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August 30, 2021

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Job: MCP-BUCKFALLS-889

**SUBJECT: BUCK GULCH FALLS TRAIL BRIDGE GEOLOGIC HAZARD ASSESSMENT AND FEASIBILITY STUDY**

## INTRODUCTION

This memorandum summarizes the preliminary findings of our review of the Buck Gulch Falls Trail stream crossing located just past the end of Fairway Drive in Lucas Valley Open Space Preserve, Marin County (Figure 1). The existing crossing consists of an unimproved wet ford located where Buck Gulch Falls Trail (gravel road) dips through Arroyo San Jose, an intermittent stream (Figure 2, Photos 1 and 2). Because this crossing can be impassable during periods of high stream flow, the District is considering installing a recreational trail bridge to allow year-round pedestrian access, while maintaining the existing ford crossing for seasonal vehicle access.

At the request of the District, we made a preliminary review of the stream crossing to assess the feasibility and constraints for a new trail bridge. This technical memorandum presents the geologic hazards at the site and summarizes our findings and presents preliminary and conceptual recommendations. Additional review and engineering will be required if a bridge is ultimately to be installed.

## SITE CONDITIONS

The project site is located where Buck Gulch Falls Trail crosses Arroyo San Jose about 150 feet upstream of the confluence with an unnamed ephemeral tributary Figure 2. The site is characterized by a gently alluvial/colluvial filled valley bounded by steep side slopes. Arroyo San Jose is incised 5 to 15 feet through these sediments. The crossing is located downstream of where Arroyo San Jose makes a sharp dogleg bend.

Buck Gulch Falls Trail follows an old ranch road that was improved in about the mid 1960's when an upstream pond was constructed (now abandoned). The type of the original crossing is unknown. Currently, the crossing is an unimproved wet ford with the road dipping 4+ feet down through the stream channel.

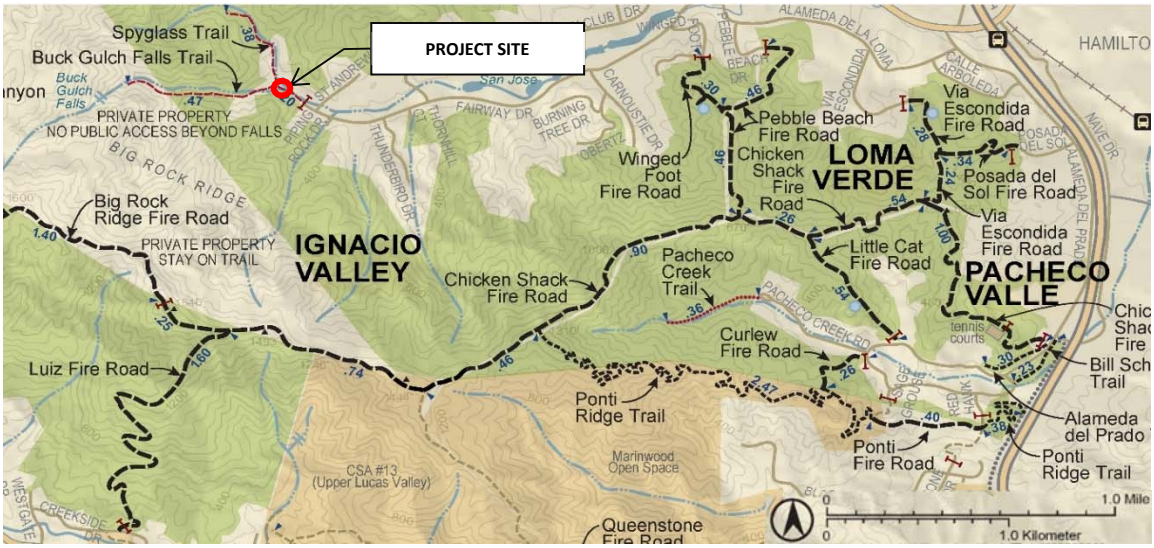



**FIGURE 1: LOCATION MAP**

Downstream of the crossing, Arroyo San Jose has been channelized and the channel banks armored with rock rip rap sometime in the late 1990's as part of residential development along Fairway Drive. In circa 2006 the confluence of Arroyo San Jose and the unnamed tributary were buried with sediment probably from a debris flow landslide extending down the unnamed tributary. The ford crossing on Arroyo San Jose does not appear to have been impacted by this failure.

**Photo 1: Looking north across existing ford crossing**

**Photo 2: Looking downstream, across existing ford crossing**

At the ford crossing Arroyo San Jose drains a 398-acre steep forested watershed. The active stream channel is approximately 10 feet wide, gravel and cobble bedded with an average channel gradient of about 2 to 2.5% (Figure 2, Photos 1, 2 and 3).

***Subsurface Conditions***

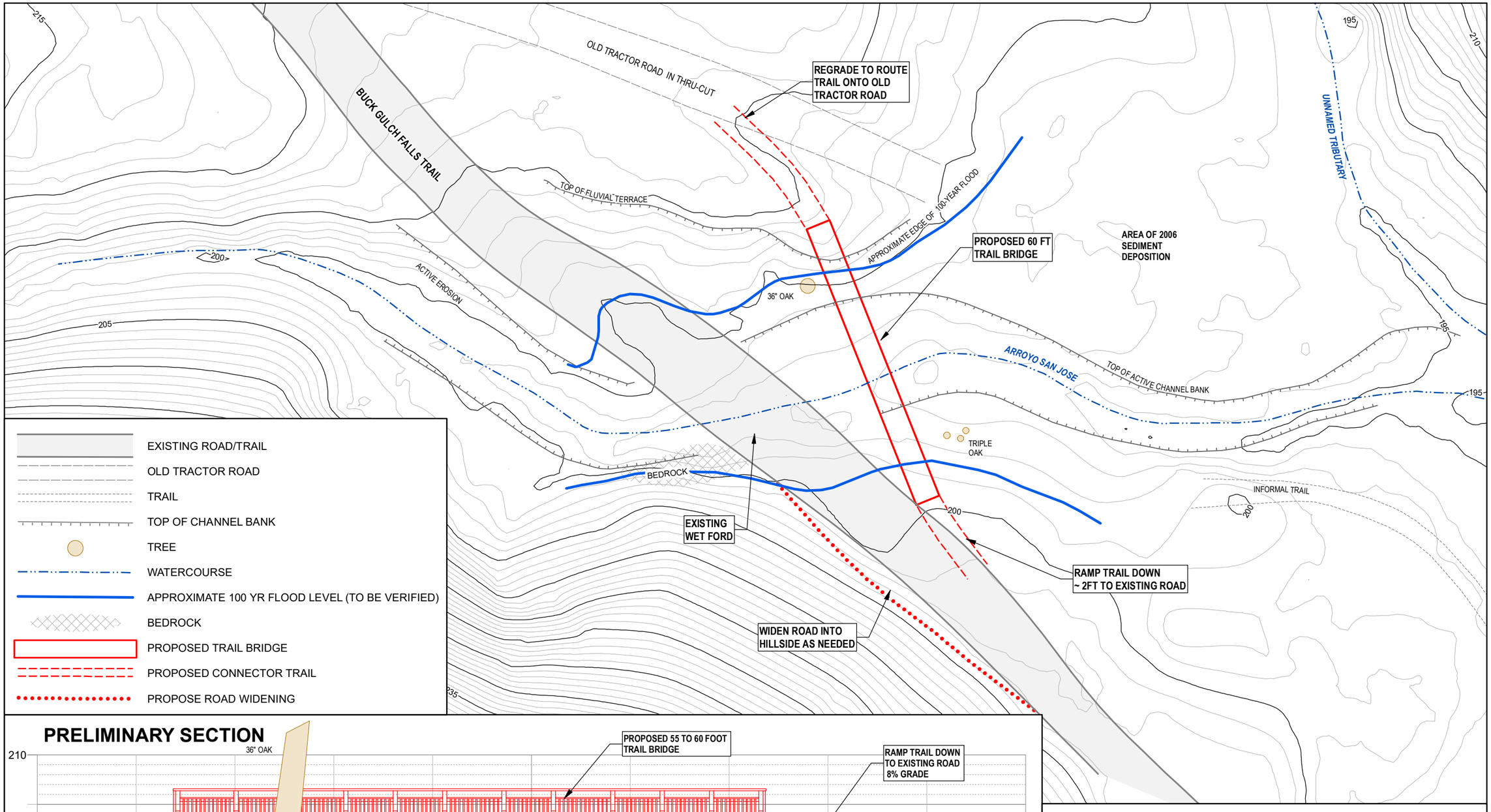
Subsurface soil conditions were evaluated from field observations of earth materials exposed in the channel banks. The native subsurface profile at the ford crossing consists of older fluvial terrace deposits and recent alluvium, overlying Franciscan sandstone bedrock. The alluvial sediments consisting of silty sand and gravel with boulders. Hard Franciscan sandstone was locally observed at the crossing along the south (right) channel bank.

## GEOLOGIC HAZARDS

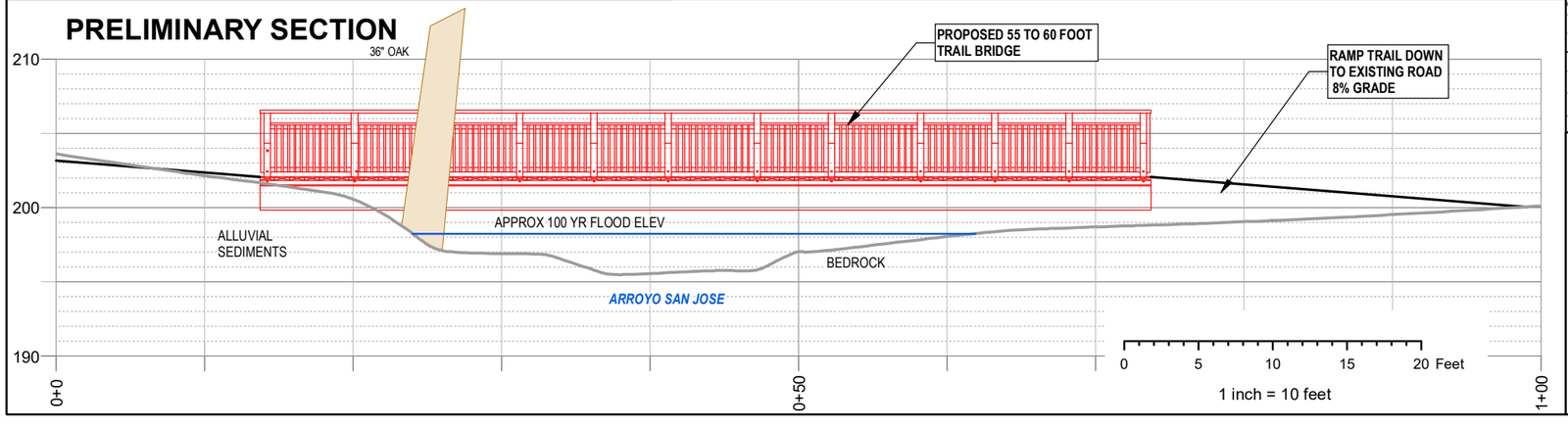
The bridge site is subject to several geologic hazards as outlined below:

### *LANDSLIDING:*

Review of LiDAR bare earth imagery and field reconnaissance did not identify recent or historic landslides directly underlying the bridge site. The steep terrain that characterizes the upland areas of the watershed, however, is inherently prone to debris flow landslide processes with runout paths that could extend down and past the bridge site. It is believed that such a debris flow landslide originating within the unnamed tributary was the source of sediment that buried the confluence of Arroyo San Jose and the tributary in circa 2006. To partially mitigate the risk to the bridge from debris flow runout the bridge should be elevated as much as feasible above the stream channel. The higher the bridge is elevated the lower the risk.




## PRELIMINARY SECTION




## PRELIMINARY SITE MAP

**NOTE:**
- SITE MAP IS APPROXIMATE AND CONCEPTUAL. TOPOGRAPHIC SURVEY REQUIRED TO CONFIRM SITE CONDITIONS AND DISTANCES.
- CONTOURS DERIVED FROM MARIN COUNTY LIDAR 1 FT CONTOUR INTERVAL
- SECTION GENERATED USING HAND-HELD DISTANCE METER AND CLINOMETER.
- FLOOD ELEVATION AND LIMITS BASED ON PRELIMINARY HYDROLOGIC AND HYDRAULIC ANALYSIS AND SHOULD BE VIEWED AS APPROXIMATE. A MORE INDEPTH ANALYSIS REQUIRED TO CONFIRM FLOOD ELEVATIONS AND LIMITS.

N

0 10 20 Feet

1 inch = 20 feet

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*PRELIMINARY DRAFT*
*NOT FOR CONSTRUCTION*

PROJECT:
**BUCK GULCH FALLS TRAIL**
LUCAS VALLEY OSP
MARIN COUNTY PARKS AND OPEN SPACE

TITLE:
**BUCK GULCH FALLS TRAIL BRIDGE**
**PRELIMINARY SITE MAP AND SECTION**

DATE: AUGUST 30, 2021
PROJECT: MCP-BUCKFALLS-889
DRAWN BY: TB
CHECKED:

FIGURE
**2**

## *STREAM FLOW AND FLOODING:*

The bridge crossing is located within the designated Zone AE special flood hazard area depicted on the Federal Emergency Management Agency's (FEMA) Flood Insurance Rate Map (Appendix 1). This map, however, does not appear to correlate very well with current LiDAR topography and therefore its usefulness is limited at this site. Our interpretation of the map indicates that the flood zone is about 30 to 35 feet wide at the crossing. To further evaluate flood hazards at the crossing we undertook a preliminary hydrologic and hydraulic analysis of the site.

### *Peak Design Flow*

Peak flow at the bridge site was calculated using USGS Magnitude and Frequency Method and is based on a set of empirical equations derived from precipitation and runoff data collected at stream gauging stations in California. It is best applied on ungauged streams with drainage areas greater than 80 acres. The method is outlined in Gotvald et al. (2012) and calculated for the project site using USGS Stream Stats Version 3 beta (USGS, 2021). The results from USGS Stream Stats Version 3 beta model are presented in Appendix 2 and summarized in Table 1 below.

**TABLE 1: PEAK STREAM FLOW**

| Recurrence Interval | Stream Flow (cfs) Q |
|---|---|
| $Q_{100}$ | 262 |

### *Flood Elevation*

The 100-year flood elevations at the bridge site was modeled using FlowMaster software based on Manning's equation. This model provides an approximate 100 year flood elevation but is judge adequate for this preliminary analysis. The flood elevation analysis was run on a single channel cross-section at the proposed bridge site. Channel cross-section and channel grade were measured using an electronic distance meter and clinometer. Channel and bank roughness (Manning's n) was chosen from field-based observations of the channel and floodplains. Roughness value of 0.07 was used for the channel representing a mountain stream with steep banks and a bottom of gravel, cobble and a few boulders based on methodologies outlined in Arcement and Schneider (1990) and McCuen (2004).

The results of the flood analysis are presented in Appendix 3 and summarized in Table 1 below.

**TABLE 2: SUMMARY OF 100-YEAR FLOOD ANALYSIS**

| Stream | Cross Section | Drainage Area (acres) | Channel Grade | Manning's n | $Q_{100}$ (cfs) | Flow Width (ft) | Flow Depth (ft) |
|---|---|---|---|---|---|---|---|
| Arroyo San Jose | Bridge | 398 | 2.5% | 0.07 | 262 | 40 | 2.75 |

Our preliminary analysis indicates the calculated 100-year discharge is moderately constrained within the incised channel with a maximum flow depth of about 2.75 feet. We recommend that bridge abutments be located outside the 100-year flood elevation and that the bottom of the bridge cord be elevated 1 foot above the calculated 100-year flood elevation to allow for passage of debris. It is important to note that the analysis presented here is preliminary and a more in depth hydrologic and hydraulic analysis using HEC-RAS is recommended.

## *STREAM BANK EROSION AND INSTABILITY:*

The proposed bridge site is located at the downstream end of a sharp left-hand bend in Arroyo San Jose. The right (south) bank, located at the outside of the bend, is underlain by Franciscan bedrock and does not appear to be experiencing significant erosion.

**Photo 3: Looking upstream at ford crossing**

The left (north) bank is underlain by alluvial sediments that are much more prone to erosion. Upstream of the crossing, Arroyo San Jose makes a sharp dogleg bend with the road paralleling the stream channel on the north side of the crossing for a distance of about 80 feet. The north channel bank in this area is experiencing active erosion, which in time could undermine the road requiring the road to be relocated further away from the stream channel. At and immediately downstream of the crossing the north channel bank appears relatively stable and partially protected by a large oak tree. To minimize the risk of stream bank erosion undermining the bridge we recommend that the north bridge abutment be located on the downstream side of the large oak tree, offset a minimum of 5 feet from the top of the channel bank, and be embedded a minimum of 4 feet below the ground surface. Abutments are not shown on the preliminary map and section (Figure 2).

## *FAULT RUPTURE:*

There are no mapped faults transecting the bridge site. Based on the foregoing the potential risk of fault rupture appears low.

## *SEISMIC SHAKING:*

Intense seismic shaking may occur at the site during the design lifetime of the proposed structure from an earthquake along one of the local fault systems. To mitigate for this hazard the proposed structure should be designed for seismic shaking in accordance with adopted seismic provisions set forth in the California Building Code (CBC).

### *LIQUEFACTION:*

Based on field observations, the potential for liquefaction appears to be relatively low. The south side of the crossing is underlain by bedrock at a shallow depth and therefore not prone to liquefaction. Depth of alluvial sediments on the north side of the crossing is unknown. Field observations of the sandy and gravely soils underlying this side of the crossing suggests they do not have a high potential for dynamic compaction. The potential for liquefaction to occur at depth, however, cannot be ruled out. To mitigate for the potential for liquefaction to occur during a large seismic event, bridge abutments founded on alluvial sediments should incorporate spread footings that are embedded a minimum of 4 feet below the ground surface.

### *LOG JAMS:*

While they are not strictly speaking a geologic hazard, log jams are a natural phenomenon in narrow streams in mountainous areas and have the potential to increase flooding and/or debris flow hazards. Future log jams could develop anywhere along the stream during large discharge events and could potentially impact the bridge site either directly or indirectly by diverting stream flow. Though the potential for a future log jam to develop at the site is difficult to quantify based on the current field observations, the risk to the bridge site appears low.

### *SUMMARY:*

Our analysis concludes that the proposed bridge may be subject to several geologic hazards including intense seismic shaking, flooding, and stream bank erosion. Incorporating the preliminary recommendations outlined in this report will mitigate this risk to a level of less than significant for recreational trail use while at the same time minimizing environmental impacts. The primary goals of these recommendations are to protect health and safety, but not necessarily to avoid structural damage, since such design may be economically and environmentally prohibitive. The District should acknowledge and accept that damage to the bridge could occur in the event of extreme seismic shaking and or runoff events and subsequent repairs may be necessary.

## DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

It is our understanding that the district would like to install a 5 foot wide trail bridge at this crossing while maintaining seasonal vehicle access at the road crossing for patrol, fire and maintenance purposes. In addition, the bridge and connecting trails should have a grade less than 8% and though not specifically ADA compliant, should be designed as close to ADA standards as reasonably feasible.

The principal constraints with a bridge at this site are 1) narrow bridge corridor constrained by steep hillside above, existing road, and active deposition area downstream, and 2) existing road which will need to be retained, and 3) flood hazards.

In our opinion, a minimum 55 to 60 foot long bridge will be required with the bridge located on the downstream side of the existing road and ford crossing as shown in Figure 2 and Photo 4. There are multiple types of bridges that can be installed including steel beam bridge with wood hand rails, similar to what the district has constructed on other projects, and prefabricated steel truss.


**Photo 4: Looking north across ford crossing with proposed bridge alignment highlighted**

The south (right) bank abutment should be located just upstream of the three-trunk oak and founded into Franciscan bedrock. The north (left) should be located on the downstream side of the large oak and offset a minimum of 5 feet back from the top edge of the channel bank. This footing should be embedded a minimum of 4 feet below the ground surface. Grading and fill placement will be required on the north bridge approach where there is a thru cut to an old and now abandoned road (See Figure 2).

The bottom cord of the proposed bridge should be elevated a minimum of 1 foot above the 100-year flood elevation for Arroyo San Jose. Our preliminary analysis indicates that this is about 3.75 feet above the channel bed. A more in depth hydrologic and hydraulic analysis using HEC-RAS is required to determine flood elevations more accurately.

For a level bridge the south abutment will need to be built up about 2 feet on import fill. The trail on this side of the crossing should then ramp down to join the existing road at a 5% to 8% grade. The existing road may need to be widened into the hillside slightly to accommodate the bridge and the trail that will need to ramp down to the bridge.

To proceed with a trail bridge, we anticipate the following tasks will be required:

- Topographic survey of the site and up and downstream channels
- Hydrologic and hydraulic analysis
- Exploratory test pits on the north side of the bridge to evaluate subsurface earth materials
- Engineering analysis and design
- Biologic surveys as needed
- Preparation of construction documents

## REFERENCES

Arcement, G. J., and Schneider, V. R., 1990, Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains: United State Geologic Survey, Water-Supply Paper 2339.

Gotvald, A. J., Barth, N. A., Veilleux, A. G., and Parrett, C., 2012, Methods for Determining Magnitude and Frequency of Floods in California, Based on Data through Water Year 2006, *in* U.S. Geological Survey Scientific Investigations Report 2012–5113, a. o. o. a. h. p. u. g. s., ed., p. 38.

McCuen, R. H., 2004, Hydologic Analysis and Design (Third Edition), Upper Saddle River, NJ, Pearson-Prentice Hall.

USGS, 2021, The StreamStats program, online at http://streamstats.usgs.gov.

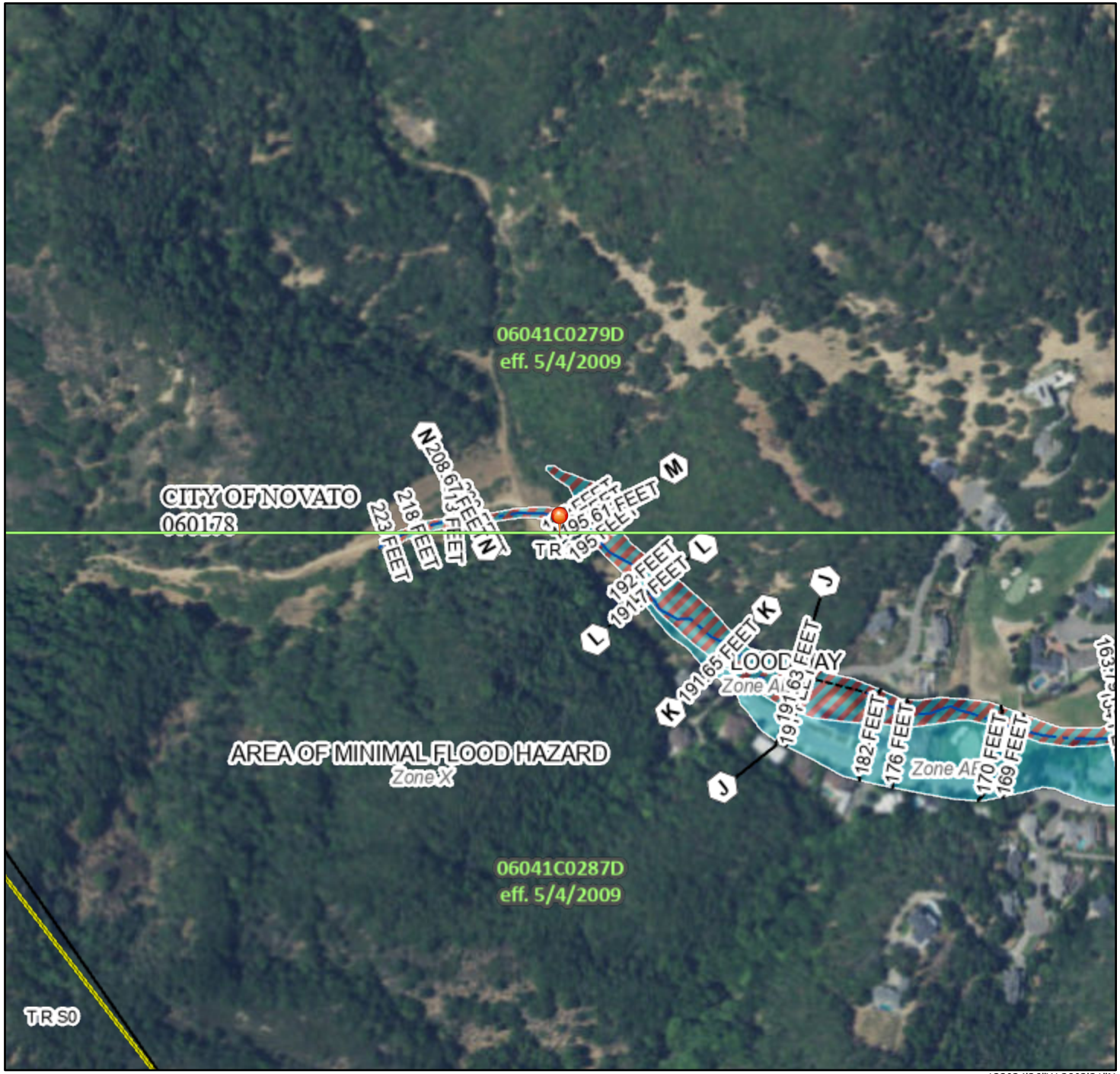
# APPENDIX 1:

**FEMA: NATIONAL FLOOD HAZARD LAYER FIRMette**

# National Flood Hazard Layer FIRMette

FEMA

122°35'14"W 38°3'59"N




122°34'36"W 38°3'31"N

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

1:6,000

*Basemap: USGS National Map: Orthoimagery: Data refreshed October, 2020*

## 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
- 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

The pin displayed on the map is an approximate point selected by the user and does not represent an authoritative property location.

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

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 8/28/2021 at 9:50 AM 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.

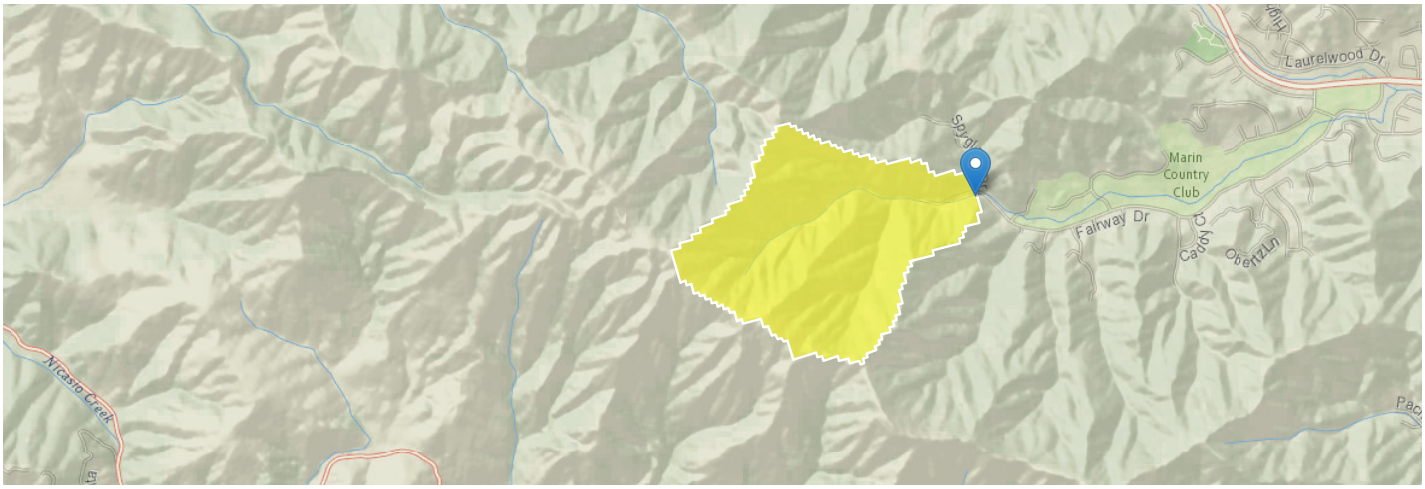
This map image is void if the one or more of the following map elements do not appear: basemap imagery, flood zone labels, legend, scale bar, map creation date, community identifiers, FIRM panel number, and FIRM effective date. Map images for unmapped and unmodernized areas cannot be used for regulatory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

# APPENDIX 2:

**STREAMSTATS PEAK FLOW DISCHARGE RESULTS: ARROYO SAN JOSE AT BUCK GULCH FALLS PROPOSED BRIDGE**

# StreamStats Report: ARROYO SAN JOSE AT PROPOSED BUCK GULCH FALLS TRAIL BRIDGE

**Region ID:** CA
**Workspace ID:** CA20210829141626454000
**Clicked Point (Latitude, Longitude):** 38.06250, -122.58243
**Time:** 2021-08-29 07:16:47 -0700




Basin Characteristics

| Parameter Code | Parameter Description | Value | Unit |
|---|---|---|---|
| DRNAREA | Area that drains to a point on a stream | 0.6 | square miles |
| PRECIP | Mean Annual Precipitation | 46 | inches |

Peak-Flow Statistics Parameters [2012 5113 Region 1 North Coast]

| Parameter Code | Parameter Name | Value | Units | Min Limit | Max Limit |
|---|---|---|---|---|---|
| DRNAREA | Drainage Area | 0.6 | square miles | 0.04 | 3200 |
| PRECIP | Mean Annual Precipitation | 46 | inches | 20 | 125 |

Peak-Flow Statistics Flow Report [2012 5113 Region 1 North Coast]

PII: Prediction Interval-Lower, PIu: Prediction Interval-Upper, ASEp: Average Standard Error of Prediction, SE: Standard Error (other -- see report)

| Statistic | Value | Unit | PII | PIu | ASEp |
|---|---|---|---|---|---|
| 50-percent AEP flood | 49.4 | ft^3/s | 20 | 122 | 58.6 |
| 20-percent AEP flood | 99.1 | ft^3/s | 46.9 | 210 | 47.4 |
| 10-percent AEP flood | 136 | ft^3/s | 66.7 | 277 | 44.2 |
| 4-percent AEP flood | 184 | ft^3/s | 93.1 | 364 | 42.7 |
| 2-percent AEP flood | 222 | ft^3/s | 112 | 440 | 42.7 |
| 1-percent AEP flood | 262 | ft^3/s | 129 | 533 | 44.3 |
| 0.5-percent AEP flood | 300 | ft^3/s | 147 | 612 | 44.4 |
| 0.2-percent AEP flood | 351 | ft^3/s | 168 | 734 | 46 |

*Peak-Flow Statistics Citations*

**Gotvald, A.J., Barth, N.A., Veilleux, A.G., and Parrett, Charles,2012, Methods for determining magnitude and frequency of floods in California, based on data through water year 2006: U.S. Geological Survey Scientific Investigations Report 2012–5113, 38 p., 1 pl. (http://pubs.usgs.gov/sir/2012/5113/)**

# APPENDIX 3:

**PRELIMINARY HYDRAULIC CALCULATIONS TO DETERMINE 100-YEAR FLOOD ELEVATIONS**

# BUCK GULCH TRAIL BRIDGE HYDRAULIC CALCS

## Project Description

| | |
|---|---|
| Friction Method | Manning Formula |
| Solve For | Normal Depth |

## Input Data

| | | |
|---|---|---|
| Channel Slope | 0.02500 | ft/ft |
| Discharge | 262.00 | ft³/s |

Section Definitions

| Station (ft) | Elevation (ft) |
|---|---|
| 0+00 | 203.50 |
| 0+21 | 201.50 |
| 0+26 | 197.00 |
| 0+33 | 196.75 |
| 0+37 | 195.50 |
| 0+47 | 195.75 |
| 0+50 | 197.00 |
| 0+64 | 198.50 |
| 0+96 | 200.00 |

Roughness Segment Definitions

| Start Station | Ending Station | Roughness Coefficient |
|---|---|---|
| (0+00, 203.50) | (0+96, 200.00) | 0.070 |

## Options

| | |
|---|---|
| Current Roughness Weighted Method | Pavlovskii's Method |
| Open Channel Weighting Method | Pavlovskii's Method |
| Closed Channel Weighting Method | Pavlovskii's Method |

## Results

| | | |
|---|---|---|
| Normal Depth | 2.75 | ft |
| Elevation Range | 195.50 to 203.50 ft | |
| Flow Area | 58.36 | ft² |
| Wetted Perimeter | 37.72 | ft |

# BUCK GULCH TRAIL BRIDGE HYDRAULIC CALCS

## Results

| | | | |
|---|---|---|---|
| Hydraulic Radius | | 1.55 | ft |
| Top Width | | 36.78 | ft |
| Normal Depth | | 2.75 | ft |
| Critical Depth | | 2.23 | ft |
| Critical Slope | | 0.06760 | ft/ft |
| Velocity | | 4.49 | ft/s |
| Velocity Head | | 0.31 | ft |
| Specific Energy | | 3.06 | ft |
| Froude Number | | 0.63 | |
| Flow Type | Subcritical | | |

## GVF Input Data

| | | |
|---|---|---|
| Downstream Depth | 0.00 | ft |
| Length | 0.00 | ft |
| Number Of Steps | 0 | |

## GVF Output Data

| | | |
|---|---|---|
| Upstream Depth | 0.00 | ft |
| Profile Description | | |
| Profile Headloss | 0.00 | ft |
| Downstream Velocity | Infinity | ft/s |
| Upstream Velocity | Infinity | ft/s |
| Normal Depth | 2.75 | ft |
| Critical Depth | 2.23 | ft |
| Channel Slope | 0.02500 | ft/ft |
| Critical Slope | 0.06760 | ft/ft |

# Cross Section for Buck Gulch Falls Trail Bridge

## Project Description

| | |
|---|---|
| Friction Method | Manning Formula |
| Solve For | Normal Depth |

## Input Data

| | | |
|---|---|---|
| Channel Slope | 0.02500 | ft/ft |
| Normal Depth | 2.75 | ft |
| Discharge | 262.00 | ft³/s |

## Cross Section Image