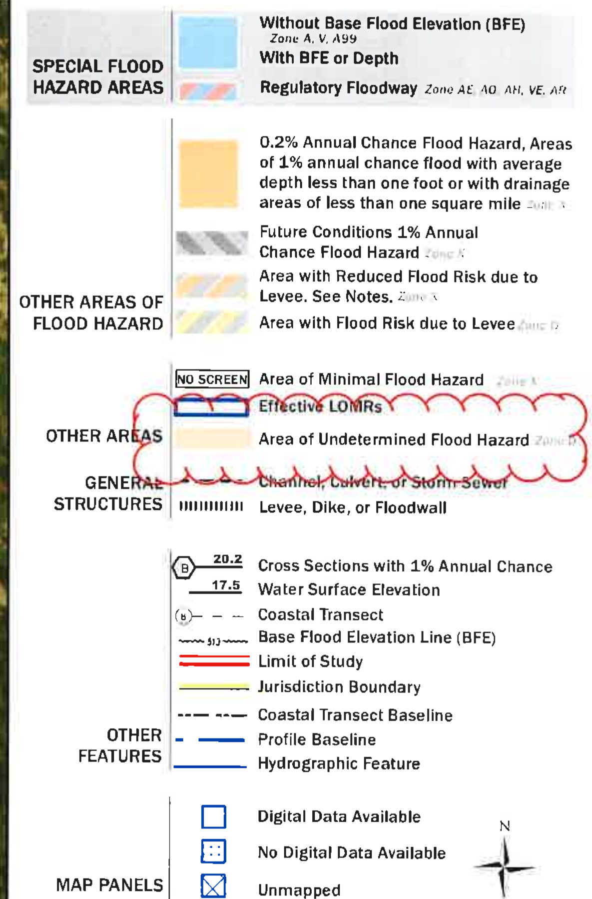
National Flood Hazard Layer FIRMette

FEMA



Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

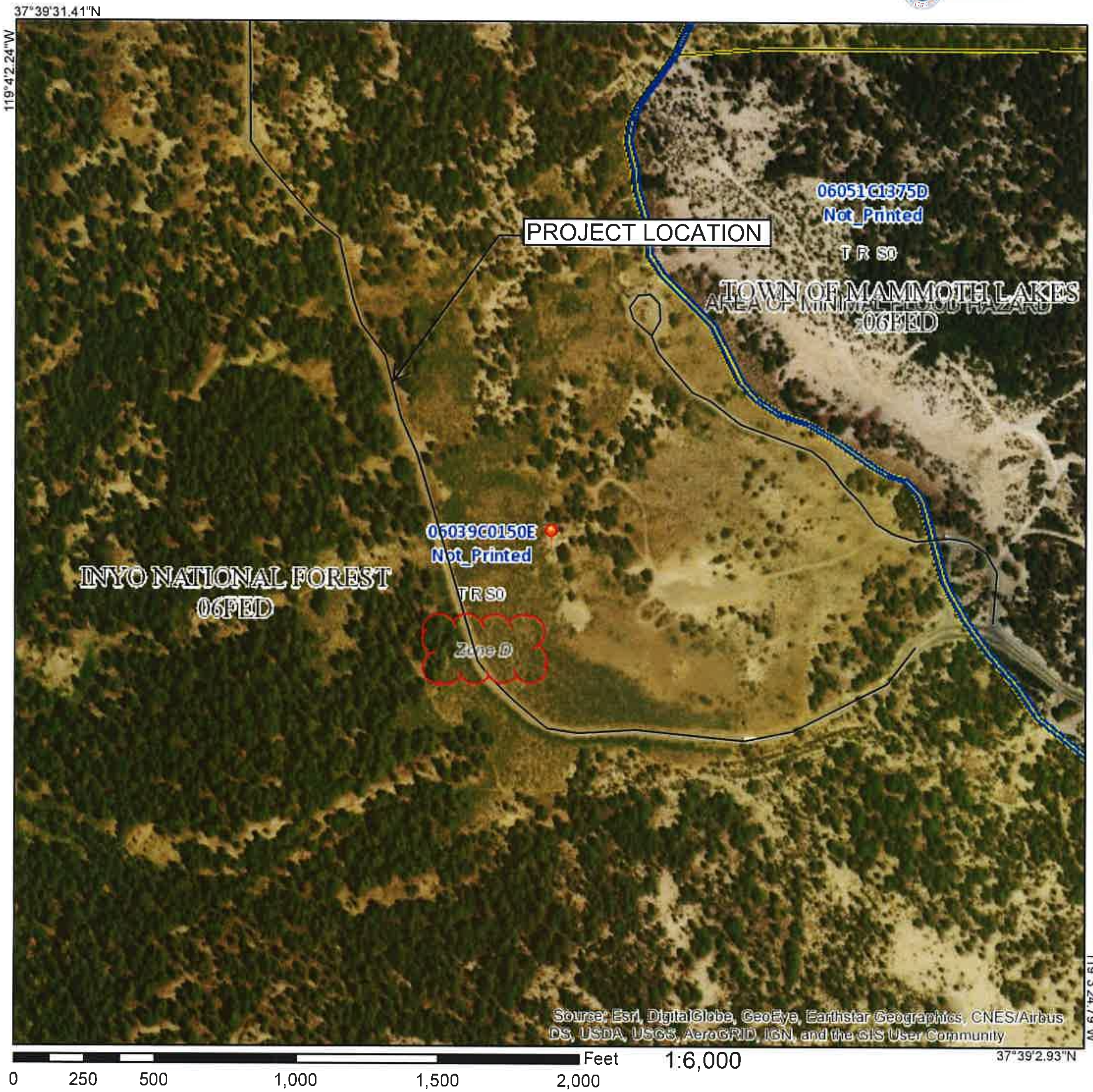


This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The base map shown complies with FEMA's base map accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 6/29/2018 at 6:23:36 PM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

This map image is void if the one or more of the following map elements do not appear: base map imagery, flood zone labels, legend, scale bar, map creation date, community identifiers, FIRM panel number, and FIRM effective date. Map images for unmapped and unmodernized areas cannot be used for regulatory purposes.

National Flood Hazard Layer FIRMette



Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS		Without Base Flood Elevation (BFE) Zone A, V, A99
		With BFE or Depth
		Regulatory Floodway Zone AE, AO, AH, VE, AR
OTHER AREAS OF FLOOD HAZARD		0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile Zone X
		Future Conditions 1% Annual Chance Flood Hazard Zone X
		Area with Reduced Flood Risk due to Levee. See Notes. Zone X
		Area with Flood Risk due to Levee Zone D
OTHER AREAS	NO SCREEN	Area of Minimal Flood Hazard Zone X
		Effective LOMRs
		Area of Undetermined Flood Hazard Zone D
GENERAL STRUCTURES		Channel, Culvert, or Storm Sewer
		Levee, Dike, or Floodwall
OTHER FEATURES	20.2 / 17.5	Cross Sections with 1% Annual Chance Water Surface Elevation
		Coastal Transect
	513	Base Flood Elevation Line (BFE)
		Limit of Study
		Jurisdiction Boundary
		Coastal Transect Baseline
		Profile Baseline
		Hydrographic Feature
MAP PANELS		Digital Data Available
		No Digital Data Available
		Unmapped

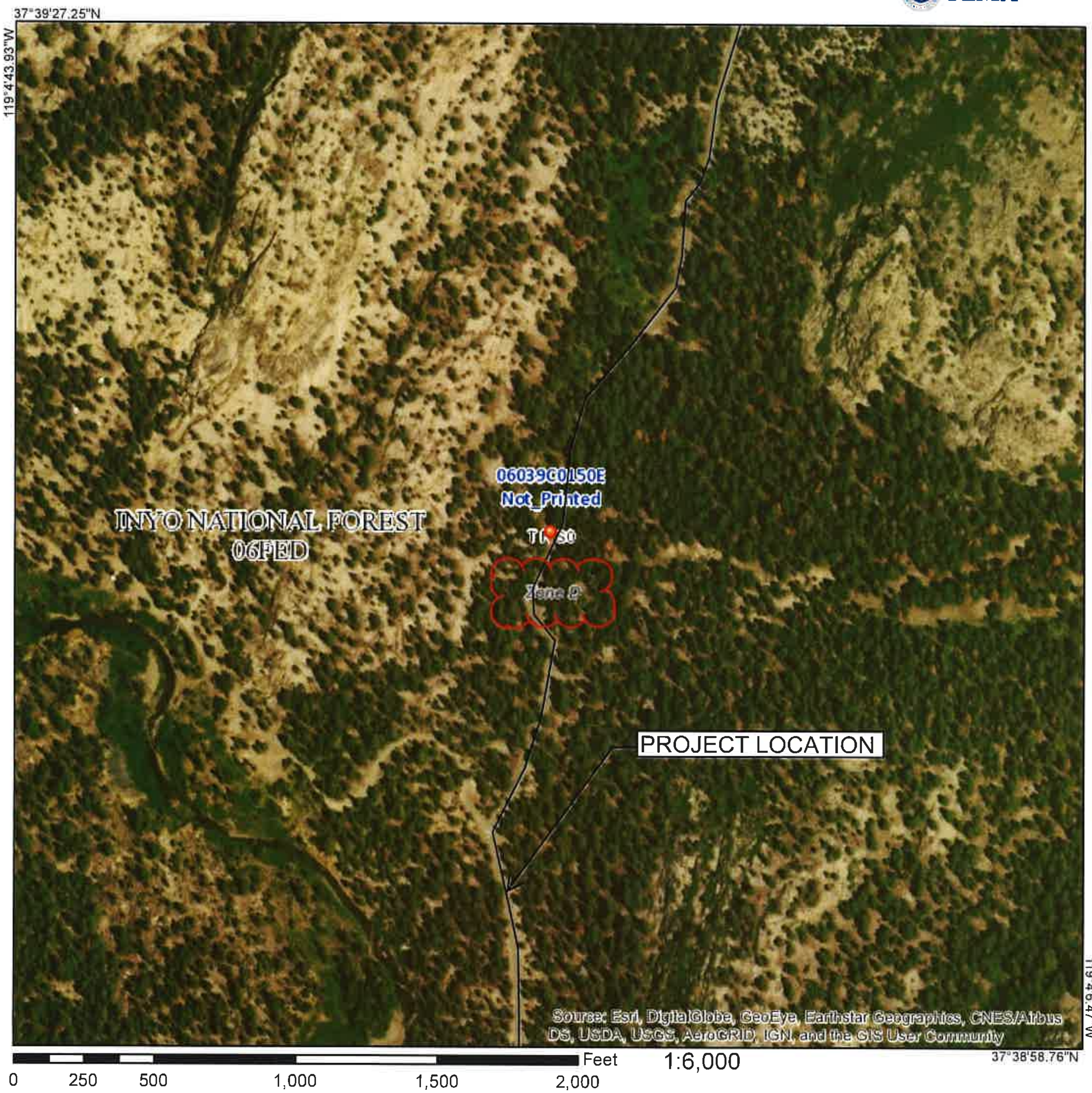
This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The base map shown complies with FEMA's base map accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 6/29/2018 at 6:26:22 PM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

This map image is void if the one or more of the following map elements do not appear: base map imagery, flood zone labels, legend, scale bar, map creation date, community identifiers, FIRM panel number, and FIRM effective date. Map images for unmapped and unmodernized areas cannot be used for regulatory purposes.

National Flood Hazard Layer FIRMette

FEMA



Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS
- Without Base Flood Elevation (BFE) *Zone A, V, A99*
- With BFE or Depth
- Regulatory Floodway *Zone AE, AO, AH, VE, AR*

OTHER AREAS OF FLOOD HAZARD
- 0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile *Zone X*
- Future Conditions 1% Annual Chance Flood Hazard *Zone X*
- Area with Reduced Flood Risk due to Levee. See Notes. *Zone X*
- Area with Flood Risk due to Levee *Zone D*

OTHER AREAS
- NO SCREEN Area of Minimal Flood Hazard *Zone X*
- Effective LOMRs
- Area of Undetermined Flood Hazard *Zone D*

GENERAL STRUCTURES
- Channel, Culvert, or Storm Sewer
- Levee, Dike, or Floodwall

OTHER FEATURES
- 20.2 / 17.5 Cross Sections with 1% Annual Chance Water Surface Elevation
- Coastal Transect
- 513 Base Flood Elevation Line (BFE)
- Limit of Study
- Jurisdiction Boundary
- Coastal Transect Baseline
- Profile Baseline
- Hydrographic Feature

MAP PANELS
- Digital Data Available
- No Digital Data Available
- Unmapped

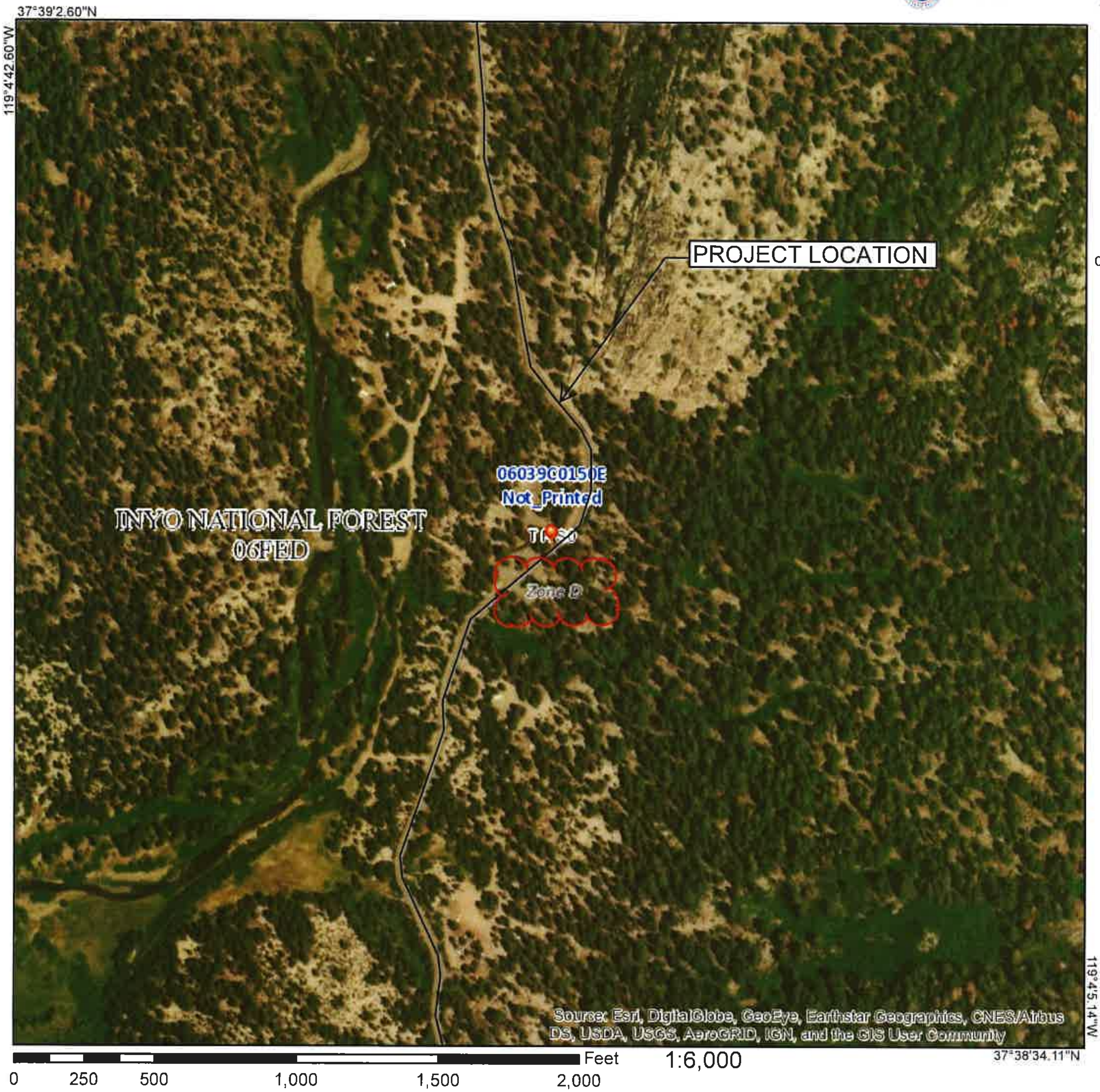
N

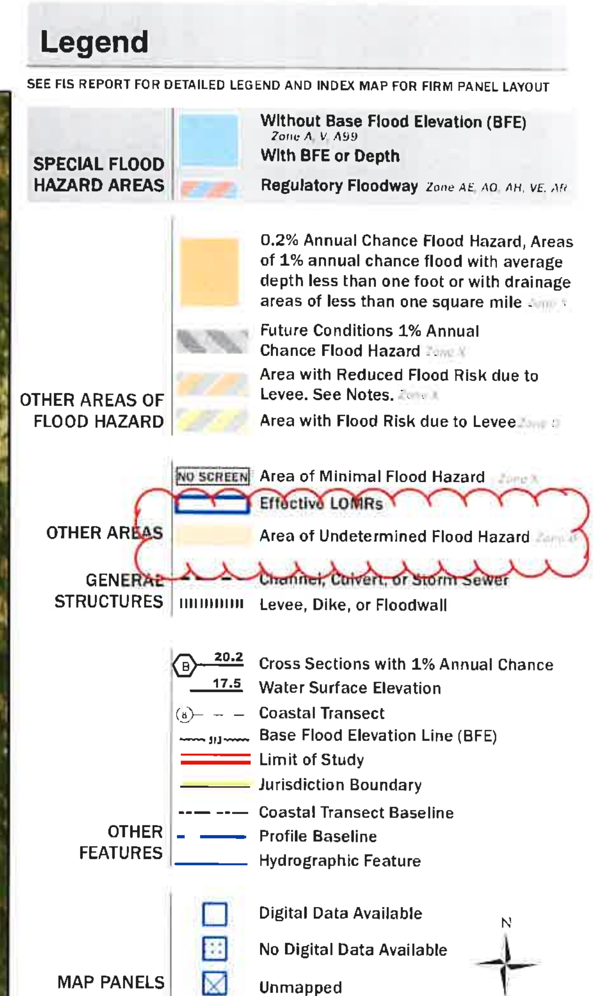
This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The base map shown complies with FEMA's base map accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 6/29/2018 at 6:29:01 PM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

This map image is void if the one or more of the following map elements do not appear: base map imagery, flood zone labels, legend, scale bar, map creation date, community identifiers, FIRM panel number, and FIRM effective date. Map images for unmapped and unmodernized areas cannot be used for regulatory purposes.

National Flood Hazard Layer FIRMette





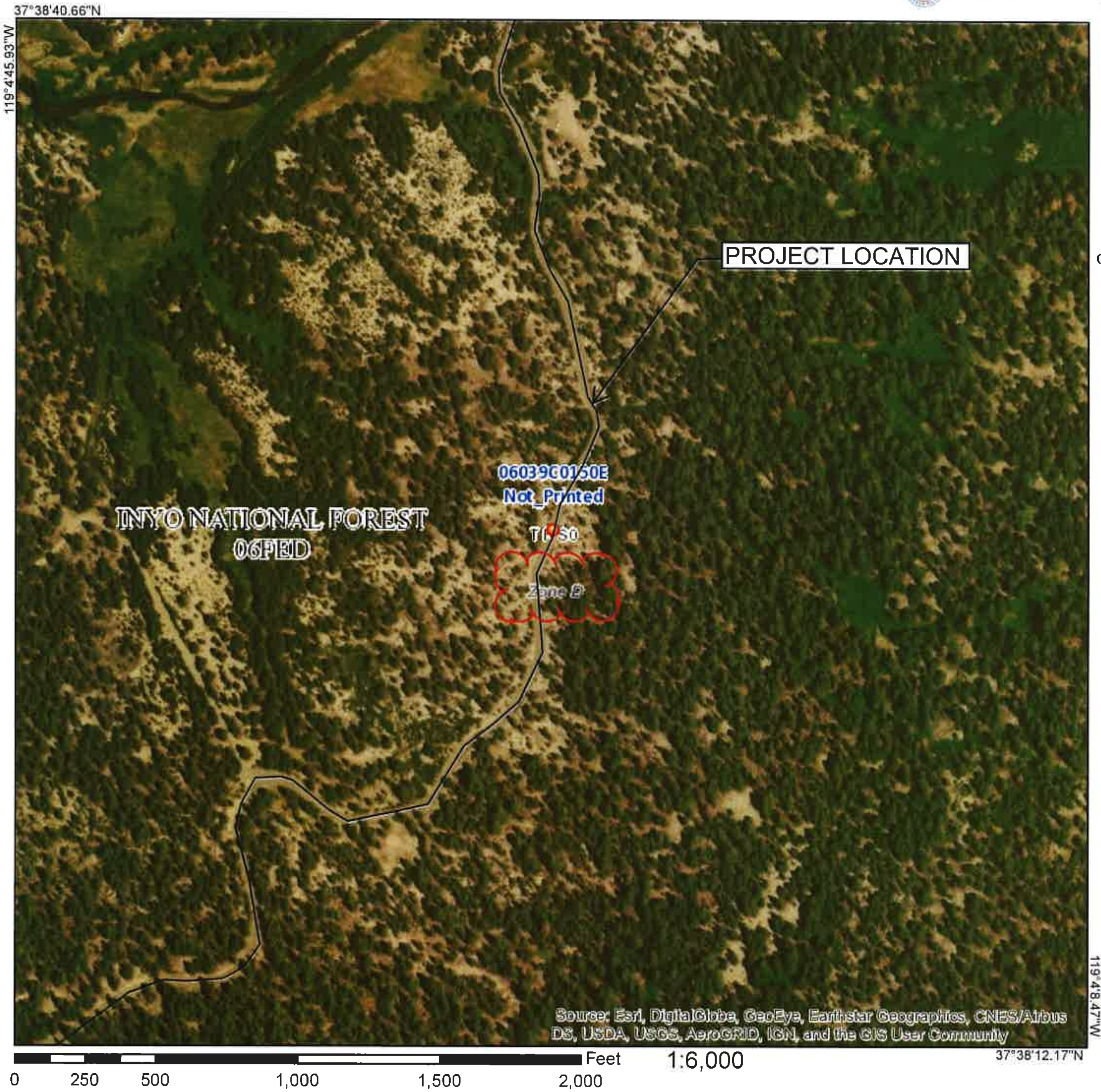
This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The base map shown complies with FEMA's base map accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 6/29/2018 at 6:31:31 PM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

This map image is void if the one or more of the following map elements do not appear: base map imagery, flood zone labels, legend, scale bar, map creation date, community identifiers, FIRM panel number, and FIRM effective date. Map images for unmapped and unmodernized areas cannot be used for regulatory purposes.

National Flood Hazard Layer FIRMette

FEMA



Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS
- Without Base Flood Elevation (BFE) *Zone A, V, A99*
- With BFE or Depth
- Regulatory Floodway *Zone AE, AO, AH, VE, AR*

OTHER AREAS OF FLOOD HAZARD
- 0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile
- Future Conditions 1% Annual Chance Flood Hazard
- Area with Reduced Flood Risk due to Levee. See Notes.
- Area with Flood Risk due to Levee

OTHER AREAS
- NO SCREEN Area of Minimal Flood Hazard
- Effective LOMRs
- Area of Undetermined Flood Hazard

GENERAL STRUCTURES
- Channel, Culvert, or Storm Sewer
- Levee, Dike, or Floodwall

OTHER FEATURES
- 20.2 / 17.5 Cross Sections with 1% Annual Chance Water Surface Elevation
- Coastal Transect
- Base Flood Elevation Line (BFE)
- Limit of Study
- Jurisdiction Boundary
- Coastal Transect Baseline
- Profile Baseline
- Hydrographic Feature

MAP PANELS
- Digital Data Available
- No Digital Data Available
- Unmapped

N

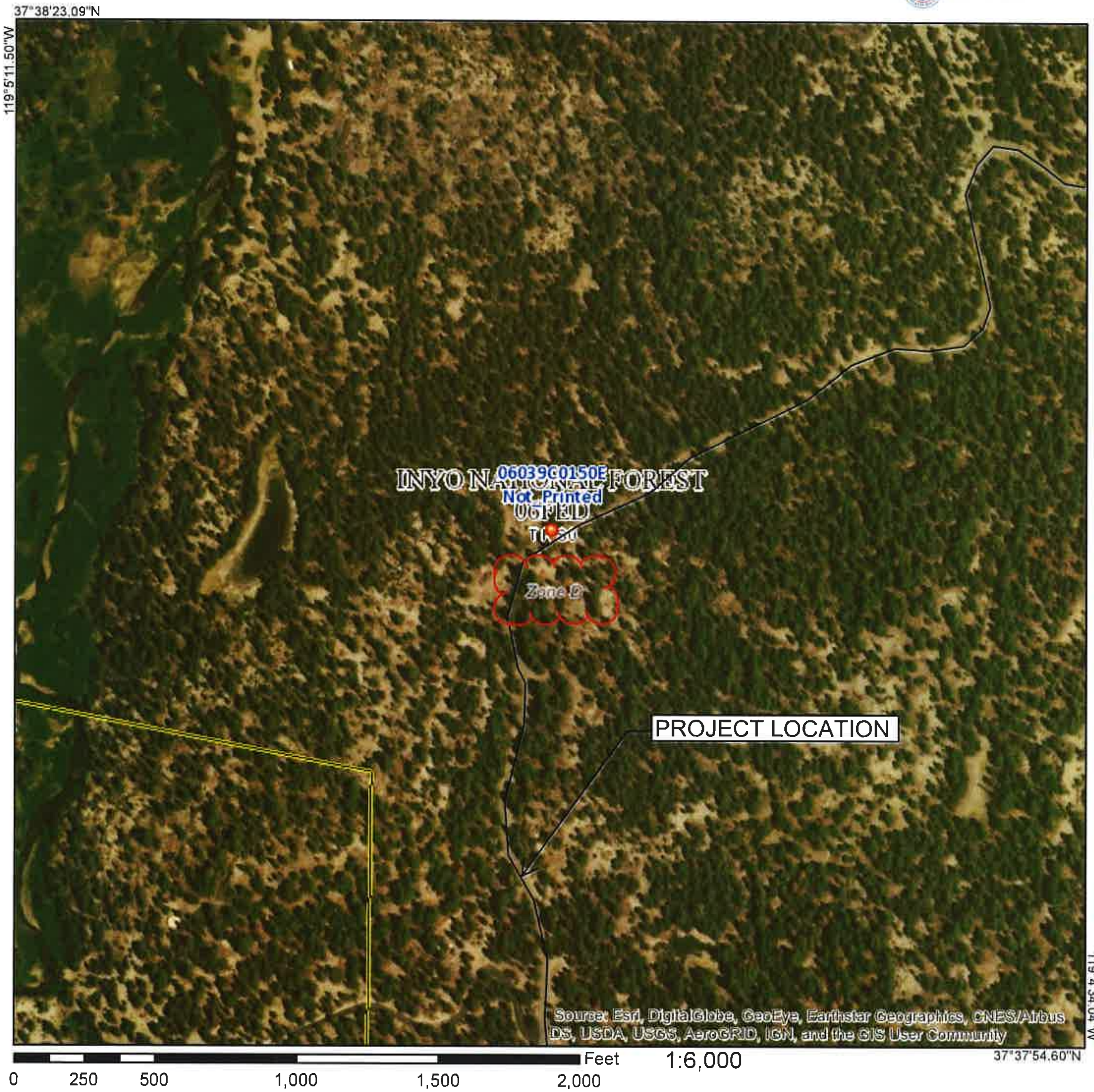
This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The base map shown complies with FEMA's base map accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 6/29/2018 at 6:33:05 PM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

This map image is void if the one or more of the following map elements do not appear: base map imagery, flood zone labels, legend, scale bar, map creation date, community identifiers, FIRM panel number, and FIRM effective date. Map images for unmapped and unmodernized areas cannot be used for regulatory purposes.

National Flood Hazard Layer FIRMette

FEMA



Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS	Without Base Flood Elevation (BFE) Zone A, V, A99
	With BFE or Depth Zone AE, AO, AH, VE, AR
	Regulatory Floodway
OTHER AREAS OF FLOOD HAZARD	0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile Zone X
	Future Conditions 1% Annual Chance Flood Hazard Zone X
	Area with Reduced Flood Risk due to Levee. See Notes. Zone X
	Area with Flood Risk due to Levee Zone D
OTHER AREAS	NO SCREEN Area of Minimal Flood Hazard Zone X
	Effective LOMRs
	Area of Undetermined Flood Hazard Zone D
GENERAL STRUCTURES	Channel, Culvert, or Storm Sewer
	Levee, Dike, or Floodwall
OTHER FEATURES	20.2 Cross Sections with 1% Annual Chance
	17.5 Water Surface Elevation
	Coastal Transect
	513 Base Flood Elevation Line (BFE)
	Limit of Study
	Jurisdiction Boundary
	Coastal Transect Baseline
	Profile Baseline
	Hydrographic Feature
MAP PANELS	Digital Data Available
	No Digital Data Available
	Unmapped

N

This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The base map shown complies with FEMA's base map accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 6/29/2018 at 6:37:13 PM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

This map image is void if the one or more of the following map elements do not appear: base map imagery, flood zone labels, legend, scale bar, map creation date, community identifiers, FIRM panel number, and FIRM effective date. Map images for unmapped and unmodernized areas cannot be used for regulatory purposes.

National Flood Hazard Layer FIRMette

FEMA

37°37'59.25"N

119°4'59.65"W

119°4'22.19"W

37°37'30.76"N

0 250 500 1,000 1,500 2,000 Feet

1:6,000

Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS	Without Base Flood Elevation (BFE) Zone A, V, A99 With BFE or Depth Regulatory Floodway Zone AE, AO, AH, VE, AR
OTHER AREAS OF FLOOD HAZARD	0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile Zone X Future Conditions 1% Annual Chance Flood Hazard Zone X Area with Reduced Flood Risk due to Levee. See Notes. Zone X Area with Flood Risk due to Levee Zone D
OTHER AREAS	NO SCREEN Area of Minimal Flood Hazard Zone X Effective LOMRs Area of Undetermined Flood Hazard Zone D
GENERAL STRUCTURES	Channel, Culvert, or Storm Sewer Levee, Dike, or Floodwall
OTHER FEATURES	20.2 / 17.5 Cross Sections with 1% Annual Chance Water Surface Elevation Coastal Transect 513 Base Flood Elevation Line (BFE) Limit of Study Jurisdiction Boundary Coastal Transect Baseline Profile Baseline Hydrographic Feature
MAP PANELS	Digital Data Available No Digital Data Available Unmapped

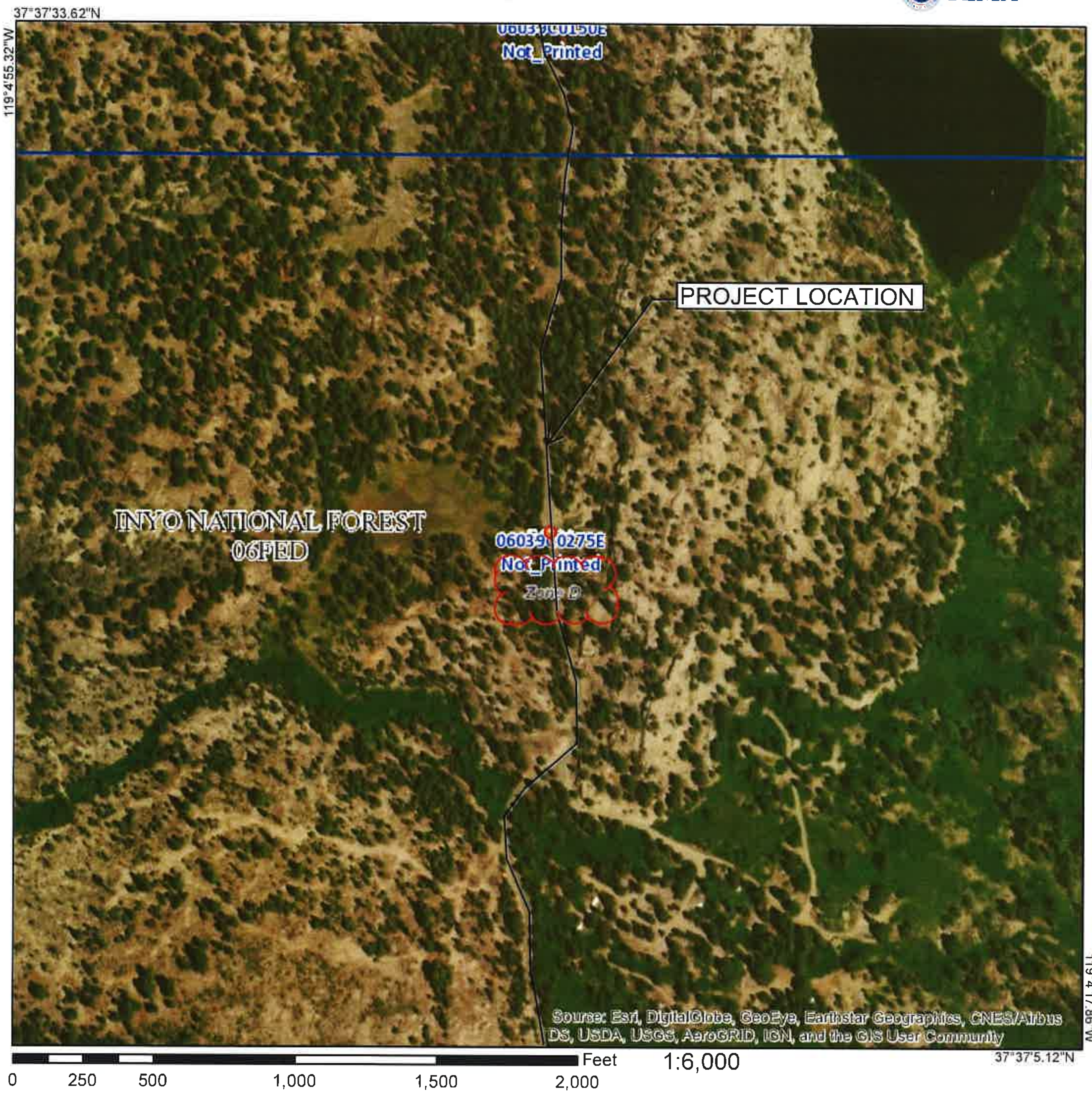
N

This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The base map shown complies with FEMA's base map accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 6/29/2018 at 6:40:52 PM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

This map image is void if the one or more of the following map elements do not appear: base map imagery, flood zone labels, legend, scale bar, map creation date, community identifiers, FIRM panel number, and FIRM effective date. Map images for unmapped and unmodernized areas cannot be used for regulatory purposes.

National Flood Hazard Layer FIRMette



Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS
- Without Base Flood Elevation (BFE) *Zone A, V, A99*
- With BFE or Depth
- Regulatory Floodway *Zone AE, AO, AH, VE, AR*

OTHER AREAS OF FLOOD HAZARD
- 0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile *Zone X*
- Future Conditions 1% Annual Chance Flood Hazard *Zone X*
- Area with Reduced Flood Risk due to Levee. See Notes. *Zone X*
- Area with Flood Risk due to Levee *Zone D*

OTHER AREAS
- NO SCREEN Area of Minimal Flood Hazard *Zone X*
- Effective LOMRs
- Area of Undetermined Flood Hazard *Zone D*

GENERAL STRUCTURES
- Channel, Culvert, or Storm Sewer
- Levee, Dike, or Floodwall

OTHER FEATURES
- 20.2 / 17.5 Cross Sections with 1% Annual Chance Water Surface Elevation
- Coastal Transect
- 513 Base Flood Elevation Line (BFE)
- Limit of Study
- Jurisdiction Boundary
- Coastal Transect Baseline
- Profile Baseline
- Hydrographic Feature

MAP PANELS
- Digital Data Available
- No Digital Data Available
- Unmapped

N

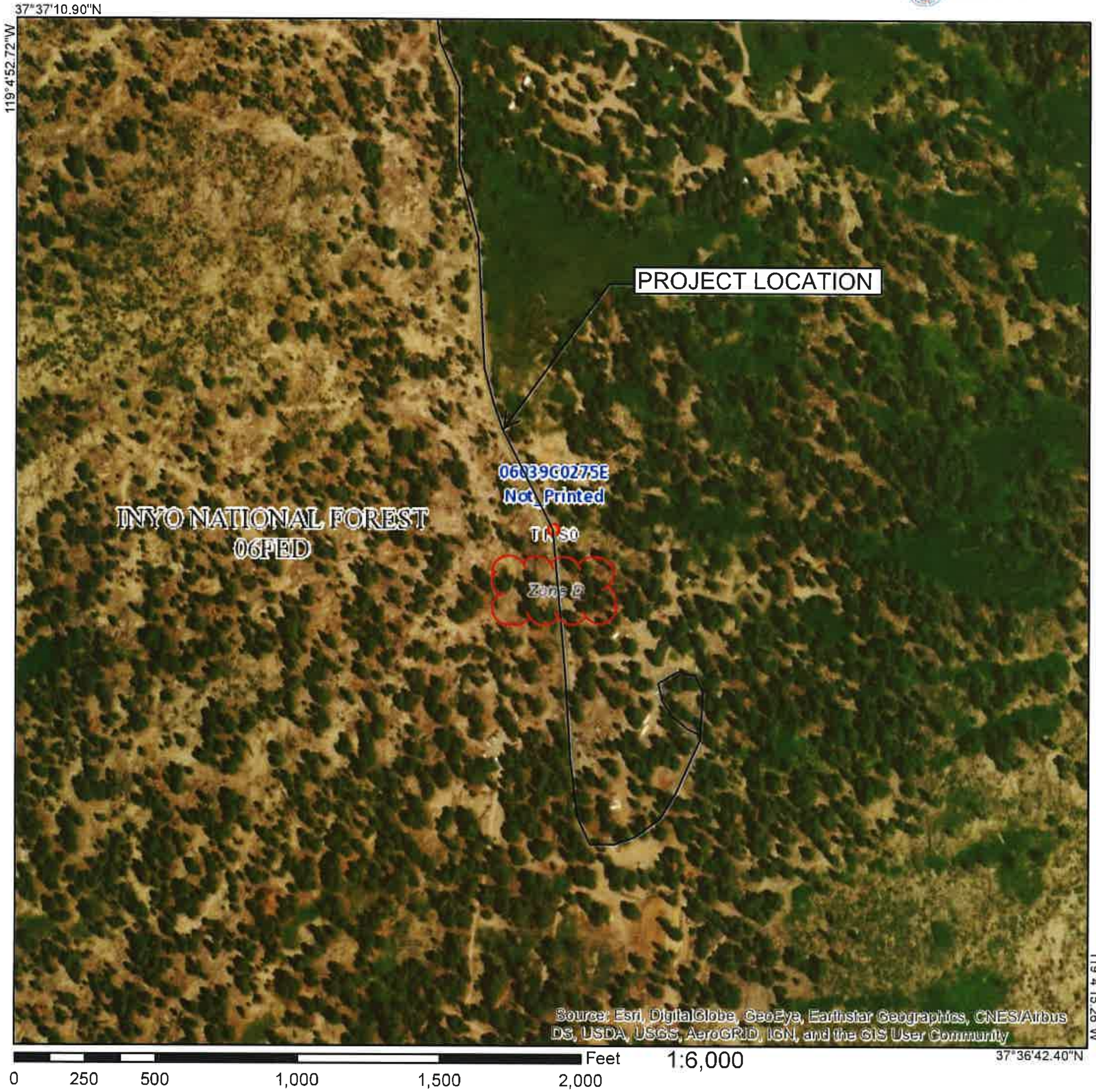
This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The base map shown complies with FEMA's base map accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 6/29/2018 at 6:43:29 PM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

This map image is void if the one or more of the following map elements do not appear: base map imagery, flood zone labels, legend, scale bar, map creation date, community identifiers, FIRM panel number, and FIRM effective date. Map images for unmapped and unmodernized areas cannot be used for regulatory purposes.

National Flood Hazard Layer FIRMette

FEMA



Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS
- Without Base Flood Elevation (BFE) Zone A, V, A99
- With BFE or Depth
- Regulatory Floodway Zone AE, AO, AH, VE, AR

OTHER AREAS OF FLOOD HAZARD
- 0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile Zone X
- Future Conditions 1% Annual Chance Flood Hazard Zone X
- Area with Reduced Flood Risk due to Levee. See Notes. Zone X
- Area with Flood Risk due to Levee Zone D

OTHER AREAS
- NO SCREEN Area of Minimal Flood Hazard Zone X
- Effective LOMRs
- Area of Undetermined Flood Hazard Zone D

GENERAL STRUCTURES
- Channel, Culvert, or Storm Sewer
- Levee, Dike, or Floodwall

OTHER FEATURES
- 20.2 / 17.5 Cross Sections with 1% Annual Chance Water Surface Elevation
- Coastal Transect
- 513 Base Flood Elevation Line (BFE)
- Limit of Study
- Jurisdiction Boundary
- Coastal Transect Baseline
- Profile Baseline
- Hydrographic Feature

MAP PANELS
- Digital Data Available
- No Digital Data Available
- Unmapped

N

This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The base map shown complies with FEMA's base map accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 6/29/2018 at 6:45:01 PM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

This map image is void if the one or more of the following map elements do not appear: base map imagery, flood zone labels, legend, scale bar, map creation date, community identifiers, FIRM panel number, and FIRM effective date. Map images for unmapped and unmodernized areas cannot be used for regulatory purposes.

Appendix F – Hydraulic Toolbox Reports

(AVAILABLE ELECTRONICALLY)