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March 1, 2021
CAInc File No. 20-643.1

Ms. Julie Passalacqua
Mark Thomas
701 University Ave, Suite 200
Sacramento, CA 95825

Subject: **Draft Geotechnical Memorandum**
NCRCD-Sulphur Creek Fish Passage (Project #30144)
Napa County, California

Dear Ms. Passalacqua,

Crawford & Associates, Inc. (CAInc) prepared this Geotechnical Memorandum for the NCRCD-Sulphur Creek Fish Passage (Project #30144) in accordance with Subcontract No. SA-20143, dated August 24, 2020. This report describes the results of the field investigation, laboratory testing, provides geotechnical design recommendations for the tieback walls, and construction considerations for the Sulphur Creek channel regrading.

To prepare this memorandum, CAInc:

- discussed the project goals and objectives with Ms. Julie Passalacqua and Jon Sampson from Mark Thomas and Brian Bartell from WRA;
- reviewed the Preliminary Design Report published March 2019 by ESA
- reviewed available published topographic, geologic, and seismic mapping of the site vicinity;
- completed a site visit on September 1, 2020;
- performed surface geologic reconnaissance of the site and immediate vicinity;
- performed three seismic refraction lines on November 10, 2020;
- drilled and sampled two borings on January 5, 2021;
- performed laboratory testing and geotechnical engineering analysis in support of the recommendations contained herein.

PROJECT LOCATION AND UNDERSTANDING

The project site is located on the western city limits of St. Helena, about 1.8 miles west of the State Route 29, where a private road crosses over Sulphur Creek. The site is approximately at latitude 38.4879° and longitude 122.4816°. See Figure 1 for the site vicinity map.

The Napa County Resource Conservation District (NCRCD) plans to remove an existing fish ladder (originally installed in 2002) within Sulphur Creek at the project location. To allow for enhanced fish passage after the fish ladder removal, we understand Sulphur Creek may be regraded (up to six ft below thalweg) from approximately 800 ft upstream to 200 ft downstream of the bridge. Generally, upstream and to the bridge (Sta. 129+00 to 121+00) will be excavated while downstream grade will be raised. We understand the new channel bed at the bridge may be lowered about three to four feet below existing grade and a retaining wall will be placed to support the bridge foundation. The bridge (located on private property) will not be replaced in this project.

SITE DESCRIPTION

Generally, the channel bed within Sulphur Creek consisted of unconsolidated, bedload materials including sand, gravel, cobbles, and boulders. Based on conversations with the land owner, the channel geometry has meandered over time. The land owner observed the channel water course change after the 2014 earthquake in Napa.

Upstream of Bridge

Upstream of the bridge, Sulphur Creek generally flows easterly/northeasterly. CAInc observed intensely to moderately weathered, moderately hard to hard shale, greenstone, and sandstone outcrops along the channel banks (see Figure 2a for approximate locations).

Bridge Vicinity

Sulphur Creek constricts to about 15 ft wide as it flows easterly under the bridge, likely increasing flow velocities and downstream bank erosion. The bridge, built in the early 1900s, is about a 28 ft long and 12 ft wide single lane, single span reinforced concrete structure. At the northern abutment, a concrete wall approximately 21 ft long runs along the western bank. At the eastern bank of the northern abutment and on both sides of the southern abutment, heavy rock has been placed to protect the banks from scour. The bridge is scour critical with the spread foundations exposed within the channel. At both abutments, repairs have been attempted to protect against scour effects. At the southern abutment, the repair has also been undermined by scour (see Photo 1).

Photo 1 – Southern abutment (looking southwest)

At the northern abutment, multiple concrete pours are visible along the footing (see Photo 2). The newest concrete pour has not yet been fully scoured. During our September 2020 site visit, CAInc excavated bedload materials at the northern footing and estimated the footing bottom at elev. 303.6 ft[1].

Photo 2 – Northern abutment (looking north)

The channel was dry during our September 2020 field review and had less than 6-inches of water (under the bridge) during our November 2020 and January 2021 field exploration. The channel bottom (thalweg) at the bridge is at about elev. 304.3 ft, about 12.5 ft below the existing bridge deck.

Downstream of Bridge

The channel widens at the fish ladder located just downstream (about 10 ft) from the bridge. A metal ladder is located in the middle of the channel with concrete spanning to both banks (see Photos 3a/b). A wired rock weir is located about 20 ft downstream from the fish ladder, creating a pool in between the structures. The fish ladder concrete encasement shows evidence of some scour but appears to be limiting the scour immediately downstream of the bridge.

[1]All elevations provided in this memorandum are referenced to the datum provided by WRA.

Photo 3a – Fish ladder (looking west)

Photo 3b – Fish ladder/rock weir (looking east)

About 200 ft downstream from the bridge, CAInc observed a 100±ft long rock outcrop consisting of intensely weathered, moderately soft to moderately hard shale. The weathered rock was overlain by silty to clayey sand with gravel. The northern bank was heavily vegetated while the southern bank was over-steepened due channel erosion. Large bedload material (such as boulders) were more prevalent downstream of the bridge (see Photo 4).

Photo 4 – Over-steepened southern bank and channel bedload (looking west)

Refer to Figures 2a and 2b for approximate location of site features.

FIELD INVESTIGATION

SEISMIC REFRACTION

A seismic survey was completed by CAInc on November 10, 2020. The seismic survey consisted of three seismic refraction profiles (S-1, S-2, and S-3) to determine the approximate depth to rock and evaluate rippability characteristics along the proposed channel regrading alignment. The seismic lines were about 100 ft long and were completed within the channel upstream and at the bridge. The locations of seismic refraction lines are shown on Figure 2a.

The data was recorded with a 24 channel ES-3000 seismometer with geophones arranged in a line running generally east to west for S-1 and southwest to northeast for S-2 and S-3. Twenty-one geophones were used for S-1, S-2, and S-3. The energy source for this testing was a 40-lb falling weight with an approximate 24-inch drop striking a steel plate at various locations along the geophone spread. The recorded data was analyzed using the Geometrics, Inc. SeisImager/SW software package. Refraction seismic profiling indicates primary wave (compression wave) velocities which are correlated to shear wave velocities. The refraction profiles and locations are shown in Figures 6A through 6C and Figure 2a, respectively.

GEOTECHNICAL BORINGS

CAInc subcontracted GeoEx Subsurface Exploration (Geo-Ex) to drill two borings (A-21-001 and A-21-002) on January 5, 2021. The borings were located along the private road on either side of the bridge. Boring A-21-001 was located closer to White Sulphur Springs Rd near the northern abutment. A summary of the explorations is provided in Table 1. See Figure 2b for the boring locations.

Table 1: Summary of Boring Exploration

<table>
<tr><th>Boring I.D.</th><th>Completion Date</th><th>Surface Elevation (feet)</th><th>Boring Depth (ft)</th><th>Drill Rig</th><th>Hammer Type</th><th>Hammer Efficiency Ratio</th><th>Drilling Equipment</th></tr>
<tr><td>A-21-001</td><td>1/5/2021</td><td>316.3</td><td>28.4</td><td rowspan="2">CME 55 (truck) Automatic Hand auger</td><td rowspan="2">Automatic (140 lbs)</td><td rowspan="2">89.3%</td><td>4-inch Solid-Stem Auger, 4-inch Mud Rotary</td></tr>
<tr><td>A-21-002</td><td>1/5/2021</td><td>318.9</td><td>20.25</td><td>4-inch Solid-Stem Auger</td></tr>
</table>

GeoEx Drilling utilized a CME 55 truck-mounted drill rig to complete the borings. Soil and weathered rock samples were recovered from the drilled borings by means of a 2.0-inch OD "Standard Penetration" split-spoon sampler (ASTM D1586) with 1.4-inch stainless steel liners and a 3.0-inch OD "Modified California" split-spoon sampler (ASTM D3550) with 2.4-inch stainless steel liners. The samplers were advanced with the standard 350-ft-lb striking force using a 140-lb automatic hammer and a drop height of 30 inches. Hammer efficiency was assumed to be 89.3% for this project, based on recent calibration provided by the driller.

In boring A-21-001, caving occurred at about 20 ft below ground surface, therefore, 4-inch diameter mud rotary drilling was utilized for the rest of the boring. The borings were drilled until auger refusal was encountered at elev. 288.3 and 298.9 in borings A-21-001 and A-21-002, respectively.

The samplers were driven 18-inches (or until sampler refusal criterion was met), and the blows required to advance the sampler each 6-inches of penetration were recorded. The sampler refusal criterion is defined as 50 or more blows with less than 6-inches of sampler advancement. The field blow counts (N) were recorded as the number of hammer blows required to drive the sampler the final 12-inches of the 18-inch total sample interval unless refusal was met. Sampler penetration resistance provides a field measure of relative densities and can be correlated to soil (or weathered/fractured rock) strength and bearing characteristics. The field-recorded (uncorrected) blow counts are shown on the boring logs provided in Appendix I.

CAI logged the explorations consistent with the Unified Soil Classification System (USCS) and the Caltrans 2010 Logging Manual. Selected portions of recovered soil and weathered/decomposed rock drive samples were retained in sealed containers for laboratory testing and reference. A bulk bag of channel material was collected at the bridge for grainsize analysis.

LABORATORY TESTING

The following laboratory tests were completed on representative soil/rock samples obtained from the borings:

- Moisture Content/Density (ASTM D2216; D7263)
- Particle-Size Distribution Using Sieve Analysis (ASTM D6913)
- pH and Minimum Resistivity (CTM 643)
- Sulfate Content, Chloride Content (CTM 417, 422)

See the Appendix II for a complete summary of all laboratory test results.

GEOLOGIC SETTING

The project is located within the Coast Ranges[2] geomorphic province of California which is characterized by a series of discontinuous northwest-trending mountain ranges extending from the Klamath Mountains on the north coast of California to the Transverse Ranges to the south. The Coast Ranges are composed of thick Mesozoic and Cenozoic sedimentary strata that have a complex structure due to intense folding and faulting. The basement rock in the northern portion of this province consists of the Great Valley Sequence, a Jurassic volcanic ophiolite sequence with associated Jurassic to Cretaceous age sedimentary rocks, and the Franciscan Complex, a subduction complex of diverse groups of igneous, sedimentary, and metamorphic rocks of Upper Jurassic to Cretaceous age.

Published geologic mapping[3] of the area shows Sulphur Creek underlain by Holocene aged (<150 years) modern steam channel deposits (Qhc) consisting of loose alluvial sand, gravel, and silt within active, natural channels. Geologic mapping also shows White Sulphur Springs Rd at/upstream of the bridge underlain by Holocene aged stream terrace point bar and overbank deposits (Qht), consisting of sand, gravel, silt, and clay. Adjacent to the southern abutment and along the southern bank upstream of the bridge, the site underlain by Jurrassic-Cretaceous aged Franciscan graywacke (KJfs) which consists of thickly bedded graywacke with minor interbedded shale. Franciscan Complex mélange (KJfm), a tectonic mixture of sandstone, greenstone, chert, garbbo, and metamorphic rocks imbedded in a sheared shaley matrix, is mapped about 200 ft northeast of the site.

Landslide deposits are mapped approximately 1,850 ft south of the site. During our November 2020 field investigation, CAInc observed a local bank landslide about 50 ft long and 30 to 40 ft tall. The landslide was located near Sta. 139+00. During the November 2020 site visit, we observed burnt trees and vegetation caused by the 2020 Glass Fire Complex. Based on our experience, the loss of vegetation is expected to cause local bank destabilization to the existing over-steepened slopes.

A geologic map of the site is included as Figure 4.

SEISMIC SETTING

The project site is located within the seismically active North Coast region of California and is subjected to seismically-induced ground shaking from nearby and distant faults. The California Geological Survey (CGS)[4], considers a fault to be active if it has shown evidence of ground displacement during the Holocene period, defined as the last 11,000 years. The nearest active

[2] https://www.coastal.ca.gov/coastalvoices/resources/California_Geomorphic_Provinces.pdf
[3] Clahan, K.B., Wagner, D.L., Bezore, S.P., Sowers, J.M., and Witter, R.C., 2005, Geologic map of the Rutherford 7.5-minute quadrangle, Sonoma and Napa counties, CA: A Digital database, v.1.0, California Geological Survey, series unknown, 1:24,000.
[4] https://maps.conservation.ca.gov/cgs/fam/

fault is the Rodgers Creek Fault, a Holocene dextral fault located approximately 9.5 miles southwest of the site.

The Browns Valley section of the West Napa Fault includes active and inactive faults. An inactive fault of the Browns Valley section is located less than 500±ft away, generally east of the bridge.

The Fault Activity Map for this site is shown on Figure 5.

SUBSURFACE CONDITIONS

SOIL/ROCK CONDITONS

Based on the material encountered/observed in the exploratory borings, seismic survey, and the site reconnaissance, the subsurface conditions encountered along the alignment are considered consistent with the cited published geologic mapping. In general, boring data indicate two general earth materials units. Refer to the boring logs in Appendix I for more specific soil/rock descriptions and boring details and Figure 3 for the approximate unit boundary.

UNIT 1

Unit 1 materials consist of light brown to gray, dense to very dense clayey sand/gravel and poorly-graded gravel with clay. Unit 1 was encountered from 7 ft above to 4 ft below bridge channel thalweg (elev. 299.3 ft in A-21-001; elev. 310.9 ft in A-21-002). We interpret the Unit 1 materials as roadway fill and alluvial deposits. Unit 1 was likely encountered deeper in boring A-21-001 due to the proximity to the stream deposits (Qht). Unit 1 was overlain by 1 to 3 inches of Asphalt and 3 inches of aggregate base.

UNIT 2

Unit 2, encountered below Unit 1 to the maximum depth explored about 16 ft below bridge channel thalweg (A-21-001; elev. 287.9 ft), consists of variably weathered/fractured sedimentary rock (graywacke and shale). The decomposed rock within Unit 2 excavated as clayey gravel to poorly-graded gravel with clay. Unit 2 was likely encountered higher in boring A-21-002 as it was located closer to the hillside where Franciscan graywacke (KJfs) is mapped.

Rock outcrops noted within the channel consisted of shale, greenstone, and sandstone. These outcrops generally match the published geologic mapping of Franciscan graywacke (KJfs) and Franciscan Complex mélange (KJfm).

SEISMIC SURVEY

Interpreted refraction seismic profiles indicate primary wave (V_p) velocities ranging from about 3,000 to 4,000 feet per second (fps) for unconsolidated granular surficial soils and about 4,000 to 15,000 fps for the underlying rock. The interpreted results/details of the seismic refraction profiles are summarized in Table 2.

Table 2: Summary of Seismic Refraction Survey

Seismic Line	Approx. Station / Offset (ft)		Approx. Depth from Thalweg to Bottom of Layer (ft)	Approx. Elevation Range at Bottom of Layer (ft)	Approximate Primary Wave Velocity, V_p (fps)
	Start	End			
S-1	134+24 / 12 Rt	135+30 / 17 Rt	7 to 15	299 to 311	3,000 to 4,000
			--	--	4,000 to 10,500
S-2	132+28 / 8 Lf	131+28 / 24 Lf	1 to 14	288 to 309.5	3,700 to 4,000
			--	--	4,000 to 8,600
S-3	130+14 / 14 Rt	129+12 / 4 Rt	13	291	4,000
			--	--	15,000

The refraction profiles and locations are shown in Figure 6A through 6C and Figure 2a, respectively.

GROUNDWATER

Groundwater levels encountered in the borings are summarized in Table 3.

Table 3: Groundwater Observations

Boring I.D.	Surface Elevation (ft)	Date Measured	Depth (ft)	Groundwater Elevation (ft)
A-21-001	316.3	1/5/2021	17.5	298.8
A-21-002	318.9	Not Encountered	Not Encountered	Not Encountered

In general, groundwater is expected to coincide with the creek water surface. The channel was dry during our September 2020 field review and had less than 6-inches of water (under the bridge) during our November 2020 and January 2021 field exploration. Based on conversations with the land owner, this portion of Sulphur Creek is generally dry between July and August.

CORROSION EVALUATION

A soil corrosivity test was completed on one soil sample obtained from the field exploration. Results of the soil corrosion test is summarized in Table 4.

Table 4: Corrosion Test Summary

Boring I.D. / Sample No.	Sample Depth (ft)	Sample Elevation (ft)	pH	Minimum Resistivity (ohm-cm)	Chloride Content (ppm)	Sulfate Content (ppm)
A-21-001 / 6 and 7	20-26.5	296.3 to 289.8	6.6	3,220	2.9	11.7

Note: According to Caltrans Corrosion Guidelines, a site is considered corrosive to foundation elements if one or more of the following conditions exist: Chloride concentration is greater than or equal to 500 ppm, sulfate concentration is greater than or equal to 1500 ppm, minimal resistivity of 1100 ohm-cm or less, or the pH is 5.5 or less. Except for MSE wall design, Caltrans does not include minimum resistivity as a parameter to define a corrosive area for structures (Caltrans Corrosion Guidelines Version 3.0, March 2018).

Based on Caltrans guidelines, the soils are not considered corrosive to structural steel/concrete elements. These tests are only an indicator of soil corrosivity and the designer should consult with a corrosion engineer if these values are considered significant.

SEISMIC DESIGN DATA AND EVALUATION

SURFACE FAULT RUPTURE

The site does not lie within an Alquist–Priolo Earthquake Fault Zone and no known active faults are mapped by the CGS within or through the project area. In our opinion the potential for surface fault rupture at the tieback wall location is considered low and is therefore not a design consideration for this project.

GROUND MOTION AND ARS CURVE

The Caltrans ARS Online (v3.0.2)[5] web-based tool was used to calculate the probabilistic acceleration response spectra for the site based on criteria outlined in Appendix B of the April 2019 Caltrans Seismic Design Criteria (SDC) Version 2.0. For probabilistic analysis, Caltrans ARS Online (v3.0.2) uses 2014 USGS hazard deaggregation results. The mean magnitude is determined from the hazard deaggregation performed at the PGA.

We used a shear wave velocity (V_{S30}) limited to 500 meters per second (corresponding to Soil Profile Type C) for the upper 100 feet of the soil profile based on the results of the seismic refraction survey completed near the existing bridge. For our evaluation, we used latitude 38.4879° and longitude 122.4816° for the site coordinates.

RECOMMENDED SEISMIC DATA

Based on the above information, we recommend that structure design be based on the following Caltrans SDC parameters:

- Shear Wave Velocity, V_{S30}: 500 meters per second (1,640 fps);
- Soil Profile Type C;
- Magnitude (M): 6.72;
- Peak Ground Acceleration (PGA): 0.64g;
- Controlling Spectra: Probabilistic Spectrum, 2014 USGS 5% in 50 years (975-year return period)

We include the recommended Seismic Design Data as Figure 8.

LIQUEFACTION POTENTIAL AND SEISMIC SETTLEMENT POTENTIAL

Soil liquefaction can occur when saturated, relatively loose sand and specific soft, fine-grained saturated soils are subject to ground shaking strong enough to create soil particle separation that results from increased pore pressure. This separation and subsequent pore pressure dissipation

[5]https://arsonline.dot.ca.gov/, accessed February 11, 2021.

can lead to decreased soil shear strength and settlement. Liquefaction is known to occur in soils ranging from low plasticity silts to gravels (generally within 50 feet of the surface). However, soils most susceptible to liquefaction are clean sands to silty sands and non-plastic silts. Due to the presence of competent soil/rock encountered above the groundwater table we consider the potential for liquefaction and seismic settlement at the site to be very low.

CONCLUSIONS

Based on our evaluation of the boring data generated/reviewed for this study, we conclude that construction of the planned wall and channel regrading is feasible from a geotechnical standpoint provided the recommendations presented below are followed.

Key geotechnical considerations for the project include excavatability/stability of the channel materials (soil, gravels, and rock) within an active channel while protecting the existing, already compromised bridge foundation during construction.

RETAINING WALL RECOMMENDATIONS

The soil conditions at the site likely allow support for a variety of retaining wall systems, however based on discussion with the design team, the use of a tie-back retaining structure appears most feasible. The tie-back wall will allow for consistent support to the existing bridge foundations and can be constructed in a top-down manner, reducing the reliance on temporary support (shoring, etc) during construction.

We provide the following considerations for development of the retaining wall structural design.

GEOTECHNICAL ENGINEERING PARAMETERS

The following generalized soil/rock profile (see Table 5) was developed for this site based on data from the test borings. We expect a groundwater elevation of 305 ft is likely appropriate for design of the retaining wall, unless more information about fluctuations in the creek level are available.

Table 5: Geotechnical Engineering Design Parameters

Unit	Material Type	USCS	Total Unit Weight (pcf)	Friction Angle (deg)	Cohesion (psf)
1	Embankment Fill/Alluvium	SC/GC/ GP-GC	130	36	0
2	“Intact” Material	Decomposed to Weathered Rock	140	40	0

LATERAL FORCES

The tie-back wall should be designed to resist applicable forces. Load combinations may include static earth pressures, horizontal pressure from vertical footing surcharge and/or lateral load, hydrostatic pressure, and seismic earth pressure.

We provide the following Geotechnical considerations for tie-back wall design. The following assumes level backfill conditions for the retaining wall and drainage behind walls is placed in accordance with Caltrans Standard Plans and Specifications with consideration given to changes in the adjacent creek water surface elevation.

Refer to Figure 7 for an example of some applicable pressure diagrams.

STATIC EARTH PRESSURES

We developed lateral earth pressures in accordance to Caltrans Memo to Designers (MTD) 5-12 and 8th Edition of AASHTO LRFD Bridge Design Specifications (AASHTO 8th Ed). The material behind the retaining walls are expected to generally consist of dense to very dense clayey sand and decomposed rock that excavates as clayey sand to poorly-graded gravel with clay.

Table 6: Recommended Equivalent Fluid Weights (EFW)

Condition	Static			
	Coefficient k (dim.)	Above Groundwater EFW (pcf)	Below Groundwater EFW (pcf)	Hydrostatic EFW (pcf)
Active	0.26	34	18	81
At-Rest	0.412	54	28	91

For top down constructed anchored walls, the soil earth pressure diagram is dependent on the levels of wall anchors. Refer to Figure 5-12.1 in Caltrans MTD 5-12 for the earth pressure diagrams for a wall with a single level or multiple levels of anchors.

Since the wall is next to an existing structure, the maximum ordinate of pressure diagram (p_a) can be evaluated using P_{total} (total load applied to wall face). Refer to equations 5.12-1 and 5-12.2 in Caltrans MTD 5-12 to calculate P_a (active lateral earth resultant) where P_{total} shall not be less than 1.44 P_a (ksf).

The static active and at-rest earth pressure coefficients in Table 6 were calculated using the Coulomb equations presented in Section 5 of Caltrans Bridge Design Specifications (BDS, August 2004) with the friction angle between the backfill material and back of wall (δ) is equal to zero.

SEISMIC EARTH PRESSURE

For seismic design, use the following incremental seismic equivalent fluid weight (ΔEFW_{EQ}).

Table 7: Incremental Seismic Equivalent Fluid Weights (EFW)

Condition	Incremental Seismic		
	Coefficient Δk (dim.)	Above Groundwater ΔEFW_{EQ} (pcf)	Below Groundwater ΔEFW_{EQ} (pcf)
Active	0.131	17	9
At-Rest	NA	29	14

The EFW values shown in Tables 6 and 7 are consistent with Caltrans standards/practice and assume:

- horizontal seismic acceleration coefficient (k_h) ≤ 0.2;
- vertical seismic acceleration coefficient (k_v) = 0.0; and

Use a uniform pressure distribution and apply the magnitude of the resultant at 0.5H from the base of the wall. The total seismic load is equal to the resultant of the incremental seismic earth pressure added to the resultant of the static earth pressure (i.e., $P_{EQ} = P_{static} + \Delta P_{EQ}$).

BRIDGE FOUNDATION PRESSURES

If applicable, additional horizonal forces may be applied to the wall from the existing bridge spread foundations due to vertical and/or lateral forces.

Refer to AASHTO 8th Ed Section 3.11.6.2 and Figure 3.11.6.2-1 for the horizonal pressure on a wall due to the abutment surcharge. The vertical surcharge loads in AASHTO 8th Ed Section 3.11.6.2 are applicable to walls that do not move and is very conservative for flexible walls.

Refer to Figure 5-.12.11 in Caltrans MTD 5-12 for the horizontal reaction and distribution due to the static horizontal reaction. In general, apply the horizontal pressure in an upside down inverted triangular distribution. The triangular base is equal to the ½ of the footing deadload divided by the distance from the wall to back of the footing.

The structural engineer should consider the additional pressures that may be applied to the retaining wall based on the existing bridge foundation.

HYDROSTATIC PRESSURE

The tieback wall face will be located within surface/groundwater. A minimum hydrostatic pressure equal to 3 ft of water should be considered for design per Caltrans Bridge Design Specifications Section 5.9.3.8.3.

GROUND ANCHOR TIE-BACKS

Resist lateral wall forces (as needed) with sub-horizontal, grouted ground anchors.

For a ground anchor, there are two components – un-bonded length and bonded length. The un-bonded length of the anchor is the portion of the anchor that is not grouted. Conversely, the bonded length is the grouted portion and provides the lateral resistance for the wall.

The un-bonded ground anchor length is required to satisfy the following conditions:

- Minimum length of 15-ft;
- Inclination angle between 10- to 45-degrees from horizontal (15 degrees typically used); and
- Extend at least 5-ft or H/5-ft beyond the active zone (based on a friction angle of 36-degrees), and/or beyond the existing bridge foundation, whichever is greater.

For preliminary design of the bonded anchor length, use a presumptive ultimate unit bond stress of 45 psi at the southern abutment and 35 psi at the northern abutment (based on very dense materials consisting primarily of clayey gravel and decomposed to weathered rock) and a minimum required bond length of 15-ft. The contractor is ultimately responsible for determining the bonded anchor length necessary to achieve the required tieback force based on their chosen installation method.

Preproduction tests, such as pullout or extended creep tests, on sacrificial anchors can be conducted in order to establish bonded lengths and capacities. Either performance or proof tests shall be conducted on every production anchor to 1.0 or greater times the factored load to verify capacity. Ground anchor construction, performance and proof tests, test acceptance criteria, and materials should be in conformance with the Caltrans 2018 Standard Specifications.

CONSTRUCTION CONSIDERATIONS

DRILLING CONDITIONS

Based on the field exploration, overall difficult drilling conditions are not expected for the tiebacks within Unit 2 “intact” material, assuming the Contractor uses appropriate equipment for drilling through a combination soils, gravels, and rock.

Caltrans Standard Special Provisions 46-2.03A and 49-403.B should be included within the project specifications to describe potential difficult and/or hard drilling conditions for ground anchors due to the following site conditions:

- Ground anchor drilling could be susceptible to caving and may require partial or full temporary casing.
- The borings reached auger refusal at elevations between 288.3 and 298.9 ft; harder/difficult drilling may be encountered below this depth range.
- Presence of groundwater.

Prior to mobilization to the site, the Contractor should prepare and submit a detailed work plan for the Engineer’s review and approval. The work plan should state explicitly all assumptions the contractor has made regarding earth materials and foundation construction conditions. The work plan should include details of proposed equipment, personnel, materials, methods, and order of work.

GROUNDWATER

Groundwater was encountered during drilling (January 2021) near the soil/rock interface. Soils/rock below groundwater are expected to be saturated and capable of transmitting substantial quantities of seepage to open excavations. The contractor is responsible for dewatering and/or diking diversion design and construction methods.

Surface water may or may not be present during the dryer months (e.g. July and August), but will most likely be present during wetter months. Adequate construction de-watering is expected to be achievable (at low channel flow) by means of diking/diversion of surface water and the use of sump pumps, but could require heavy pumping. Temporary diversion/piping of all surface water around/through the site is considered desirable, if feasible.

EXCAVATION

The Caterpillar Handbook of Ripping, 12th Edition estimates shale—the bedrock type we encountered—is rippable with a CAT D9R with a single ripping shank up to a p-wave velocity of 7,400 fps, marginally rippable up to a p-wave velocity of 8,000 fps, and non-rippable with a p-wave velocity above 9,500 fps. Based on our review of the 30% plans, the channel will be excavated to a maximum 6 ft bgs. Our seismic results generally indicate the materials within the upper 7 to 15 ft have a p-wave velocity of 4,000 fps. Near station 132+28 we observed P-wave velocities of 8,400 fps within a few feet of existing grade likely indicating some harder rock may be encountered closer to the surface during construction and require additional excavation effort and or the use of pneumatic hammers and/or large equipment.

RISK MANAGEMENT

Our experience and that of our profession indicate that the risks of costly design, construction, and maintenance problems can be significantly lowered by retaining the Geotechnical Engineer of Record to provide additional services during design and construction.

For this project, CAInc should be retained as the Geotechnical Engineer of Record to:

- Review and provide comments on the final plans and specifications, insofar as they rely upon this report, prior to construction bidding to verify consistency with the recommendations contained herein.
- Review the tie-back and retaining wall construction plan.
- Monitor construction to check and document our report assumptions. At a minimum, CAInc should monitor initial ground anchor drilling, installation, and review pull test results.
- Update this report if design changes occur, two (2) years or more lapse between this report and construction, or site conditions have changed.

Should there be any change in the project or should subsurface conditions differ from those described in this report be encountered during construction, this office should be contacted/notified for evaluation and supplemental recommendations, as needed.

CAInc is not responsible for any other parties' interpretation of this report and recommendations contained herein, as well as subsequent addendums, letters, and discussions. If others perform the construction observation, they should review this report and either accept the conclusions and recommendations herein as their own or provide alternative recommendations.

LIMITATIONS

CAInc performed services in accordance with generally accepted geotechnical engineering principles and practices currently used in this area. Where referenced, ASTM or Caltrans standards are used as a general (not strict) guideline only. We do not warrant our services.

This report is based on the current site and project conditions and should only be used for the evaluation and design of repair alternatives for the NCRCD-Sulphur Creek Fish Passage Project #30144. It is assumed the soil/rock and groundwater conditions interpreted/encountered in the explorations (see logs provided in Appendix I) are representative of the subsurface conditions at the site. Actual conditions between explorations will vary along the project alignment. The interface shown between soil/rock materials on the exploration logs is approximate; the transition between material types may be abrupt or gradual. The recommendations contained herein are based on the final exploration logs, which represent our interpretation of the field logs and general knowledge of the site and geological conditions.

Modern design and construction are complex, with many regulatory sources/restrictions, involved parties, and construction alternatives. It is common to experience changes and delays. The owner should set aside a reasonable contingency fund based on project complexities and cost estimates to cover changes and delays.

CLOSING

Please contact us if you have any questions regarding the above recommendations or require additional information.

Sincerely,

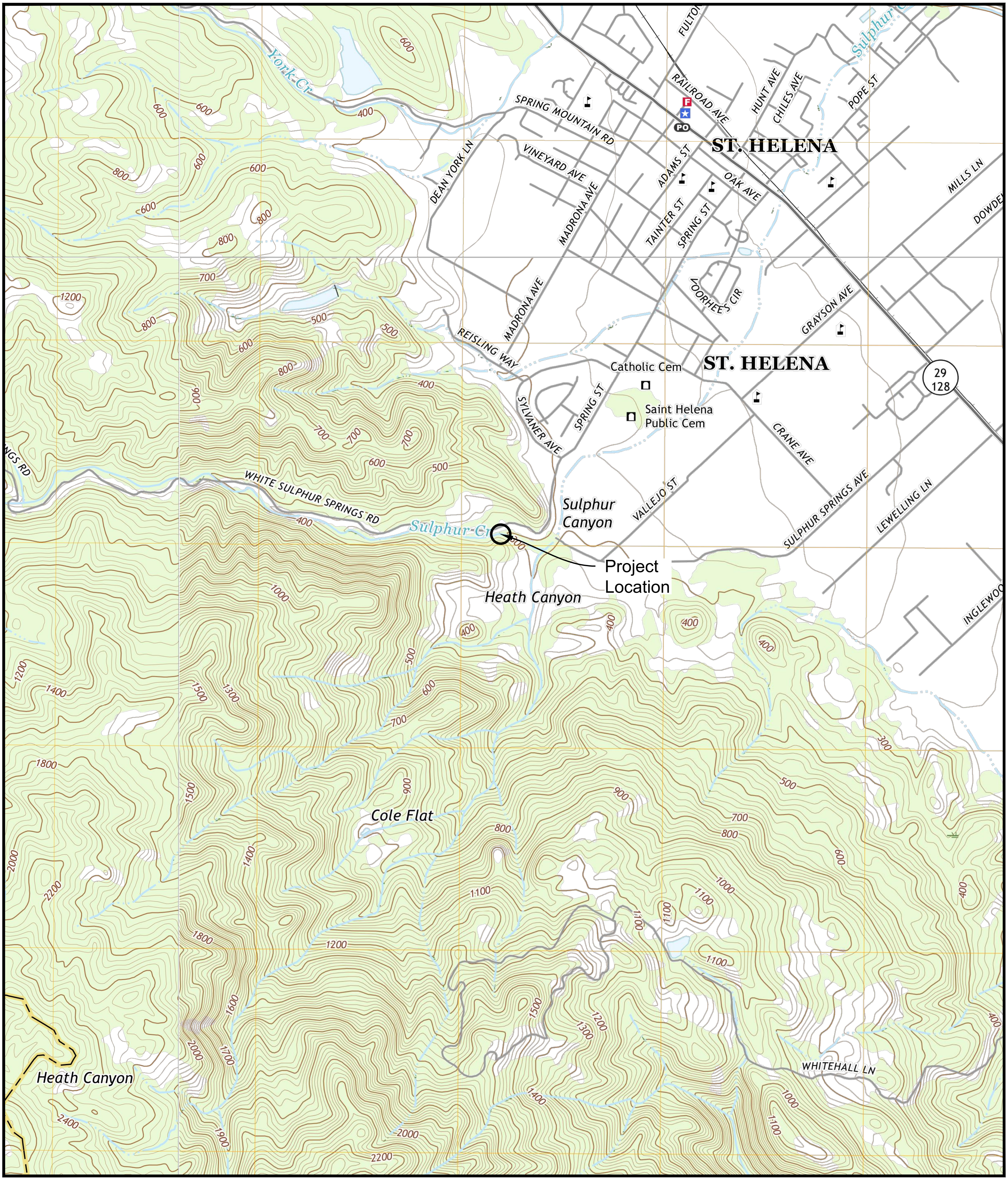
Crawford & Associates, Inc.

Ellen Tiedemann, PE
Project Engineer

Benjamin Crawford, PE, GE
Principal *Geotechnical Engineer*

Yosief Ghebremicael, EIT
Project Engineer

FIGURES



North

Source:

USGS 7.5' Topographic Maps, Calistoga, Sonoma County, California, 2018, Scale: 1:24,000

USGS 7.5' Topographic Maps, Kenwood, Sonoma County, California, 2018, Scale: 1:24,000

USGS 7.5' Topographic Maps, Rutherford, Sonoma County, California, 2018, Scale: 1:24,000

USGS 7.5' Topographic Maps, Saint Helena, Sonoma County, California, 2018, Scale: 1:24,000

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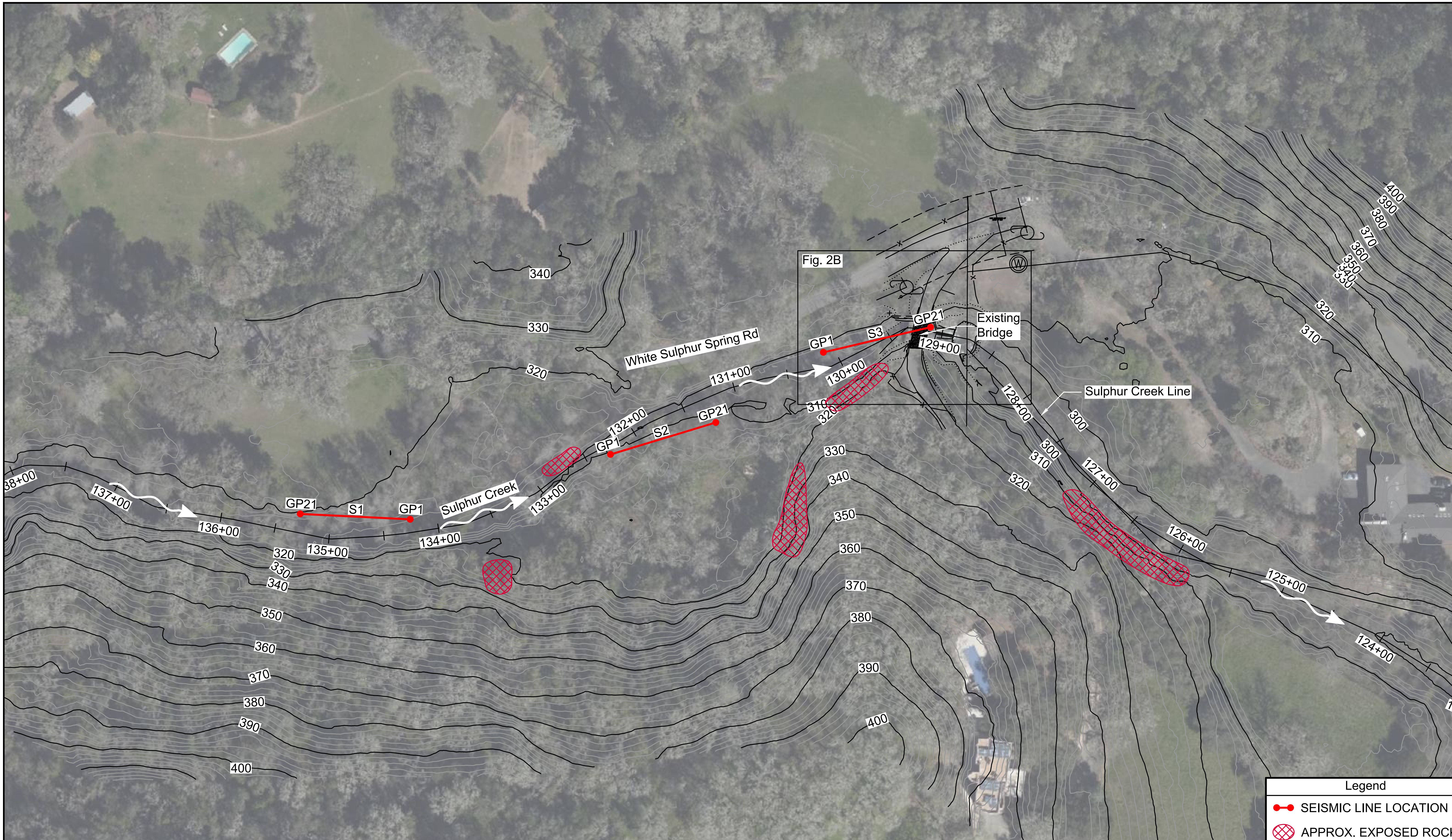
NCRCD-SULPHUR CREEK FISH PASSAGE (PROJECT #30144)

NAPA COUNTY, CALIFORNIA

Figure 1

Vicinity Map

Proj. No:	20-643.1
Scale:	1"=4,000'
Date:	2/4/21



North

Source:
Basemap: AutoCAD Civil3D Geolocation Tool, using Bing Maps

Topographic and plan files provided by WRA via electronic transfer on 08/12/2020 and 11/09/2020

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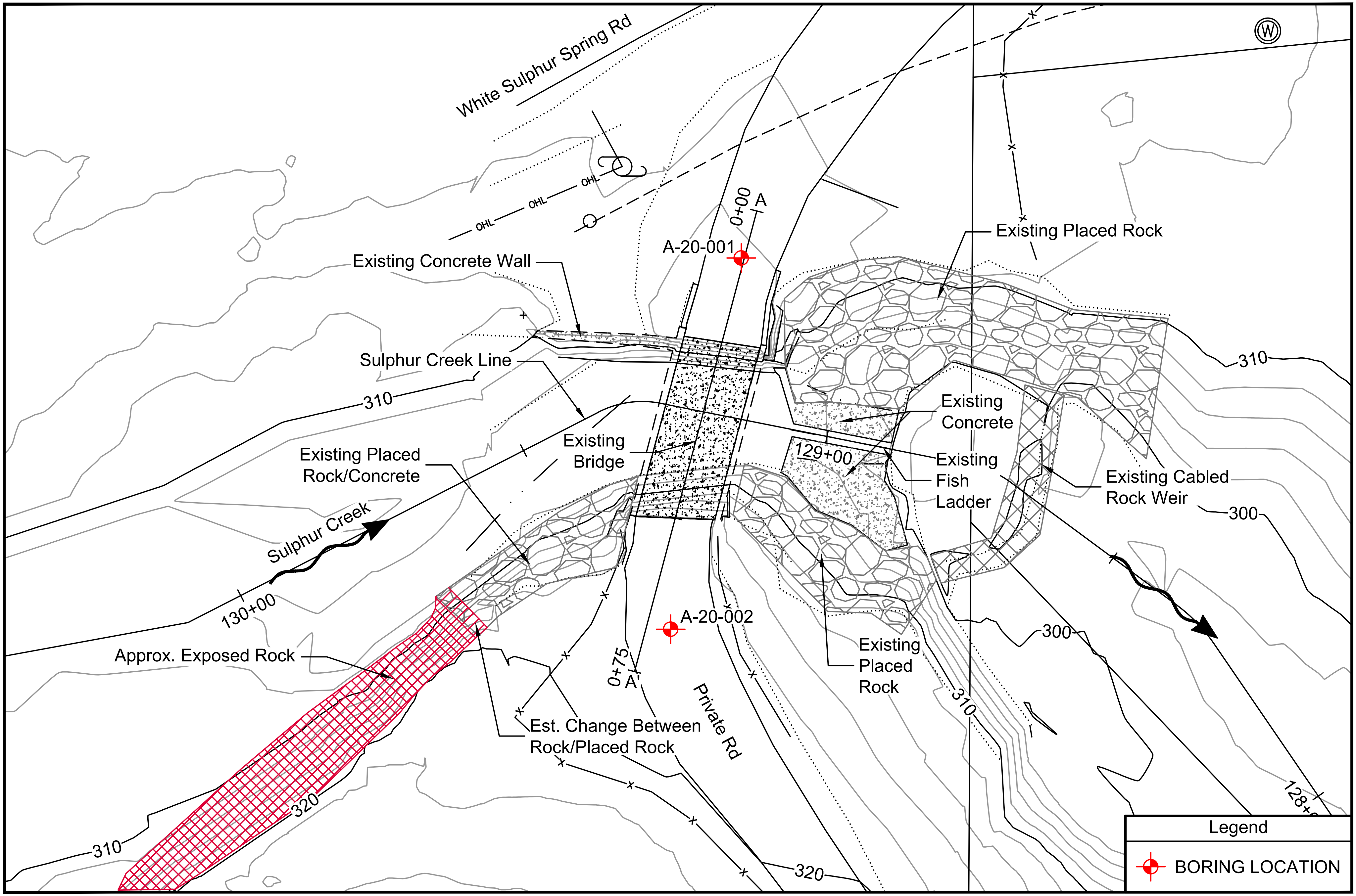
NCRCD-SULPHUR CREEK FISH PASSAGE (PROJECT #30144)

NAPA COUNTY, CALIFORNIA

Figure 2A
Exploration Map

Proj. No: 20-643.1
Scale: 1"=80'
Date: 2/9/21



North

Source:
Basemap: AutoCAD Civil3D Geolocation Tool, using Bing Maps

Topographic and plan files provided by WRA via electronic transfer on 08/12/2020 and 11/09/2020

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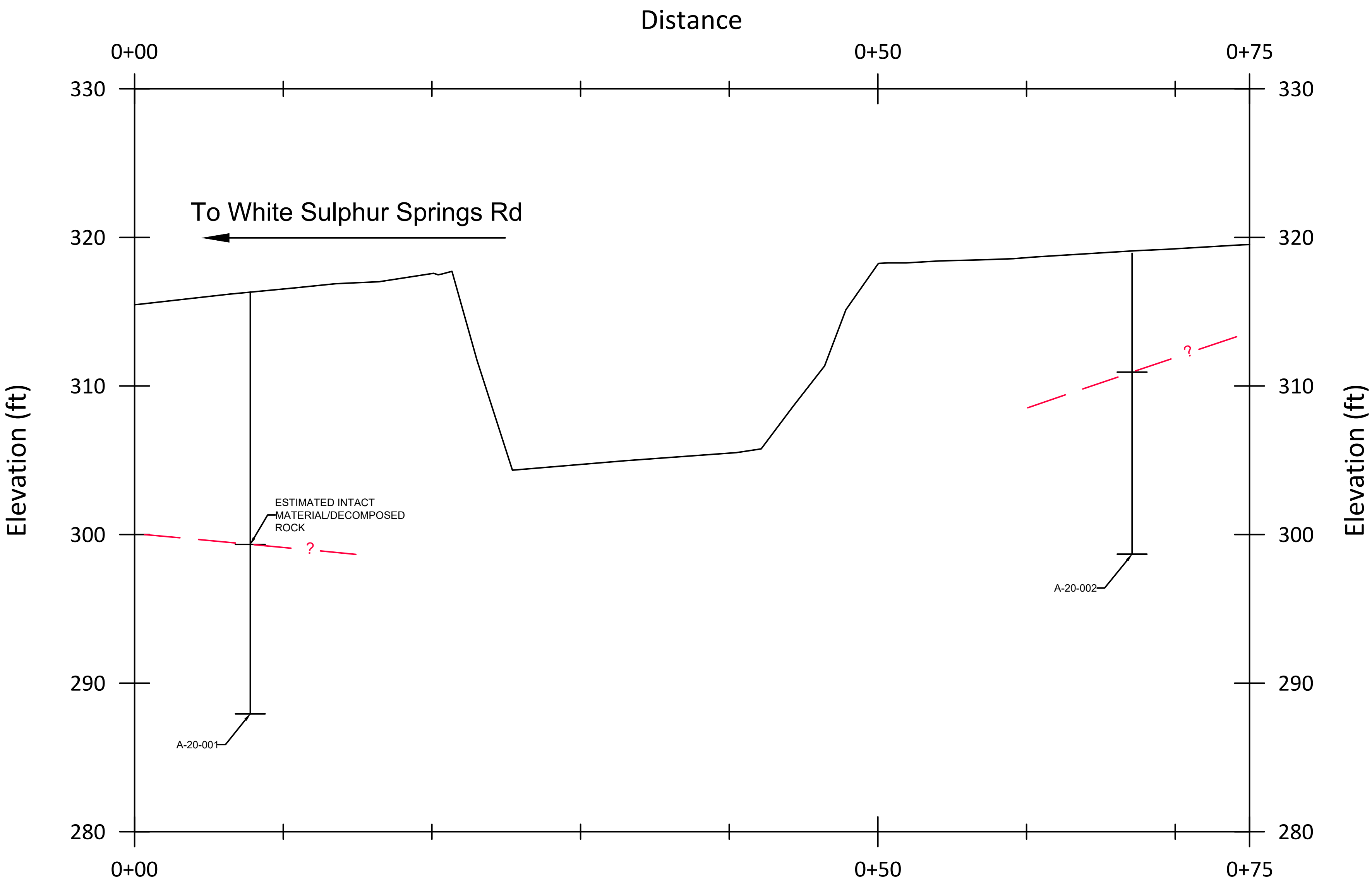
NAPA COUNTY, CALIFORNIA

Figure 2B
Exploration Map

Proj. No:	20-643.1
Scale:	1"=20'
Date:	2/10/21



Cross Section A

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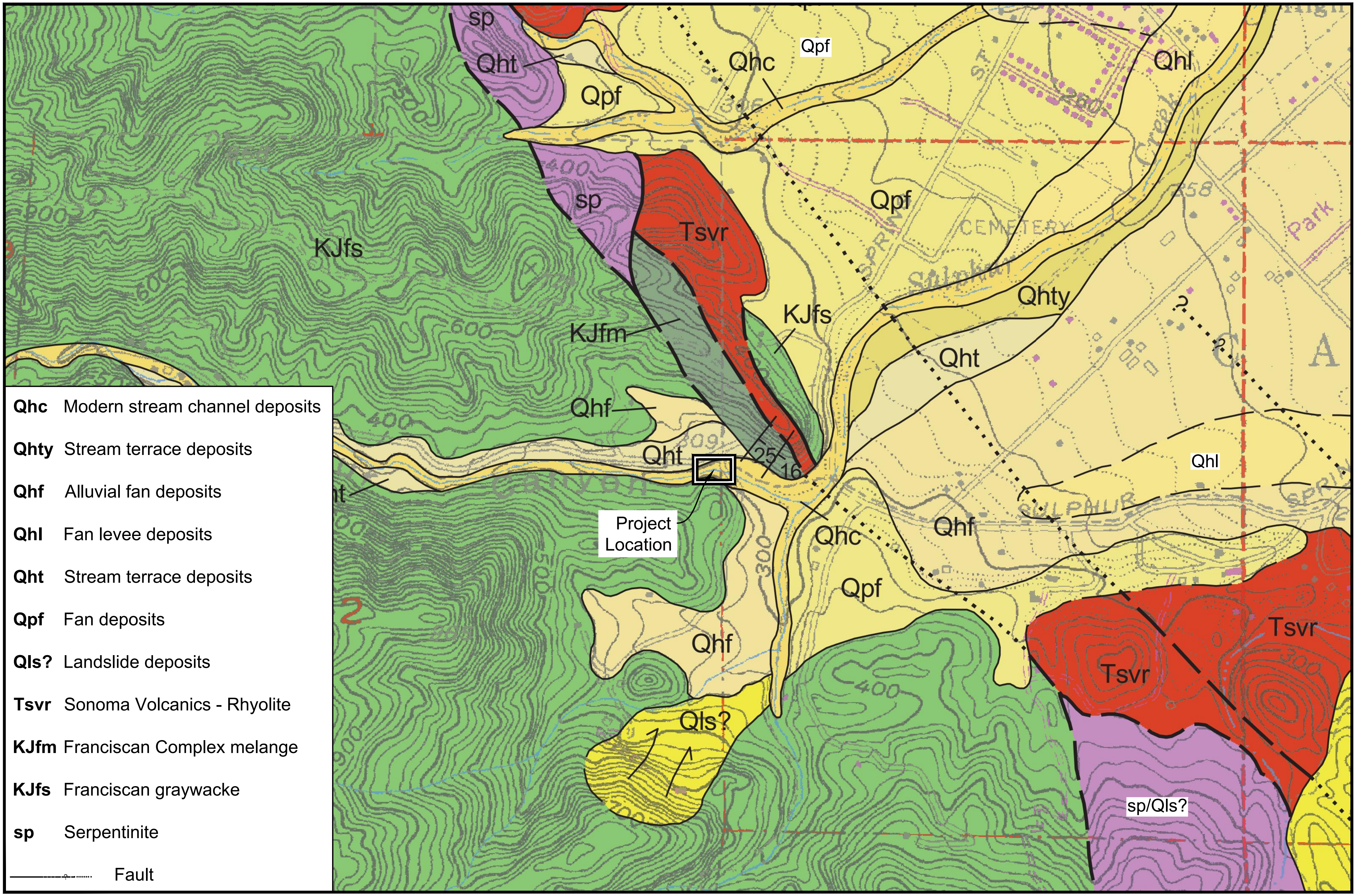
NCRCD-SULPHUR CREEK FISH PASSAGE (PROJECT #30144)

NAPA COUNTY, CALIFORNIA

Figure 3
Cross Section A

Proj. No:	20-643.1
Scale:	1"=10'
Date:	2/5/21



North

Source: Clahan, K.B., Wagner, D.L., Bezore, S.P., Sowers, J.M., and Witter, R.C.; Geologic map of the Rutherford 7.5-minute quadrangle, Sonoma and Napa counties, CA: A Digital database, v.1.0; Preliminary Geologic Maps; Scale: 1:24,000; California: California Geologic Survey, 2005.

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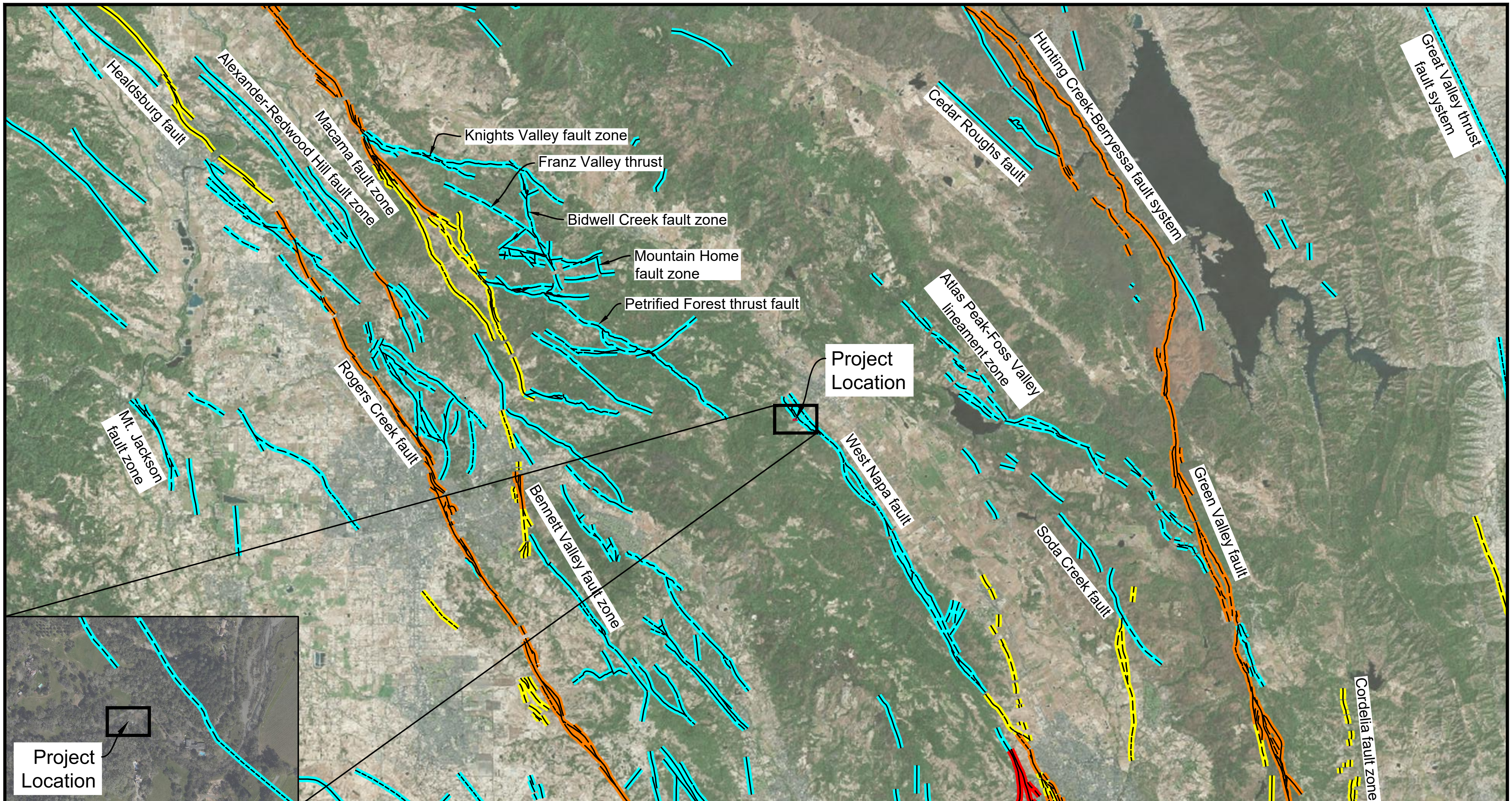
NCRCD-SULPHUR CREEK FISH PASSAGE (PROJECT #30144)

NAPA COUNTY, CALIFORNIA

Figure 4
Geologic Map

Proj. No:	20-643.1
Scale:	1"=1,000'
Date:	2/4/21



LEGEND

Quaternary Fault (Age)	Quaternary Fault (Age)	Location
<150 years	<750,000 years	Well Constrained
<15,000 years	<1.6 million years	Moderately Constrained
<130,000 years		Inferred

North

Source:
Basemap: AutoCAD Civil3D Geolocation Tool, using Bing Maps

Fault Data: USGS GIS Data

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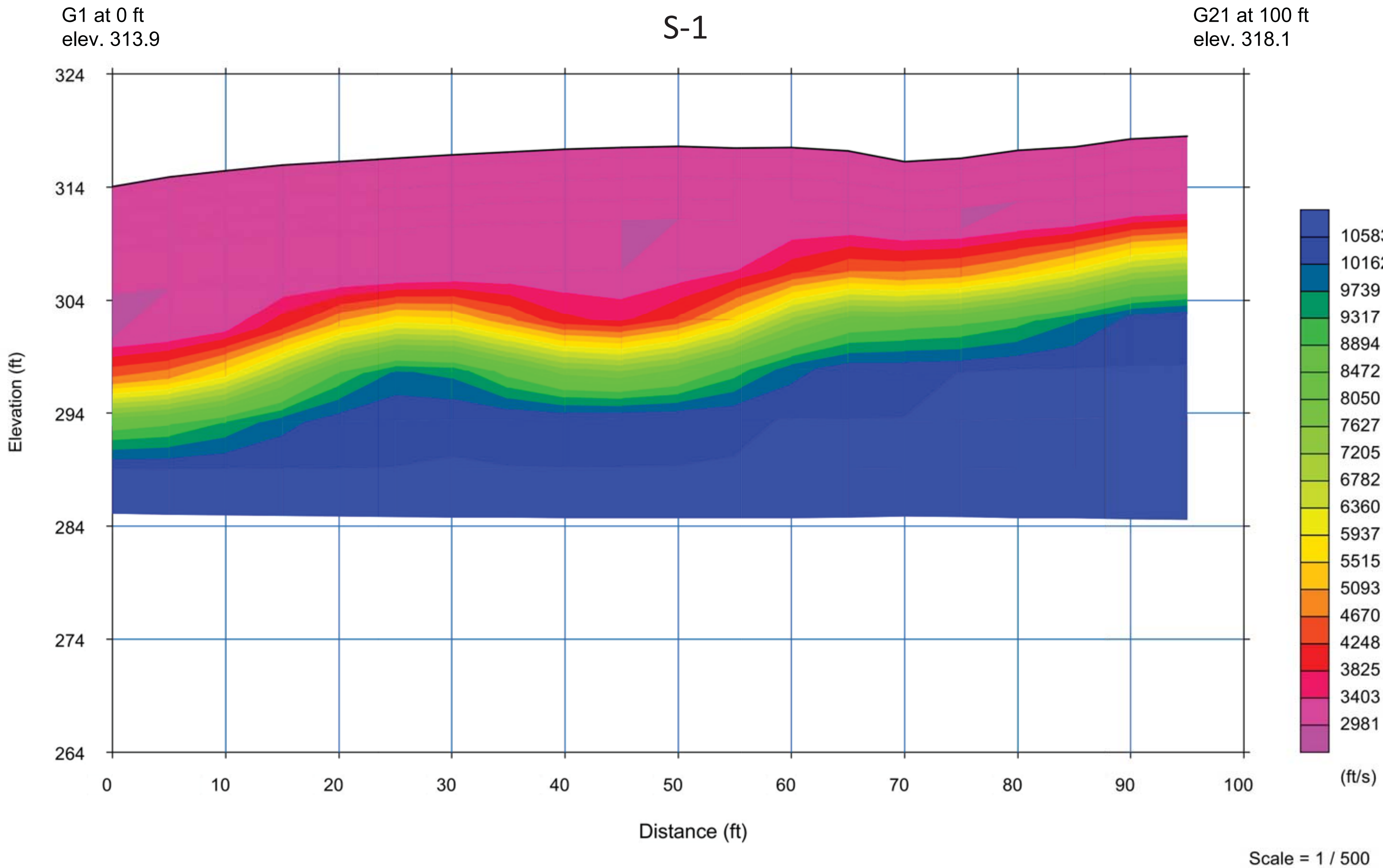
NCRCD-SULPHUR CREEK FISH PASSAGE (PROJECT #30144)

NAPA COUNTY, CALIFORNIA

Figure 5
Fault Map

Proj. No: 20-643.1
Scale: 1"=25,000'
Date: 2/4/21



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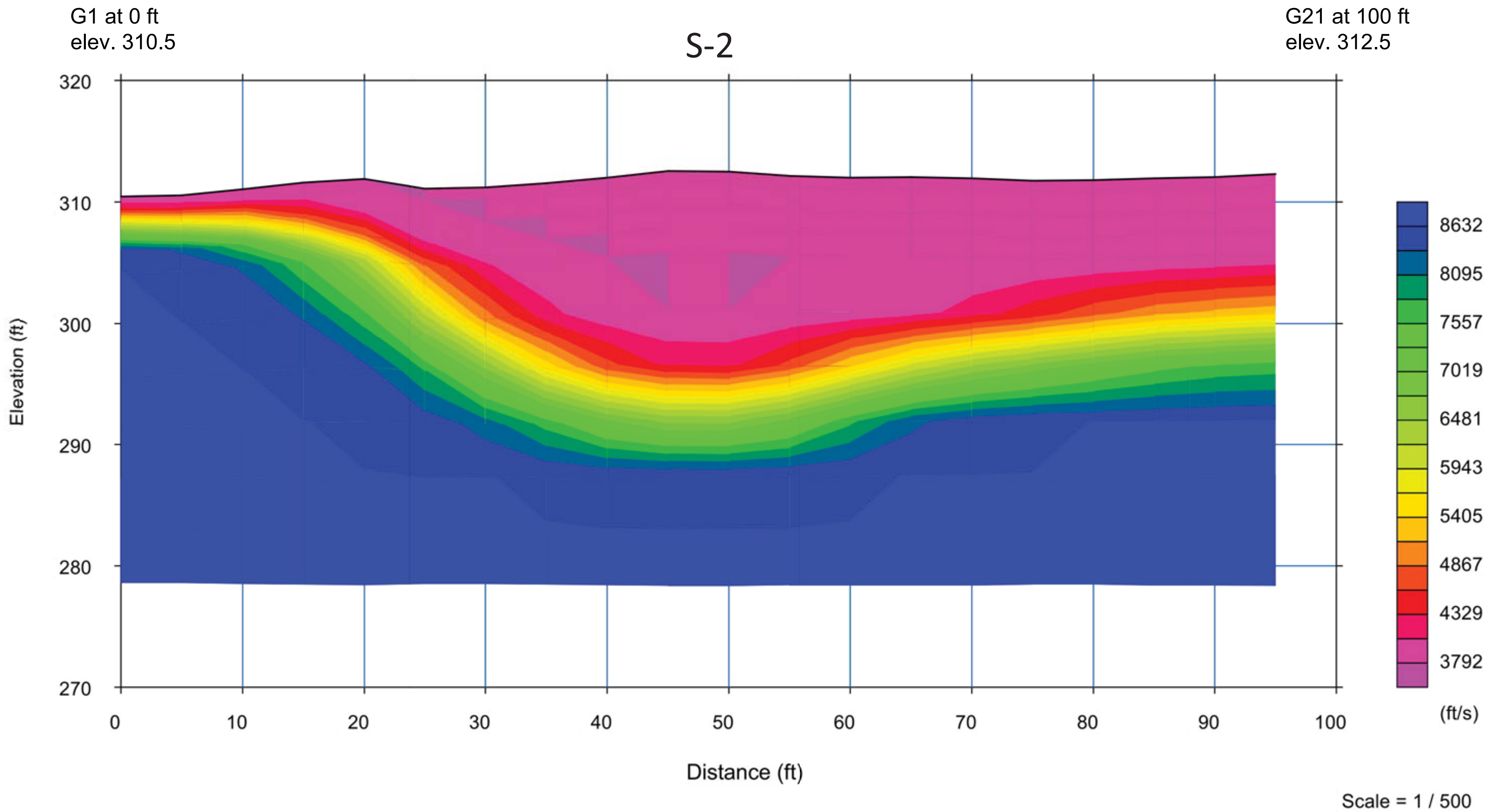
NCRCD-SULPHUR CREEK FISH PASSAGE (PROJECT #30144)

NAPA COUNTY, CALIFORNIA

Figure 6A
Seismic Refraction Profile 1 of 3

Proj. No:	20-643.1
Scale:	N/A
Date:	2/12/21



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NCRCD-SULPHUR CREEK FISH PASSAGE (PROJECT #30144)

NAPA COUNTY, CALIFORNIA

Figure 6B
Seismic Refraction Profile 2 of 3

Proj. No:	20-643.1
Scale:	N/A
Date:	2/12/21

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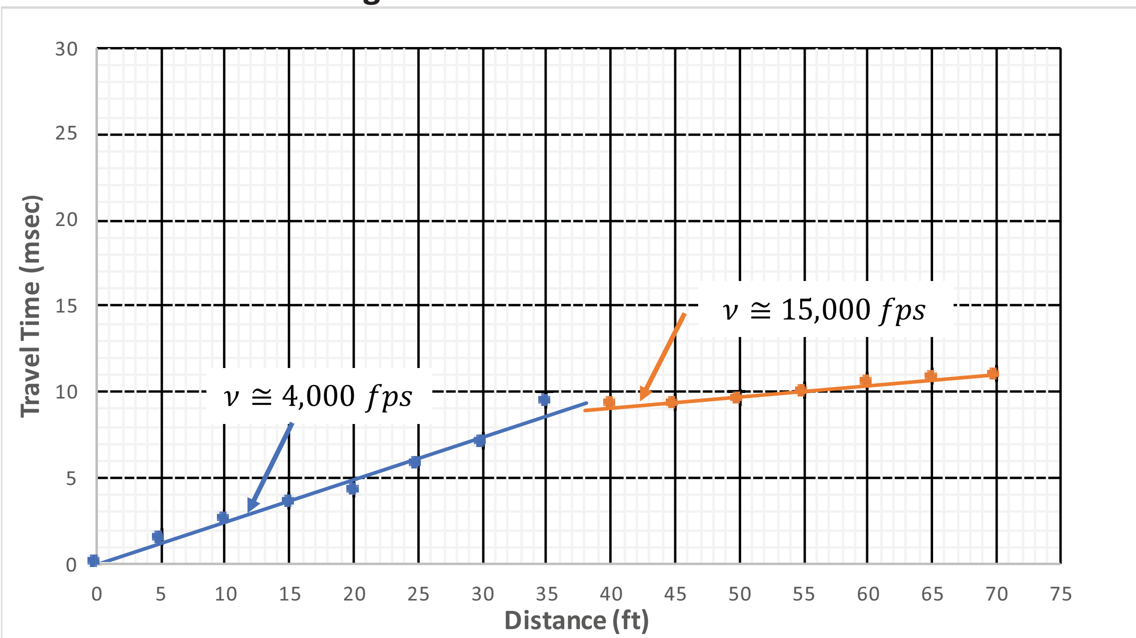
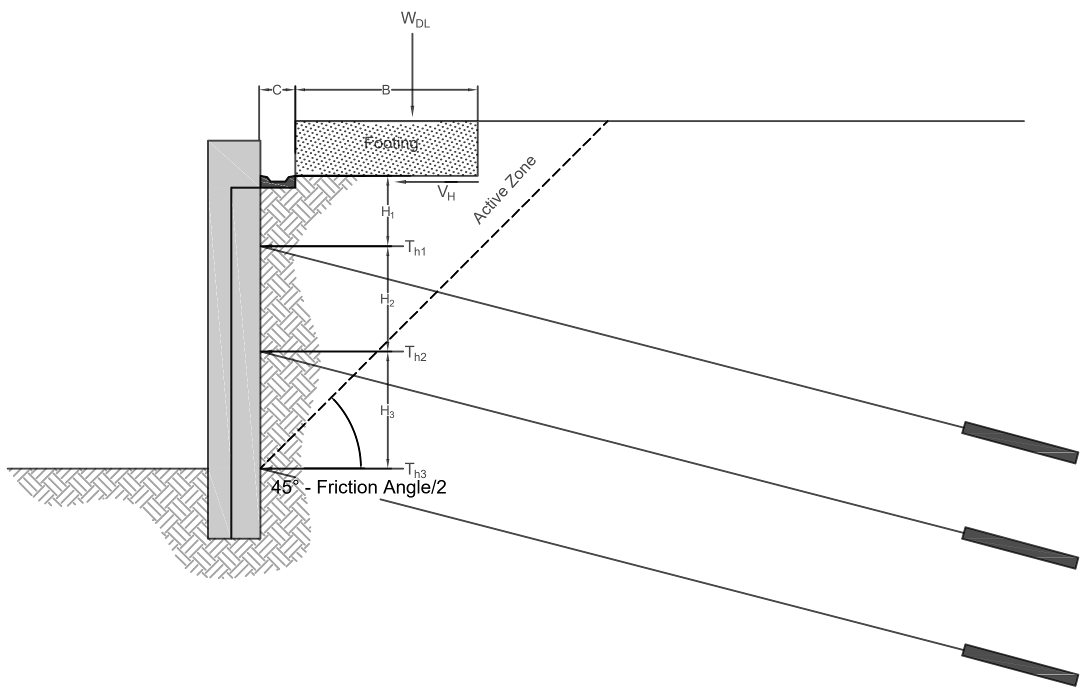
Project Name: NCRCD - Sulphur Creek Fish Passage
Project Number: 20-643.1
Date: February 10, 2021
Location: St. Helena, CA

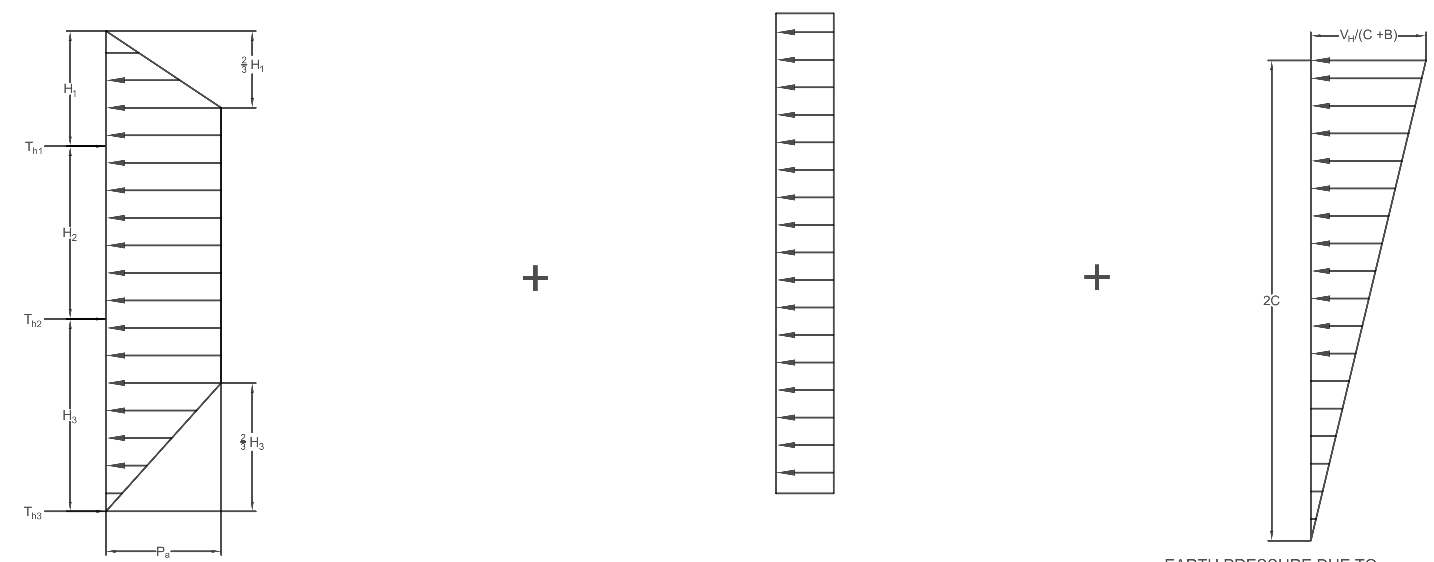
Figure 6c: Seismic Refraction



Seismic Refraction Data Log			
Line Number: S3	Line Length: 100-ft.	Shot Location: 0-ft.	Orientation: 238°SW
Approximate Depth to Rock: 13-ft.			

Geophone Number	Impact Distance (ft)	Travel Time (msec)
14	0	0.0
13	5	1.5
12	10	2.6
11	15	3.6
10	20	4.3
9	**25**	5.8
8	**30**	7
7	**35**	9.4
6	**40**	9.2
5	**45**	9.3
4	**50**	9.5
3	**55**	10
2	**60**	10.5
1	**65**	10.8
0	**70**	10.9





STATIC LATERAL EARTH PRESSURE (AASHTO LRFD 2017 BRIDGE DESIGN SPECIFICATIONS, 8TH EDITION, Section 3.11.5.7)

$P_A = K_a \gamma H^2/(1.5H - 0.5H_1 - 0.5H_3)$

where:
P_A = maximum ordinate of pressure diagram (ksf)
K_a = active earth pressure diagram behind the beam wall
= 0.26
γ = unit weight of soil (kcf)
= 0.13
H = total excavation depth (ft)
H_1 = distance from ground surface to uppermost ground anchor (ft)
H_2 = distance from uppermost ground anchor to second ground anchor (ft)
H_3 = distance from second ground anchor to lowermost ground anchor(ft)
T_{hi} = horizontal load in ground anchor i (kip/ft)

SEISMIC LATERAL EARTH PRESSURE (AASHTO LRFD 2017 BRIDGE DESIGN SPECIFICATIONS, 8TH EDITION, Section 11.6.5.3)

$\Delta P_{EQ} = 0.5(\Delta EFW_{AEQ})H^2$

$EFW_{ae} = \Delta K_{ae} \gamma = 0.131 x 0.13 = 0.017$ kcf

where:
ΔEFW_{ae} = incremental seismic active lateral earth pressure (kcf)
K_{ae} = seismic active earth pressure coefficient (dim)
= 0.391
ΔK_{ae} = incremental seismic active earth pressure coefficient (dim)
= $K_{ae} - K_a$ = 0.391-0.26 = 0.131
γ = unit weight of soil (kcf)
= 0.13

EARTH PRESSURE DUE TO HORIZONTAL PRESSURE FROM SLIDING FRICTION (CALTRANS LRFD, MEMO TO DESIGNERS 5-12, JULY 2012, FIGURE 5-12.10)

$V_H = 0.5W_{DL}$ but > P_A

where:
W_{DL} = deal load reaction at base of footing
C = distance from wall to front of footing

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NCRCD-SULPHUR CREEK FISH PASSAGE (PROJECT #30144)

NAPA COUNTY, CALIFORNIA

Figure 7
Example Earth Pressures

Proj. No: 20-643.1
Scale: No Scale
Date: 2/17/21

SEISMIC DESIGN DATA

NCRCD-Sulphur Creek Fish Passage (Project #30144)

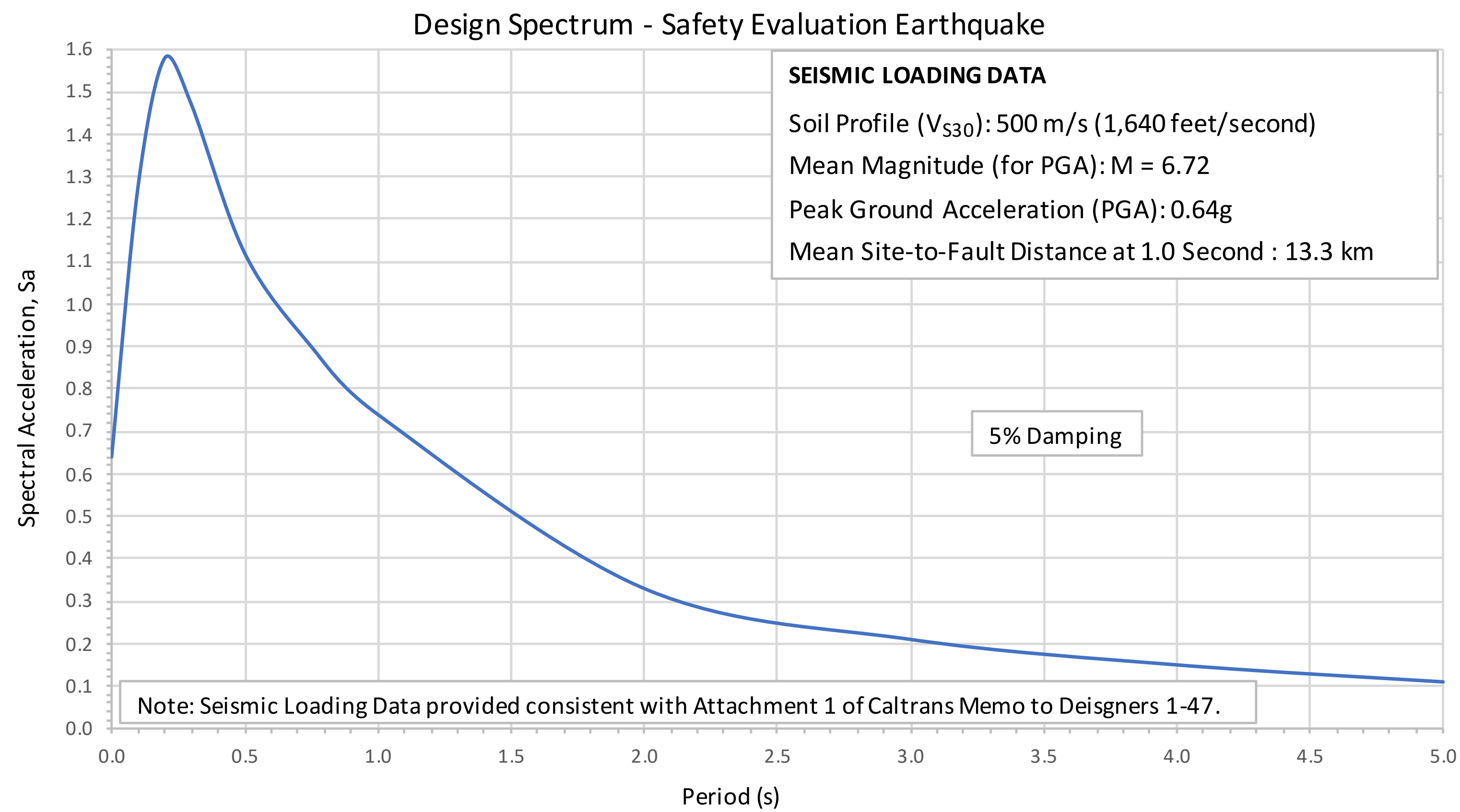
Napa County, California

Caltrans Seismic Design Criteria: V2.0

Caltrans ARS Online Version: V3.0.2

Date Accessed: 2/11/2021

Period (s)	Spectral Acceleration, Sa (g)
0.00	0.64
0.10	1.28
0.20	1.58
0.30	1.47
0.50	1.12
0.75	0.90
1.00	0.74
2.00	0.33
3.00	0.21
4.00	0.15
5.00	0.11



The Design Spectrum is the probabilistic repsonse spectrum obtained from the Caltrans ARS online version V3.0.2 for the 5 % probability of exceedance in 50 years (975 year return period) from the 2014 USGS Hazard Data.

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Site Latitude: 38.4879

Site Longitude: -122.4816

FIGURE 8

APPENDIX I

BORING LOGS LEGEND
BORING LOGS

GROUP SYMBOLS AND NAMES

Graphic / Symbol	Group Names
GW	Well-graded GRAVEL Well-graded GRAVEL with SAND
GP	Poorly graded GRAVEL Poorly graded GRAVEL with SAND
GW-GM	Well-graded GRAVEL with SILT Well-graded GRAVEL with SILT and SAND
GW-GC	Well-graded GRAVEL with CLAY (or SILTY CLAY) Well-graded GRAVEL with CLAY and SAND (or SILTY CLAY and SAND)
GP-GM	Poorly graded GRAVEL with SILT Poorly graded GRAVEL with SILT and SAND
GP-GC	Poorly graded GRAVEL with CLAY (or SILTY CLAY) Poorly graded GRAVEL with CLAY and SAND (or SILTY CLAY and SAND)
GM	SILTY GRAVEL SILTY GRAVEL with SAND
GC	CLAYEY GRAVEL CLAYEY GRAVEL with SAND
GC-GM	SILTY, CLAYEY GRAVEL SILTY, CLAYEY GRAVEL with SAND
SW	Well-graded SAND Well-graded SAND with GRAVEL
SP	Poorly graded SAND Poorly graded SAND with GRAVEL
SW-SM	Well-graded SAND with SILT Well-graded SAND with SILT and GRAVEL
SW-SC	Well-graded SAND with CLAY (or SILTY CLAY) Well-graded SAND with CLAY and GRAVEL (or SILTY CLAY and GRAVEL)
SP-SM	Poorly graded SAND with SILT Poorly graded SAND with SILT and GRAVEL
SP-SC	Poorly graded SAND with CLAY (or SILTY CLAY) Poorly graded SAND with CLAY and GRAVEL (or SILTY CLAY and GRAVEL)
SM	SILTY SAND SILTY SAND with GRAVEL
SC	CLAYEY SAND CLAYEY SAND with GRAVEL
SC-SM	SILTY, CLAYEY SAND SILTY, CLAYEY SAND with GRAVEL
PT	PEAT
	COBBLES COBBLES and BOULDERS BOULDERS

Graphic / Symbol	Group Names
CL	Lean CLAY Lean CLAY with SAND Lean CLAY with GRAVEL SANDY lean CLAY SANDY lean CLAY with GRAVEL GRAVELLY lean CLAY GRAVELLY lean CLAY with SAND
CL-ML	SILTY CLAY SILTY CLAY with SAND SILTY CLAY with GRAVEL SANDY SILTY CLAY SANDY SILTY CLAY with GRAVEL GRAVELLY SILTY CLAY GRAVELLY SILTY CLAY with SAND
ML	SILT SILT with SAND SILT with GRAVEL SANDY SILT SANDY SILT with GRAVEL GRAVELLY SILT GRAVELLY SILT with SAND
OL	ORGANIC lean CLAY ORGANIC lean CLAY with SAND ORGANIC lean CLAY with GRAVEL SANDY ORGANIC lean CLAY SANDY ORGANIC lean CLAY with GRAVEL GRAVELLY ORGANIC lean CLAY GRAVELLY ORGANIC lean CLAY with SAND
OL	ORGANIC SILT ORGANIC SILT with SAND ORGANIC SILT with GRAVEL SANDY ORGANIC SILT SANDY ORGANIC SILT with GRAVEL GRAVELLY ORGANIC SILT GRAVELLY ORGANIC SILT with SAND
CH	Fat CLAY Fat CLAY with SAND Fat CLAY with GRAVEL SANDY fat CLAY SANDY fat CLAY with GRAVEL GRAVELLY fat CLAY GRAVELLY fat CLAY with SAND
MH	Elastic SILT Elastic SILT with SAND Elastic SILT with GRAVEL SANDY elastic SILT SANDY elastic SILT with GRAVEL GRAVELLY elastic SILT GRAVELLY elastic SILT with SAND
OH	ORGANIC fat CLAY ORGANIC fat CLAY with SAND ORGANIC fat CLAY with GRAVEL SANDY ORGANIC fat CLAY SANDY ORGANIC fat CLAY with GRAVEL GRAVELLY ORGANIC fat CLAY GRAVELLY ORGANIC fat CLAY with SAND
OH	ORGANIC elastic SILT ORGANIC elastic SILT with SAND ORGANIC elastic SILT with GRAVEL SANDY elastic ELASTIC SILT SANDY ORGANIC elastic SILT with GRAVEL GRAVELLY ORGANIC elastic SILT GRAVELLY ORGANIC elastic SILT with SAND
OL/OH	ORGANIC SOIL ORGANIC SOIL with SAND ORGANIC SOIL with GRAVEL SANDY ORGANIC SOIL SANDY ORGANIC SOIL with GRAVEL GRAVELLY ORGANIC SOIL GRAVELLY ORGANIC SOIL with SAND

FIELD AND LABORATORY TESTS

C	Consolidation (ASTM D 2435)
CL	Collapse Potential (ASTM D 4546)
CP	Compaction Curve (CTM 216)
CR	Corrosion, Sulfates, Chlorides (CTM 643, CTM 417, CTM 422)
CU	Consolidated Undrained Triaxial (ASTM D 4767)
DR	Drained Residual Shear Strength (ASTM D 6467)
DS	Direct Shear (ASTM D 3080)
EI	Expansion Index (ASTM D 4829)
M	Moisture Content (ASTM D 2216)
OC	Organic Content (ASTM D 2974)
P	Permeability (CTM 220)
PA	Particle Size Analysis (ASTM D 422)
PI	Liquid Limit, Plastic Limit, Plasticity Index (AASHTO T 89, AASHTO T 90)
PL	Point Load Index (ASTM D 5731)
PM	Pressure Meter
R	R-Value (CTM 301)
SE	Sand Equivalent (CTM 217)
SG	Specific Gravity (AASHTO T 100)
SW	Swell Potential (ASTM D 4546)
UC	Unconfined Compression - Soil (ASTM D 2166) Unconfined Compression - Rock (ASTM D 7012-C)
UU	Unconsolidated Undrained Triaxial (ASTM D 2850)
UW	Unit Weight (ASTM D 7263)

SAMPLER GRAPHIC SYMBOLS

- Standard Penetration Test (SPT)
- Standard California Sampler (ID 2.0 in.)
- Modified California Sampler (ID 2.5 in.)
- Shelby Tube
- Piston Sampler
- NX Rock Core
- HQ Rock Core
- Bulk Sample
- Other (see remarks)

DRILLING METHOD SYMBOLS

- Auger Drilling
- Rotary Drilling
- Dynamic Cone or Hand Driven
- Diamond Core

WATER LEVEL SYMBOLS

- First Water Level Reading (during drilling)
- Static Water Level Reading (short-term)
- Static Water Level Reading (long-term)

REFERENCE: Caltrans Soil and Rock Logging, Classification, and Presentation Manual (2010) with Errata Sheet (2015).

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Boring Record Legend

Soil Legend

CONSISTENCY OF COHESIVE SOILS

Descriptor	Unconfined Compressive Strength (tsf)	Pocket Penetrometer (tsf)	Torvane (tsf)	Field Approximation
Very Soft	< 0.25	< 0.25	< 0.12	Easily penetrated several inches by fist
Soft	0.25 - 0.50	0.25 - 0.50	0.12 - 0.25	Easily penetrated several inches by thumb
Medium Stiff	0.50 - 1.0	0.50 - 1.0	0.25 - 0.50	Can be penetrated several inches by thumb with moderate effort
Stiff	1.0 - 2.0	1.0 - 2.0	0.50 - 1.0	Readily indented by thumb but penetrated only with great effort
Very Stiff	2.0 - 4.0	2.0 - 4.0	1.0 - 2.0	Readily indented by thumbnail
Hard	> 4.0	> 4.0	> 2.0	Indented by thumbnail with difficulty

APPARENT DENSITY OF COHESIONLESS SOILS

Descriptor	SPT N_{60} (blows / 12 inches)
Very Loose	0 - 5
Loose	5 - 10
Medium Dense	10 - 30
Dense	30 - 50
Very Dense	> 50

MOISTURE

Descriptor	Criteria
Dry	No discernable moisture
Moist	Moisture present, but no free water
Wet	Visible free water

PERCENT OR PROPORTION OF SOILS

Descriptor	Criteria
Trace	Particles are present but estimated to be less than 5%
Few	5 to 10%
Little	15 to 25%
Some	30 to 45%
Mostly	50 to 100%

SOIL PARTICLE SIZE

Descriptor		Size
Boulder		> 12 inches
Cobble		3 to 12 inches
Gravel	Coarse	3/4 inch to 3 inches
	Fine	No. 4 Sieve to 3/4 inch
Sand	Coarse	No. 10 Sieve to No. 4 Sieve
	Medium	No. 40 Sieve to No. 10 Sieve
	Fine	No. 200 Sieve to No. 40 Sieve
Silt and Clay		Passing No. 200 Sieve

PLASTICITY OF FINE-GRAINED SOILS

Descriptor	Criteria
Nonplastic	A 1/8-inch thread cannot be rolled at any water content.
Low	The thread can barely be rolled, and the lump cannot be formed when drier than the plastic limit.
Medium	The thread is easy to roll, and not much time is required to reach the plastic limit; it cannot be rerolled after reaching the plastic limit. The lump crumbles when drier than the plastic limit.
High	It takes considerable time rolling and kneading to reach the plastic limit. The thread can be rerolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit.

CEMENTATION

Descriptor	Criteria
Weak	Crumbles or breaks with handling or little finger pressure.
Moderate	Crumbles or breaks with considerable finger pressure.
Strong	Will not crumble or break with finger pressure.

REFERENCE: Caltrans Soil and Rock Logging, Classification, and Presentation Manual (2010).

ROCK GRAPHIC SYMBOLS

- IGNEOUS ROCK
- SEDIMENTARY ROCK
- METAMORPHIC ROCK

BEDDING SPACING

Descriptor	Thickness or Spacing
Massive	> 10 ft
Very thickly bedded	3 ft - 10 ft
Thickly bedded	1 ft - 3 ft
Moderately bedded	4 in - 1 ft
Thinly bedded	1 in - 4 in
Very thinly bedded	1/4 in - 1 in
Laminated	< 1/4 in

WEATHERING DESCRIPTORS FOR INTACT ROCK

	Diagnostic Features					
	Chemical Weathering-Discoloration-Oxidation		Mechanical Weathering and Grain Boundary Conditions	Texture and Solutioning		
Descriptor	Body of Rock	Fracture Surfaces		Texture	Solutioning	General Characteristics
Fresh	No discoloration, not oxidized	No discoloration or oxidation	No separation, intact (tight)	No change	No solutioning	Hammer rings when crystalline rocks are struck.
Slightly Weathered	Discoloration or oxidation is limited to surface of, or short distance from, fractures; some feldspar crystals are dull	Minor to complete discoloration or oxidation of most surfaces	No visible separation, intact (tight)	Preserved	Minor leaching of some soluble minerals may be noted	Hammer rings when crystalline rocks are struck. Body of rock not weakened.
Moderately Weathered	Discoloration or oxidation extends from fractures usually throughout; Fe-Mg minerals are "rusty"; feldspar crystals are "cloudy"	All fracture surfaces are discolored or oxidized	Partial separation of boundaries visible	Generally preserved	Soluble minerals may be mostly leached	Hammer does not ring when rock is struck. Body of rock is slightly weakened.
Intensely Weathered	Discoloration or oxidation throughout; all feldspars and Fe-Mg minerals are altered to clay to some extent; or chemical alteration produces in situ disaggregation (refer to grain boundary conditions)	All fracture surfaces are discolored or oxidized; surfaces are friable	Partial separation, rock is friable; in semi-arid conditions, granitics are disaggregated	Altered by chemical disintegration such as via hydration or argillation	Leaching of soluble minerals may be complete	Dull sound when struck with hammer; usually can be broken with moderate to heavy manual pressure or by light hammer blow without reference to planes of weakness such as incipient or hairline fractures or veinlets. Rock is significantly weakened.
Decomposed	Discolored of oxidized throughout, but resistant minerals such as quartz may be unaltered; all feldspars and Fe-Mg minerals are completely altered to clay		Complete separation of grain boundaries (disaggregated)	Resembles a soil; partial or complete remnant rock structure may be preserved; leaching of soluble minerals usually complete		Can be granulated by hand. Resistant minerals such as quartz may be present as "stringers" or "dikes".

Note: Combination descriptors (such as "slightly weathered to fresh") are used where equal distribution of both weathering characteristics is present over significant intervals or where characteristics present are "in between" the diagnostic feature. However, combination descriptors should not be used where significant identifiable zones can be delineated. Only two adjacent descriptors shall be combined. "Very intensely weathered" is the combination descriptor for "decomposed to intensely weathered".

PERCENT CORE RECOVERY (REC)

$$\frac{\Sigma \text{ Length of the recovered core pieces (in.)}}{\text{Total length of core run (in.)}} \times 100$$

ROCK QUALITY DESIGNATION (RQD)

$$\frac{\Sigma \text{ Length of intact core pieces > 4 in.}}{\text{Total length of core run (in.)}} \times 100$$

Note: RQD* indicates soundness criteria not met

ROCK HARDNESS

Descriptor	Criteria
Extremely Hard	Specimen cannot be scratched with pocket knife or sharp pick; can only be chipped with repeated heavy hammer blows
Very hard	Specimen cannot be scratched with pocket knife or sharp pick; breaks with repeated heavy hammer blows
Hard	Specimen can be scratched with pocket knife or sharp pick with heavy pressure; heavy hammer blows required to break specimen
Moderately Hard	Specimen can be scratched with pocket knife or sharp pick with light or moderate pressure; breaks with moderate hammer blows
Moderately Soft	Specimen can be grooved 1/16 in. with pocket knife or sharp pick with moderate or heavy pressure; breaks with light hammer blow or heavy hand pressure
Soft	Specimen can be grooved or gouged with pocket knife or sharp pick with light pressure, breaks with light to moderate hand pressure
Very Soft	Specimen can be readily indented, grooved, or gouged with fingernail, or carved with pocket knife; breaks with light manual pressure.

FRACTURE DENSITY

Descriptor	Criteria
Unfractured	No fractures
Very Slightly Fractured	Core lengths greater than 3 ft.
Slightly Fractured	Core lengths mostly from 1 ft. to 3 ft.
Moderately Fractured	Core lengths mostly from 4 in. to 1 ft.
Intensely Fractured	Core lengths mostly from 1 in. to 4 in.
Very Intensely Fractured	Mostly chips and fragments.

REFERENCE: Caltrans Soil and Rock Logging, Classification, and Presentation Manual (2010).

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Taber Since 1954

Boring Record Legend

Rock Legend

Sheet 1 of 1

LOG OF BORING A-21-001

PROJECT NO: 20-643.1
PROJECT: NCRCD-Sulphur Creek Fish Passage (Project #30144)
LOCATION: St. Helena
COUNTY: NAP
CLIENT: Mark Thomas
LOGGED BY: KBH
DEPTH OF BORING: 28.40 (ft)

BEGIN DATE: 01/05/2021
COMPLETION DATE: 01/05/2021
SURFACE ELEVATION: 316.30 (ft)
SURFACE CONDITION: Asphalt
WATER DEPTH: 17.5 ft
READING TAKEN: 01/05/21
HAMMER EFFICIENCY: 89.3 (%)

DRILLING CONTRACTOR: GeoEx Subsurface Exploration
DRILLING METHOD: SS Augers 4.0"
DRILL RIG: CME 55 (Truck Mounted)
HAMMER TYPE: Automatic; 140 lbs; 30 in. drop
SAMPLER TYPE & SIZE: MCAL (2.4" ID), SPT (1.4" ID)
BOREHOLE DIAMETER: 4.0 in.
BACKFILL METHOD: Neat Cement Grout

ELEVATION (ft)	DEPTH (ft)	SAMPLE NO	BLOWS PER 6 IN.	BLOWS PER FOOT	POCKET PEN. (TSF)	DESCRIPTION	RECOVERY(%)	RQD (%)	PLASTIC LIMIT	LIQUID LIMIT	MOISTURE (%)	D. DENSITY (PCF)	% PASSING 200 SIEVE	REMARKS
316	0					ASPHALT .								AC=1" AB=3"
						AGGREGATE BASE .								
315–312	1–4					CLAYEY GRAVEL with SAND (GC); very dense; gray; dry; mostly coarse to fine GRAVEL; little coarse to fine SAND; little fines; [FILL].								Chatter from gravels observed 0-5'
311	5	1	50/5	REF		CLAYEY SAND (SC); very dense; gray; dry; mostly medium to fine SAND; some fines; moderate cementation.	0							
306	10	2	21 50	50/6		coarse to fine SAND; trace fine, subrounded GRAVEL; moderate cementation	100							Sampler rebounding Grinding observed at 11'
303	12.5	3	25 44 44	88		dry to moist; few coarse to fine, subrounded GRAVEL	67							
301	15	4	22 50	50/6			25							Sampler reboundin
300	16					Poorly-graded GRAVEL with CLAY (GP-GC); very dense; gray; dry; mostly coarse, subangular GRAVEL; few medium to fine SAND; few fines.								Driller notes harder drilling 16-17'.
298	17.5	5	9 28 30	58		Sedimentary (Shale); gray with reddish oxidation; very intensely weathered; soft to moderately soft; very intensely to intensely fractured; (wet).	61				11.9	127.7		
296	20	6	2 12 17	29		decomposed; soft	17							
294–292	22–24													Grinding observed 23-25'. Hole caved to 20' using SSA; switch to mud rotary at 25'.
291	25	7	21 40 50	90		intensely weathered	56				9.3	132.6		Soil pH: 6.60 Min. Resistivity: 3,220 ohm-c Chloride: 2.9 ppm Sulfate: 11.7 ppm
289	27					Sedimentary (Graywacke); gray; intensely weathered; soft; (moist).								Slow drilling and rig shaking observed at 27';
288	28	8	50/5	REF			80				9.2	136.1		auger refusal at 28'.
						Bottom of borehole at 28.4 ft bgs								

Crawford & Associates, Inc.
Geotechnical Engineering, Design and Construction Services

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PROJECT NO: 20-643.1
PROJECT: NCRCD-Sulphur Creek Fish Passage (Project #30144)
BORING: A-21-001
ENTRY BY: KBH
CHECKED BY: ETT

LOG OF BORING A-21-002

PROJECT NO: 20-643.1
PROJECT: NCRCD-Sulphur Creek Fish Passage (Project #30144)
LOCATION: St. Helena
COUNTY: NAP
CLIENT: Mark Thomas
LOGGED BY: KBH
DEPTH OF BORING: 20.25 (ft)

BEGIN DATE: 01/05/2021
COMPLETION DATE: 01/05/2021
SURFACE ELEVATION: 318.90 (ft)
SURFACE CONDITION: Asphalt
WATER DEPTH: Not Encountered
READING TAKEN: N/A
HAMMER EFFICIENCY: 89.3 (%)

DRILLING CONTRACTOR: GeoEx Subsurface Exploration
DRILLING METHOD: SS Augers 4.0", Mud Rotary 4.0"
DRILL RIG: CME 55 (Truck Mounted)
HAMMER TYPE: Automatic; 140 lbs; 30 in. drop
SAMPLER TYPE & SIZE: MCAL (2.4" ID), SPT (1.4" ID)
BOREHOLE DIAMETER: 4.0 in.
BACKFILL METHOD: Neat Cement Grout

ELEVATION (ft)	DEPTH (ft)	SAMPLE NO	BLOWS PER 6 IN.	BLOWS PER FOOT	POCKET PEN. (TSF)	DESCRIPTION	RECOVERY(%)	RQD (%)	PLASTIC LIMIT	LIQUID LIMIT	MOISTURE (%)	D. DENSITY (PCF)	% PASSING 200 SIEVE	REMARKS
	0					ASPHALT .								AC=3"
318	1					AGGREGATE BASE .								AB=3"
317–315	2–4					CLAYEY SAND (SC); dense; light brown; dry; mostly medium to fine SAND; trace fine, subround GRAVEL; little medium plasticity fines.								Driller notes gravelly drilling 0-5'
314–313	5–6	1	7 17 22	39			67							Driller notes harder drilling 5-10', grinding observed
311	8					Sedimentary (Graywacke); gray; intensely to moderately weathered; moderately soft.								
309	10	2	50	REF			0							Sampler rebounding
304	15	3	50/4	REF			100				5.5			Driller notes harder drilling 10-15'
301	18	4	38 50/4	50/4		soft	10							
299	20	5	50/3	REF		moderately weathered	33							Auger Refusal
						Bottom of borehole at 20.2 ft bgs								

APPENDIX II

LABORATORY TEST RESULTS

Crawford & Associates, Inc.
Geotechnical Engineering, Design and Construction Services

Project Name: NCRCD-Sulphur Creek Fish Passage (Project #30144)
CAInc File No: 20-643.1
Date: 1/26/20
Technician: OMR

MOISTURE-DENSITY TESTS - D2216/D7263

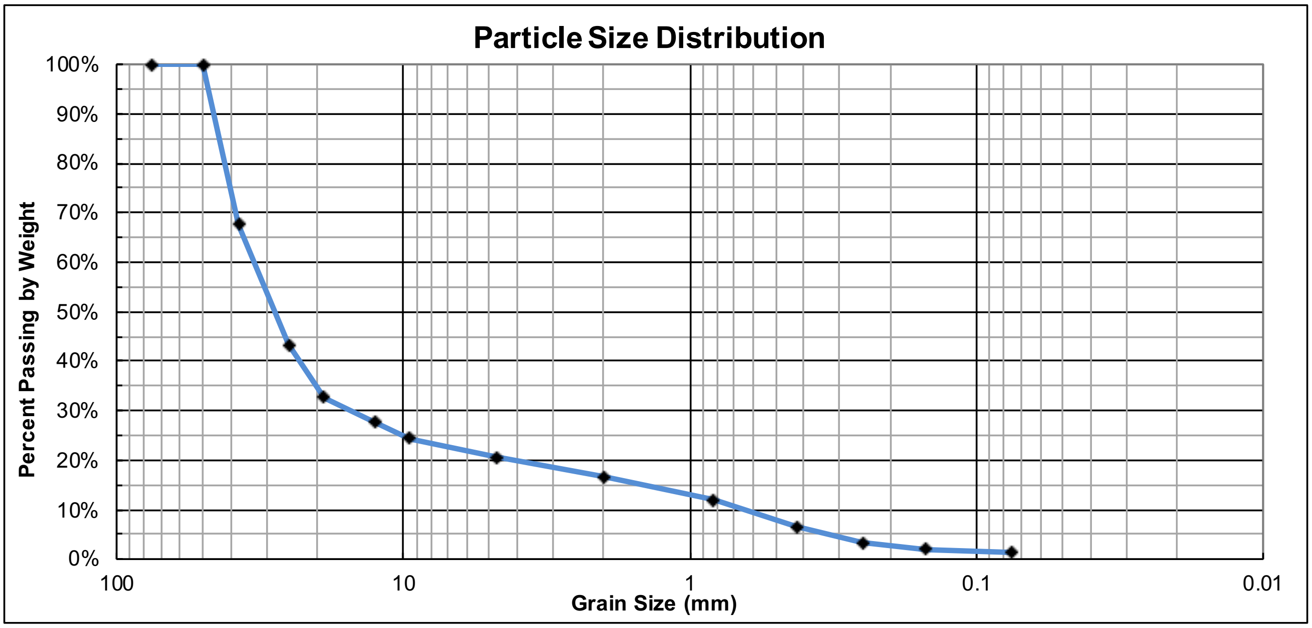
	1	2	3	4	5
Sample No.	A-21-001-5A	A-21-001-7A	A-21-001-8A	A-21-002-3A	
USCS Symbol	SC	SC	GP-GC	SC	
Depth (ft.)	18.5	26	28	15	
Sample Length (in.)	2.952	4.948	3.005	-	
Diameter (in.)	1.385	1.428	1.402	-	
Sample Volume (ft^3)	0.00257	0.00458	0.00268	-	
Total Mass Soil+Tube (g)	166.9	423.5	312.3	-	
Mass of Tube (g)	0.0	122.2	131.4	-	
Tare No.	D6	D15	155	G24	
Tare (g)	13.7	13.9	14.1	13.7	
Wet Soil + Tare (g)	73.9	67.4	71.0	76.8	
Dry Soil + Tare (g)	67.5	62.8	66.3	73.5	
Dry Soil (g)	53.8	48.9	52.2	59.9	
Water (g)	6.4	4.6	4.8	3.3	
Moisture (%)	**11.9**	**9.3**	**9.2**	**5.5**	
Dry Density (pcf)	**127.7**	**132.6**	**136.1**	**-**	

Notes:

Crawford & Associates, Inc.
Geotechnical Engineering, Design and Construction Services

Project Name: NCRC Sulphur Creek Fish Passage (Project #30144)
CAInc File No: 20-643.1
Date: 1/28/21
Technician: O.R.
Sample ID: Channel Bulk
Depth (ft): Channel
USCS Classification: Poorly Graded Gravel with Sand (GP)

ASTM 6913 - Method A



% Cobble	% Gravel		% Sand			% Fines
	Coarse	Fine	Coarse	Medium	Fine	Silt/Clay
	67	12	4	11	5	
0	**79**		**20**			**1**

		Sieve #	Opening mm	Cummulative Mass Retained (g)	% Passing %
Cobbles		**3"**	75	0.0	100%
Gravel	Coarse	**2"**	50	0.0	100%
		1-1/2"	37.5	379.3	68%
		1"	25.0	666.5	43%
		3/4"	19.0	790.5	33%
	Fine	**1/2"**	12.5	850.6	28%
		3/8"	9.50	888.6	24%
		#4	4.75	931.6	21%
Sand	Coarse	**#10**	2.00	980.1	17%
	Medium	**#20**	0.825	1033.2	12%
		#40	0.425	1098.4	6%
	Fine	**#60**	0.250	1136.1	3%
		#100	0.150	1150.6	2%
		#200	0.075	1158.3	1%

Coefficient of Uniformity	Coefficient of Curvature	50% of Cumulative Mass
Cu = 49.3	Cc = 10.7	D_{50} = 28.46