ENGINEERING GEOLOGIC INVESTIGATION TECHNICAL MEMORANDUM EAGLE CANYON FISH PASSAGE IMPROVEMENT IN BATTLE CREEK

MANTON, CALIFORNIA



Prepared for:
California Department of Fish & Wildlife
1812 Ninth Street, Suite 100
Sacramento, California 95811

August 2016

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TECHNICAL MEMORANDUM

To: Michael Love & Associates, Inc.
Michael Love, Principal Engineer,

From: Cotton, Shires and Associates, Inc.
David Schrier – Principal Geotechnical Engineer
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Dale Marcum – Principal Geologic Engineer
John Wallace – Principal Engineering Geologist

Date: August, 2016

Re: Engineering Geologic Investigation Technical Memorandum
Eagle Canyon Fish Passage Improvements in Battle Creek

1.0 INTRODUCTION

This technical memorandum presents the results of Cotton, Shires and Associates, Inc. (CSA) engineering geologic investigation for the Eagle Canyon Fish Passage Improvements project located on the North Fork of Battle Creek near Manton, California (see Figure 1). The study area, which consists of an Upper Barrier Site (UBS) and a Lower Barrier Site (LBS), is located about 1.5 miles west of Manton, California, and about 25 miles east-northeast of Red Bluff, California, near the confluence of the North Fork Battle Creek and Digger Creek. In the site vicinity, North Fork Battle Creek serves as the dividing line between Shasta County to the north, and Tehama County to the south. This memorandum summarizes the results of Task 3 work carried out under Work Authorization 2, entitled, "Eagle Canyon Fish Passage Improvements in Battle Creek", dated June 3, 2015 between Michael Love and Associates, Inc. (MLA) and Cotton, Shires and Associates, Inc. (CSA).

2.0 SCOPE OF WORK

The work performed for this investigation included:

- Background research and stereo-pair aerial photograph research and analysis;
- Engineering geologic and reconnaissance level mapping;

- Preparation of engineering geologic cross sections;
- Sampling and laboratory testing;
- Geologic characterization and kinematic analyses;
- Geophysical investigation using Refraction Microtremor (ReMI) methods (under Work Authorization 3); and
- Preparation of this geologic investigation technical memorandum.

3.0 BACKGROUND INFORMATION

3.1 Project Information

The UBS is located just upstream of the confluence of North Fork Battle Creek (NFBC) and Digger Creek, while the LBS is located approximately 1/4-mile downstream of the UBS. The Eagle Canyon Diversion Dam, which is owned and operated by Pacific Gas & Electric Company (PG&E), is located approximately 750 feet downstream of the confluence. The construction date of the dam is believed to have been in the early 1900s (Hepler, 2010). The dam is part of PG&E's Battle Creek Hydroelectric Project that was first licensed in 1919. The project consists of five diversion dams on the North Fork Battle Creek and three diversion dams on the South Fork Battle Creek, along with 30 canals totaling 54 miles in length that feed five high-head low-volume hydroelectric power plants. The Eagle Canyon Diversion Dam directs water into the Eagle Canyon Canal, which consists of a short tunnel segment near the dam, elevated steel Lennon-type flumes, and unlined canal segments. The Eagle Canyon Canal merges with the Inskip Canal, and the combined water is delivered to the Inskip Penstock and Powerhouse.

Due to declining salmonid populations in the Sacramento River system, a multi-agency agreement was made with PG&E in 1999 to restore and enhance about 48 miles of fish habitat. As part of this program, the Eagle Canyon Diversion Dam was retrofitted with a fish ladder in 2011. The agreement also includes bypassing or removing the two boulder barriers located near the Eagle Canyon Diversion Dam that are the subject of this memorandum. The UBS is located about 800 feet upstream of the dam, and just upstream of the confluence with Digger Creek. The LBS is about 500 feet below the dam, or about ¼ mile downstream of the confluence. These barriers are composed of large boulders that form natural, and in the case of the LBS, partially man-induced blockages to the upstream migration of steelhead and salmon. In 2012, an engineering geologic investigation of the LBS was performed by the California Department of Fish and Game (Smelser, 2012). This study characterized the conditions of the barrier, and discussed a failed attempt in 1997 to split one of the boulders by drilling a hole and filling it with an expanding grout compound. The study concluded that removal of all of the rocks that form

the LBS was not feasible. Instead it was recommended that the barrier be mitigated by removing two of the rocks (by blasting) as well as a portion of bedrock on the north side of the canyon. We observed a web based video, entitled "Battle Creek Rock Exploded To Allow Fish Passage", dated October 17, 2012, that shows the blasting of a large boulder at the LBS. We do not know how much time was required to drill the boulder prior to the blast, but the technique appears to be an effective tool for reducing block sizes in the creek channel.

3.2 Topographic Setting

The Battle Creek watershed lies on the west slope of Mt. Lassen, and the creek is a cold water snowmelt and spring-fed tributary to the Sacramento River. In the site vicinity, the creek has carved a slot canyon (Eagle Canyon) through a plateau that slopes gently to the west. The canyon is relatively narrow with precipitous to locally overhanging slopes. At the UBS, the canyon is about 40 to 50 feet wide and about 50 feet deep, and at the LBS, the canyon is about 350 feet wide by 200 feet deep. At the LBS, the south side of the canyon intercepts groundwater, resulting in abundant springs and waterfalls, likely fed by snowmelt from Mt. Lassen.

3.3 Regional Geology

The subject site is located on the southern edge of the Cascade Range geomorphic province of California. The Cascade Range includes a chain of prominent volcanic peaks that extend from Northern California through Oregon and into Washington. The southern extent of the province is Mt. Lassen, located about 22 miles east of the site.

The northern Sacramento Valley has a diverse and complex geologic history. Convergence of the Pacific and North American plates has created tectonic stresses that caused the present-day northern Sacramento Valley to go through many changes. From the Mesozoic era through the mid-Cenozoic era, the present-day northern Sacramento Valley was inundated with Pacific Ocean waters, and the Pacific shoreline oscillated back and forth from the eastern side to the western side of the valley. From the mid-Cenozoic era to present, the Pacific shoreline migrated westward to its current position west of the California Coast Ranges, exposing the emergent valley as it looks today. The Sierran metamorphic and plutonic basement rocks extend to the west beneath the valley, and these are unconformably overlain by shales and sandstones of the Great Valley sequence. Beginning in the early-Miocene (about 23 million years ago), volcanism began and this process is still active today (e.g., Mount Lassen's latest eruptions occurred from 1914 to 1917). On the east side of the valley, the Tuscan Formation (Pliocene age), overlies the Great Valley rocks, and contains layered ash, volcanic mudflows and some alluvium. In the site vicinity, The Tuscan Formation unit is generally covered by young volcanic flows extending from

east to west. In the Manton area, the young basalts that underlie the broad plain are exposed on the walls of Eagle Canyon and have been mapped by Helly and Harwood (1985) as the Basalt of Eagle Canyon. A portion of this regional map that includes the area of interest has been reproduced as Figure 2. The rocks that underlie much of the broad plain in the Manton Area are described in the referenced literature as dark grey, vesicular olivine basalt.

3.4 Seismic Setting

The site is located in an area of moderate seismicity. The United States Geological Survey (USGS, 2008a) shows no historic faults (less than 150 years) in the site vicinity. The north-south trending Hat Creek fault (latest Pleistocene fault, less than 15,000 years) is located about 32 miles to the northeast, and the east-west trending Battle Creek Fault Zone (late Quaternary fault, less than 130,000 years) is located about 2 miles north of the site where the broad plain characteristic of the Manton area meets Shingletown Ridge.

Using the interactive website USGS deaggregation procedure (USGS, 2008b, see Appendix D), the peak ground acceleration with a 2% chance of being exceeded in 50 years (about a 2,500 year return period) is 0.40g. The modal distance and magnitude were 3.6km and M6.5, respectively. A screening analysis outlined in the CGS Special Publication 117A (2008) was used to estimate an appropriate seismic coefficient for a displacement threshold of 5 cm (2 inches). In this method, keq = feq * MHA (keg=seismic coefficient, feq is a factor related to the seismicity, and MHA is the maximum horizontal acceleration at the site). Based on the modal distance and magnitude, the feq factor is about 0.48, which gives a keq of 0.19.

3.5 Geophysical Investigation

A geophysical investigation was performed by CSA using Refraction Microtremor (ReMi) shear wave survey lines as part of this investigation. Two survey lines were performed on both the UBS and LBS, and the data and results are included in Appendix A. Pertinent results from the survey are discussed in general terms in the main body of this technical memorandum; however, the reader is referred to Appendix A for a complete discussion of the methods and results.

3.6 Laboratory Testing

CSA performed laboratory testing on rock core samples and bulk soil materials from the UBS and the LBS. The rock testing included compressive strength and unit weight, while the soil testing consisted of Atterberg Limits, particle size (sieve analysis, hydrometer and percent minus #200), corrosivity, and residual and fully softened peak torsional shear strength. In general, the UBS

rock testing yielded unit weights that varied from 130.9 pcf to 168.6 pcf, and had compressive strengths of 7,960 psi to 16,310 psi, while the LBS rock tests yielded unit weights of 155.1 pcf to 164.4 pcf, and compressive strengths of 14,880 psi to 16,320 psi. There are two low unit weight tests from the UBS (132.1 and 130.9 pcf) that were performed on vesicular cobbles that likely were transported downstream to the site, and are not representative of the in-place rock exposed on the canyon walls or the large boulders that comprise the in-stream barriers.

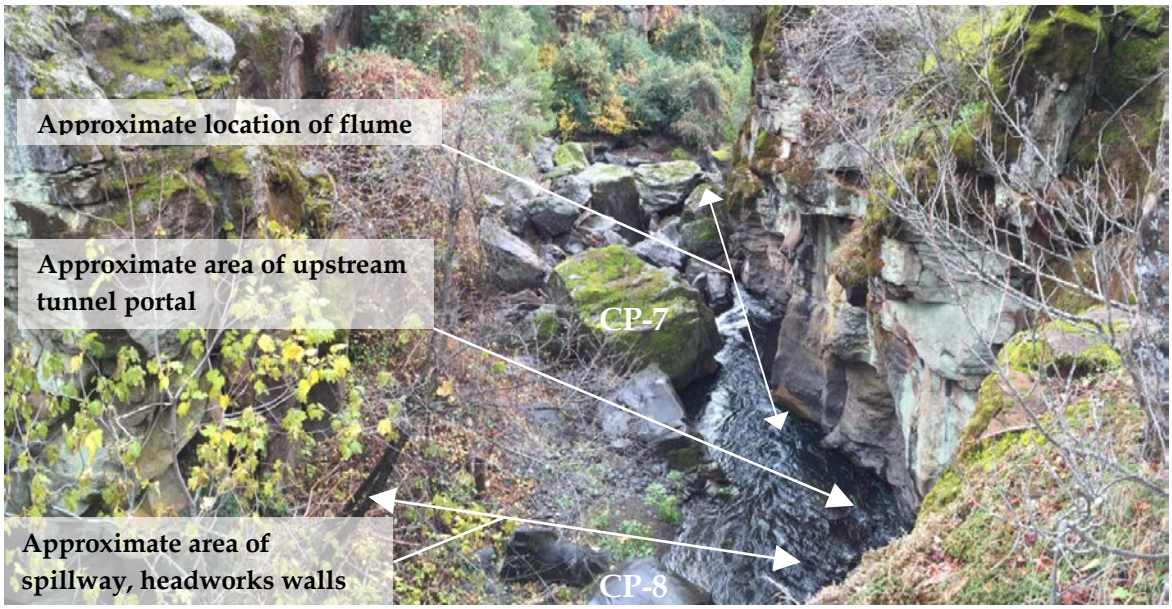
Our laboratory testing on the UBS soils indicates that the materials are silty sands and sandy silts with low plasticity (PI=7). The sand has low fines content (<2%), moderate to high fully softened peak and residual shear strengths ($\phi=32^0$ and $\phi_r=31^0$), and low corrosivity (chloride < 2 mg/kg, Sulfate = 54 mg/kg, Min Resistivity = 5095 Ohm-cm).

Our laboratory testing on the LBS soils indicates that the materials are non-plastic silty sands with moderate fines content (8% to 18.3%), moderate to high fully softened peak and residual shear strengths ($\phi=33^0$ and $\phi_r=33^0$), and low corrosivity (chloride = 2 mg/kg, Sulfate = 45 mg/kg, Min Resistivity = 16,366 Ohm-cm). The Laboratory test results are presented in Appendix B, and the locations of the samples are shown on Plates 1 and 4 for the UBS and LBS, respectively.

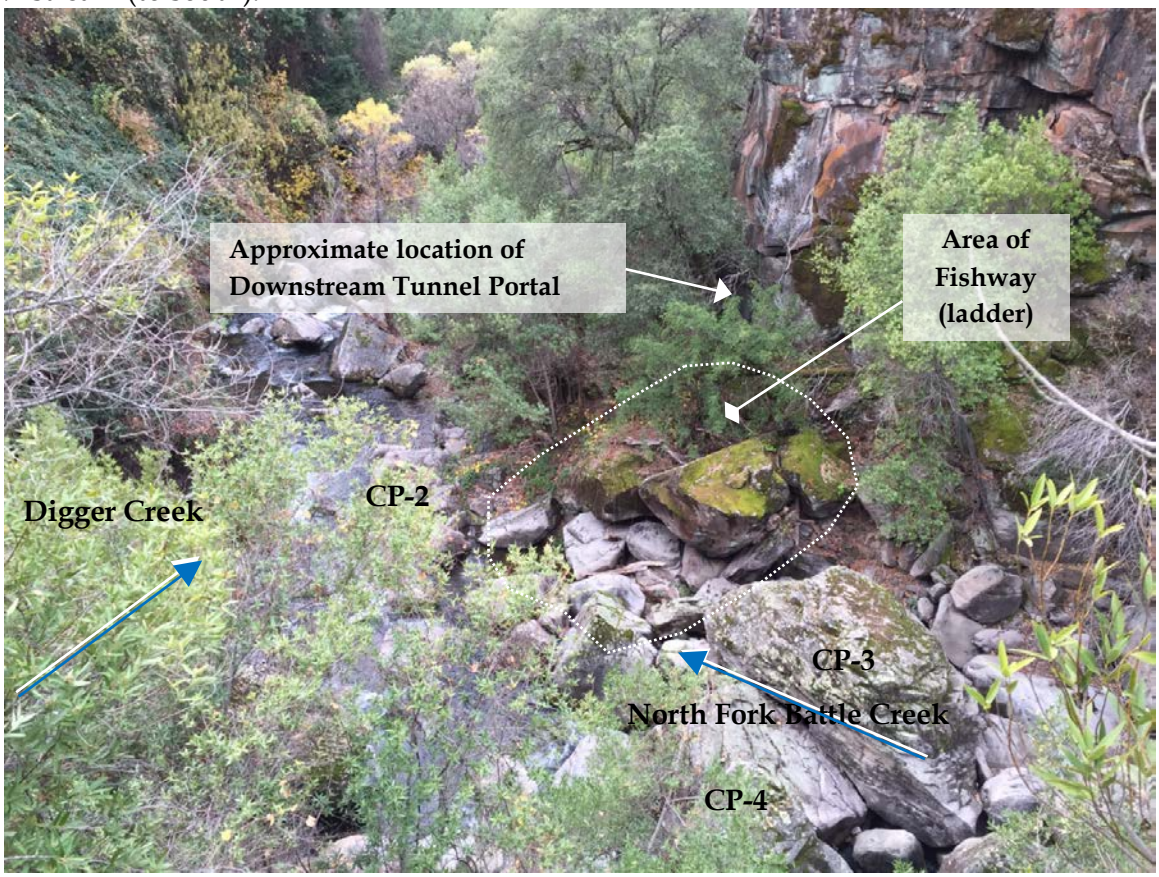
4.0 UPPER BARRIER

4.1 Preliminary Fish Bypass Concepts

The UBS is located on NFBC just upstream of the Digger Creek confluence, and includes many large boulders tens of feet in size that create an impassable barrier for fish. Prior to our investigation, preliminary fish bypass concepts were prepared by Michael Love & Associates, Inc. and depicted in drawings dated November 2015. Photographs 1 and 2 (below) show the general character of the canyon in this area, as well as some of the locations of proposed improvements that are discussed below. The concepts are discussed briefly in this section, as the elements are referred to in our descriptions of the fieldwork. A more detailed discussion of the concepts, the potential hazards, and constructability issues are presented in a later section of this technical memorandum.

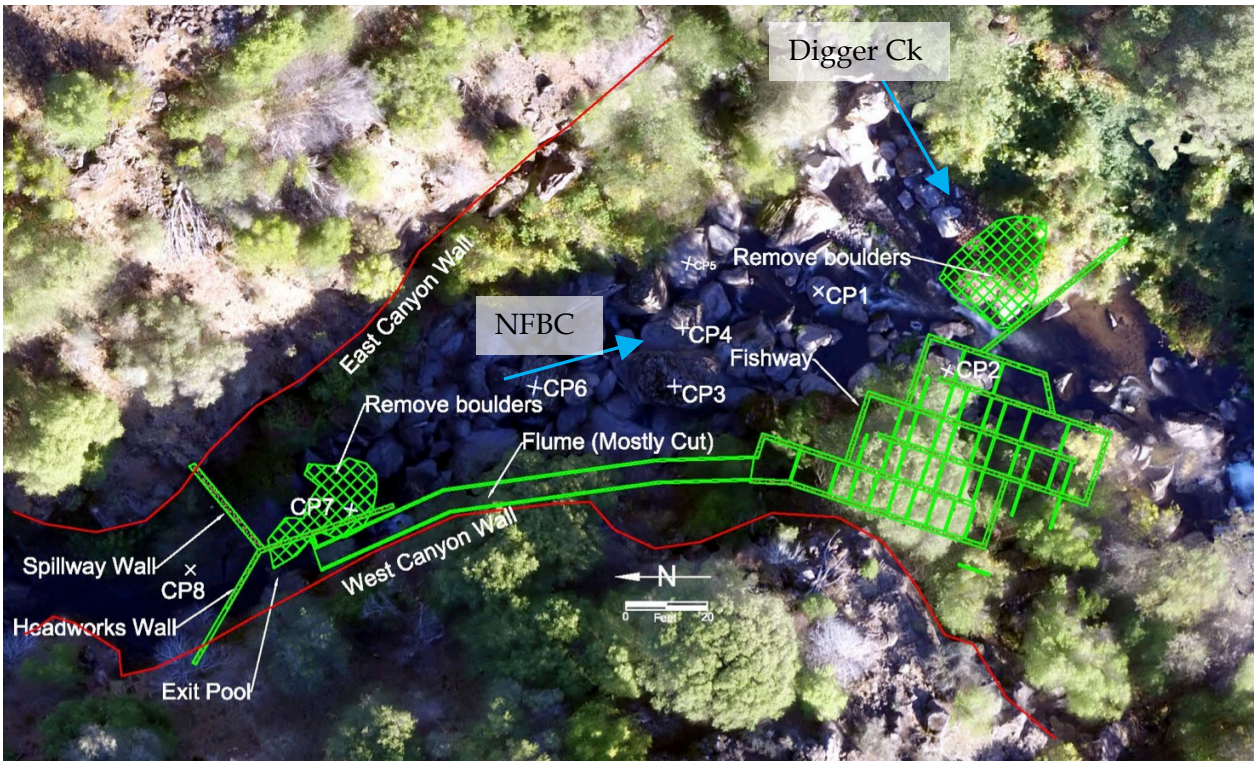


Photograph 1 – Battle Creek just upstream of the confluence with Digger Creek. Rocks with Control Points 7 and 8 are noted. West Canyon Wall on right, East Canyon Wall on left. View downstream (to south).



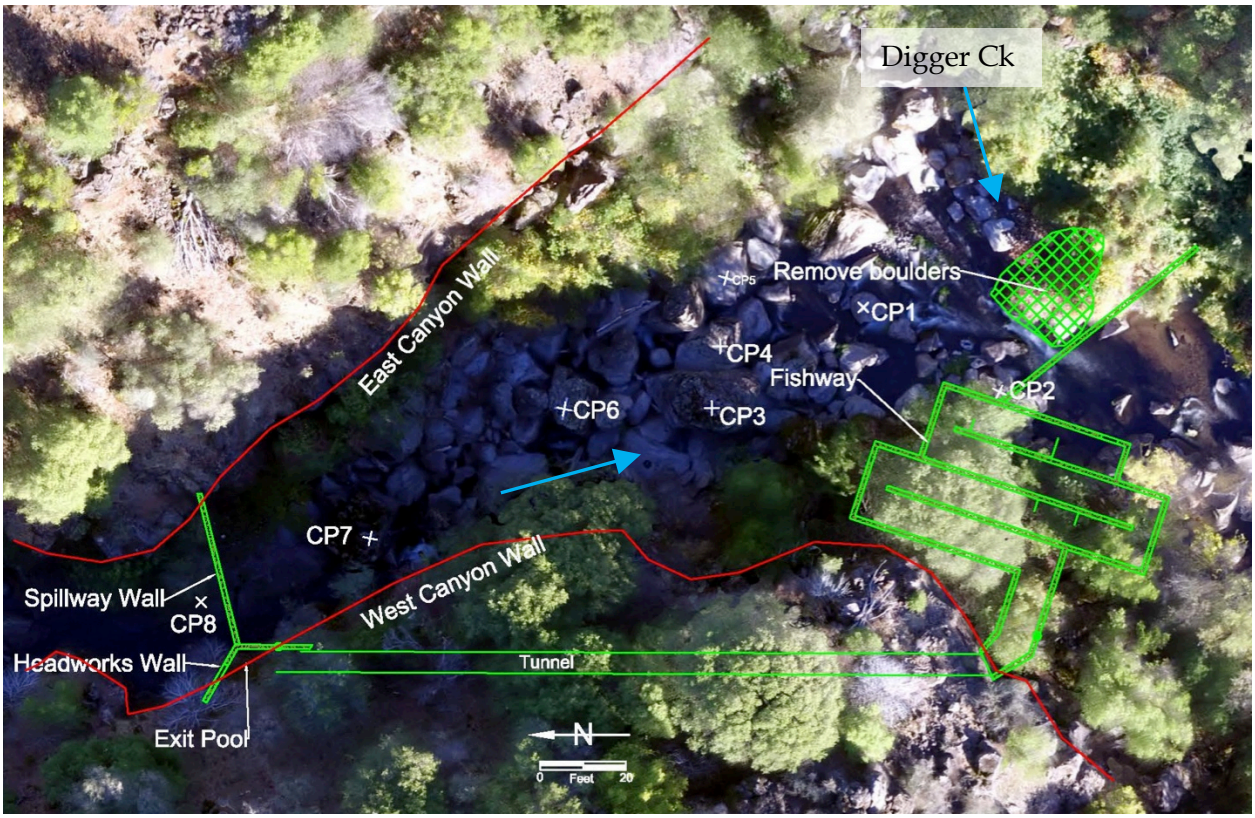
Photograph 2 – The confluence of Digger Creek and Battle Creek looking downstream. Control Points CP-2, 3 and 4 are noted. The proposed location of the fish ladder is over an apron of boulder alluvium, and closer to the west canyon wall slope debris.

4.1.1 Concept 1 – Flume and Fish Ladder - This flume and fish ladder concept is shown below in Photograph 3, and includes a concrete ramp fishway at the downstream end (in the vicinity of CP-2, see Photograph 2), a flume, spillway, and headwalls at the upstream end (in the vicinity of CP-7 and 8, see Photograph 1).



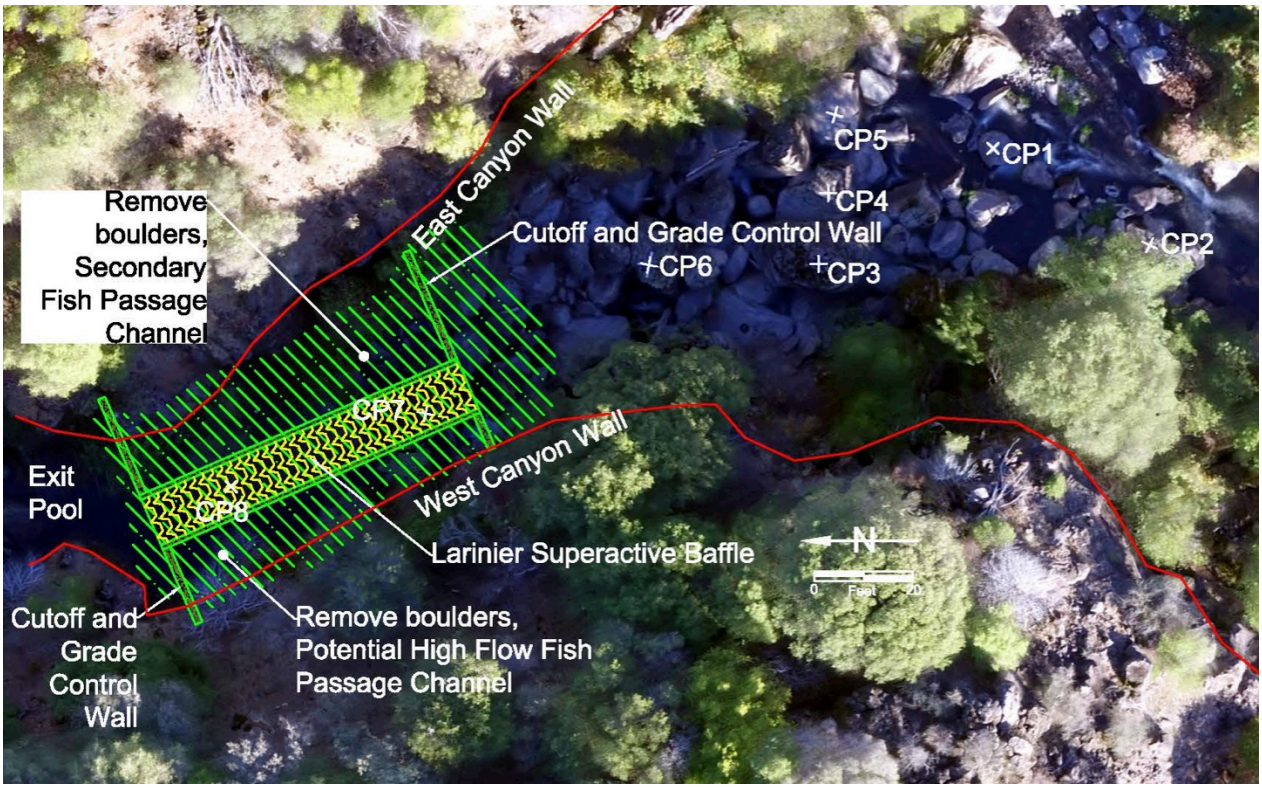
Photograph 3 – A photo-illustration of the Flume and Fish Ladder alternative (Concept 1). North is to the left.

4.1.2 Concept 2 – Tunnel and Ladder – This concept has some of the same elements as Concept 1, such as a fishway ladder, the removal of boulders, a spillway, and headworks walls installed at the upstream end. However, instead of a flume, the fish would enter into a tunnel at the end of the fishway. The concept is shown below in Photograph 4, and the approximate locations of the upstream and downstream tunnel portals are shown in Photographs 1 and 2.



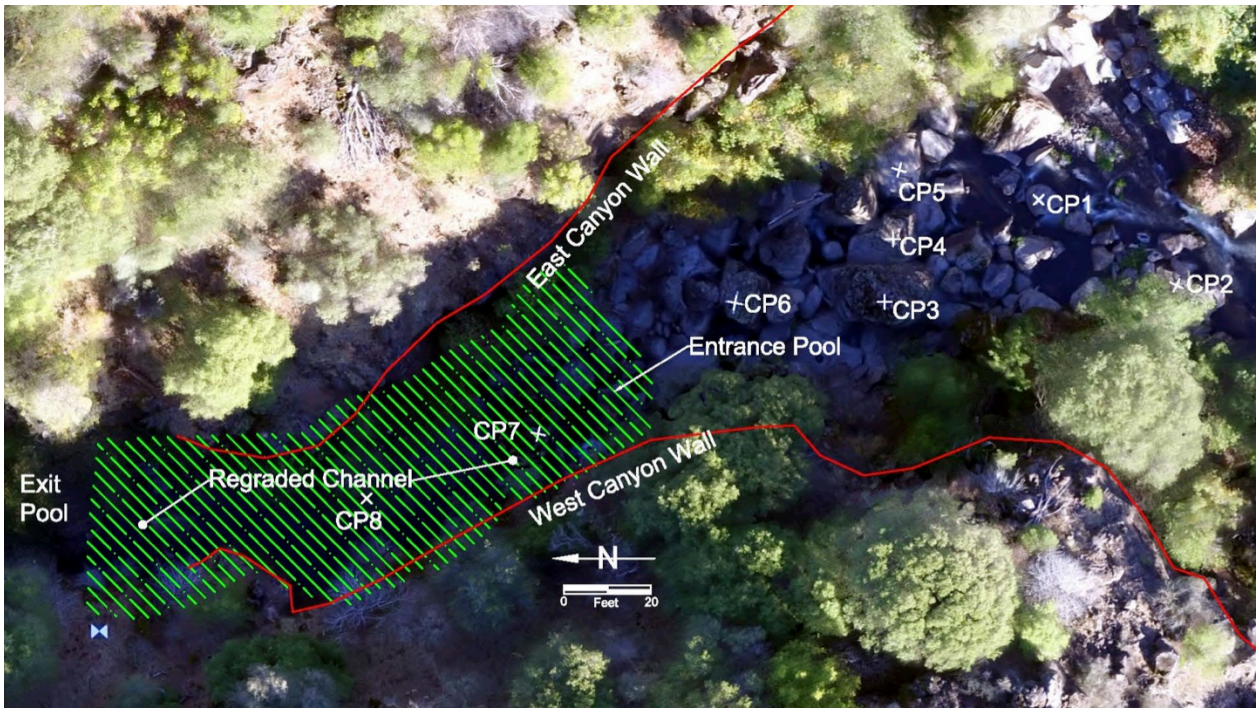
Photograph 4 – A photo-illustration of the Tunnel and Ladder alternative (Concept 2). North is to the left.

4.1.3 Concept 3 – Regrade (with Larinier Superactive Baffle) – This concept is shown below in Photograph 5. The passage would be created by constructing a concrete box ramp (at a 14% grade) between two concrete walls, and installing a series of baffles (Larinier) to slow the water flow.



Photograph 5 – A photo-illustration of the alternative of regrading the central Battle Creek channel with a Larinier Superactive Baffle (Concept 3). North is to the left.

4.1.4 Concept 4 – Regrade (Natural) – This concept is shown below in Photograph 6. This option creates a channel at a 10% gradient with a natural rock surface instead of the baffle structure.



Photograph 6 – A photo-illustration of the alternative that includes regrading the creek bed (Concept 4). North is to the left.

4.2 Field Program

Fieldwork was performed at the UBS by John Wallace (engineering geologist) and Dale Marcum (geologic engineer) on December 1 and 2, 2015, and from February 29 through March 2 of 2016 with John Wallace, Dale Marcum, Patrick Shires (geophysicist) and Marcel Peliks (staff geologist). The work included engineering geologic mapping, rock mass characterization, joint characterization, sample retrieval, Schmidt hammer testing, geophysical surveying, and rock slope evaluations. GMA Hydrology surveyed the site between July 13 and November 4, 2015 for the purpose of generating a topographic base map, which was used by CSA for geologic mapping and rock face logging.

The results of the engineering geologic mapping are presented on the Engineering Geologic Map (Plate 1), the West Wall Geologic Face Log (Plate 2), and the East Wall Geologic Face Log (Plate 3). Prior to entering the field, horizontal views of the west and east canyon walls were prepared using the LiDAR point cloud data. In addition, photographs were taken by CSA of the west and east canyon walls from the canyon rims, and the photographs were printed out prior to mapping. Both the west and east canyon walls had areas obscured by vegetation where the point cloud views and the photographs were obscured. In these areas, we made sketches of the walls using measuring tape and laser hand tools. The methods used to map the face logs (point cloud, photographs or measurements) are noted along the base of the logs in Plates 2 and 3. Based on the methods used, we estimate the horizontal and vertical accuracy of the features we mapped is likely within about 5 feet.

Observations and mapping performed to characterize the rock mass and to gather the data for this evaluation were made from the top of the west and east rims, and along the base of the west and east walls. The bottom of the canyon was accessed by descending into Digger Creek, and also by descending a game trail on the west canyon rim that intersected the NFBC about 300 feet upstream of the study area. For future reference, we noted a black bear on this game trail during our December 2015 mapping. The east canyon rim was accessed by crossing the NFBC at the game trail, and hiking up another game trail on the east side.

4.3 Earth Materials

The earth materials in the vicinity of the UBS consist of bedrock materials of the Eagle Canyon Basalt and several non-bedrock units consisting of colluvial soil, creek bed alluvium, slope debris, and unstable bedrock blocks along the precipitous Battle Creek embankment walls. These materials are described as follows, and their spatial distribution is illustrated on Plate 1 (Engineering Geologic Map):

Colluvial Soil (Qc) – The young, resistant character of the Eagle Canyon Basalt results in very shallow soil development. Soil materials consist of thin (generally less than several feet), sandy, clayey silt with large basalt rock fragments. On Plate 1, these materials are identified as Qc over Qeb, indicating very shallow soil cover blanketing bedrock.

Alluvium (Qa) – Within the incised NFBC corridor, thin, small pockets of sand and gravel are locally deposited in protected areas and back-eddy locations. Due to the precipitous embankment sidewalls, the sudden nature of the flood flows, and 'slot canyon' character of the gorge, these deposits are limited in size, and likely temporary in their location.

Slope Debris/Talus (Qsd) – In isolated portions of the NFBC gorge, talus and debris shed from the precipitous upper slopes have accumulated as aprons along the lower portion of the canyon. Slope debris that has been mobilized and deposited into the flow path of the creek has been eroded of all but the largest blocks, stranding these within the creek bed. Plate 1 illustrates some (but not all) of the larger blocks within the creek where slope failures have deposited large blocks into the NFBC and formed the upper fish barrier.

Rock Topple/Unstable Basalt Rock Face (Qbb) – Massive basalt exposures flank the UBS just upstream from the confluence with Digger Creek, and the vertical rock walls contain pervasive vertical cooling joints that are highly susceptible to rock topple. Additional discussions regarding possible mechanisms that initiate block toppling at the site are discussed in a later section.

Eagle Canyon Basalt (Qeb) – The NFBC gorge area is underlain by the Eagle Canyon Basalt, which is characterized by a thick-bedded to massive, slightly weathered to fresh, very hard and very strong basalt. Bedrock is exposed along the plateaus above the gorge where soil cover is sparse, and excellent exposures crop out in the canyon bottom. The Red Bluff Formation volcaniclastic deposit was not identified in the UBS, but crops out near the LBS at an elevation consistent with that of creek level at the UBS. Potential ramifications of this are discussed in a later section.

4.4 In-Place Rock Strength

The strength of the rock was estimated using three different methods:

1) Field estimates of rock strength using a rock hammer and a qualitative scale (Hoek and Brown, 1997) varied from strong (unconfined compressive strength between 7,250 and 14,500 psi) to extremely strong (unconfined compressive strength greater than 36,000 psi).

2) Schmidt Hammer tests were performed at various locations along the west canyon wall. The locations of the tests are presented on Plate 1, and the results are included in Appendix C. The unconfined compressive strength correlations for the tests along the west wall varied from about 22,000 psi to 50,000 psi, with an average of about 33,500 psi. We note that typical unconfined compressive strengths for basalt published by Attewell & Farmer (1976) range from about 15,000 psi to 45,000 psi, so these results place the strength of this rock near the upper end of that range. We used a Proceq Model L/LR Schmidt Hammer and correlation between the rebound number and unconfined compressive strength from Deere and Miller, 1966, as published by Hoek and Bray, 1997 to estimate the unconfined compressive strength.

3) Unconfined compression laboratory tests (see Appendix B) were performed on two rock fragments taken from the ground surface close to the base of the west wall near the downstream portal of the proposed tunnel (Option 2). The results included unconfined compressive strengths of 7,960 psi, 11,510 psi and 16,540 psi. The 7,960 psi result was from a vesicular boulder that was likely transported downstream to this position, and we do not consider this sample representative of the rock exposed on the canyon walls.

In general, there appears to be a large difference between the laboratory unconfined compressive test results, and the field estimates using rock hammers and the Schmidt Hammer. We suspect the laboratory test results were lower due either to disturbance from coring in the lab, and/or the presence of micro fractures in the basalt.

4.5 Boulder Strength

The unconfined compressive strength of several of the large boulders was also estimated using qualitative methods and Schmidt Hammer testing. Field estimates of rock strength using a rock hammer varied from very strong (unconfined compressive strength between 14,500 and 36,250 psi) to extremely strong (unconfined compressive strength greater than 36,000 psi). Field estimates were also made using a Schmidt Hammer on six of the boulders at the UBS, and the results ranged from 25,000 psi to 75,000 psi, with an average of about 37,000 psi. The locations of the Schmidt Hammer tests are shown on Plate 1, and the results are included in Appendix C. As noted above, published unconfined tests for basalt range from about 15,000 psi to 45,000 psi, so although the highest Schmidt Hammer result of 75,000 psi appears unrealistically high, the boulders likely have unconfined compressive strengths in the upper end of the published range.

4.6 Rock Mass Characterization

The rock exposed in both the west and east canyon walls is generally non-vesicular basalt with a structure that varies from thin sub-horizontal flow structures (less than 1 foot thick) to massive. The rock is generally fresh to slightly weathered, with fractures that vary from widely spaced (3 feet to 10 feet), to extremely widely spaced (greater than 10 feet). We characterized the rock mass using the Geologic Strength Index (GSI) developed by Hoek et al (2013). Visually, we classified the structure of the rock as "blocky" and the surface conditions as good to very good, resulting in a qualitative GSI for the rock mass of 60 to 90. We also used two numerical methods to estimate the GSI (Hoek et al, 2013) which uses the average number of joints per meter, and qualitative characterizations of the joints ($Jcond_{89}$ from Bieniawski, 1989, and Jr/Ja from Barton, 1974). The GSI values from these quantitative methods were 78 and 91, respectively.

To estimate Mohr Coulomb strength parameters for the rock mass, we used the computer program RocLab (Rockscience, 2013). Using the lower GSI value from our visual assessment (60), an unconfined compressive strength of 16,000 psi, a disturbance factor (to characterize effects of blasting) of 0.0 (i.e., no blasting disturbance), and an 'mi' of 25 (typical value for basalt given by the computer program), the resulting strength envelope parameters for the rock mass (using a stress range appropriate for a 100-foot high slope) are Ø=65°, c = 176 psi. The computer plot from RocLab is included in Appendix C.

4.7 Rock Joint Characterization

As shown on Plates 2 and 3, although the rock mass is infrequently dissected by joints, the joints are moderately continuous (10 feet to 30 feet in length), to highly continuous (30 feet to 100 feet in length). The joints are strongly curvilinear and relatively smooth. Barton Choubey (1977) devised a method to estimate friction angles for joints that take into account the increased strength due to joint roughness. The Joint Roughness Coefficient (JRC) is a number (selected qualitatively) that represents the roughness of the joint surfaces (higher numbers correspond to rougher joints). We characterized the joints as having JRC's that vary from 2 to 12, with typical values of about 5 to 7. Using Barton and Choubey's equation and a JRC=5, an unconfined strength of 8,000 psi along the joints, and a base friction angle (friction angle of the material without any roughness) for basalt of 31 degrees (low end of published values in the reference), the best fit representative joint friction angle for the canyon walls is 42 degrees. A spreadsheet showing these calculations is included in Appendix C. For conservatism, however, we recommend using 35 degrees, which is the upper value given in the reference for base friction angles for basalt.

The joint apertures varied from tight to up to 2 inches wide, and were generally open ¼ to ½ inch. We estimated the Jcond89 value (Bieniawski, 1989) to be 16, which places the joints between the categories for Jcond89 = 10 (described as slickensided surfaces or gouge <5mm thick, and 1-5mm of separation) and Jcond89 = 20 (described as slightly rough surfaces, <1mm of separation, highly weathered walls). These are general descriptions from Bieniawski, and although the joints did not exhibit slickensides or contain clay gouge, the low score is the result of the continuous nature of the joints, the apertures, and the relative smoothness of the joint walls. We also evaluated the Jr (Joint roughness) and the Ja (Joint alteration number) after Barton (1974). We assigned the joints a Jr = 2.5, between the categories for Jr = 2 (smooth, undulating) and Jr = 3 (rough and irregular, undulating). We assigned the joints a joint alteration (Ja) = 1, corresponding to the description of "unaltered joint walls, surface staining only".

We took attitude measurements (strike and dips) of the joints on the west and east canyon walls, and plotted the data (the normals or poles to the planes) on a lower hemisphere stereonet, included as Figure 3a. The analysis and plots were prepared using Dips by Rocscience (2003). The shaded contours show concentrations of poles, and the mean attitudes of the three major joint sets (i.e., the joints that are commonly repeated) were determined using Dips, and these are shown in Figure 3b. The major joint sets are:

Set 1) "Northeast" N55E, 90
Set 2) "North-South" N10W, 88E
Set 3) "Northwest" N62E, 90

For our purposes, the 88 degree dip for Set 2 will be treated as vertical (i.e., 90), and the major joint sets are also shown on Plate 1. Note that these are mean orientations, and the strikes of the joints in the field can vary by up to 15 to 20 degrees. We note that most rock masses are commonly dissected by anywhere from two to five major joint sets, so the number of major joint sets at the site (three) is relatively common. What is somewhat unusual in our experience is all three of the major joint sets have vertical to near-vertical orientations.

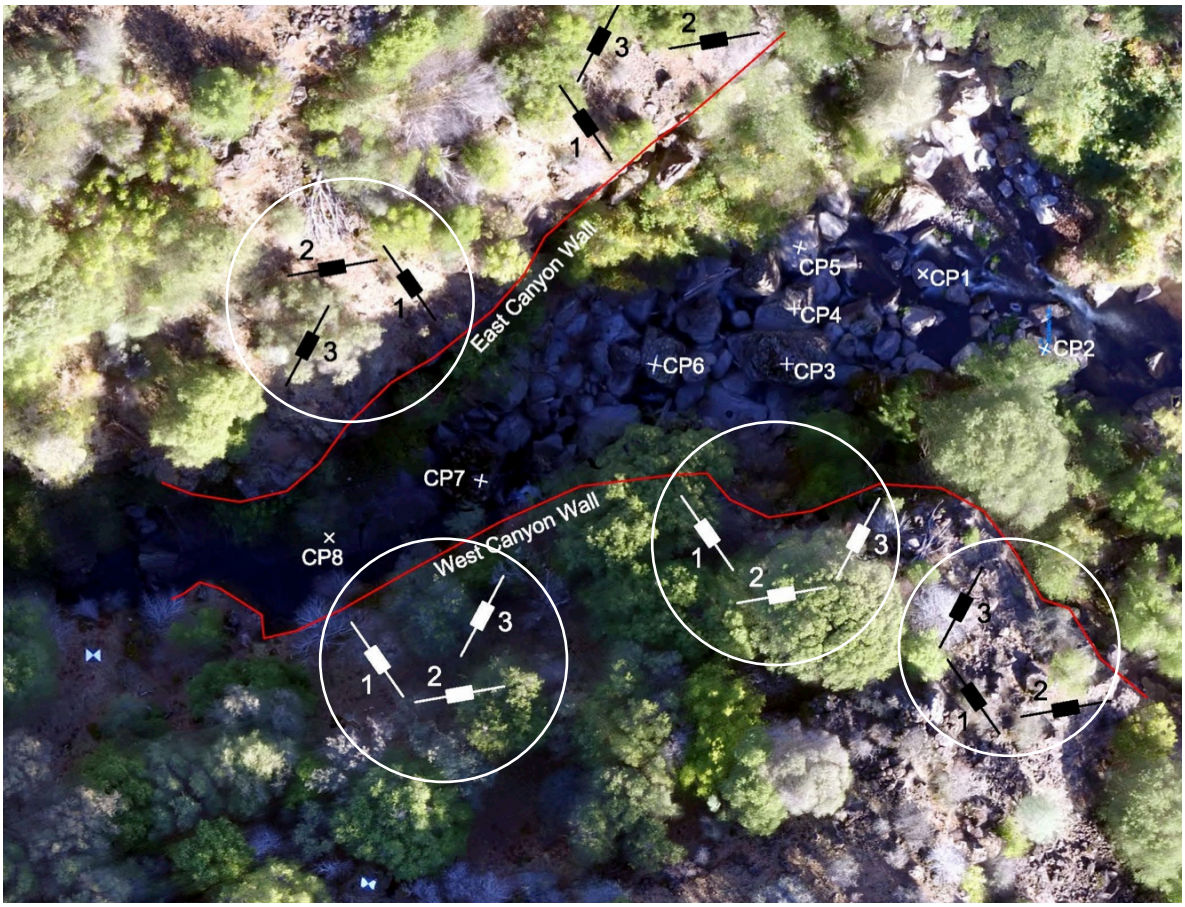
4.8 Kinematic Analyses

Kinematic analyses are commonly used in rock slope investigations to gain insights into the type of rock block failures that can be anticipated (e.g., block sliding, wedge sliding, toppling), and the general stability of the features. The great circles of the major joint sets are typically plotted on a lower hemisphere stereonet, along with the great circle of the plane representing the slope face. If the dip vector of a joint plane plots outside the great circle that represents the attitude of the rock slope, then block sliding could occur. Likewise, if the intersection of two joint planes plots

outside the great circle of the rock slope, then wedge sliding could occur. Consequently, we plotted the great circles of the three major joint sets on Figure 4a, along with the three major orientations of the west canyon wall in the site vicinity. As can be seen on this figure, all of the planes (joints and rock slope orientations) are vertical, and all intersect each other at a single point in the middle of the stereo net. This suggests that typical rock block failure modes, such as blocks on inclined planes or wedges that daylight in a slope face will not be predominate failure modes at the site. What these joints will form, however, are rock columns (rectangular or triangular shaped prisms).

Rock columns (made of near-vertical side walls) will likely be subject to block toppling, and as will be discussed in a later section, we observed this failure mode occurring at the UBS. The kinematic test for flexural rock toppling involves plotting the joint normals on a lower hemisphere stereonet, plotting the great circle of the slope face on the same stereonet, along with a safe zone equal to the friction angle of the joint interface, and an unsafe zone beyond the friction angle. Joint normals that plot outside of the friction angle may be subject to flexural toppling. Although we know block toppling is occurring at the site, and the kinematic test for rock toppling is for flexural toppling, we performed a kinematic analysis for flexural toppling along the west canyon wall to see if we could gain additional insights. The results are shown on Figure 4b, where we used a joint friction angle of 35°, and where the unsafe zones for the three orientations of the west wall are shown in shaded red. In this figure, the Northeast joint set plots in the unsafe zone for the downstream portal area (where it is subparallel to the canyon wall), and the North-South joint plots in the unsafe zones for the middle and upstream areas of the west wall (where it is also subparallel to the strike of the canyon). Although flexural toppling does not appear to be an important failure mechanism at this site, this exercise suggests the joints may be releasing joints (i.e. back joints) in rock columns at these locations, and may have structurally controlled the orientation of the canyon in this area.

As shown on Plate 1, we placed the major joint sets in groups along the west and east canyon walls to estimate which sets may be forming rock columns for the different areas, and these are reproduced below in Photograph 7.



Photograph 7 – Possible column-forming major joint sets.

4.9 Block Toppling Discussion

A rock column with vertical sides and a horizontal base will be in contact with the rock slope via vertical joints, and the weight vector of the rock column will also be vertical. Therefore, the friction of the joint interfaces on the vertical joints should not have a significant effect on the stability of a detached column. Instead, the criteria that control the stability of block toppling in this case are the width of the base versus the height (i.e., tall narrow columns are more subject to block toppling than shorter wider columns), and destabilizing forces that act to tip the block past the center of gravity. Lateral forces that can start the toppling process can include frost (ice) jacking, undercutting, hydrostatic forces, seismic forces, creep of overlying soil, and stone jacking. Stone jacking is a process where small rocks enter an open joint, and as the joint aperture widens due to temporary temperature changes, the stone falls further into the joint and acts as a cam to keep it open. This process is repeated seasonally until the joint opens to the point where the column becomes unstable and topples. At the subject site, we observed this process occurring along a joint on the east canyon rim (see Photograph 8, below).



Photograph 8 – Stone jacking occurring in the releasing joint of a rock column above the east rim of the canyon.

Another column destabilizing mechanism that we observed at the site was undercutting of the columns by river erosion (see Photograph 9).



Photograph 9 – Rock column (termed "The Wave") actively being undercut by the river below the water line, with evidence of past scour preserved above. A prominent toppling releasing joint is at the rear of the block, and close near-horizontal fractures in the rock mass attest to rock stress.

Thus, of the list of potential destabilizing forces that could initiate block toppling, two were observed at the site, and we suspect hydrostatic, frost jacking, and seismic forces also play a role in block topple initiation.

4.10 West Canyon Wall Mapping

Mapping of the west canyon wall was performed by viewing the wall from the base of the slope, and from the east canyon rim. As described previously, a graphic log was prepared and is included as Plate 2. The following discussion of the west wall will be presented from upstream to downstream, and pertinent portions of Plate 2 have been copied and embedded into the text for convenience. The identified rock blocks were characterized by their potential to fail using the legend presented below

High – Failure could occur at any time, but likely within 10 years.
Moderate to high – Failure likely within 10 to 50 years
Moderate – Failure possible in 50 to 100 years
Low – Failure unlikely within 100 years

Stations 0+00 to 0+30 – This section is just upstream of the fish passage concepts 1 through 3, and at the upstream end of concept 4 (the natural grading option). The NFBC begins to bend to a north-south orientation in this area, and the water is forced up against the west side of the canyon, resulting in high scour velocities and erosion of the rock walls. The erosion has undercut a large rock column labeled "The Wave" or Block W1 (Photograph 9 and Figure A, below) that has begun to topple along a back joint within the north-south joint set. The joint is open 1 to 2 feet at the top, is in-filled with soil and vegetation, and is tight near the river. The downstream end of The Wave is about 1 to 15 feet upstream of the walls for Concepts 1, 2 and 3. We estimate the block has a moderate to high failure potential, and although the proposed concrete walls for some of the concepts are not in contact with the block, failure of the column could damage the improvements.

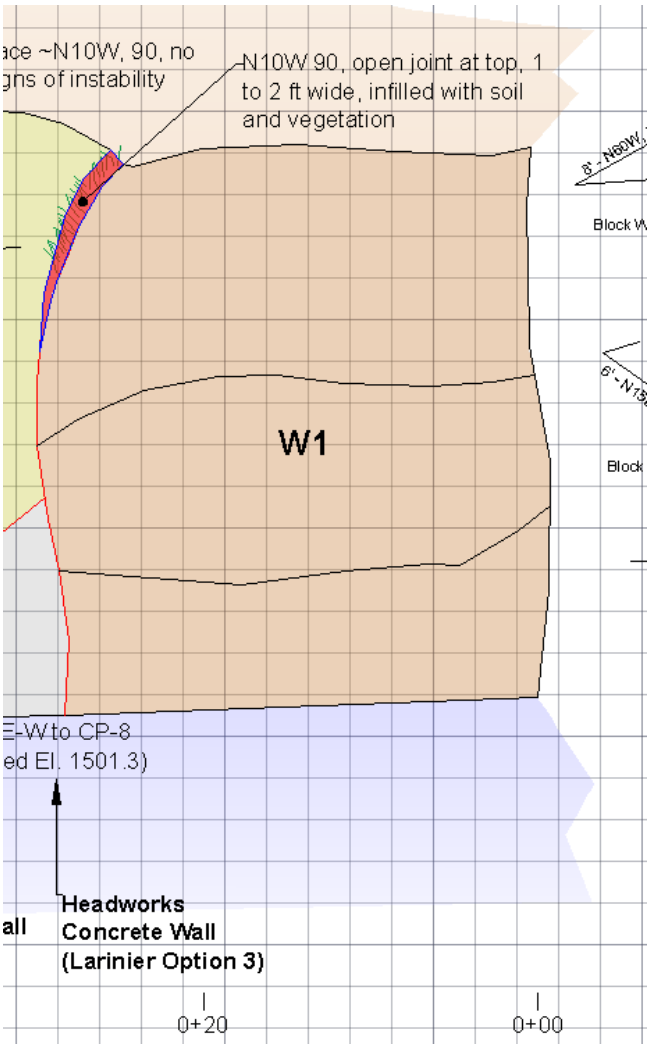


Figure A – Stations 0+00 to 00+30 West Wall Geologic Face Log.

Stations 0+30 to 0+80 - The headwalls for Concepts 1, 2 and 3, as well as the upstream tunnel portal for Concept 2 are located within this section of the west canyon wall (Figure B and Photographs 10 and 11, below). The locations where the various conceptual concrete walls would be in contact with the canyon wall contain a block with a moderate failure potential, labeled Block W2. Block W2 (moderate to high failure potential) is bounded on the upstream side by a large open joint, and there are a series of near-horizontal fractures within the block that may indicate the build-up of compressive stresses due to removal of support by river erosion and incipient toppling. The upstream tunnel portal for Concept 2 daylights in Block W6 (moderate to high failure potential due to horizontal fracturing) and is below the highly unstable Blocks W3, W4 and W5. These blocks are currently failing due to undercutting, have multiple open joints, and have a high potential to fail. These blocks are also rectangular prisms that have been formed by

the northwest joint set along the back (releasing joint), by the northeast joint set on both sides, and by the northwest joint set at the front.

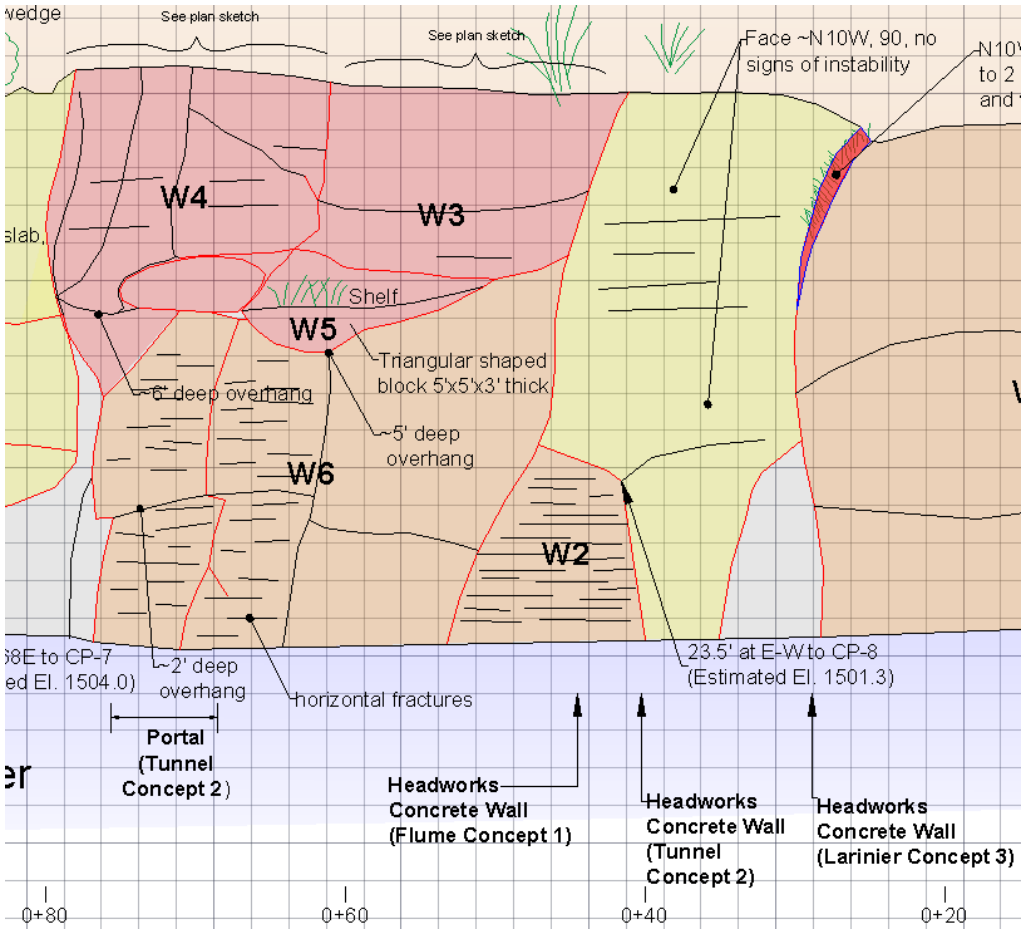
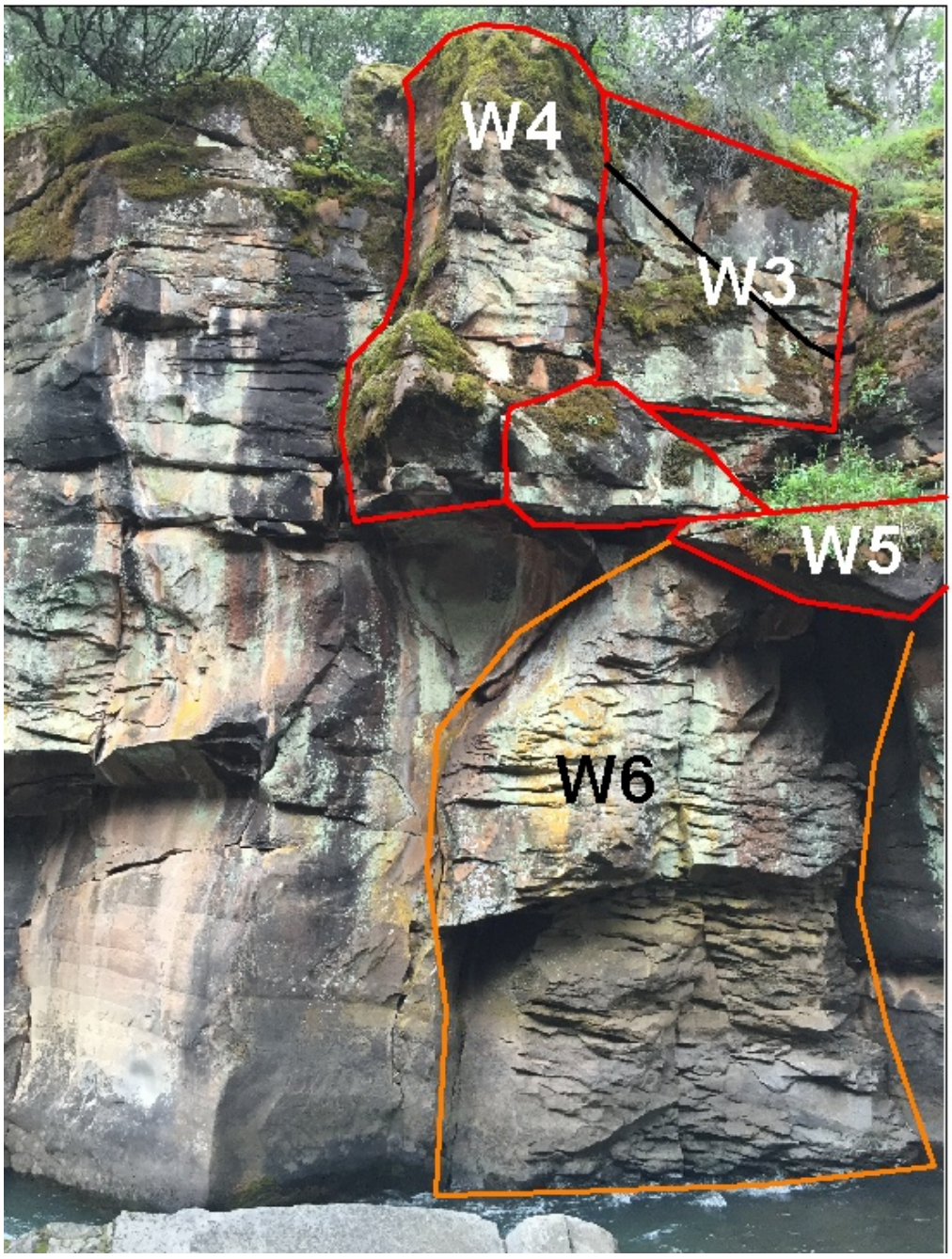
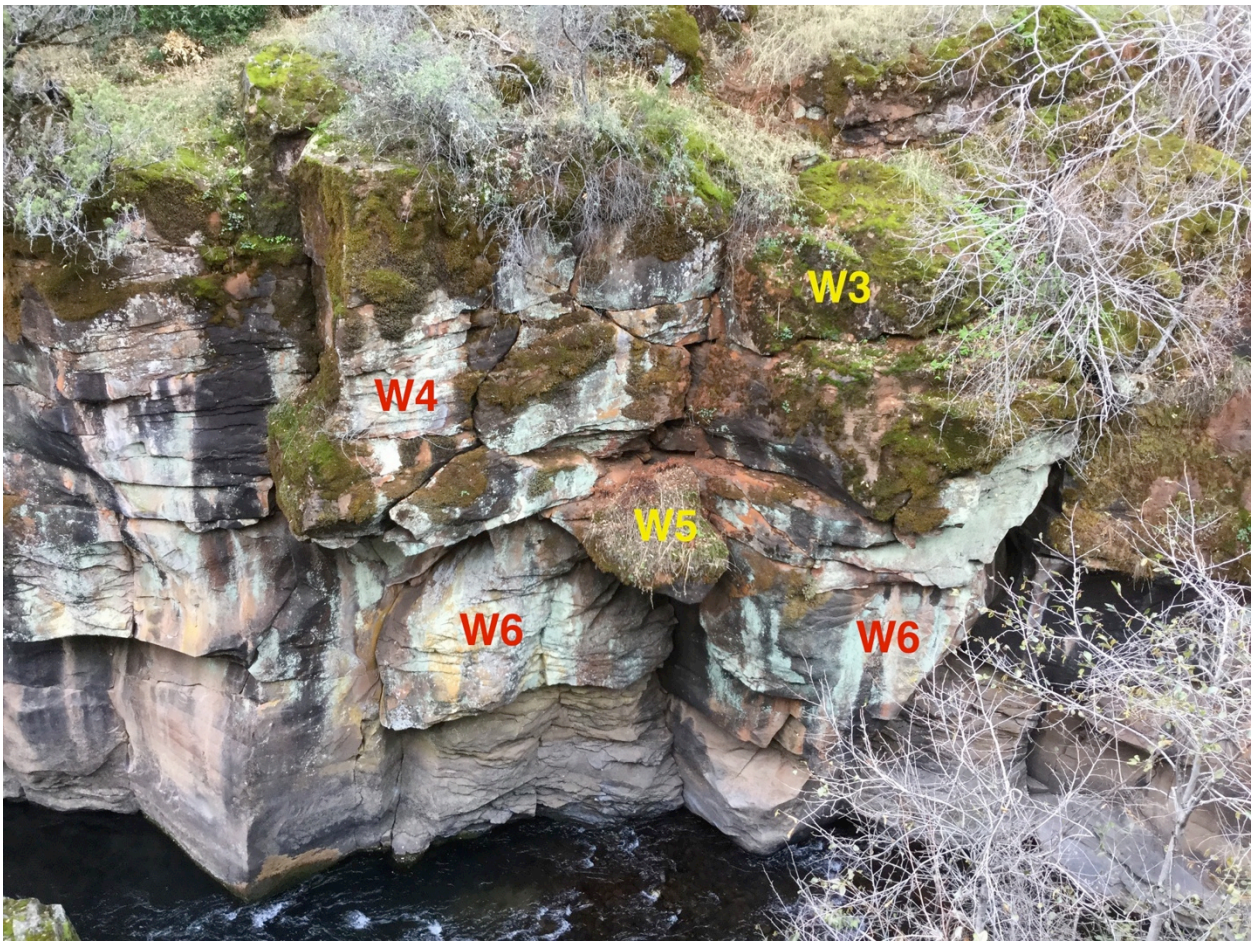


Figure B – Stations 00+30 to 00+80 West Wall Geologic Face Log.



Photograph 10 – The west canyon wall at the location of proposed upstream tunnel portal where loose blocks are above the portal area, and are causing stress fractures in the rock below.



Photograph 11 – Unstable blocks W3 – W6 on the west canyon wall.

Stations 00+80 to 1+50 - This portion of the canyon wall (Figure C, below) would be traversed along its base by the flume in Concept 1, and the downstream wall for Concept 3 would abut the canyon wall near Station 1+00. There are two relatively small blocks with a high potential to fail (Blocks W8 and W10), and a medium sized block (W7) that is partially detached and has a moderate to high failure potential. Much of this portion of the wall contains moulds, or cavities where previous rock column failures evacuated (likely from toppling), and these past failures may be the source of some of the large boulders in the NFBC that formed the UBS. Many of the moulds suggest that the rock columns were triangular and rectangular shaped prisms formed on the sides by the northwest and northeast joint sets, and at the front by the north-south joint set.

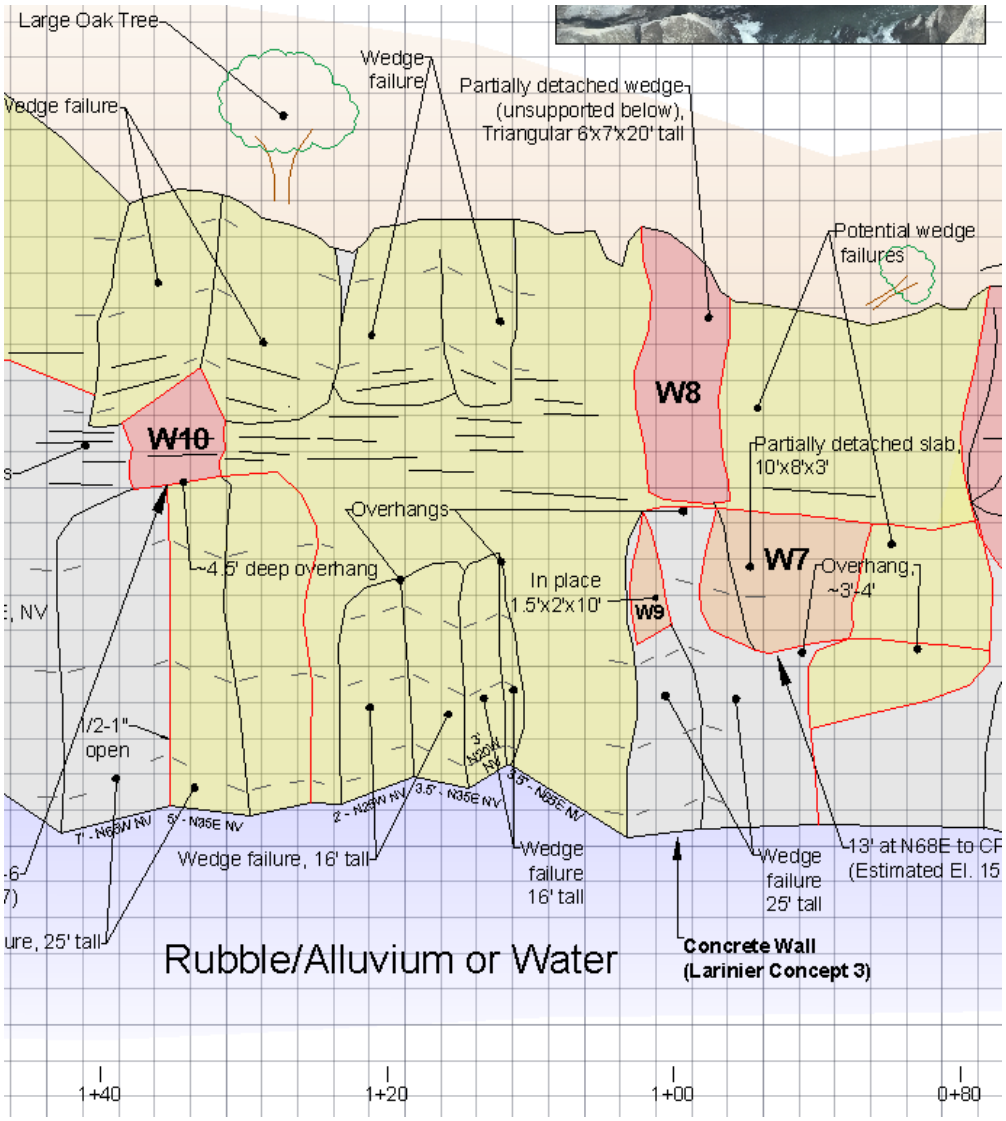


Figure C - Stations 00+80 to 1+50 West Wall Geologic Face Log.

Stations 1+50 to 2+20 - This section of the wall is near the confluence with Digger Creek where the NFBC (and the canyon wall) begins to bend toward the southwest. Many blocks are actively failing and have a high failure potential (Figure D, below). Many of the blocks are completely detached from the wall (e.g. W14, W18, W19, W 20 and W-21), and several are partially detached (W13, W15, W16 and W17). In general, the blocks are triangular and rectangular shaped prisms or wedges formed by the northwest and northeast joint sets. Due to the number and size of the blocks, this area was named the "Block Party". The semi-circular indentation in the edge of the cliff (see Plate 1) is likely the result of previous large rock block failures. The channel below this area contains numerous boulders that are part of the UBS, and we suspect many came from the Block Party area. This area would be traversed along its base by the flume in Concept 1. The

fishway ladder for Concept 1 would end near Station 1+90 and would be below this area, and the ladder for Concept 2 would end around Station 2+10 (i.e., would end near the edge of this zone). Dense vegetation prevented good photographs of this area.

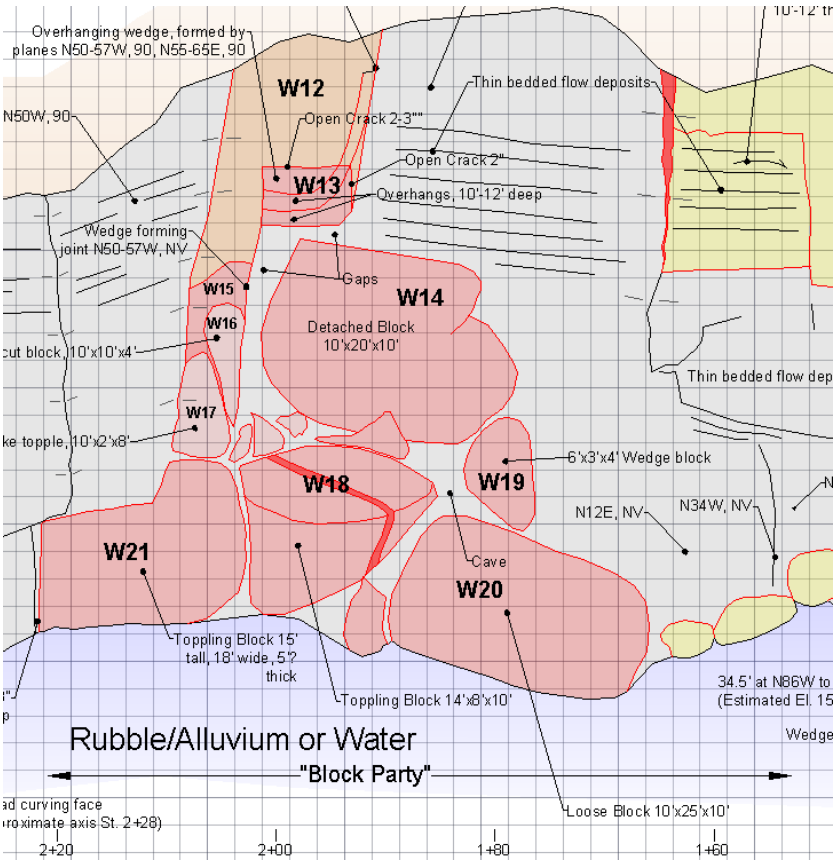


Figure D - Stations 1+50 to 2+20 West Wall Geologic Face Log.

Stations 2+20 to 2+80 - This area of the west canyon wall is oriented in the northeast-southwest direction, and is the most stable area we observed on the west canyon wall. As shown below in Figure E, the downstream portal for the tunnel in Concept 2 is located in this area. There are several relatively small blocks with a high failure potential, and a rock column on the rim of the canyon (see Plate 1), that may pose a hazard; however, the hazard is generally low to moderate. Due to the dense vegetation in this area photographic coverage was poor, consequently the geologic face log was prepared using tape and hand-held laser measurements.

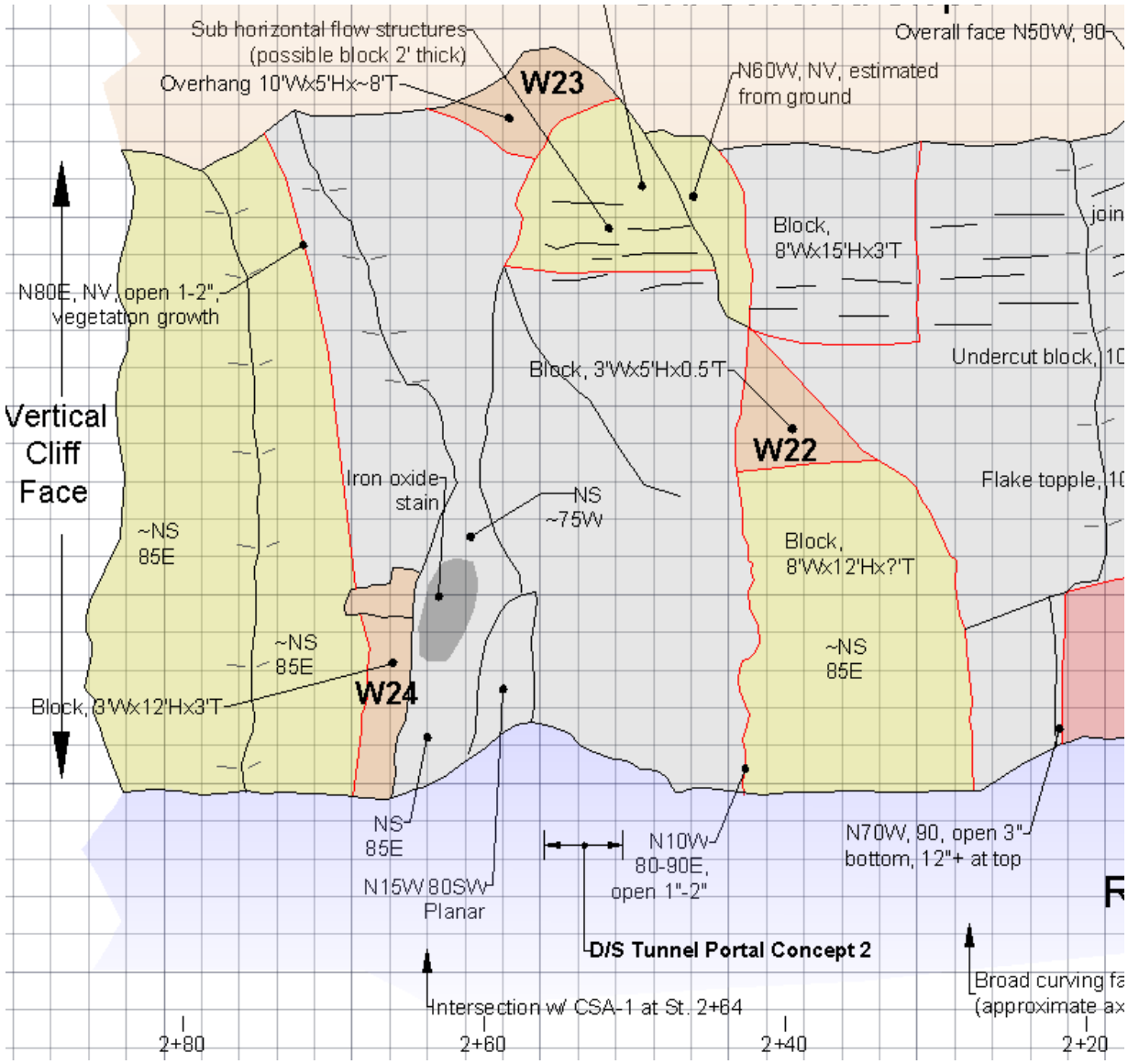


Figure E - Stations 2+20 to 2+80 West Wall Geologic Face Log.

4.11 East Canyon Wall Mapping

Mapping of the east canyon wall was performed by viewing the wall from the base of the slope, and from the west canyon rim. A graphic log of the wall was prepared and is included as Plate 3. The following discussion of the east wall will be presented from upstream to downstream, and pertinent portions of the Plate 3 have been copied and embedded into the text.

Stations 0+00 to 0+80 – The section of the east canyon wall (Figure F, below) contains the proposed headwalls for Concepts 1 through 3. Within the area where the proposed concrete walls would abut the canyon wall, there are two large rock columns (E2 and E4) that have open back joints of ½" to possibly several inches (i.e., are actively toppling), and one smaller block (E5) that appears to be toppling. These blocks have a moderate to high failure potential. In general, the columns are formed by the northwest and northeast joint sets.

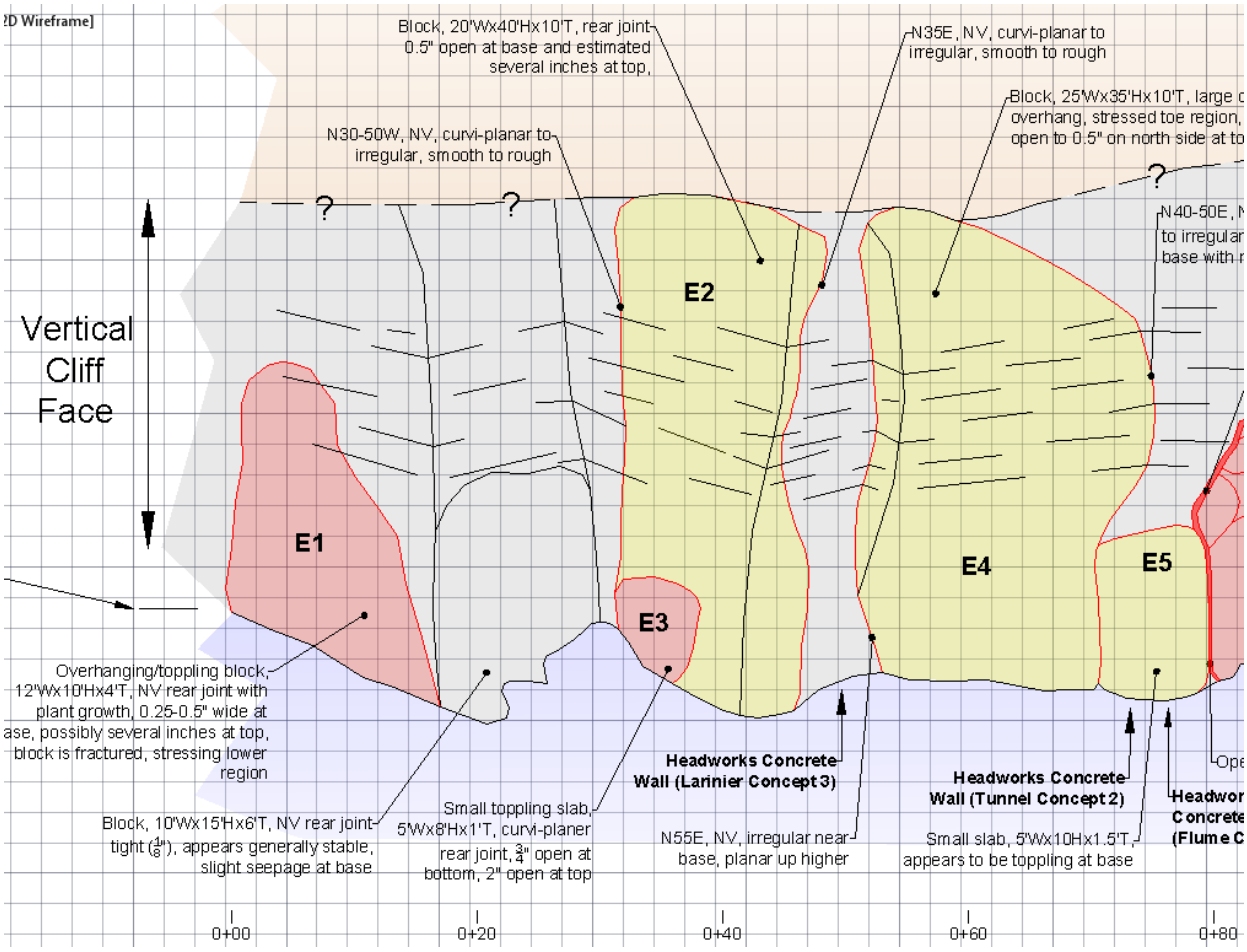


Figure F - Stations 0+00 to 0+80 East Wall Geologic Face Log.

Stations 0+80 to 1+70 – This section of the east canyon wall (Figure G, below) includes the proposed location of the downstream concrete wall for Concept 3. The wall would be located near the edge of a series of toppling blocks that have open joints (up to 4 inches wide) and a high potential to fail (Block E7). The portion of the wall from Station 1+20 to 1+70 has no observed joints, and is relatively stable.

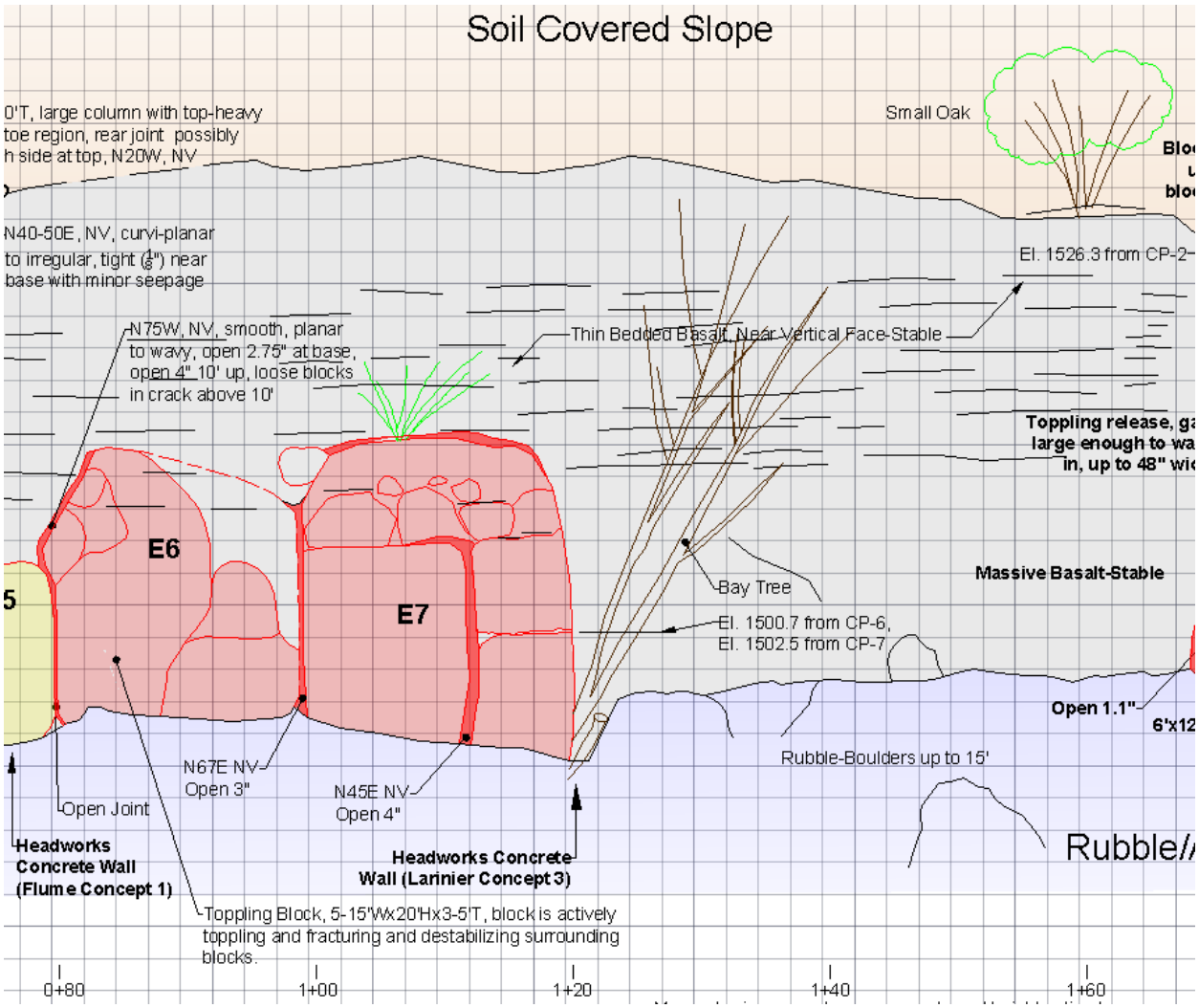


Figure G - Stations 0+80 to 1+70 East Wall Geologic Face Log.

Stations 1+70 to 2+40 – This portion of the east canyon wall (Figure H, and Photograph 12 below) contains many, very large and tall blocks that are in various stages of active toppling failure, and the area was labeled "Land of the Giants". The joints are open anywhere from about 1 inch (Block E9), up to 2-4 feet wide (Blocks E8, E9 and E10). The area in front of the toppling columns has numerous large boulders that contribute to the UBS, and we suspect many came from this area of the canyon wall.

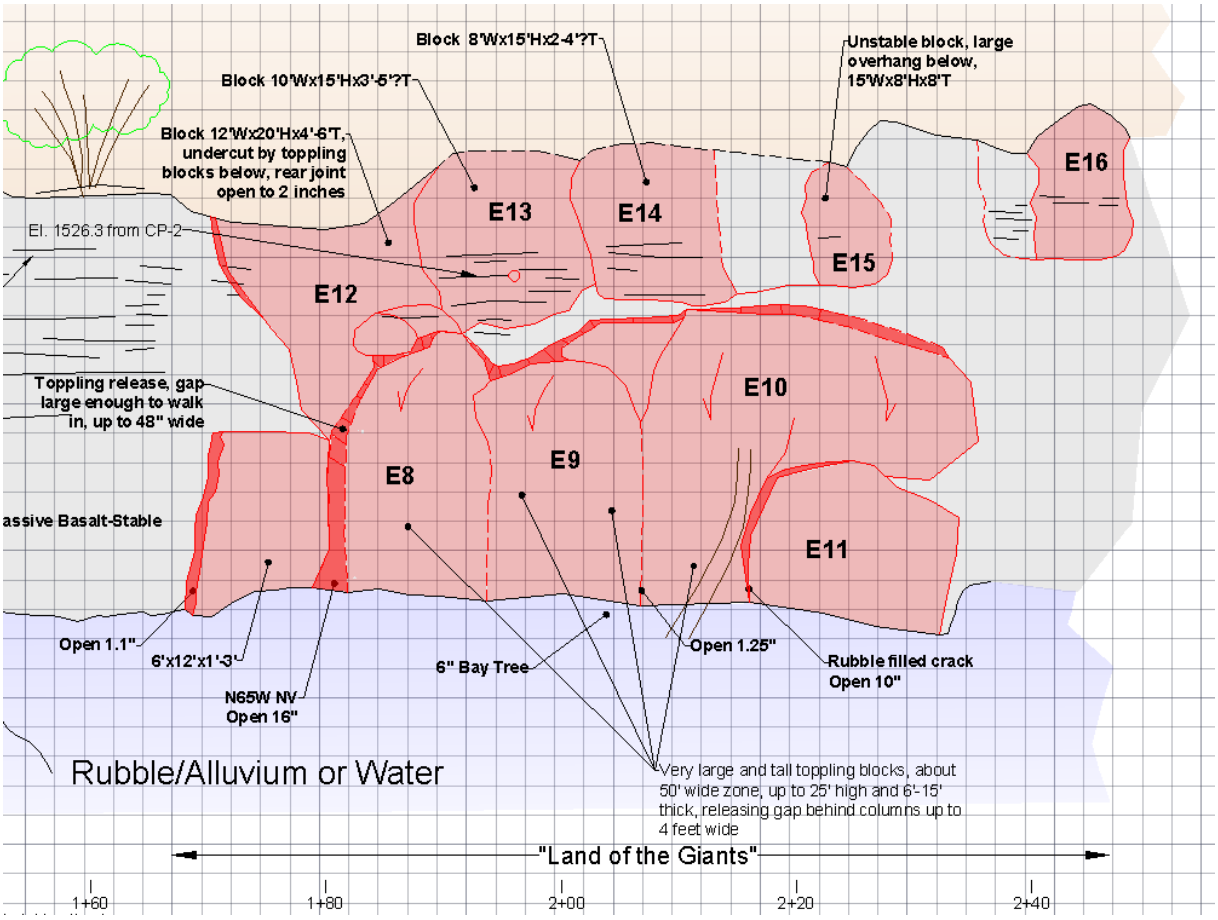


Figure H - Stations 1+70 to 2+40 East Wall Geologic Face Log.



Photograph 12 – Large toppling blocks in the 'Land of the Giants' area of the east canyon wall. This photograph was taken from directly above the 20 to 30-foot tall blocks, and illustrates the large gaps at the backs of these blocks up to 4 feet in width.

4.12 Major Toppling Zones

As discussed in the preceding section, there is a major zone of block toppling occurring on the west wall (the "Block Party") and another on the east wall ("Land of the Giants"), and both areas are near the confluence with Digger Creek. The west and east walls also contain other smaller, localized toppling zones with moderate to high potential for failure. We note that the canyon dramatically widens and deepens below the confluence with Digger Creek, likely due to

increased scour potential from the combined hydraulic forces of the two creeks, and due to geologic factors discussed below. We note that the canyon is only approximately 40 feet in width upstream of the UBS, and approximately 3 to 5 times that width immediately downstream. Since these two major toppling zones appear to have generated many of the rock blocks that make up the UBS, the purpose of this section is to discuss possible mechanisms responsible for these concentrated areas of instability.

In the case of the Block Party, the west wall changes orientation at Digger Creek, and this has created more open space (more free face exposures, or freedom of movement) for blocks to move. Thus, geometry and kinematics appear to be a contributing factor for the instability at the Block Party location. This is not the case, however, at the Land of the Giants, where the east wall is only slightly curved.

Another contributing factor could be the Red Bluff Formation. This is a volcaniclastic alluvial deposit that stratigraphically lies below the Eagle Canyon Basalt (which forms the walls of the UBS), and above the Basalt of Coleman Forebay, which forms the lower walls of the LBS. We observed likely outcrops of the Red Bluff Formation at the LBS, and it appears to be a permeable unit that is responsible for the abundant springs along the south wall. We also observed overhangs and unstable blocks of Eagle Canyon Basalt above the Red Bluff Formation at the LBS. We note that at the LBS, the Red Bluff Formation crops out an elevation that is roughly consistent with the level of the creek at the UBS. We did not observe the Red Bluff Formation at the UBS, but our geophysical surveys reveal that there is an average of 10 to 15 feet of alluvium and large rock blocks choking the creek at the UBS, and the likely location of the Red Bluff Formation would be at the base of the alluvium, where scour at high flood flow would undercut the near-vertical cliff face. Consequently, we postulate that the dramatic widening of the canyon just downstream of the confluence of Battle and Digger Creeks, and the two major block toppling zones (i.e., the Block Party and the Land of the Giants), may be related to the location of this confluence, and their combined ability to erode into the weaker Red Bluff Formation volcaniclastic deposit and undercut the massively bedded Eagle Canyon Basalt. The Red Bluff Formation may also be a source of high water pressures that are pushing upwards on the base of the blocks and decreasing stability. Under this scenario, in a geologic sense, the UBS represents the active headward extent of canyon widening, where recent massive basalt blocks have been undercut, have toppled, and have choked the narrow gorge, but have not yet been reduced to smaller block sizes that can be transported downstream.

4.13 Mitigation Concepts, Constructability and Geologic Hazards

All of the mitigation concepts involve removing boulders in the channel, and one involves tunneling through the canyon wall. Some level of blasting will likely be required to break up the larger boulders. We observed a video of a boulder being blasted at the lower barrier (https://youtu.be/vdgYSdcRUAE), and that technique appears to have been very effective. Due to the large number of detached boulders on the walls of the canyon, safety and/or monitoring measures will also be needed to protect the workers from vibration induced rockfalls during blasting.

As mentioned previously, the canyon has numerous rock slope instability hazards that pose a risk to most of the concepts. For typical permanent repairs where the consequence of failure is high (i.e., steep slopes above roadways or habitable structures), a common rock slope mitigation method is to add support using tensioned rock bolts that are grouted in place and have a Double Corrosion Protection (DCP) system. However, there are several challenges associated with using DCP rock bolts at the UBS, including: 1) Safety – Due to the number of open joints, fractures and partially to fully detached rock blocks that characterize some of the hazardous areas, an experienced contractor will be needed to perform the work safely and ensure that construction, specifically drilling for the rock bolts, doesn't trigger rock falls. We suspect that prior to drilling, the contractor will need to apply a layer of shotcrete reinforced with wire mesh to safely move the drill rigs around on the slope and drill, which will increase the cost. 2) Grouting – Achieving a fully grouted rock bolt may be difficult due to the numerous open fractures. A method to contain the grout that is sometimes successful is the use of grout socks. Another possibility is the use of rock bolts that do not require grout, such as bolts with resin cartridges or the use of mechanical rock bolts. These types of bolts are not double corrosion protected, are not suitable for protection of important structures, and are generally only used for temporary support. However, a conversation with a rock bolt manufacturer (Williams Form Engineering) indicates these types of anchors have been used for permanent repairs in the past. 3) Environmental – This is related to the rock bolt grouting. Due to the numerous open fractures and potential for grout loss, there is a moderate to high potential for the grout to enter the creek, and provisions to monitor for and contain the grout will likely be needed.

Other factors that will affect the cost include: 1) the remoteness of the site; 2) difficult access to get equipment to the bottom of the canyon; and 3) lack of staging area and difficult maneuvering of equipment and resources in the bottom of the narrow canyon. Consequently, construction at the UBS will likely be significantly more costly than typical construction projects of similar size. Also, depending on the effort expended to mitigate the various hazards, all of the options will likely require some level of long term maintenance to remain operational.

4.13.1 *Concept 1 – Flume and Fishway Ladder* - The elements of this option are shown in purple coloring on Figure 5 (attached) along with notes depicting the rock slope hazards that were identified during our mapping program and the layout of the geophysical ReMi survey lines. In general, this concept appears to be the most highly constrained by geologic hazards.

Constructability - As mentioned previously, the fishway ladder for this option begins near Control Point CP-2, and extends upslope toward the west canyon wall along the apron of alluvium (and possibly slope debris near the rock wall) that occupies this area. The concept drawings show the ladder is a formed concrete box structure with a slab foundation. The ReMi line RM-2 passes through the middle of the ladder, and the estimated average depth to fresh bedrock using the Refraction Micro-tremor data is about 9 feet. The cuts along the path of the fishway ladder may extend to more than 10 feet below the existing ground surface, and most of the deeper cuts will likely need to extend through large boulders that protrude above the surface and possibly into the underlying bedrock. Once the boulders have been split and removed, the subgrade below the ladder foundation will likely be composed of large boulders within a matrix of sand and cobbles, possibly with voids, and will likely be subject to settlement over time. Drilling piers through this material into bedrock to support the ladder would likely be very difficult and costly given the range of block sizes, rock hardness, and the cohesionless nature of the materials. Possible mitigation methods for a shallow foundation could include extending the excavation into bedrock, or grouting and/or heavier reinforcement in the slab foundation to protect the structure against future settlement.

The flume portion of this concept is mostly in cut, which would likely have similar foundation conditions as the fishway ladder. Perhaps the best option to support the flume, from a constructability viewpoint, would be to attach the flume to the wall of the canyon with braced steel supports. However, as discussed in previous sections, the wall is subject to rockfall hazards. Since the flume hugs the west wall of the canyon, the alluvium may be shallow, and piers embedded in bedrock may be an option. The upstream 30 feet or so of the flume is shown on the drawings to be elevated about 4 feet. The river current is directed toward this area, so supporting the flume on rocky fill would be problematic unless the materials could be protected against erosion.

The ReMi survey line RM-1 passes through upstream area where the spillway and headworks concrete walls are proposed, and the average estimated depth to bedrock across the line is about 6 feet. Construction of the walls into bedrock will require shoring and dewatering efforts. Embedment of the concrete walls into bedrock will require significant work with mechanized hand tools and/or backhoe mounted mechanized hammers.

Geologic Hazards – As shown on Figure 5, the upstream end of the fishway ladder, and about 40 feet of the flume will be directly below the area with multiple detached blocks termed the Block Party. There is a high potential for rock falls in this area and consequent damage to the fishway or the flume. This area contains partially detached rocks high on the wall, fully detached rocks that are still in place on the wall, and fully detached rocks that have fallen downslope, some apparently resting on and supported by the blocks below. Possible mitigation measures could include the installation of rock bolts on the upper part of the wall, and removing the fully detached boulders using hand tools or air bladders. With respect to the blocks that have fallen downslope, we are concerned that if these are removed for construction of the fishway and flume, boulders above could mobilize. This is a somewhat unique rock slope hazard that will require non-standard mitigation methods. One possible method would be to fill the voids between the boulders with concrete in an effort to create a solid mass that could be restrained with rock bolts or rock anchors. Another less robust option with a lower chance of success would be to restrain the boulders with a high strength cable net drapery that is connected with cables to the more stable rock at the edges of the area.

The flume would abut the west wall of the canyon, and would pass directly below five rock blocks with a high potential to fail, and many other areas with a moderate to high failure potential. These hazards could be mitigated by scaling (removal), shotcrete and the installation of rock bolts.

The headworks wall abuts the west canyon wall just downstream of The Wave block. This is a very large block with a partially open fracture that poses a moderate to high risk of failure. Due to the large size of the block, high capacity rock bolts, or possibly strand anchors, would likely be needed. Another option may be to avoid the hazard by moving the wall farther downstream. Scaling, shotcrete and rock bolts will likely be needed to protect the headworks wall from Blocks W3, W4, W5, and W6 on the west wall.

4.13.2 Concept 2 – Tunnel and Fishway Ladder - The elements of this option are shown on Figure 6 with notes depicting the approximately location of the mapped rock slope hazards. In general, this concept has less constructability issues that Concept 1, and less exposure to geologic hazards.

Constructability - The fishway ladder for this option is similar in location to Concept 1 (including cuts of at least 10 feet deep, thus, the challenges associated with the foundation of the fishway ladder would the same as described for Concept 1.

With respect to the tunnel, the proposed alignment generally parallels the canyon wall. The maximum distance the tunnel is located west of the canyon wall is about 25 feet, and the tunnel alignment is only about 10 west of the semi-circular evacuation in the wall made by previous

failure of rock blocks in the Block Party region. Given the persistent nature of the joints exposed in the wall during our mapping, open joints may be encountered during the tunneling. We did not observe any springs on the west wall during our mapping, so we would not expect the joints to contain significant water (water bearing fractures could curtail drilling progress). However, due to the numerous joints, it is likely that tunnel water will escape into the fractures when the tunnel is operational. This may affect minimum flows in the tunnel needed for fish passage, and water loss into the fractures could also trigger rock slope failures on the west wall (in particular at the Block Party), which could impact the tunnel. This hazard might be mitigated by re-routing the tunnel further away from the canyon wall, and/or lining the tunnel.

Construction of the headwork walls into bedrock will require shoring and dewatering efforts. Embedment of the walls into bedrock will require significant work with mechanized hand tools and/or backhoe mounted mechanized hammers/hoe rams.

Geologic Hazards – The west canyon walls above the fish ladder and the downstream tunnel portal are relatively stable compared to the rest of the canyon walls, and would require much less stabilization effort than Concept 1. The upstream tunnel portal and the headwork walls are located below potentially unstable blocks W3, W4, W5, and W6, and scaling, shotcrete and rock bolts would be needed to stabilize this area. The headworks wall abuts the east wall just upstream of block E6, and the headworks wall could be moved slightly upstream to reduce the hazard.

4.13.3 Concept 3 – Regrade (with Larinier Super Baffle) - The elements of this option are shown on Figure 7, along with our notes depicting the approximate location of the mapped rock slope hazards. Based on our understanding of the concept, this option appears to have less constructability issues and geologic hazard exposure than Concepts 1 and 2.

Constructability – This concept includes a significant amount of boulder splitting, grading and removal, which as previously discussed, will be difficult and time consuming. This baffle structure appears to be a formed concrete box structure, and will likely be founded on a mixture of large boulders in a matrix of cobbles and sand. Thus, the challenges associated with the foundation would be similar to the Concept 1 fishway ladder. The concrete walls at the upstream and downstream ends of the structure will require shoring to avoid slumping of the cohesionless material into the foundation excavation, as well as dewatering. Embedment of the walls into bedrock will require significant work with mechanized hand tools and/or backhoe mounted mechanized hammers/hoe rams.

Geologic Hazards – This concept shadows high hazard blocks W-3, W-4. W-5, W-7, W-8 and W-9 on the west wall, and blocks E-6 and E-7 on the east side. In addition, the upstream concrete wall

is located at the downstream edge of the Wave. Mitigating these hazards will require scaling, shotcrete and rock bolts. However, this structure is located near the center of the channel, and is approximately 6 to 15 feet away from the west wall, and about 14 to 29 feet away from the east wall. Thus, the exposure to rock slope stability hazards is less than Concepts 1 and 2. In addition, the structure appears to be more robust than a flume. Consequently, it is possible that future rock falls from the canyon walls may not damage the structure enough to render it inoperable. That said, we note that the secondary fish passage channel (on the east side of the Larinier baffle) includes the removal of up to 8 feet of material. If the excavation extends to the east wall and exposes portions of the canyon wall that are currently buried and buttressed by alluvium, existing rock block hazards may pose a higher risk, and new rock block hazards may be uncovered. The hazard posed by The Wave might be mitigated by moving the structure slightly downstream.

4.13.4 *Concept 4 – Regrade (Natural)* - The elements of this option are shown on Figure 8, along with our notes regarding the rock slope hazards. This concept appears to have the least amount of possible constructability issues and exposure to geologic hazards than the other concepts.

Constructability – This concept involves removing a significant volume of alluvium and numerous large boulders, and has the same constructability issues associated with removing the boulders as the other concepts (although to a greater degree due to the larger volume of removal).

Geologic Hazards – The grading proposed for this concept shadows six high hazard blocks on the west wall (including The Wave, which is rated moderate to high), and four high hazard blocks on the east wall, and if mitigation of these hazards is desired, scaling, shotcrete and rock bolting will likely be required. However, it is possible a rock block failure would not render the passage inoperable. Since there are no "breakable" structures involved in this concept, if the passage does become blocked by a rock fall, the repair (i.e., removing the boulder or breaking it into smaller pieces) would appear to be significantly less expensive than repairing rock fall damage to a structure associated with the other concepts (which would also include the cost of removing the rock). Based on the conceptual drawing we reviewed, it is not clear if the excavation in the channel will be planer from wall to wall, or if the finished grade will be lower in the middle and higher along the edges. If the excavation will be planer and exposes portions of the canyon walls that are currently buried and buttressed by alluvium, existing rock block hazards may pose a higher risk than currently assessed, and new rock block hazards may be uncovered.

4.14 UBS Modified Mitigation Concepts

Following the submittal of this report as a draft, MLA modified the mitigation concepts to reflect the new information regarding geologic hazards. CSA reviewed the modified concepts, and offer

the following comments below. Figures showing these concepts can be found in the report by MLA.

General Comments – CSA viewed a video prepared by MLA of a large flood event that was captured in January of 2016, using time lapse photography. This videoed flood event underscores the need to support new structures firmly into bedrock to mitigate scouring and undermining during large flow events. In a related comment, due to access and environmental issues, our geophysical lines were not calibrated with subsurface borings, and the ReMi lines give an average depth to bedrock below the entire line. Consequently, the bedrock surface may be shallower or deeper than estimated, and likely are undulating with uniform surfaces interspersed with scour holes. Consequently, we recommend the construction documents request unit costs for extra excavation into bedrock and additional concrete, if needed, to extend improvements into bedrock.

Alternative A – Tunnel & Fishway, dated July 2016

This alternative is similar to the original Concept 2 – Tunnel and Fishway Ladder described in the previous section. The entry and exit points for the tunnel are similar to the original design, and the upstream portal will be subject to the same rockfall hazards as described previously. The headwall for the tunnel is much shorter, and does not extend to the east canyon wall. Thus, rockfall hazards on east canyon wall should not significantly impact the design. The modified tunnel alignment is farther away from the canyon wall, so the potential for intersecting open joints should be lower. We note that the modified footprint of the fishway extends farther upstream than the original design, and is now within the shadow of the Block Party. Thus, the fishway structure is subject to rock fall hazards from the Block Party area that the previous design did not contain.

Alternative B – Super Active Baffle, dated July 2016

This alternative is similar to Concept 3 – Regrade (with Larinier Super Baffle). The new baffle structure is broken into two sections with a resting pool in the middle. The structure has been moved to the west compared to the original location. The upper section is about 5 to 10 feet away from the west canyon wall, and the lower section abuts the west wall in some locations. Thus, this new location is subject to more rockfall hazards than the original location. Grading is proposed on the east side of the structure that consists of chutes and pools and excavations down to bedrock. We note that if the excavations expose portions of the canyon wall that are currently buried and buttressed by alluvium, the existing rock block hazards may be exacerbated, and new rock block hazards may be uncovered.

Alternative C – Regrade, dated July 2016

This alterative is similar to the previous Concept 4 – Regrade (Natural). The proposed grading is similar to Alternative B, with chutes and pools and excavations down to bedrock. Although this alternative is exposed to rockfall hazards, maintenance of the facility after a rockfall event (e.g., blasting and removal of rocks) should be significantly less expensive and quicker than repairs to the structures proposed in Alternatives A and B. Excavations against the canyon walls should be limited to avoid exposing new rock fall hazards (that are currently buried), or exacerbating the identified rock fall hazards.

5.0 LOWER BARRIER

5.1 Preliminary Fish Bypass Concepts

We do not have preliminary drawings of bypass concepts for the LBS; however, based on discussions with MLA, we understand there is a concept that involves bypassing the current blockage by creating a new bypass channel to the south (river left) of the main channel.

5.2 Geophysical Investigation

Two Refraction Microtremor (ReMi) shear wave survey lines were performed on the LBS, and the data and results are included in Appendix A. One survey line (Lower RM-1) was located sub-parallel to the creek on the south bank, and the second line (Lower RM-2) was also south of the creek, but higher on the bank. The geophysical data suggest that bedrock is located about 14 feet below the ground surface across Lower RM-1, and is 10 feet below the surface on Lower RM-2.

5.3 Boulder Strength

The unconfined compressive strength of four of the large boulders along the south side of the creek was estimated using a Schmidt Hammer during the geophysical survey. The locations of the tests are shown on Plate 4 (Reconnaissance Map – Lower Barrier) and the results are presented in Appendix C. The average results (rounded down) from the tests on the four boulders were 31,000 psi, 45,000 psi, 24,000 psi and 35,000 psi. As noted previously, published unconfined tests for basalt ranges from about 15,000 psi to 45,000 psi, so the boulders likely have unconfined compressive strengths in the middle to the upper end of the published range.

We plan to obtain 2 large rock fragments from the LBS, and have them cored in a laboratory and tested for unconfined compressive strength. When completed, the testing results will be provided in an addendum.

5.4 Field Reconnaissance and Rock Slope Mapping

Reconnaissance-level engineering geologic mapping was performed at the LBS by John Wallace (engineering geologist) and Dale Marcum (geologic engineer) on February 29, 2016. Mapping of the south side of the canyon was performed using the PG&E stairs and catwalks, and accessing the south side of the river at the canyon bottom via PG&E's Eagle Canyon flume. The creek was not crossed to map the north side due to private property restrictions and safety concerns. Potential hazards on the north side of the canyon were also mapped from the stairs and catwalks on the south side. The north side of the canyon was accessed via the gate off of Battle Creek Bottom Road. There are two near-vertical canyon wall exposures on the north side, and the team hiked to the top of the upper wall for views and mapping of the south canyon wall, and limited mapping of the north side.

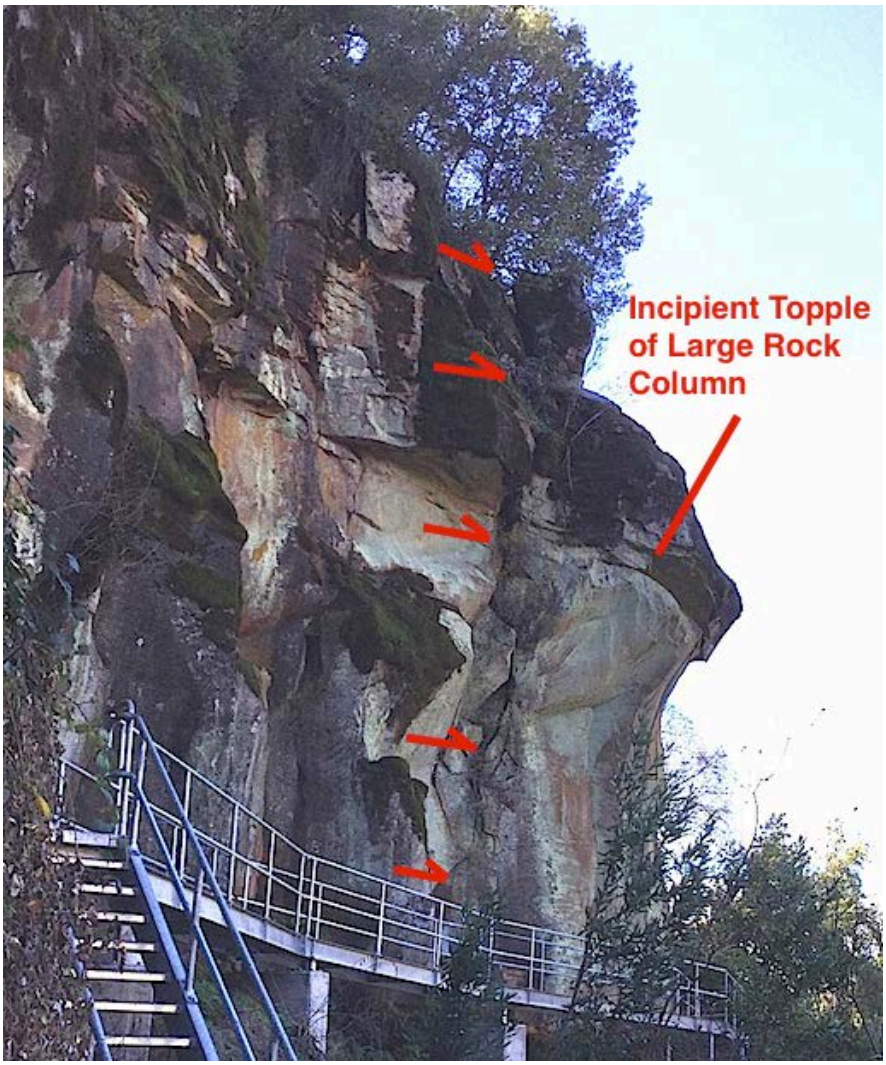
The field mapping of the LBS was performed on an aerial photograph base taken by a drone flown by MLA. This photograph is not geometrically corrected (i.e., it is not an orthophoto). We scaled and stretched the photograph to fit the topography as best as practical in AutoCad, and the results of the reconnaissance mapping are presented on the Reconnaissance Map – Lower Barrier, Plate 4. The fit with the contours is approximate and there is photographic distortion; however, the plate serves to illustrate the topography and visual characteristics of the LBS area. The notes on the plate were located to correspond to features on the photograph, not the topography. The data used to create the topographic contours were acquired by GMA Hydrology between July 13 and November 4, 2015.

5.5 South Canyon Wall

There are two vertical to near-vertical rock walls on the south side of the canyon. The upper canyon wall on the south side is about 40 to 60 feet high, near-vertical, and is composed of massive basalt of the Eagle Canyon Basalt Formation. The wall contains two very large blocks that are actively toppling (high failure potential), and one thinner block (flake) that also has a high failure potential (see Photographs 13 and 14, and Plate 4).

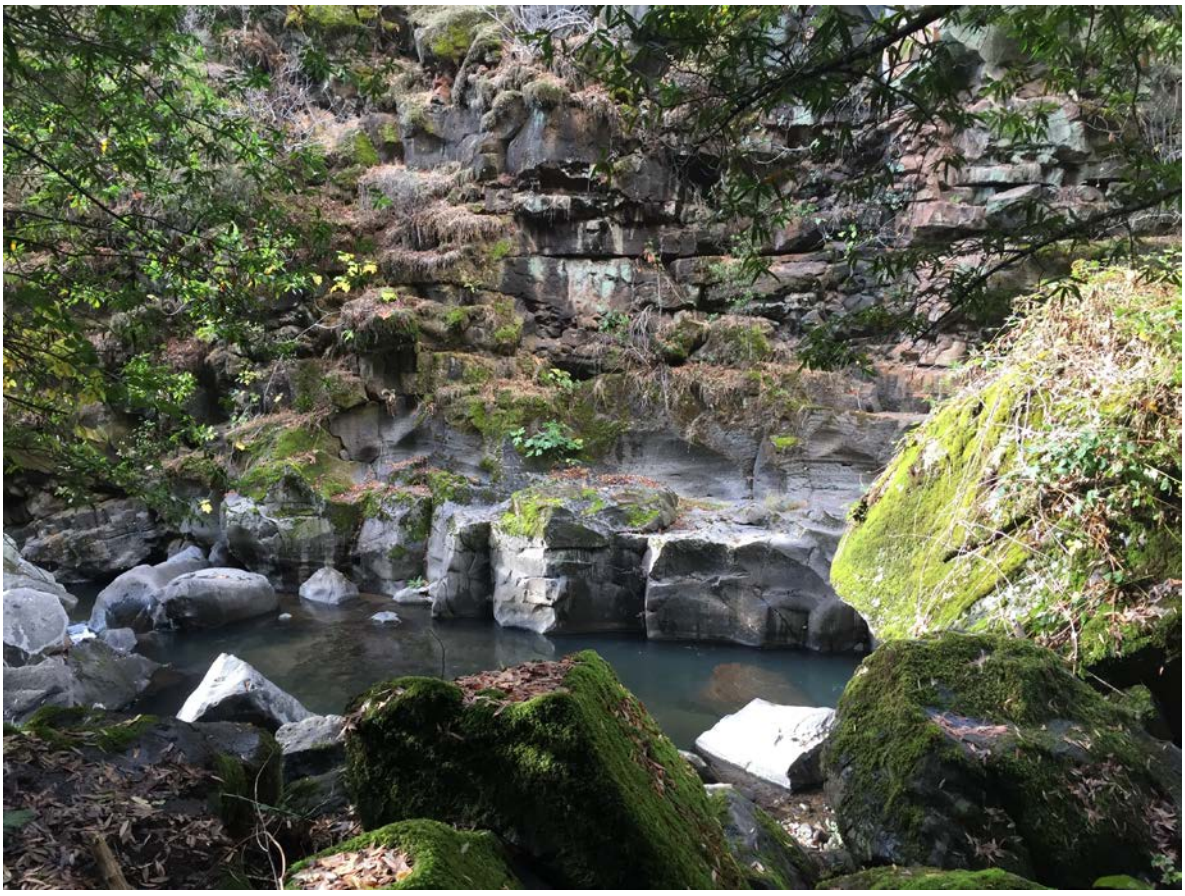


Photograph 13 – The upper canyon rock face composed of Eagle Canyon Basalt with abundant seeps occurring along the base of the formation where the massive basalt is in contact with the highly permeable volcaniclastic Red Bluff Formation. Several large unstable rock columns are experiencing incipient toppling in this area (see Plate 4). View to the south.



Photograph 14 – Incipient topple of large, massive basalt rock column on south canyon upper rock face. Red arrows depict tension crack along the rear of the block, gradually increasing in width toward the top of the block. View to the west.

The lower wall on the south side is about 30' to 50' high, 50-degrees to locally near-vertical, and composed of relatively thin-layered basalt flows (i.e., generally less than 5 feet in thickness). We attribute this volcanic rock to be the Basalt of Coleman Forebay, which has a distinctly different character and stability state than the Eagle Canyon Basalt. The thin layering of the basalt (see Photograph 15) and lack of pervasive near-vertical cooling joints typical of massive basalt, results in rock falls that are typically much smaller in size. There are a number of small rock blocks, but they are generally less than about 5 feet in maximum dimension, and generally contain no obvious large dilatations. There are some overhangs, but in general, the joints appear to be short and fairly tight, resulting in low rock fall hazards along the lower canyon wall.



Photograph 15 – The north canyon rock face at the lower canyon wall displaying thinly layered basalt, characteristic of the Basalt of Coleman Forebay that is stratigraphically below the Eagle Canyon Basalt.

The rocks blocks on the canyon walls at the LBS are composed of large (tens of feet), massive basalt blocks that could only have been derived from the upper canyon walls. As described by Smelser (2012), these large blocks were likely deposited by rock and debris slides generated from the south canyon wall, with some and possibly a majority of the blocks being the result of the excavation efforts stemming from the Eagle Canyon flume and tunnel construction.

5.6 North Canyon Wall

There are also two near-vertical rock walls on the north side of the canyon, referred to as an upper canyon wall and a lower canyon wall. The sloped area above the upper wall has some loose and detached rocks on the surface that are generally less than 2'-3' in size, with several that are up to 5 feet in size. If these rocks were to mobilize, they could be funneled toward the LBS area shown on Plate 4. However, in general the rock fall hazard of the upper sloped area above the upper

canyon wall is considered low under static conditions, and low to moderate under seismic loading.

We did not observe any obvious, high rock fall hazards on the upper canyon wall, which is characterized by a near-vertical rock wall about 40 feet high, and composed of massive Eagle Canyon Basalt. However, this face was observed primarily from the south side of the canyon using binoculars, and thus, a comprehensive inspection of the wall face was not possible. A sloped area is located below the upper canyon wall and contains isolated large rock blocks, indicating that block failures from the upper wall are at least partially contained in this area and do not necessarily reach Battle Creek. Upper canyon wall instability appears to be characterized predominantly by toppling along near-vertical joints. Several toppled rock columns were noted on the slope below the upper wall, and the source area evacuations are evident near the base of the wall (see Plate 4). One area on this slope contains a large rubble field immediately beneath a scarp concavity upslope where numerous rock blocks appear to have toppled and came to rest near the top of the lower canyon wall. Based on observations from the south side of the canyon, and observations from above the upper wall on the north side, the hazard is estimated to be low under static conditions, and moderate during seismic events.

The near-vertical lower wall on the south side rises up to 50 feet in height from the creek. The canyon wall exposes thinly layered Basalt of Coleman Forebay with 6-inch to 4-foot thick basalt layers (Photograph 15). We did not observe any obvious dilations suggesting that large blocks are forming; however, even if rock slope instability occurs along the rock face, the rock blocks created would likely be small. In general, the rock fall hazard from this area is considered low.

5.7 Source of Boulders in Lower Barrier

As mentioned previously, an engineering geologic investigation of the LBS was performed by the California Department of Fish and Game in 2012 (Smelser, 2012). This study concluded that the most likely source of the boulders that form the LBS was from construction of tunnels and flumes for the Eagle Canyon canal. We generally agree with this hypothesis since the construction of the flume and canal occurred very near the base of the massive basalt and would have likely included blasting. However, we note that the walls on both the north and south sides of the canyon exhibit active toppling and signs of previous toppling failures. Natural rock falls may have also been a source of debris contributing to the restriction in the canyon at this location, which likely would have come from the upper rock face on the south canyon wall due to the profuse seepage and natural undercutting of the massive Eagle Canyon Basalt at the contact with the Red Bluff Formation. We have mapped several unstable large rock blocks (up to 40 feet in height) in this

area that have heavy seepage at their base, are partially undercut, and experiencing active toppling, and if they were to fail, could result in large basalt blocks reaching Battle Creek.

5.8 LBS Mitigation Concepts

The following are our comments regarding constructability and geologic hazards for two mitigation concepts that were prepared after our draft report was completed. Figures showing these concepts can be found in the report by MLA.

General Comments - The general comments provided in Section 4.14 for the UBS apply here as well. Based on our understanding of the drawings, the LBS concepts involve excavating into bedrock. Blasting into bedrock will transmit more energy into the surrounding canyon walls than blasting surface boulders. Thus, in addition to normal blasting safety procedures, we recommend that the stability of the flume footings above the site, and the stability of the three rock blocks that were identified as having a high hazard on the south side of the canyon be analyzed for seismic stability. The seismic stability of the three rock blocks might be estimated by comparing estimated blast accelerations to estimated accelerations from previous earthquakes. These features (the flume and the rock blocks) should also be monitored during construction. The hazard could be significantly reduced by allowing blasting only on surface boulders; however, this would also raise construction costs.

Alternative A –Fishway, dated July 2016.
This concept contains a concrete chute along the north side of the channel to provide fish passage. The structure will be subject to rockfall from the north canyon wall; however, based on our observations made during our reconnaissance, we consider this hazard to have a low risk under static conditions. In addition, the structure appears robust, and repairs after a rockfall event may only require the removal of rock fragments in the chute. The structure should be founded on bedrock to avoid scouring and undermining during large flow events.

Alternative B –Regrade, dated July 2016
This concept involves the removal of large boulders and slope debris to create natural channels that fish can navigate. As this option does not contain concrete or steel structures, repair and maintenance costs following a rockfall event should be reduced compared to other alternatives. This option includes the removal of material along the south bank of the river. The area contains an accumulation of slope debris that may become unstable if undercut, possibly requiring more excavation than anticipated. It is our understanding that this grading would also be needed for Alternative A, so if this regrading concept does not work, the effort and expense would not be wasted.

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FIGURES



Source: Google Maps

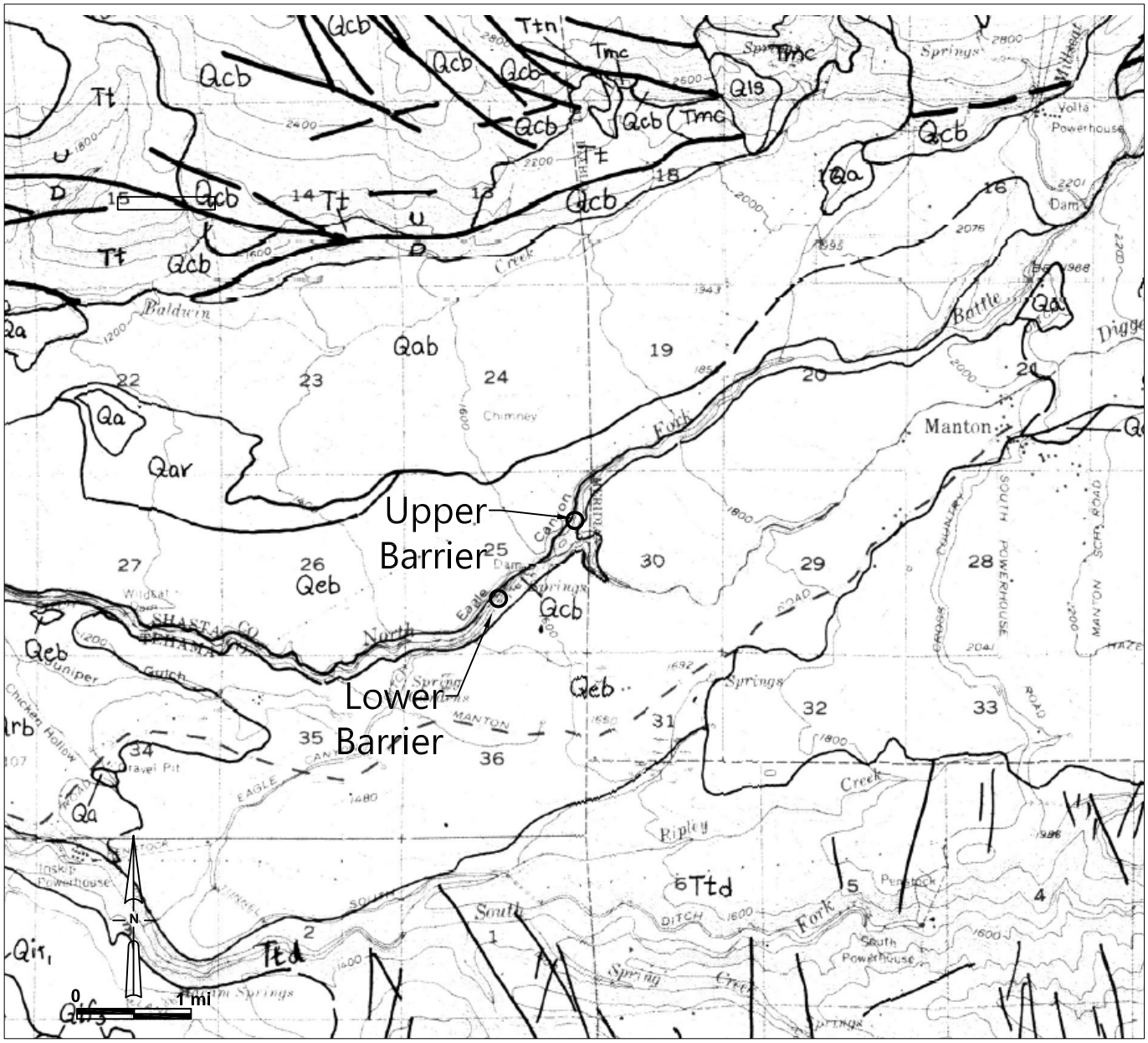


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Site Location Map

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GEO/ENG BY	SCALE	PROJECT NO.
DRM	As Shown	E5285B
APPROVED BY	DATE	FIGURE NO.
DRM	August 2016	1



Source: Harwood and Helley, 1985

Geologic Units:
Qa - Alluvium
Qab - Andesite of Brokeoff Mountain
Qar - Rockland Ash Bed
Qeb - Basalt of Eagle Canyon
Qcb - Basalt of Coleman Forebay
Ttd - Tuscan Formation

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Regional Geologic Map

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GEO/ENG BY	SCALE	PROJECT NO.
DRM	As Shown	E5334
APPROVED BY	DATE	FIGURE NO.
DRM	August 2016	2

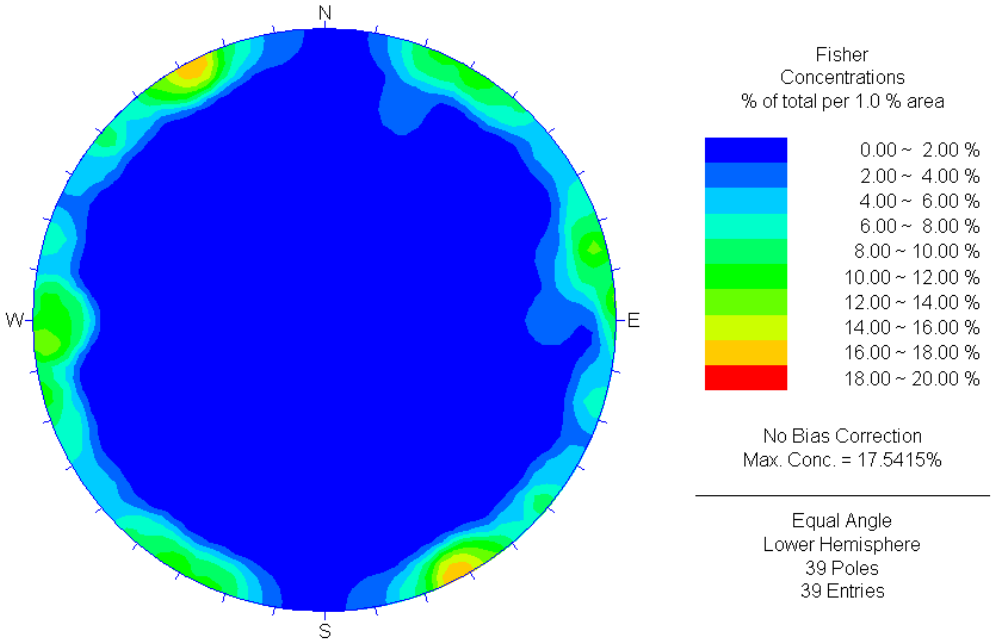


Figure 3a - Lower Hemisphere Plot

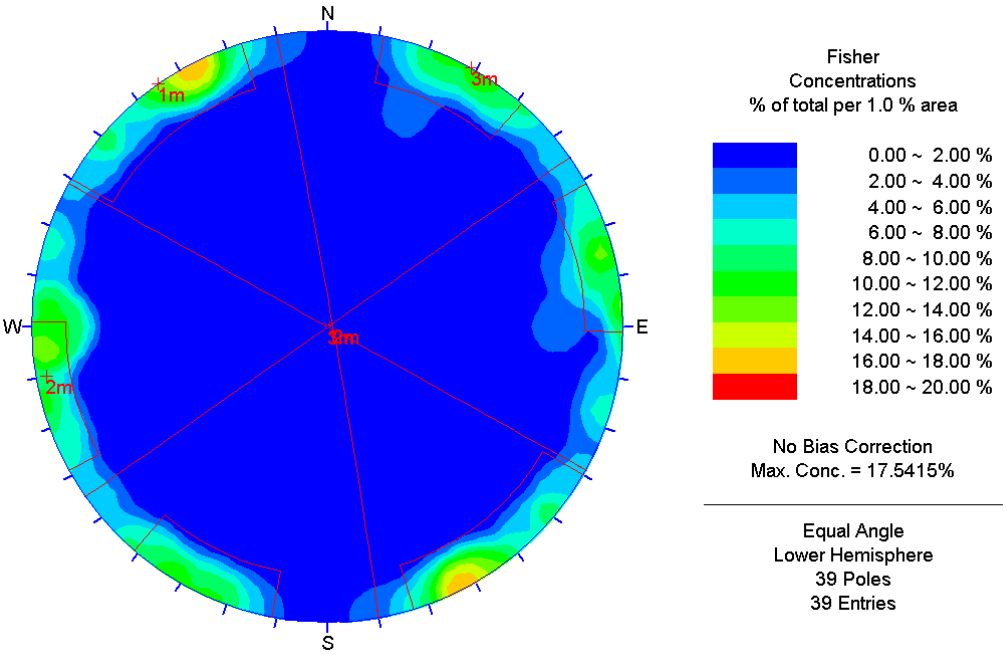


Figure 3b - Lower Hemisphere Plot With Major Joint Sets

Major Joint Sets
1) Northeast N55E, 90
2) North-South N10W, 90
3) Northwest N62W, 90

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Stereonet Plots
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DRM	August 2016	3

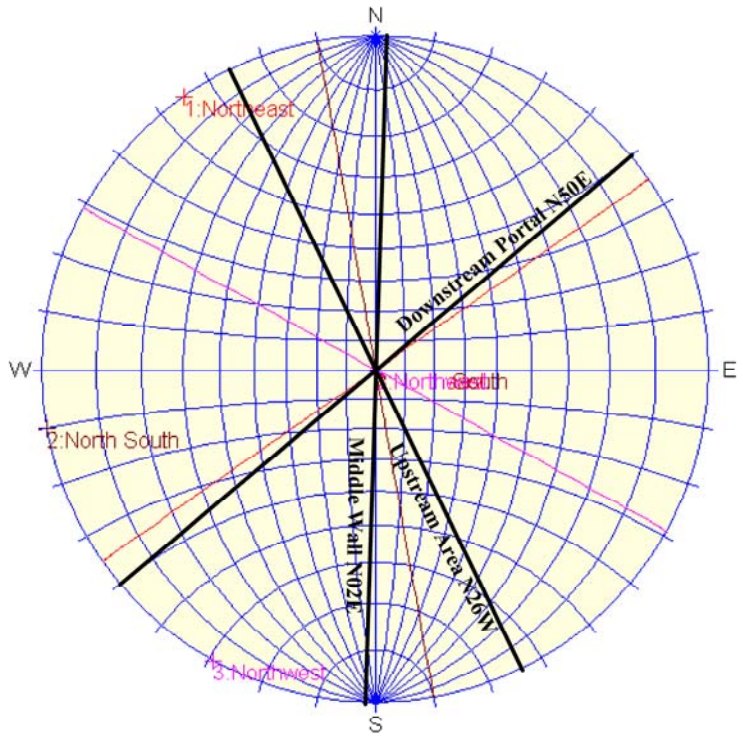


Figure 4a - Major Joint Sets and West Canyon Wall

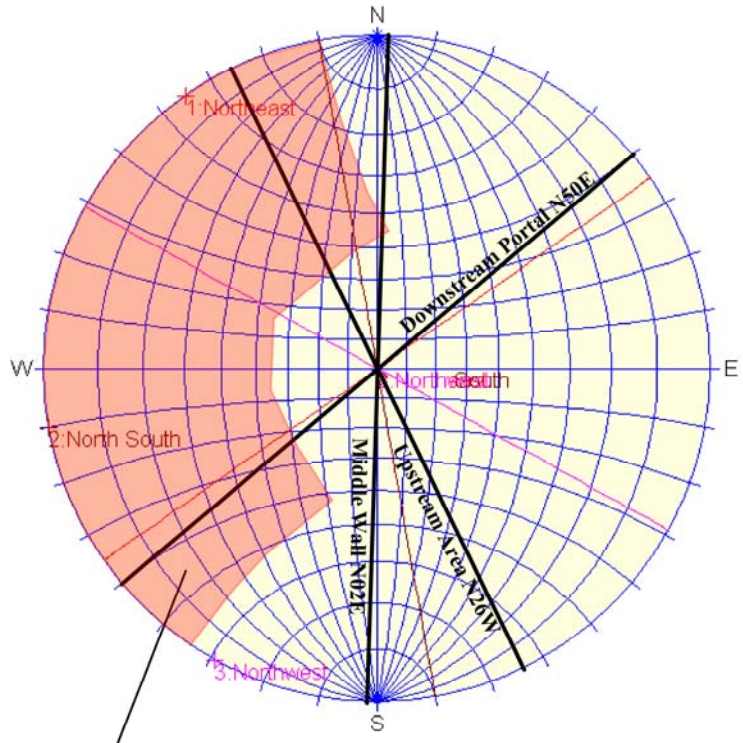


Figure 4b - Toppling Kinematic Test West Canyon Wall

Red shade denotes unsafe zones for flexural toppling

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Kinematic Analysis West Wall

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N

0 Feet 20

Land of the Giants
(multiple large detached blocks)

Geophysical line Upper RM-1 and
Geophone location

Geophysical line Upper RM-2
and Geophone location

Block E7 (166 tons)

Block E6 (66 tons)

Block E1 (40 tons)

Block E3 (3 tons)

Spillway

East Wall Geologic Face Log

0+00

1+00

2+00

CP1

CP2

CP3

CP4

CP5

CP6

CP7

CP8

Upper RM-1

Upper RM-2

1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 1.10 1.11 1.12

2.1 2.2 2.3 2.4 2.5 2.6 2.7 2.8 2.9 2.10 2.11 2.12

Flume

Headwall

Headwall

Block Party
(multiple large
detached blocks)

Fishway

Blocks W7 (20 tons), W8
(69 tons), W9 (2 tons)

Block W10 (10 tons)

Blocks W3 (87 tons),
W4 (74 tons), W5 (6 tons)

Block W1 (The Wave - 607 tons)

West Wall Geologic Face Log

End
2+86

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Concept 1 - Flume and Fish Ladder

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DRM	As Shown	E5285B
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DRM	August 2016	5

N

0 Feet 20

Land of the Giants
(multiple large detached blocks)

Geophysical line Upper RM-2
and Geophone location

Geophysical line Upper RM-1 and
Geophone location

Block E7 (166 tons)

Block E6 (66 tons)

Block E1 (40 tons)

Block E3 (3 tons)

East Wall Geologic Face Log

0+00

1+00

2+00

CP1

CP2

CP3

CP4

CP5

CP6

CP7

CP8

Upper RM-1

Upper RM-2

1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 1.10 1.11 1.12

2.1 2.2 2.3 2.4 2.5 2.6 2.7 2.8 2.9 2.10 2.11 2.12

Spillway

Headwall

Block W1 (The Wave - 607 tons)

Blocks W3 (87 tons),
W4 (74 tons), W5 (6 tons)

Blocks W7 (20 tons), W8
(69 tons), W9 (2 tons)

Block W10 (10 tons)

Tunnel

Block Party
(multiple large
detached blocks)

Fishway

West Wall Geologic Face Log

End
2+86

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Concept 2 - Tunnel and Ladder

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GEO/ENG BY	SCALE	PROJECT NO.
DRM	As Shown	E5285B
APPROVED BY	DATE	FIGURE NO.
DRM	August 2016	6

N

0 Feet 20

Land of the Giants
(multiple large detached blocks)

Geophysical line Upper RM-1 and
Geophone location

Geophysical line Upper RM-2
and Geophone location

Block E7 (166 tons)

Block E6 (66 tons)

Block E1 (40 tons)

Regrade creek bed

Larinier baffles

Block E3 (3 tons)

East Wall Geologic Face Log

0+00

1+00

2+00

CP1

CP2

CP3

CP4

CP5

CP6

CP7

CP8

Upper RM-1

Upper RM-2

1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 1.10 1.11 1.12

2.1 2.2 2.3 2.4 2.5 2.6 2.7 2.8 2.9 2.10 2.11 2.12

Cutoff wall

Cutoff wall

Block Party
(multiple large
detached blocks)

Blocks W7 (20 tons), W8
(69 tons), W9 (2 tons)

Block W10 (10 tons)

Blocks W3 (87 tons),
W4 (74 tons), W5 (6 tons)

Block W1 (The Wave - 607 tons)

West Wall Geologic Face Log

End
2+86

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Concept 3 - Regrade (Larinier)

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APPROVED BY	DATE	FIGURE NO.
DRM	August 2016	7

N

0 Feet 20

Land of the Giants
(multiple large detached blocks)

Geophysical line Upper RM-1 and
Geophone location

Geophysical line Upper RM-2
and Geophone location

Block E7 (166 tons)

Block E6 (66 tons)

Block E1 (40 tons)

Regrade creek bed

Block E3 (3 tons)

East Wall Geologic Face Log

0+00

1+00

2+00

CP5

CP1

CP4

CP6

CP3

CP2

CP7

CP8

Upper RM-1

Upper RM-2

1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 1.10 1.11 1.12

2.1 2.2 2.3 2.4 2.5 2.6 2.7 2.8 2.9

Block Party
(multiple large
detached blocks)

Blocks W7 (20 tons), W8
(69 tons), W9 (2 tons)

Block W10 (10 tons)

West Wall Geologic Face Log

End
2+86

Blocks W3 (87 tons),
W4 (74 tons), W5 (6 tons)

Block W1 (The Wave - 607 tons)

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Concept 4 - Regrade Natural

Engineering Geologic Investigation
Eagle Canyon Fish Passage Improvements in Battle Creek
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GEO/ENG BY	SCALE	PROJECT NO.
DRM	As Shown	E5285B
APPROVED BY	DATE	FIGURE NO.
DRM	August 2016	8

PLATES

EXPLANATION

EARTH MATERIALS

- Qeb: Eagle Canyon Basalt, Precipitous Wall Face with Potentially Unstable Blocks
- Qbb: Eagle Canyon Basalt Blocks in Unstable, Precarious Slope Positions
- Qa/Qsd: Alluvium, Slope Debris and Large Rock Blocks in Low Slope Positions
- Qc/Qeb: Colluvial Soil Over Eagle Canyon Basalt
- Approximate Low Flow Limits of Battle and Digger Creeks

MAP SYMBOLS

- UB-3 ● Rock Sample Location
- UB B-7 ● Bag Sample Location
- SH-W6 ● Schmidt Hammer Test Location on Canyon Wall
- SH-B11 ● Schmidt Hammer Test Location on Boulder
- 3) N62W Major Joint Set and Number
- CP-8 × Survey Control Point by GMA Hydrology
- Large Basalt Blocks Within or Near The Battle Creek Low Flow Channel

Digger Creek

Qa/Qsd

Qc/Qeb

Qbb

Qeb

"Land of the Giants" Large Block Topple Field

East Wall Geologic Face Log

West Wall Geologic Face Log

"Block Party" Unstable zone of toppling

Block Party

CP1 CP2 CP3 CP4 CP5 CP6 CP7 CP8

SH-B4 SH-B5 SH-B6 SH-B7 SH-B8 SH-B9 SH-B10 SH-B11

SH-W1 SH-W2 SH-W3 SH-W4 SH-W5 SH-W6

UB B-1 UB B-2 UB B-3 UB B-4 UB B-5 UB B-6 UB B-7 UB-1 UB-2 UB-3

CSA Field Point

0+00 1+00 2+00 End 2+86

1) N55E 90 2) N10W 3) N62W

Two detached boulders (5'x5'x7', 9'x5'x7',)

Detached boulder at edge (7'x6'x5?')

Two dilated boulders at edge

Dilated rock topple forming, 1'+ movement

Open joint forming large detached block

Large toppling block, 6'x6'x20'

Possible wedge pillar forming

North Fork Battle Creek

N

0 Feet 20

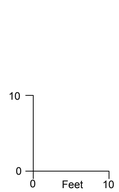
The topographic base map was prepared by GMA Hydrology using data acquired between July 13 and November 4, 2015. Primary geodetic control was taken from existing monuments established by the California Department of Water Resources, and the datums are assumed to be NAD 1983 horizontal, and NAVD 1988 vertical. Eight control points were established using GNSS and total station techniques. The topography was surveyed using a ground based laser scanner, and total station surveying.

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Engineering Geologic Map

Engineering Geologic Investigation
Eagle Canyon Fish Passage Improvements in Battle Creek
Shasta and Tehama Counties, California

GEO/ENG BY DRM/JW	SCALE 1"10'	PROJECT NO. E5285B
APPROVED BY DRM/JW	DATE August, 2016	PLATE NO. 1

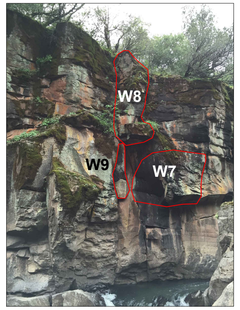


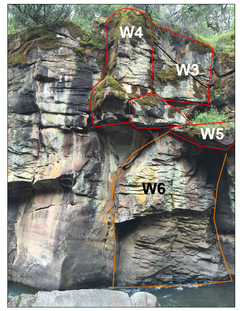




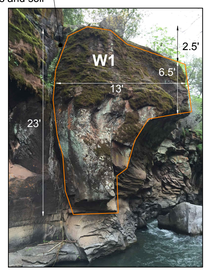












Back Joint □N10W, 90, e□tension of u/s face, dilated □1-2' at top, filled □ith grass and soil

The Wave Block Profile Sketch (nts)
Vie□ to North (upriver)

Soil Covered Slope

□Overall N70E, NV (estimated from ground), very irregular and wavy, ±30° strike and dip

Su□hori□ontal flo□ structures (possi□le □lock 2' thick)

Overhang 10'W□5'H□8'T

W23

N60W, NV, estimated from ground

Overall face N50W, 90

Overhanging □edge, formed □y planes N50-57W, 90, N55-65E, 90

Wedge intersection

Wedge forming □oint face N55-64E, NV

Toppling □lock, e□tension crack controls □ackside, 10'-12' thick

Large Oak Tree

Wedge failure (evacuated)

Partially detached □edge (unsupported □elo□), Triangular 6'□7'□20' tall

Soil Covered Slope

Potential □edge failures

See plan sketch

See plan sketch

Face □N10W, 90, no signs of insta□ility

N10W 90, open □oint at top, 1 to 2 ft □ide, infilled □ith soil and vegetation

W12

W13

Open Crack 2-3""

Open Crack 2"

Overhangs, 10'-12' deep

Thin □edded flo□ deposits

Block, 8'W□15'H□3'T

Wedge forming □oint N50-57W, NV

W15

W16

W17

Gaps

W14

Detached Block 10'□20'□10'

Undercut □lock, 10'□10'□4'

Block, 3'W□5'H□0.5'T

W22

Flake topple, 10'□2'□8'

Thin □edded flo□ deposits

W10

W8

Partially detached sla□ 10'□8'□3'

W4

W3

Shelf

W5

Triangular shaped □lock 5'□5'□3' thick

5' deep overhang

6' deep overhang

W6

W2

W1

Vertical Cliff Face

N80E, NV, open 1-2", vegetation gro□th

□NS 85E

Iron o□ide stain

NS □75W

Block, 3'W□12'H□3'T

W24

NS 85E

N15W 80SW Planar

N10W 80-90E, open 1"-2"

D/S Tunnel Portal Concept 2

Intersection □/ CSA-1 at St. 2+64

N70W, 90, open 3"-□ottom, 12"+ at top

Broad curving face (appro□imate a□is St. 2+28)

Block, 8'W□12'H□□'T

□NS 85E

W18

W19

6'□3'□4' Wedge □lock

Cave

W20

N12E, NV

N34W, NV

N22E, NV

W21

Toppling Block 15' tall, 18' □ide, 5'□ thick

Toppling Block 14'□8'□10'

Loose Block 10'□25'□10'

Ru□□le/Alluvium or Water

"Block Party"

Ru□□le/Alluvium or Water

Ru□□le/Alluvium or Water

34.5' at N86W to CP-6 (Estimated El. 1513.7)

Wedge failure, 25' tall (evacuated)

1/2-1" open

4.5' deep overhang

Overhangs

In place 1.5'□2'□10'

W9

W7

Overhang, □3'□4'

Wedge failure, 16' tall (evacuated)

Wedge failure 16' tall

Wedge failure 25' tall (evacuated)

Concrete Wall (Larinier Concept 3)

13' at N68E to CP-7 (Estimated El. 1504.0)

2' deep overhang

Portal (Tunnel Concept 2)

hori□ontal stress fractures

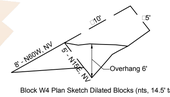
Headworks Concrete Wall (Flume Concept 1)

Headworks Concrete Wall (Tunnel Concept 2)

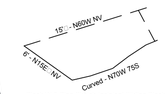
Headworks Concrete Wall (Larinier Concept 3)

23.5' at E-W to CP-8 (Estimated El. 1501.3)

1,500 msl, average of 3 hand laser measurements from CP's to □all (2.2 feet vertical variation □et□een high and lo□)



Block W4 Plan Sketch Dilated Blocks (nts, 14.5' tall)



Block W-3 Plan Sketch Incipient Sliding Block (nts, 14-15' tall)

Mapped using ground measurements and height estimates

Mapped using LiDAR point cloud hori□ontal vie□

Mapped using LiDAR point cloud hori□ontal vie□

2+80 2+60 2+40 2+20 2+00 1+80 1+60 1+40 1+20 1+00 0+80 0+60 0+40 0+20 0+00

2+86 2+21

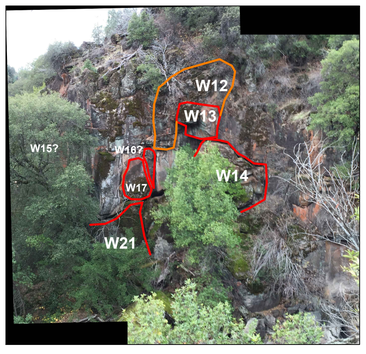
N47E 2+28 N10E 1+88 N35E 1+71 N11W 1+15 N26W 0+78 N30W 0+31 N29E 0+16 NS 0+09 N35W

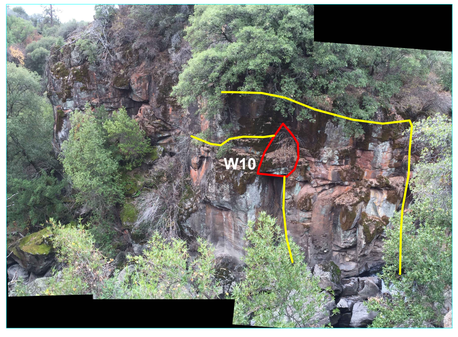
LEGEND

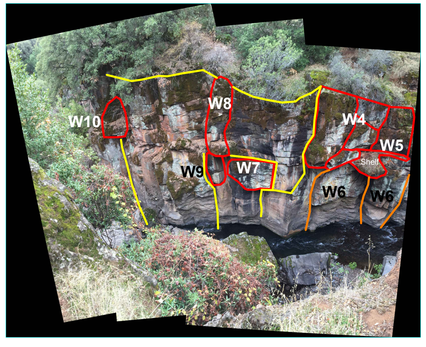
- High - Failure could occur at any time, □ut likely □ithin 10 years
- Moderate to High - Failure likely □ithin 10 to 50 years
- Moderate - Failure possi□le in 50 to 100 years
- Lo□ - Failure unlikely □ithin 100 years

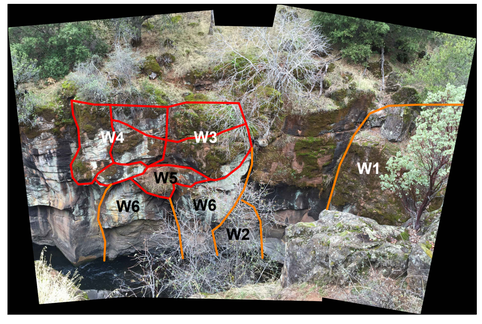
Notes□

- All Block dimensions given as Wide (W) □y High (H) □y Thickness (T), unless other□ise noted.
- NV = Near Vertical









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West Wall Geologic Face Log

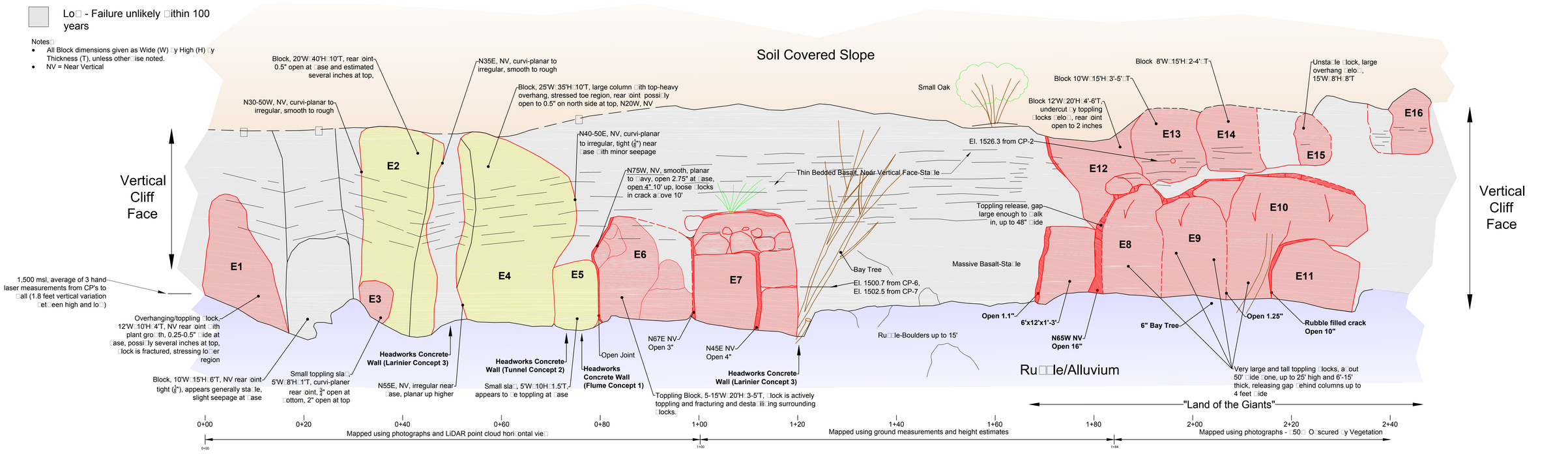
Engineering Geologic Investigation
Eagle Canyon Fish Passage Improvements in Battle Creek
Shasta and Tehama Counties, California

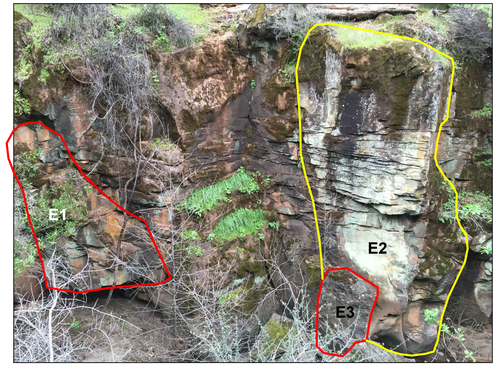
GEO/ENG BY	SCALE	PROJECT NO.
DRM/JW	1"=10'	E5285
APPROVED BY	DATE	PLATE NO.
DRM/JW	August, 2016	2

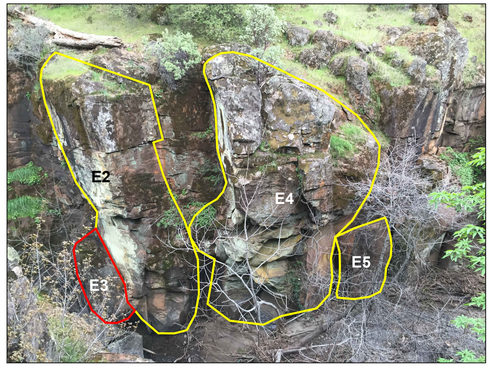
LEGEND

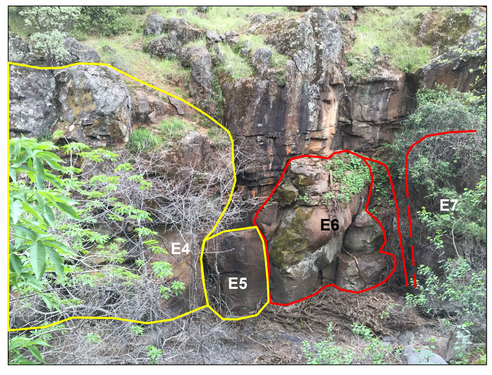
- High - Failure could occur at any time, □ut likely □ithin 10 years
- Moderate to High - Failure likely □ithin 10 to 50 years
- Moderate - Failure possi□le in 50 to 100 years
- Lo□ - Failure unlikely □ithin 100 years

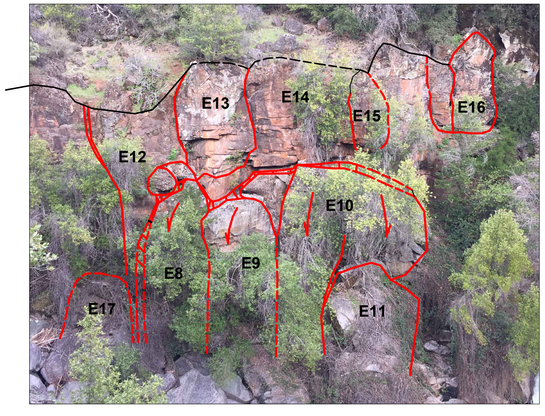
Notes□
- All Block dimensions given as Wide (W) □y High (H) □y Thickness (T), unless other□ise noted.
- NV = Near Vertical











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East Wall Geologic Face Log - Upper Barrier
Engineering Geologic Investigation
Eagle Canyon Fish Passage Improvements in Battle Creek
Shasta and Tehama Counties, California

GEO/ENG BY DRM/JW	SCALE 1"=10'	PROJECT NO. E5285
APPROVED BY DRM/JW	DATE August, 2016	PLATE NO. 3

Loose □oulders on slope generally less than 2'-3', several 5'W □5'H ⁄ 5'T. If mo□ili□ed, □ill □e funneled to □est side of this topographic catchment area. Ha□ard generally lo□ (static) to lo□ to moderate (seismic)

Flakes forming on cliff, □2" gap at top, 8'W□3'T, height not kno□n (15'+□), lo□ to moderate ha□ard

Large sloping overhang, small □locks less than 3' most likely, □ut larger □locks possi□le, lo□ ha□ard

Small detached □lock a□ove flume, 3'W □3'H □4'T, □ill □e slo□ed or stopped □y flume

6'-7' overhang □elo□ stairs, large 10'+ □lock possi□le, □ut flume footings should dissipate energy

Incipient block topple
15'W x 40'H x 4'-8'T,
small $\frac{1}{4}$"-2" crack at top

Up to 50' vertical to near-vertical cliff, generally thinly bedded basalt 6 inches to 4' thick, generally small blocks possible, no obvious dilations suggesting large blocks, some 3' to 4' overhangs, low hazard

30'-50' near-vertical cliff, generally small blocks (less than 5'), no obvious large dilations, some overhangs but joints fairly tight, low hazard

LB1

LB B-2

LB2

SH-B2

SH-B3

SH-B1

SH-B4

LB B-1

Zone of apparent detached or partially detached boulders. Area off limits during mapping, so hazard estimated from distance to be low (static) and low to moderate (seismic)

Thin Flake
10'W x 5'H x 0.5'T

Heavy seepage along base of near-vertical massive basalt rock face

Block (Flake), 6-inch wide tension crack at top of block, seepage at base
8'W x 10'H x 3'T

Incipient block topple, heavy seepage from fractures at toe, large (6-inch) tension crack at top,
20'-25'W x 40'H x 8'-10'T

Block 10'W x 12'H x 7'T

Tall column of unstable, stacked blocks, approximately 8'-20'W x 50'H x 5'-15'T

Block 9'W x 12'H x 5'T,
1"-2" open crack

N

0 Feet 20

The topographic □ase map □as prepared □y GMA Hydrology using data ac□uired □et□een July 13 and Novem□er 4, 2015. Primary geodetic control □as taken from e□isting monuments esta□lished □y the California Department of Water Resources, and the datums are assumed to □e NAD 1983 hori□ontal, and NAVD 1988 vertical. Eleven control points □ere esta□lished using GNSS and total station techni□ues. The topography □as surveyed using a ground □ased laser scanner, and total station surveying. The aerial photograph □as taken □y GMA Hydrology using a drone on Novem□er 2, 2015. The photograph □as not ortho-corrected. Cotton, Shires and Associates, Inc. scaled and stretched the photograph to match the topography, ho□ever, the fit is appro□imate and the photograph is included for visual purposes only.

LEGEND

- High - Failure could occur at any time, □ut likely □ithin 10 years
- Moderate to High - Failure likely □ithin 10 to 50 years
- Moderate - Failure possi□le in 50 to 100 years
- Lo□ - Failure unlikely □ithin 100 years

SH-B4 Schmidt Hammer Location

LB B-2 Bag Sample Location

LB2 Rock Core Sample Location

Seepage

Notes□

- All Block dimensions given as Wide (W) □y High (H) □y Thickness (T), unless other□ise noted.
- NV = Near Vertical

COTTON, SHIRES AND ASSOCIATES, INC.
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Reconnaissance Map - Lower Barrier

Engineering Geologic Investigation
Eagle Canyon Fish Passage Improvements in Battle Creek
Shasta and Tehama Counties, California

GEO/ENG BY DRM/JW	SCALE 1"=20'	PROJECT NO. E5285
APPROVED BY DRM/JW	DATE August, 2016	PLATE NO. 4

APPENDIX A

Geophysical Exploration

APPENDIX A
GEOPHYSICAL EXPLORATION

1.0 INTRODUCTION

In this appendix, we describe the methods and equipment used, interpreted results, limitations and references of our geophysical exploration of two sites located along Battle Creek in the Eagle Canyon area of Plumas County, California. The geophysical exloration consisted of the performance of two Refraction Microtremor (ReMi) shear wave survey lines at each of two sites (downstream and upstream) for a total of four (4) ReMi lines.

1.1 Project Description

The project consists of mitigating two barriers along Battle Creek, (the Upper Barrier and the Lower Barrier), to improve fish migration. In order to facilitate the foundation type selection for several of the mitigation alternatives, Cotton, Shires and Associates, Inc. (CSA) was charged with investigating the subsurface conditions at the upstream and downstream barriers, and hopefully determining the thickness of boulders and depth of bedrock in the creek channel. CSA elected to use ReMi surveying as the most appropriate geophysical tool to evaluate the thickness of boulders and depth of bedrock because high flows in the channel generate too much noise for seismic refraction surveying and ReMi surveying uses surface wave noise to generate spectral wave input for determining shear wave velocity profiles with depth.

1.2 Purpose and Scope of Investigation

The purpose of our investigation was to: 1) investigate two subsurface shear wave velocity profiles at each of the two barrier sites using ReMi geophysical methods; and to 2) evaluate the thickness of boulders over bedrock in the vicinity of the two barriers. The scope of work included two field ReMi surveys on consecutive days followed by geophysical analysis of the acquired data, geologic analysis of the subsurface conditions with respect to the proposed channel improvements and preparation of this appendix to our report.

1.3 Geologic and Topographic Setting

The Upper and Lower Barrier sites are characterized by a deeply incised channel that has downcut through volcanic bedrock with large and small boulders that have dislodged from the steep canyon walls and fallen into the creek channel. The canyon walls are very steep (vertical to overhanging in places) and the creek channel is full of large and small irregularly shaped boulders in a sand and gravel matrix. During the time of our surveys, flow in the creek channel was approximately 500 cubic-feet-per-second.

2.0 ReMi SURVEY

A total of two (2) individual ReMi (Refraction Microtremor) lines with spread lengths (distance between first and last geophones) of approximately 110 feet each were recorded on February 29, 2016 at the Lower Barrier site and two (2) individual ReMi lines with spread lengths of approximately 110 feet each were recorded on March 1, 2016 at the Upper Barrier site. Locations of the ReMi lines* are depicted on Figure A1, ReMi Shear Wave Survey Line Locations, and interpreted results are presented on Figures A2 through A5 for the Lower Barrier site and A6 through A9 for the Upper Barrier site. The method and equipment used, the interpreted results, limitations and a summary of pertinent conclusions are discussed in the following sections of this report.

2.1 ReMi Method and Equipment Used

The ReMi survey procedure used consisted of placing twelve (12) geophones in as straight a line as practical (in plan) spaced at approximate 10-foot intervals along as constant a slope as practical (in profile). Surface waves were generated by the creek flow and two staff personnel walking back and forth adjacent to the lines. The creek flow and walking generated seismic surface (Rayleigh) waves which were received by the deployed geophones. The surface waves were monitored for seven individual periods of 30 seconds each by a digital seismograph with an on-board computer and displayed graphically in analog form on a computer monitor. Digital records stored in the computer were field checked, stored on a hard drive and returned to our office for data reduction and interpretation. Processing was conducted using the computer program SeisOpt ReMi Version 4.0 by Optim Software and Data Solutions (2006) and included a spectral analysis of the surface waves by making picks on the dispersion model and plotting the period, s, against the Rayleigh wave phase velocity in feet per second for both calculated dispersion and picked dispersion [see attached ReMi Survey Data (Supportive Illustration)]. Finally, a plot of shear wave velocity, Vs, in feet per second with depth in feet was produced from this information [see attached ReMi Shear Wave Model (Vs Model)]. Shear wave velocity was interpreted as an average velocity with depth for the entire line beneath the centers of each 12-geophone array.

The equipment used for the ReMi seismic survey consisted of twelve (12) geophones of 4.5 Hz natural frequency. The geophones were connected to a 10-foot take-out spacing (gathered to accommodate smaller spacings) cable using Mueller clips. The cables were connected to the 24-channel DAQ II seismograph that was controlled using a field laptop computer.

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* For the purposes of this report, a ReMi line is defined as twelve geophones spaced at equal intervals of approximately 10 feet along a straight line and monitored

simultaneously while the creek flows adjacent to the line and personnel walk adjacent to each twelve-geophone array.

2.2 Interpreted ReMi Results (Lower Barrier Site)

ReMi survey lines Lower RM-1 and Lower RM-2 were both 110-foot long lines that were recorded at the Lower Barrier site in the locations shown on Figure A1. ReMi data are presented on Figures A2 and A4, and results are presented on Figures A3 and A5 for lines Lower RM-1 and Lower RM-2, respectively.

Survey line Lower RM-1 was performed directly adjacent to the flowing creek channel on the left bank (facing downstream). Survey line Lower RM-2 was performed in a rockfall debris pile upslope of the left bank of the creek channel between the steep canyon walls and the flowing creek (see Figure A1). The following table presents the average shear wave velocities recorded for the two Lower Barrier lines over the indicated depth intervals beneath the centers of the lines.

Line No.	Depth Interval (feet)	Shear Wave Velocity (feet/second)
Lower RM-1	0 – 1.3	392
Lower RM-1	1.3– 7.7	496
Lower RM-1	7.7 – 10.2	878
Lower RM-1	10.2 – 14.2	998
Lower RM-1	14.2 – 18.8	2,264
Lower RM-1	18.8 – 50.0	3,389
Lower RM-2	0 – 1.0	162
Lower RM-2	1.0 – 3.7	907
Lower RM-2	3.7 – 6.2	1043
Lower RM-2	6.2 – 10.0	1404
Lower RM-2	10.0 – 20.8	2,218
Lower RM-2	20.8 – 50.0	3,393

Based on these shear wave velocity profiles, it appears that boulders and sand matrix extends to a depth of 14 feet below the creek channel bottom along line Lower RM-1. Below 14 feet, there is a marked increase in shear wave velocity from less than 1,000 feet per second to over 2,200 feet per second which indicates the likelihood of relatively fresh volcanic bedrock (Figure A-10). The rockfall debris pile beneath line Lower RM-2 likely extends to a depth of approximately 10 feet beneath the ground surface. Below 10 feet, there is a marked increase in shear wave velocity from about 1,400 feet per second to over 2,200 feet per second, which indicates the likelihood of relatively fresh volcanic.

2.3 Interpreted ReMi Results (Upper Barrier Site)

ReMi survey lines Upper RM-1 and Upper RM-2 were both 110-foot long lines that were recorded at the Upper Barrier site in the locations shown on Figure A1. ReMi data are presented on Figures A6 and A8, and results are presented on Figures A7 and A9 for lines Upper RM-1 and Upper RM-2, respectively.

ReMi line Upper RM-1 was performed directly adjacent to the flowing creek channel on the left bank at the upstream end of the Upper Barrier Site. ReMi line Upper RM-2 was performed on the right bank at the downstream end of the Upper Barrier Site. The following table presents the average shear wave velocities recorded for each Upper Barrier Site line over the indicated depth intervals beneath the centers of the lines.

Line No.	Depth Interval (feet)	Shear Wave Velocity (feet/second)
Upper RM-1	0 – 1.0	342
Upper RM-1	1.0– 1.9	275
Upper RM-1	1.9 – 3.5	342
Upper RM-1	3.5 – 5.6	1,405
Upper RM-1	5.6 – 8.0	2,263
Upper RM-1	8.0 – 50.0	3,482
Upper RM-2	0 – 1.0	342
Upper RM-2	1.0 – 1.9	416
Upper RM-2	1.9 – 6.6	600
Upper RM-2	6.6 – 8.6	1,049
Upper RM-2	8.6 – 11.0	2,263
Upper RM-2	11.0 – 50.0	3,443

Based on these shear wave velocity profiles, it appears that boulders and a sand matrix extend to a depth of approximately 6 feet below the creek channel along line Upper RM-1. Below 6 feet, there is a marked increase in shear wave velocity from about 1,400 feet per second to over 2,200 feet per second which indicates the likelihood of relatively fresh volcanic bedrock (Figure A-11). The boulders and sand matrix beneath line Upper RM-2 likely extends to a depth of approximately 9 feet beneath the ground/boulder surface. Below 9 feet there is a marked increase in shear wave velocity from less than 1,100 feet per second to over 2,200 feet per second which indicates the likelihood of relatively fresh volcanic bedrock.

3.0 INVESTIGATION LIMITATIONS

The subsurface shear wave velocity profiles presented in this report represent the most reasonable interpretation of geophysical survey data based on our limited knowledge of the existing geologic conditions at the site. The results are presented for

evaluation information only and are not intended to serve as information for determining construction procedures. Interpretations were made in accordance with generally accepted geophysical methods and practices. This warranty is in lieu of all other warranties, express or implied.

The quality of ReMi data for this survey was limited due to the irregular topography and boulders. These factors limit the accuracy of spectral signatures and interpretation. ReMi results should be correlated with direct subsurface exploration and subsurface exploration has not been conducted at these sites yet. Consequently, it should be understood that additional correlation would be desirable to confirm interpretations. The maximum depth of reliable ReMi results was limited to approximately 50 feet beneath the middle of each line. These results are not intended to determine construction proceedures and the contractor should make their own interpretation of excavation conditions.

4.0 REFERENCES

Optim Software and Data Solutions (2006), SeisOpt ReMi Version 4.0.

Untitled and undated topographic map of the site.

Lower Site

Lower RM-1
GP1.12
GP1.11
GP1.10
GP1.9
GP1.8
GP1.7
GP1.6
GP1.5
GP1.4
GP1.3
GP1.2
GP1.1
B7
B6
B4

Lower RM-2
GP2.12
GP2.11
GP2.10
GP2.9
GP2.8
GP2.7
GP2.6
GP2.5
GP2.4
GP2.3
GP2.2
GP2.1

Midpoint of ReMi Survey
Average Geophone Elevation = 1367.5'
(Location of Lower RM-1 Vs Model, Figure A3)

Midpoint of ReMi Survey
Average Geophone Elevation = 1374.2'
(Location of Lower RM-2 Vs Model, Figure A5)

North

0 15 30 60
(feet)

Upper Site

Upper RM-1
GP1.1
GP1.2
GP1.3
GP1.4
GP1.5
GP1.6
GP1.7
GP1.8
GP1.9
GP1.10
GP1.11
GP1.12
CP8
CP7
CP6

Midpoint of ReMi Survey
Average Geophone Elevation = 1491.1'
(Location of Upper RM-1 Vs Model, Figure A7)

CP3
CP4
CP5

Upper RM-2
GP2.1
GP2.2
GP2.3
GP2.4
GP2.5
GP2.6
GP2.7
GP2.8
GP2.9
GP2.10
GP2.11
GP2.12
CP1
CP2

Midpoint of ReMi Survey
Average Geophone Elevation = 1477.7'
(Location of Upper RM-2 Vs Model, Figure A9)

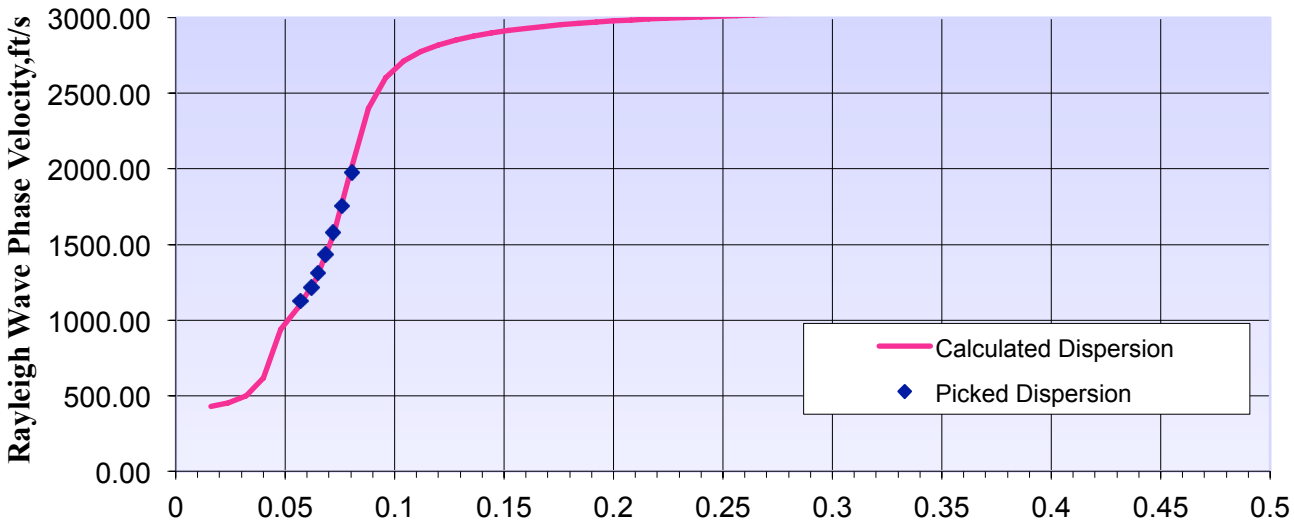
COTTON, SHIRES AND ASSOCIATES, INC.
CONSULTING ENGINEERS AND GEOLOGISTS

ReMi Shear Wave Line Location Map
Engineering Geologic Investigation
Eagle Canyon Fish Passage Improvements in Battle Creek
Shasta and Tehama Counties, California

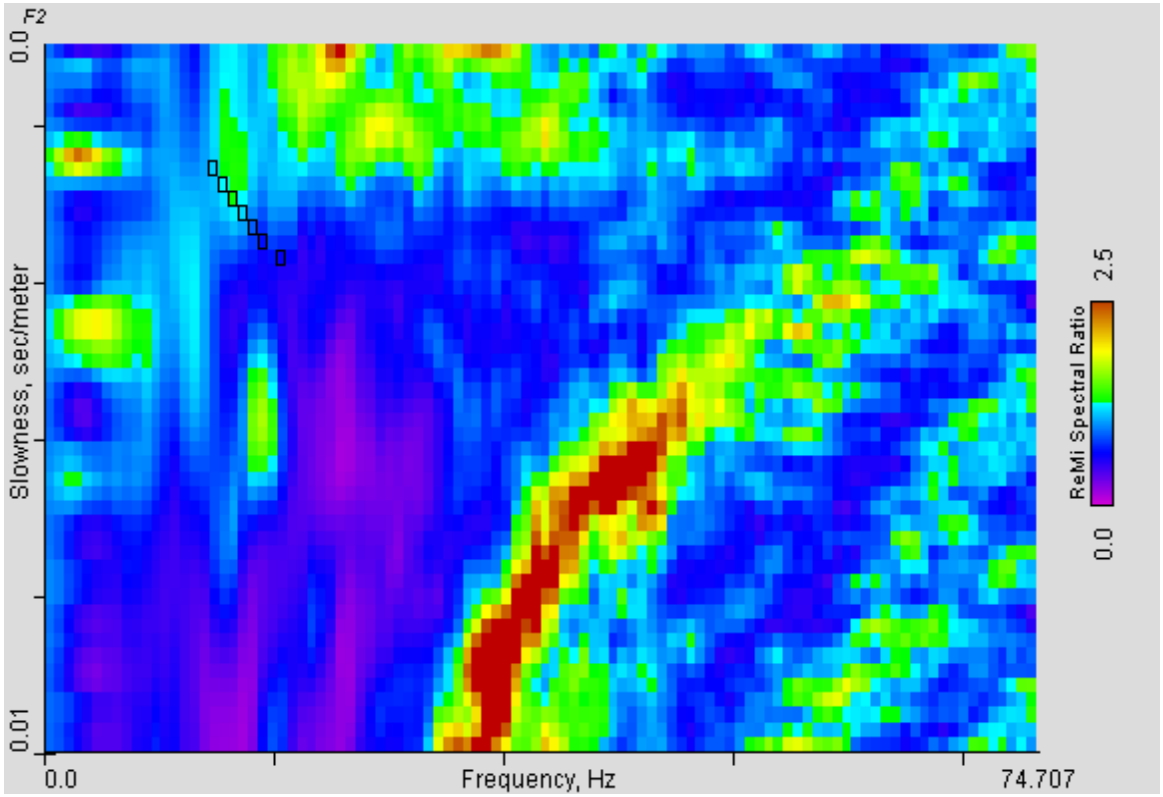
GEO/ENG BY	SCALE	PROJECT NO.
POS/MMP	1"=30'	E5285
APPROVED BY	DATE	FIGURE NO.
POS	August 2016	A1

Lower RM-1: Supportive Illustration

Dispersion Curve Showing Picks and Fit

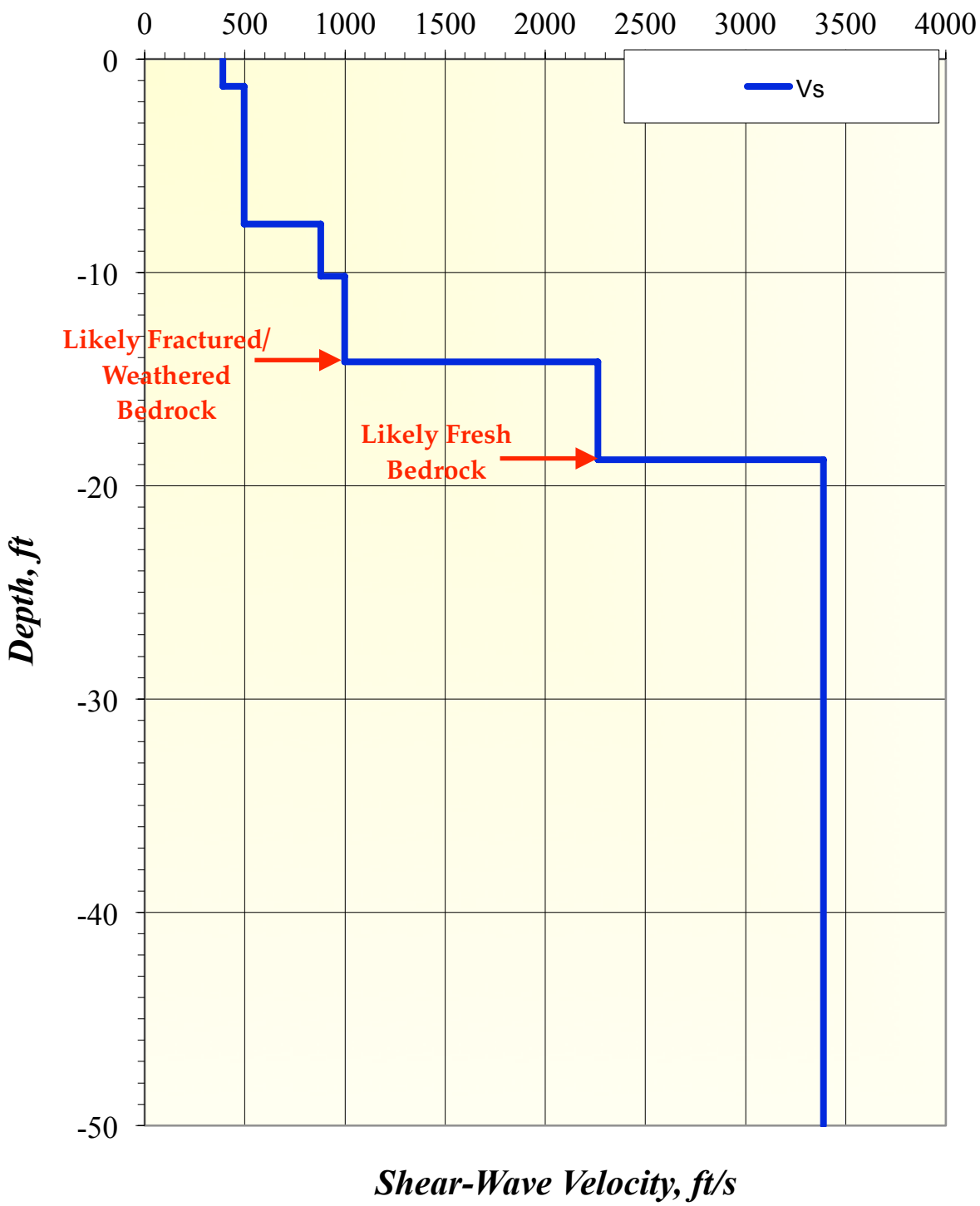


p-f Image with Dispersion Modeling Picks



Eagle Canyon ReMi Survey
Lower RM-1 Supportive Illustration
Figure A2

COTTON, SHIRES AND ASSOCIATES, INC.

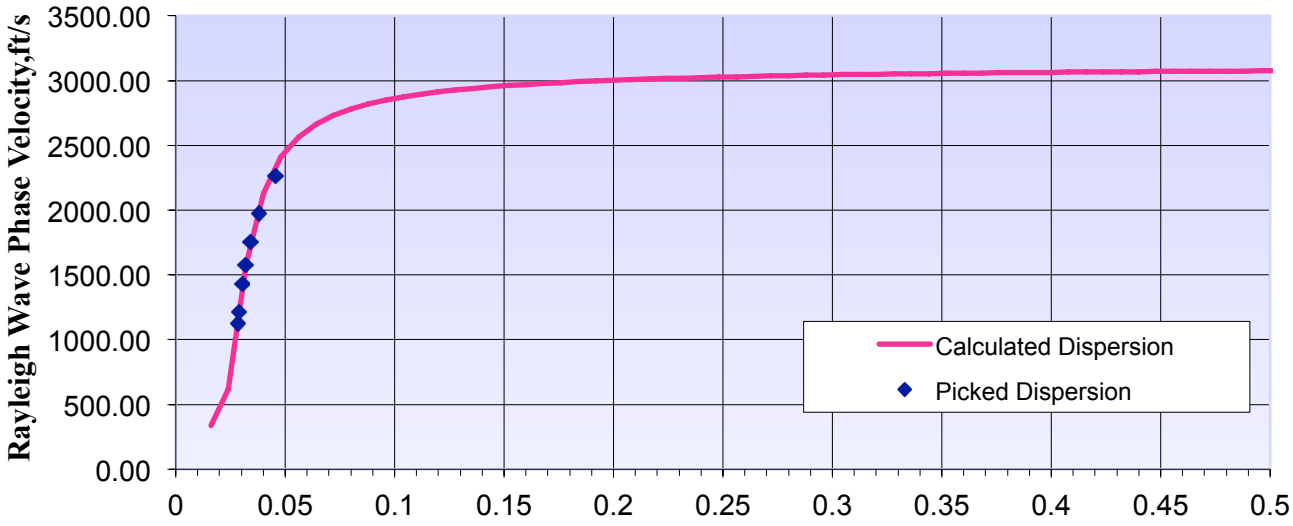


Eagle Canyon ReMi Survey
Lower RM-1 Vs Model
Figure A3

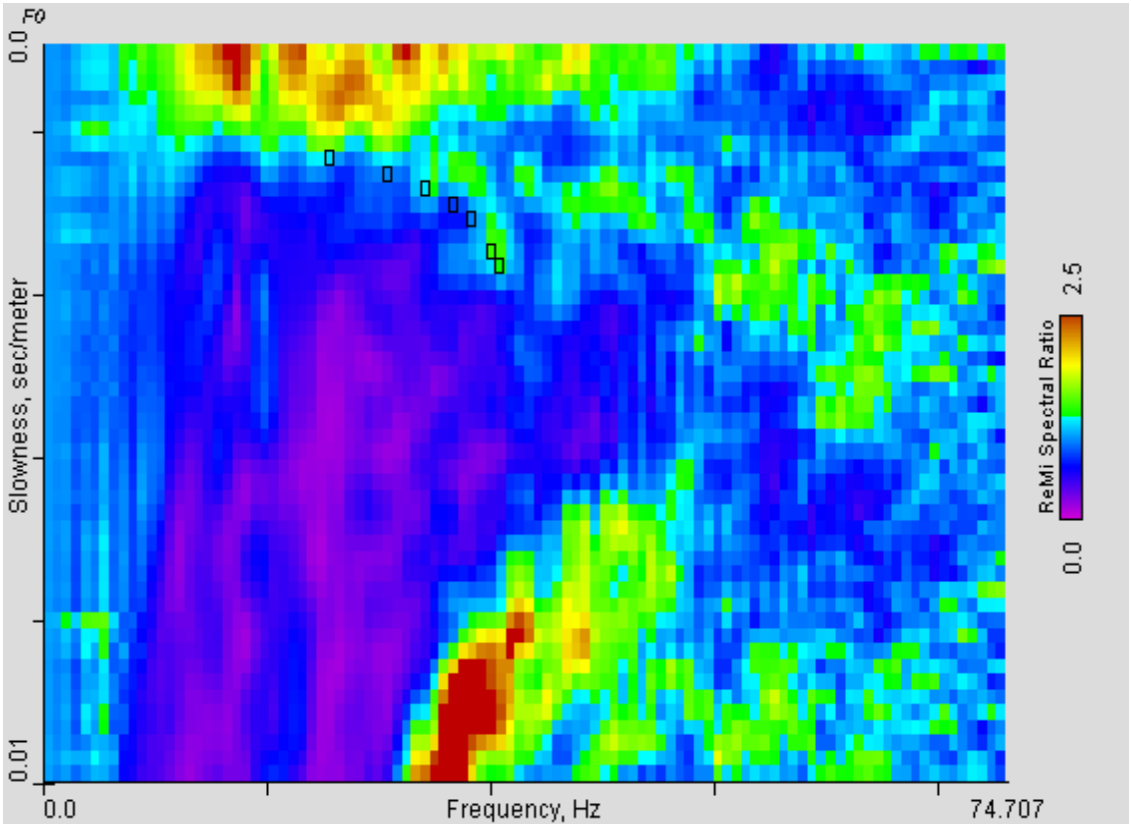
COTTON, SHIRES AND ASSOCIATES, INC.

Lower RM-2: Supportive Illustration

Dispersion Curve Showing Picks and Fit

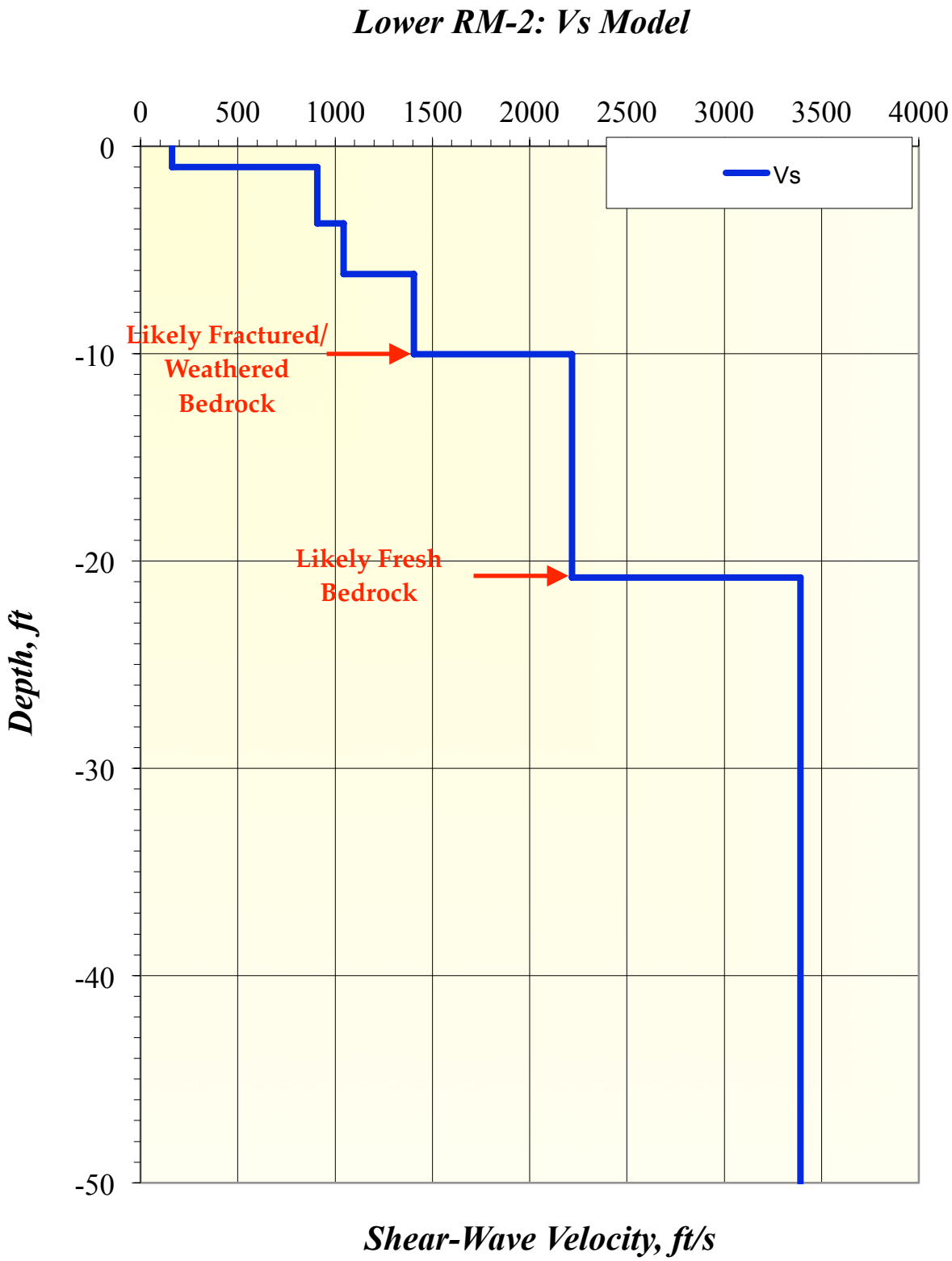


p-f Image with Dispersion Modeling Picks



Eagle Canyon ReMi Survey
Lower RM-2 Supportive Illustration
Figure A4

COTTON, SHIRES AND ASSOCIATES, INC.

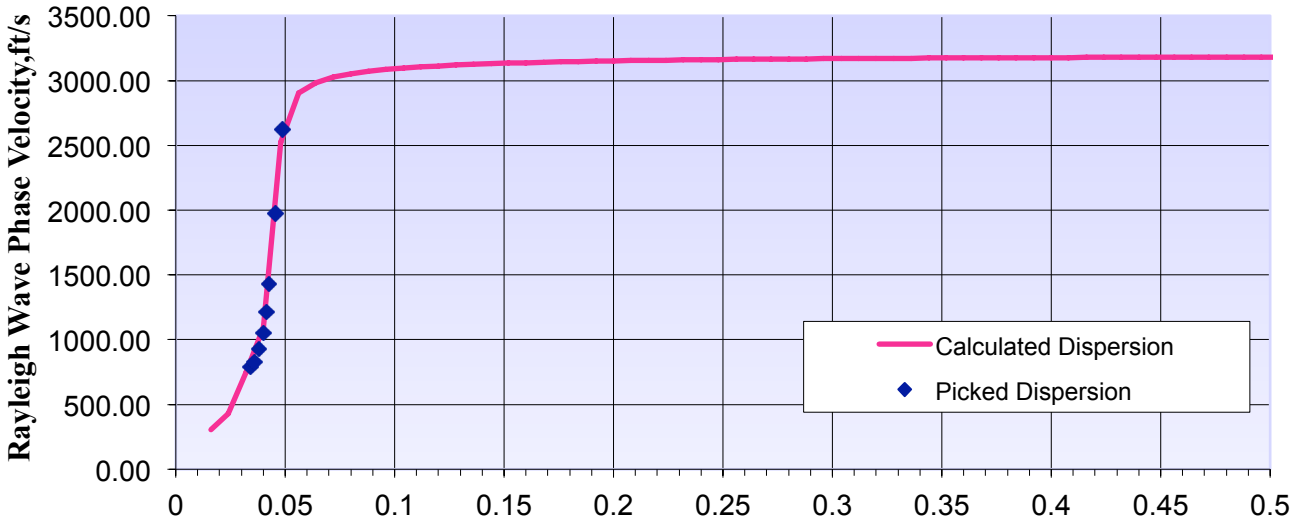


Eagle Canyon ReMi Survey
Lower RM-2 Vs Model
Figure A5

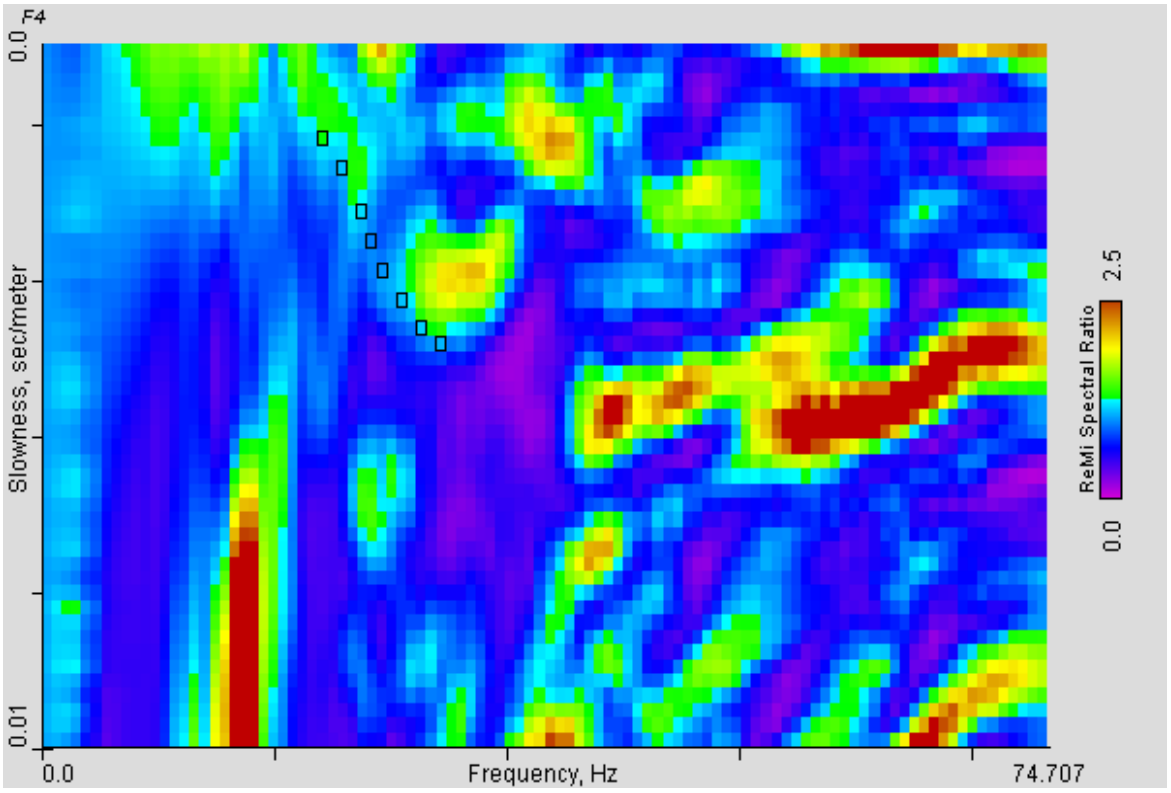
COTTON, SHIRES AND ASSOCIATES, INC.

Upper RM-1: Supportive Illustration

Dispersion Curve Showing Picks and Fit

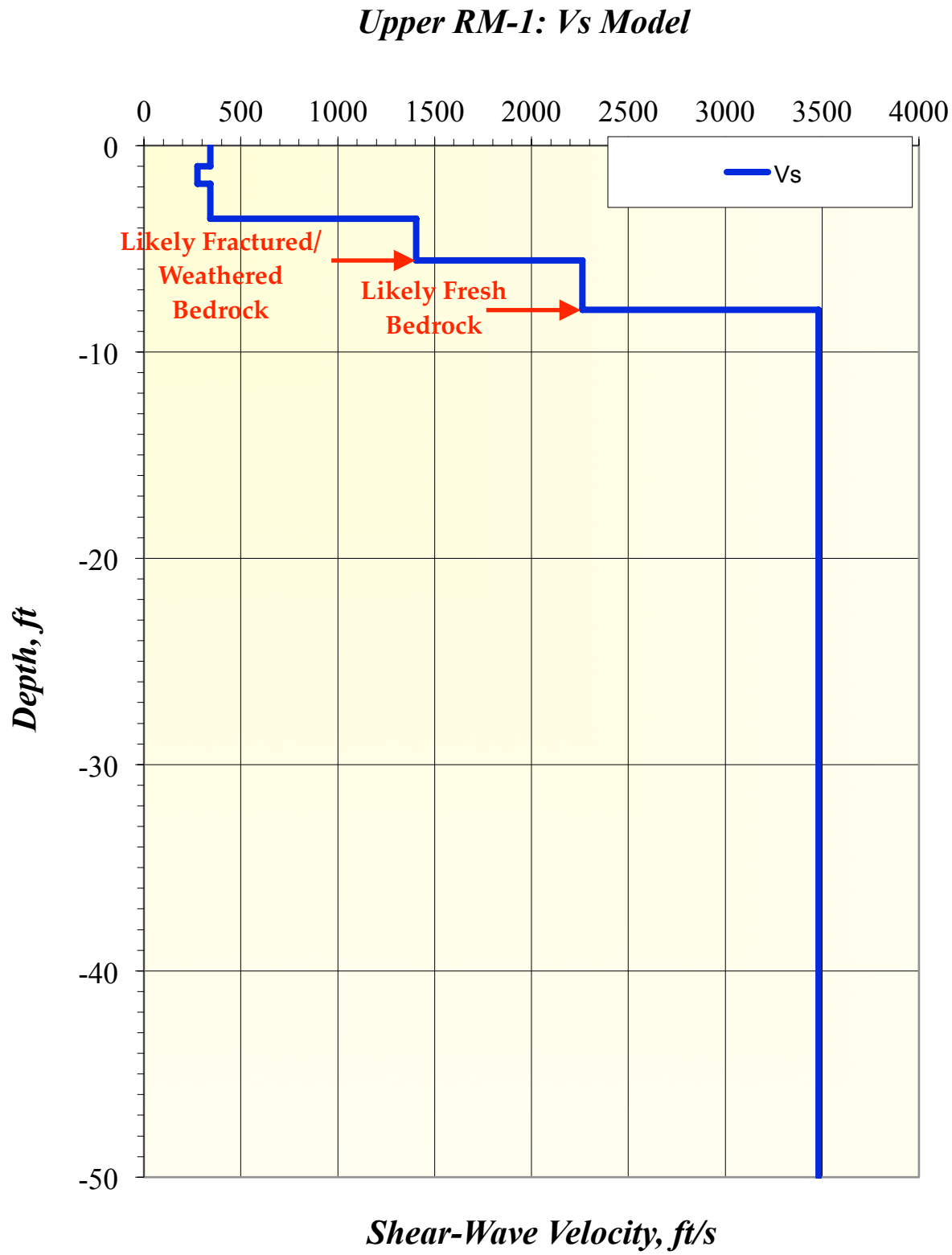


p-f Image with Dispersion Modeling Picks



Eagle Canyon ReMi Survey
Upper RM-1 Supportive Illustration
Figure A6

COTTON, SHIRES AND ASSOCIATES, INC.

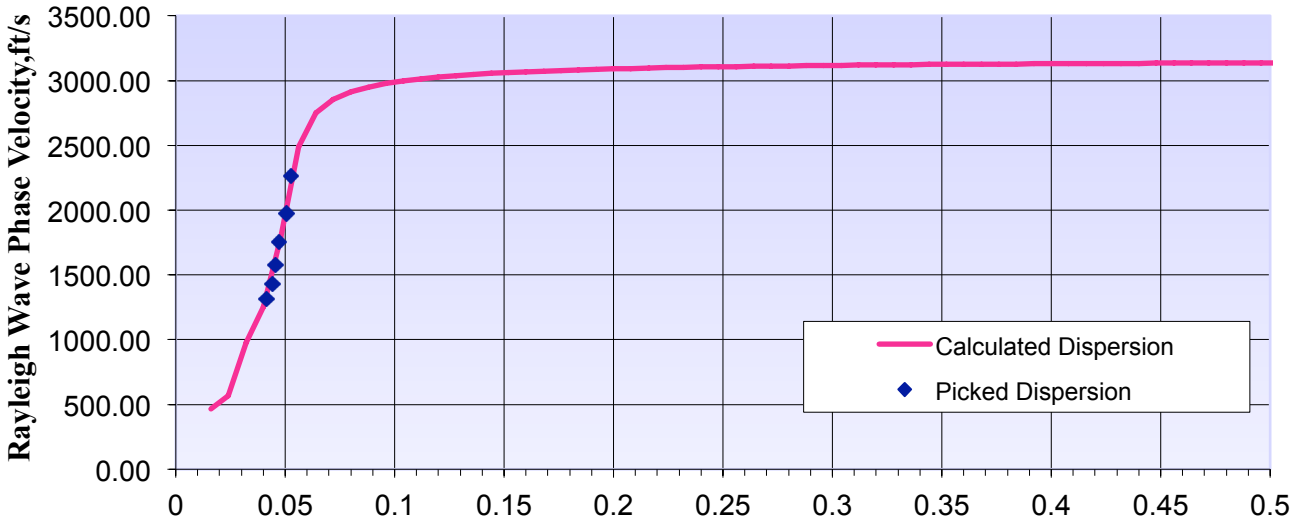


Eagle Canyon ReMi Survey
Upper RM-1 Vs Model
Figure A7

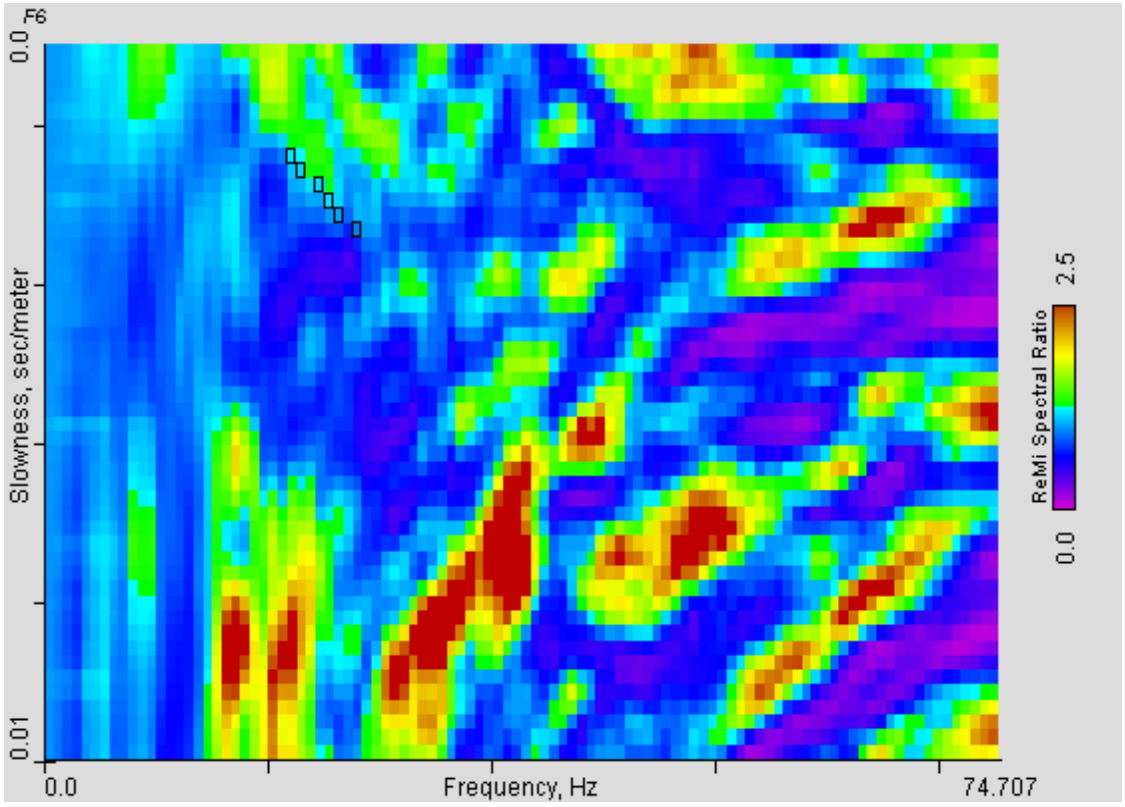
COTTON, SHIRES AND ASSOCIATES, INC.

Upper RM-2: Supportive Illustration

Dispersion Curve Showing Picks and Fit

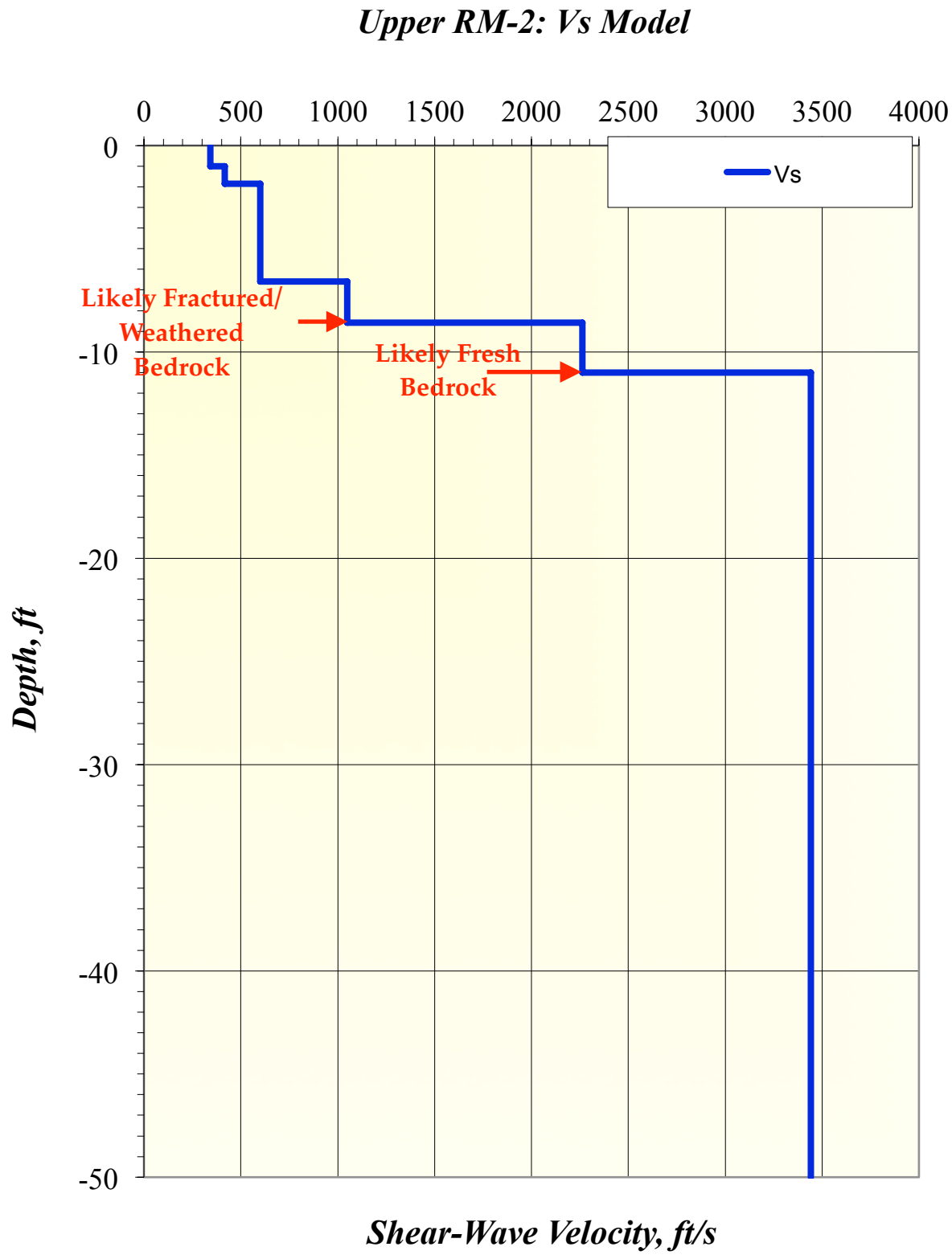


p-f Image with Dispersion Modeling Picks



Eagle Canyon ReMi Survey
Upper RM-2 Supportive Illustration
Figure A8

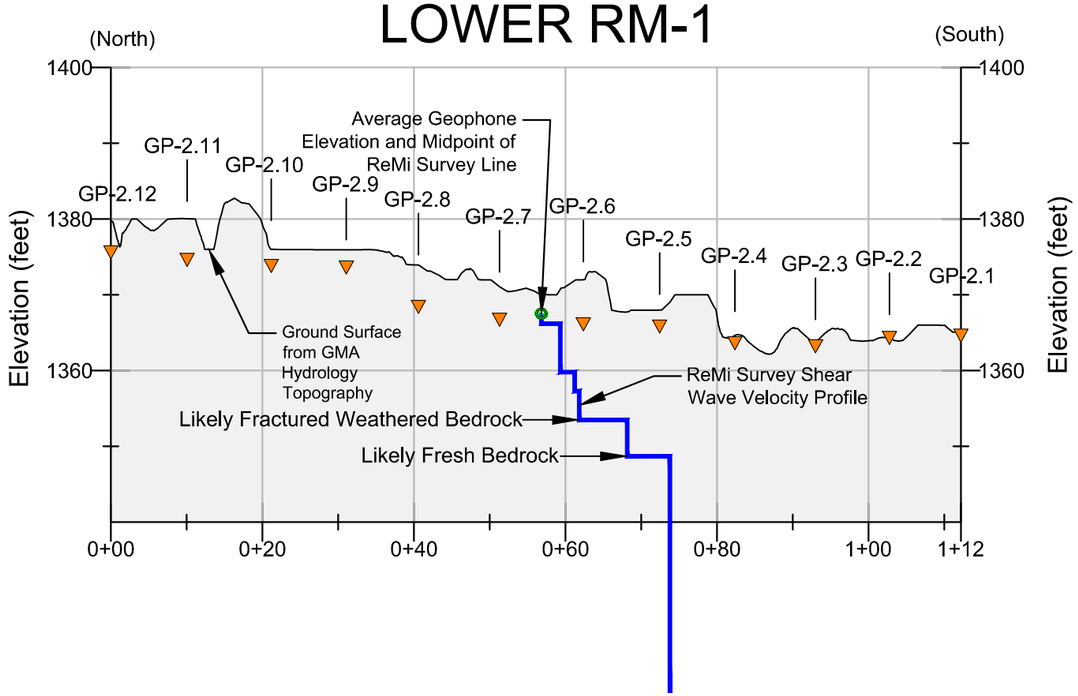
COTTON, SHIRES AND ASSOCIATES, INC.



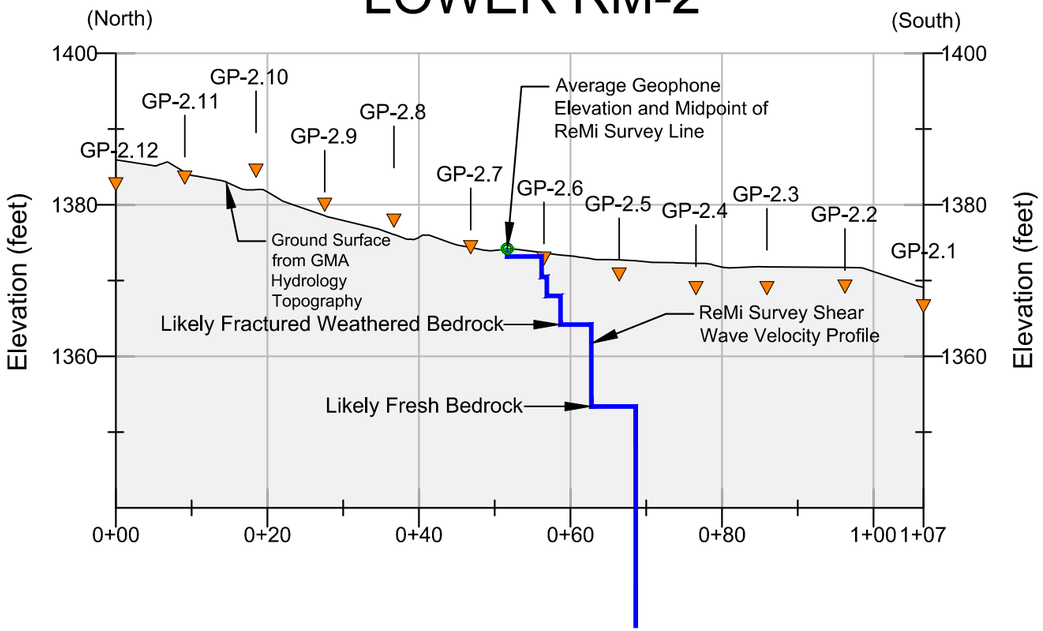
Eagle Canyon ReMi Survey
Upper RM-2 Vs Model
Figure A9

COTTON, SHIRES AND ASSOCIATES, INC.

LOWER RM-1



LOWER RM-2



EXPLANATION

GP-2.12 — Geophone Location

Average Elevation and Midpoint of ReMi Survey Line

0 1000 2000 4000
Velocity (ft/s)

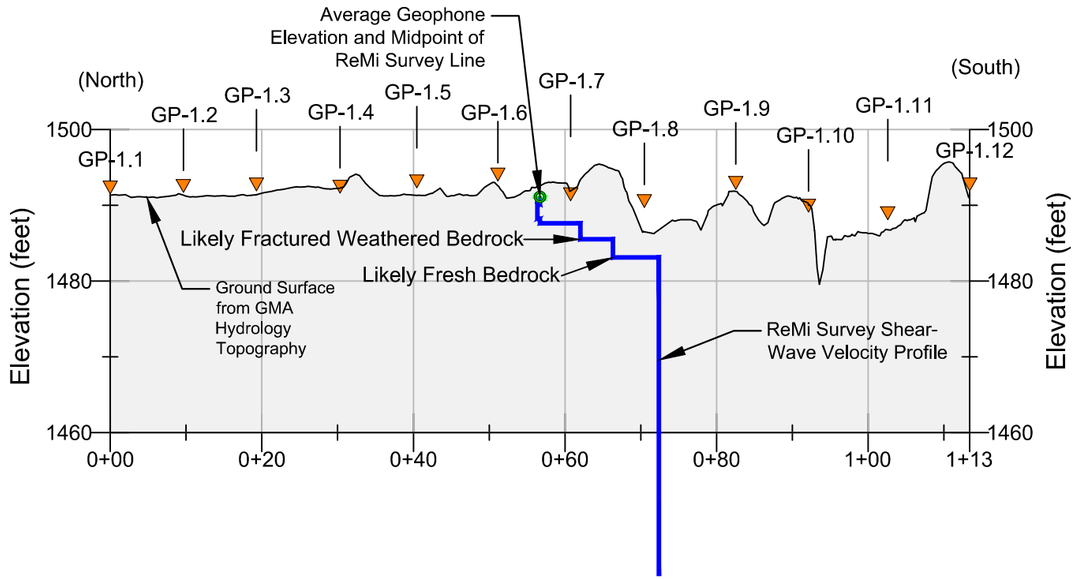
ReMi Survey Profile Shear-Wave Velocity Scale

COTTON, SHIRES AND ASSOCIATES, INC.
CONSULTING ENGINEERS AND GEOLOGISTS

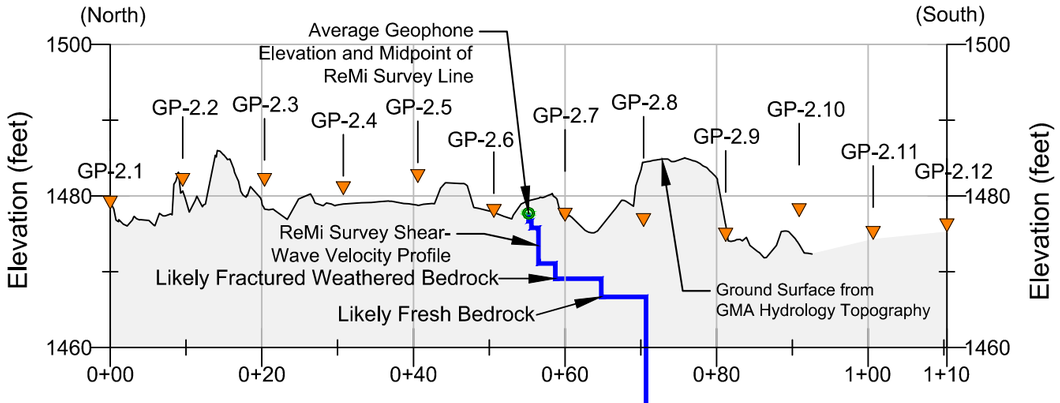
ReMi Survey Line L/RM-1 and L/RM-2
Lower Site Topographic Profiles
Engineering Geologic Investigation
Eagle Canyon Fish Passage Improvements in Battle Creek
Shasta and Tehama Counties, California

GEO/ENG BY POS/MMP	SCALE 1"=20'	PROJECT NO. E5285
APPROVED BY POS	DATE August 2016	FIGURE NO. A10

UPPER RM-1



UPPER RM-2



EXPLANATION

GP-2.12 ▽ Geophone Location

Average Elevation and Midpoint of ReMi Survey Line

0 1000 2000 4000
Velocity (ft/s)

ReMi Survey Profile Shear-Wave Velocity Scale

COTTON, SHIRES AND ASSOCIATES, INC.
CONSULTING ENGINEERS AND GEOLOGISTS

ReMi Survey Line U/RM-1 and U/RM-2
Upper Site Topographic Profiles
Engineering Geologic Investigation
Eagle Canyon Fish Passage Improvements in Battle Creek
Shasta and Tehama Counties, California

GEO/ENG BY	SCALE	PROJECT NO.
POS/MMP	1"=20'	E5285
APPROVED BY	DATE	FIGURE NO.
POS	August 2016	A11

APPENDIX B

Laboratory Testing

SMITH-EMERY SAN FRANCISCO
An Independent Commercial Testing Laboratory

1940 Oakdale Ave
San Francisco, CA
Fax (415) 642-7056
(415) 642-7326

PROJ./JOB NO.: 69876-1
LAB NO.: 16L070

March 18, 2016

CLIENT: Cotton Shires Associates
330 Village Lane
Los Gatos , CA

PROJECT: Cotton Shires General Services
Various

SUBJECT: Compressive Strength and Density of Concrete Core Specimens
SOURCE: Cotton Shires General Services
STANDARD: ASTM C 42-94 "Strength Method of Obtaining and Testing Drilled Cores and Sawed Beams of Concrete."
Location: Brought into SE by Client

REPORT OF TESTS

	1	2	3	4
Location:	UB1	UB1	UB2	UB2
Laboratory Core No.:	A	B	C	D
Age, Days:	5	5	5	5
Moisture Condition, (1):	Dry	Dry	Dry	Dry
Length Received, Ins.:	5.40		4.70	
Length Before Capping Ins.:	5.40		4.70	
Length After Capping, Ins.:	5.60		4.90	
Diameter, Ins.:	2.70		2.70	
Cross-Sectional Area, Sq. Ins.:	5.73		5.73	
Maximum Load, Lbs.:	45,620		94,790	
Compressive Strength, PSI:	7,960		16,540	
Length to Diameter Ratio:	2.07		1.81	
Strength Correction Factor:	1.00		0.99	
Corrected Compressive Strength, PSI:	7,960		16,310	
Design PSI:	N/A	N/A	N/A	N/A
Density,lbs/ft³:	132.1	130.9	165.3	168.6

Respectfully submitted,
SMITH-EMERY SAN FRANCISCO

Wylie Stevenson
Laboratory Manager

SMITH-EMERY SAN FRANCISCO
An Independent Commercial Testing Laboratory

1940 Oakdale Ave
San Francisco, CA
Fax (415) 642-7056
(415) 642-7326

PROJ./JOB NO.: 69876-1
LAB NO.: 16L070A

June 24, 2016

CLIENT: Cotton Shires Associates
330 Village Lane
Los Gatos , CA

PROJECT: Cotton Shires General Services
Various

SUBJECT: Compressive Strength and Density of Concrete Core Specimens
SOURCE: Cotton Shires General Services
STANDARD: ASTM C 42-94 "Strength Method of Obtaining and Testing Drilled Cores and Sawed Beams of Concrete."
Location: Brought into SE by Client

REPORT OF TESTS

	1	2	3
Location:	LB1	LB2	UB3
Laboratory Core No.:	A	B	C
Age, Days:	5	5	5
Moisture Condition, (1):	Dry	Dry	Dry
Length Received, Ins.:	4.80	4.50	3.80
Length Before Capping Ins.:	4.80	4.50	3.80
Length After Capping, Ins.:	5.00	4.70	4.00
Diameter, Ins.:	2.70	2.70	2.70
Cross-Sectional Area, Sq. Ins.:	5.73	5.73	5.73
Maximum Load, Lbs.:	86,020	95,530	68,840
Compressive Strength, PSI:	15,010	16,670	12,010
Length to Diameter Ratio:	1.85	1.74	1.48
Strength Correction Factor:	0.991	0.979	0.958
Corrected Compressive Strength, PSI:	14,880	16,320	11,510
Design PSI:	N/A	N/A	N/A
Density*,lbs/ft^3:	164.4	155.1	163.1

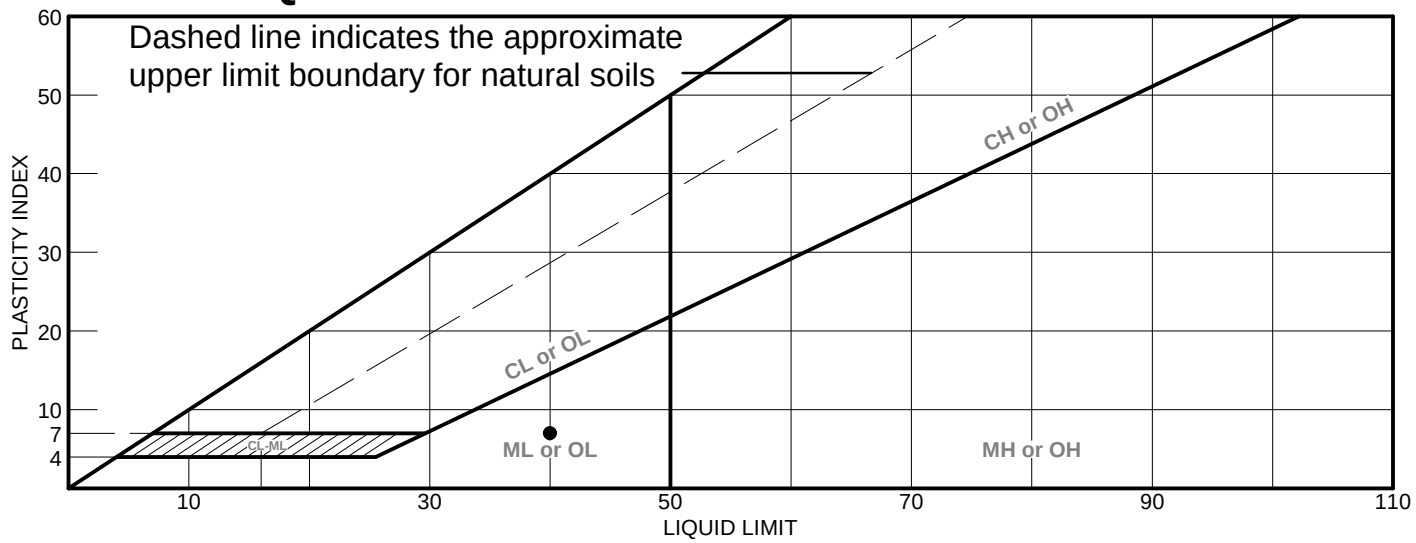
* By "Chunk Density"

Respectfully submitted,
SMITH-EMERY SAN FRANCISCO

Wylie Stevenson
Laboratory Manager

ALL REPORTS ARE SUBMITTED AS THE CONFIDENTIAL PROPERTY OF CLIENTS. AUTHORIZATION FOR PUBLICATION OF OUR REPORT CONCLUSIONS, OR EXTI
FROM OR REGARDING THEM IS RESERVED PENDING OUR WRITTEN APPROVAL AS A MUTUAL PROTECTION TO CLIENTS, THE PUBLIC AND OURSELVES.

LIQUID AND PLASTIC LIMITS TEST REPORT





	MATERIAL DESCRIPTION	LL	PL	PI	%<#40	%<#200	USCS
●	Strong Brown SILT w/ Sand	40	33	7	87.8	73.9	ML
■	Strong Brown Silty SAND w/ organics		NP	NP	67.4	18.3	SM

Project No. 026-608 **Client:** Cotton, Shires & Associates

Project: Eagle Canyon - E5285

● **Source:** UB B7 **Sample No.:** Upper Barrier

■ **Source:** LB B-2 **Sample No.:** Lower Barrier

Remarks:

●

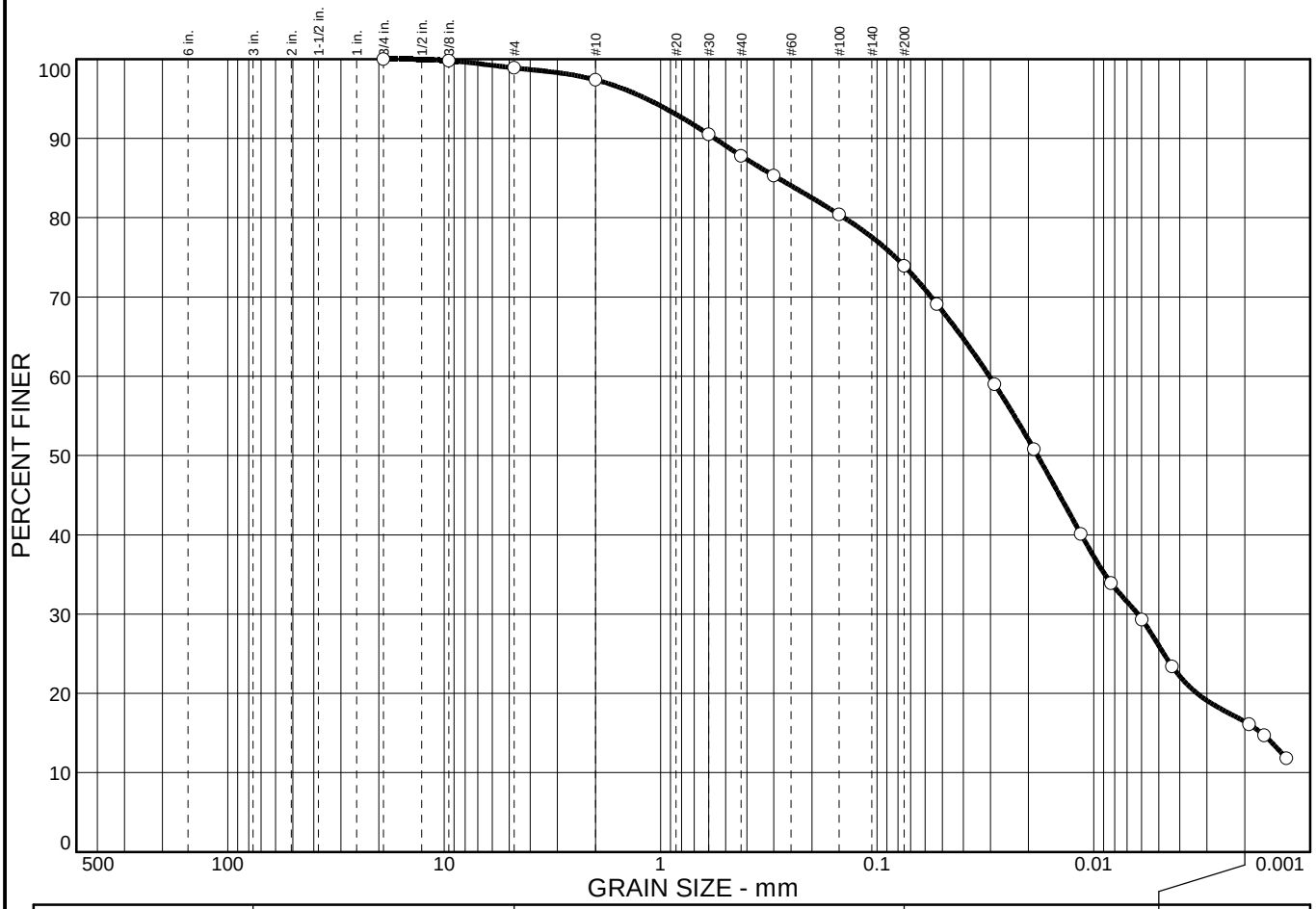
■ Could not roll out. Sample slides in bowl. Non-plastic.

LIQUID AND PLASTIC LIMITS TEST REPORT

COOPER TESTING LABORATORY

Figure

Particle Size Distribution Report



% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY
0.0	1.1	25.0	57.5	16.4

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4 in.	100.0		
3/8 in.	99.8		
#4	98.9		
#10	97.4		
#30	90.5		
#40	87.8		
#50	85.3		
#100	80.4		
#200	73.9		
#270	69.1		
0.0287 mm.	59.0		
0.0189 mm.	50.8		
0.0114 mm.	40.1		
0.0083 mm.	33.9		
0.0060 mm.	29.3		
0.0043 mm.	23.4		
0.0019 mm.	16.1		
0.0016 mm.	14.7		
0.0013 mm.	11.8		

* (no specification provided)

Soil Description

Strong Brown SILT w/ Sand

Atterberg Limits

PL= 33 LL= 40 PI= 7

Coefficients

D_{85}= 0.287 D_{60}= 0.0303 D_{50}= 0.0182
D_{30}= 0.0063 D_{15}= 0.0017 D_{10}=
C_u= C_c=

Classification

USCS= ML AASHTO=

Remarks

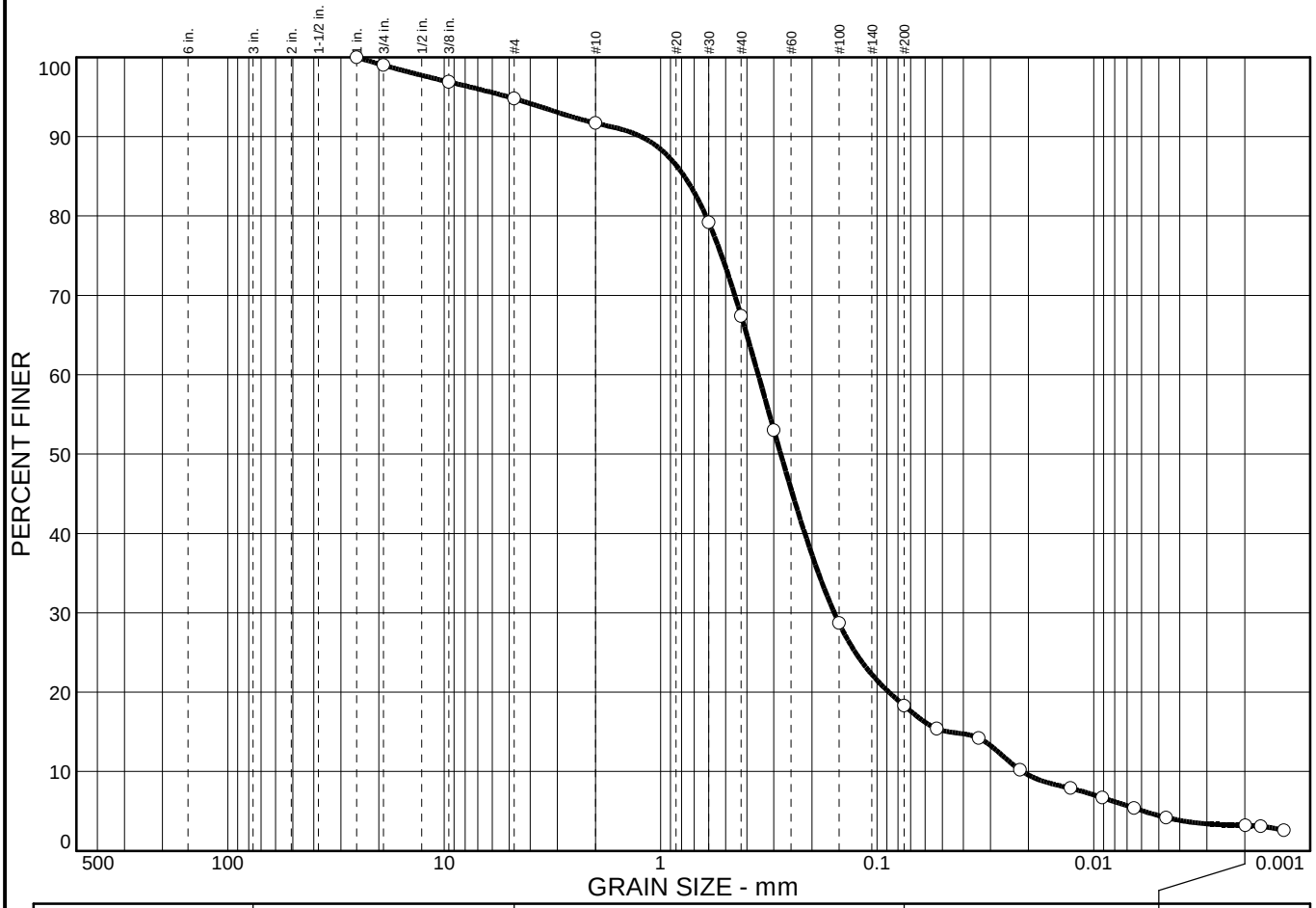
Sample No.: Upper Barrier **Source of Sample:** UB B-7 **Date:** 6/20/16
Location: **Elev./Depth:**

COOPER TESTING LABORATORY

Client: Cotton, Shires & Associates
Project: Eagle Canyon - E5285

Project No: 026-608 **Figure**

Particle Size Distribution Report



% COBBLES	% GRAVEL	% SAND	% SILT	% CLAY
0.0	5.2	76.5	15.1	3.2

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1 in.	100.0		
3/4 in.	99.0		
3/8 in.	96.9		
#4	94.8		
#10	91.7		
#30	79.2		
#40	67.4		
#50	53.0		
#100	28.7		
#200	18.3		
#270	15.4		
0.0339 mm.	14.2		
0.0219 mm.	10.2		
0.0128 mm.	7.9		
0.0091 mm.	6.7		
0.0065 mm.	5.4		
0.0046 mm.	4.2		
0.0020 mm.	3.2		
0.0017 mm.	3.1		
0.0013 mm.	2.6		

* (no specification provided)

Soil Description

Strong Brown Silty SAND w/ organics

Atterberg Limits

PL= NP LL= PI= NP

Coefficients

D_{85}= 0.778 D_{60}= 0.354 D_{50}= 0.279
D_{30}= 0.158 D_{15}= 0.0465 D_{10}= 0.0213
C_u= 16.61 C_c= 3.29

Classification

USCS= SM AASHTO=

Remarks

Sample No.: Lower Barrier **Source of Sample:** LB B-2 **Date:** 6/20/16
Location: **Elev./Depth:**

COOPER TESTING LABORATORY

Client: Cotton, Shires & Associates
Project: Eagle Canyon - E5285

Project No: 026-608 **Figure**

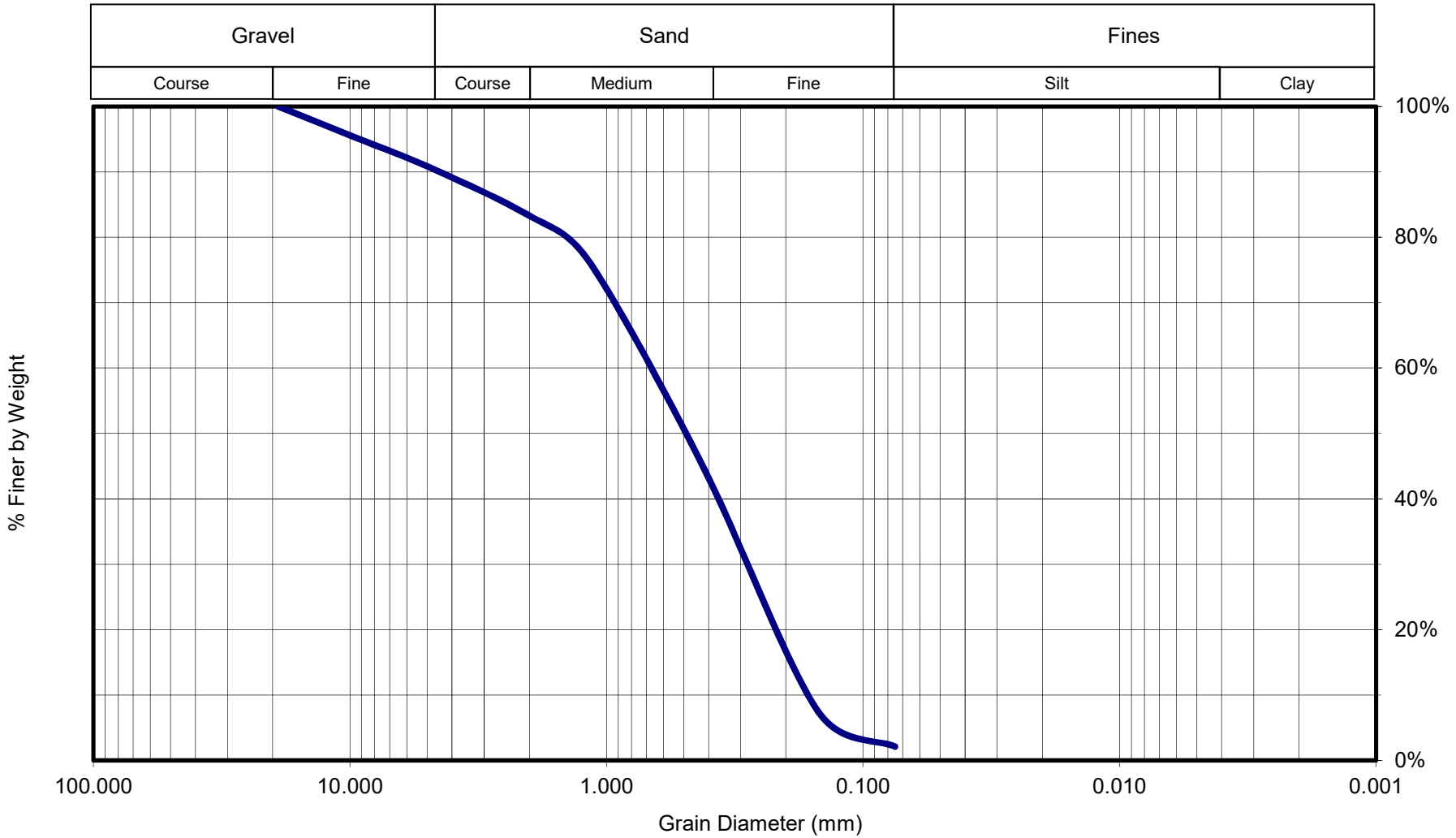


Figure 1: Grain Size Analysis UB B-4

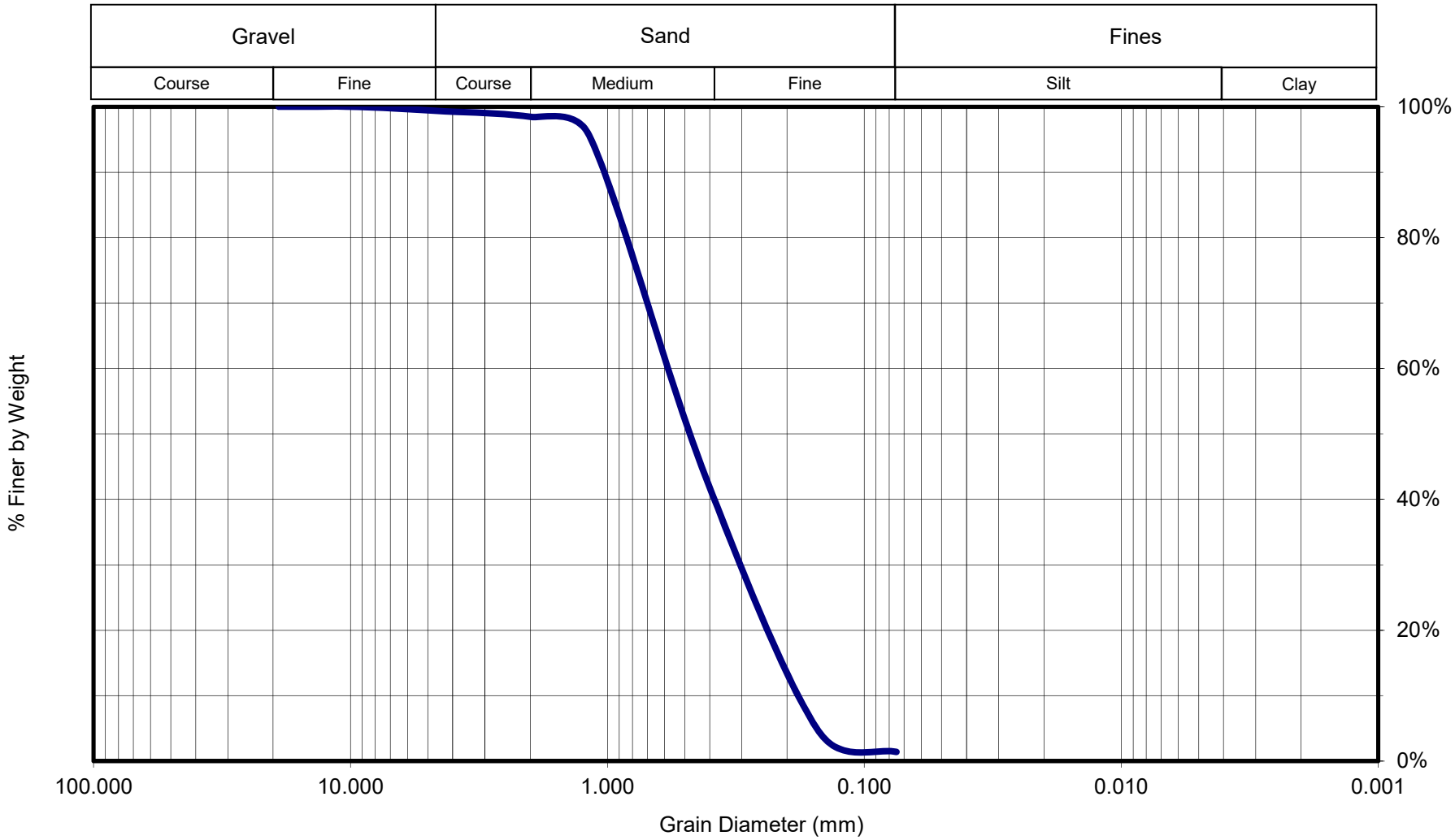


Figure 1: Grain Size Analysis for UB B-5

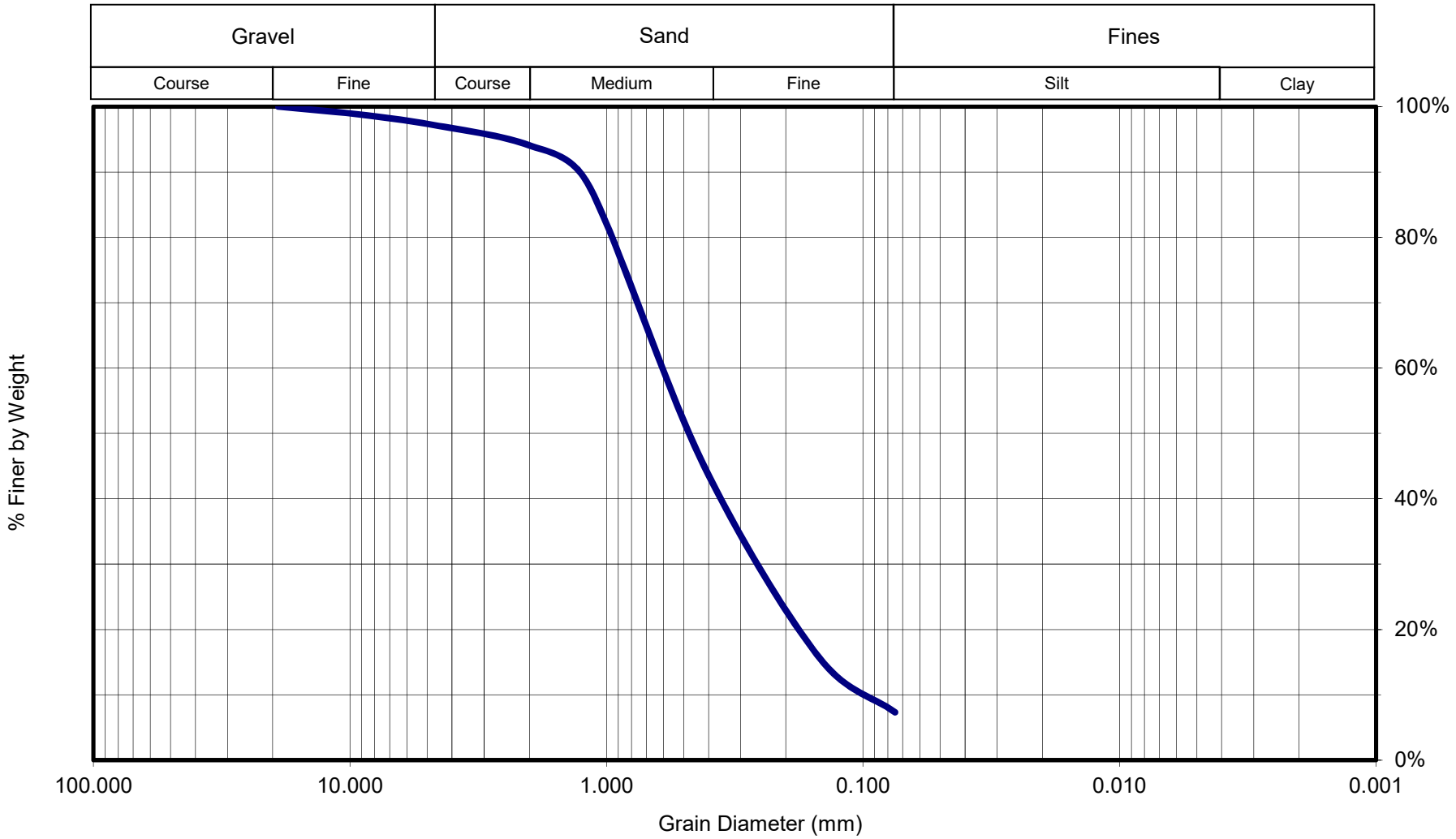
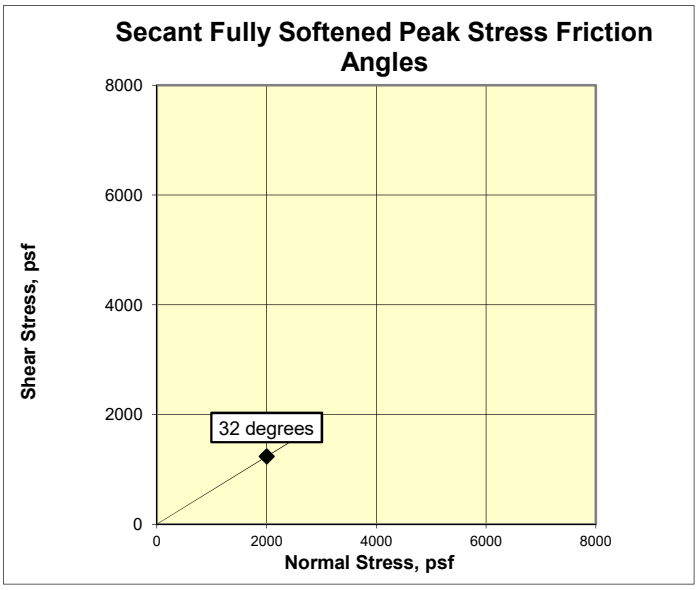


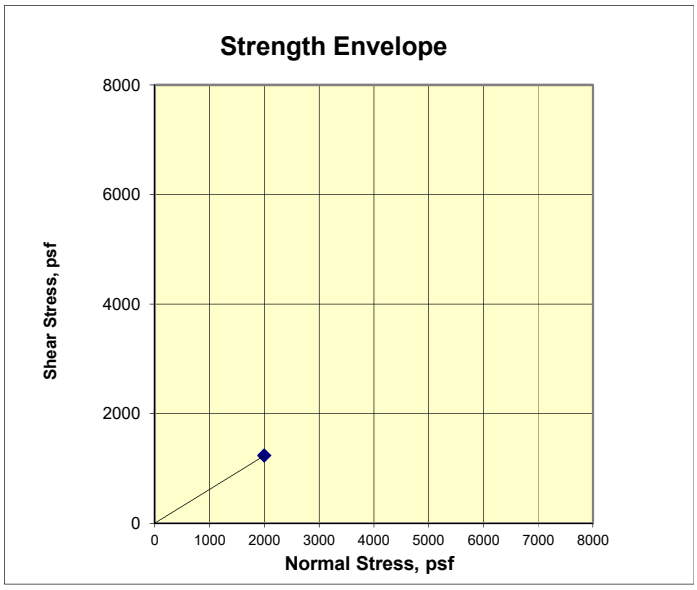
Figure 1: Grain Size Analysis for LB B-2

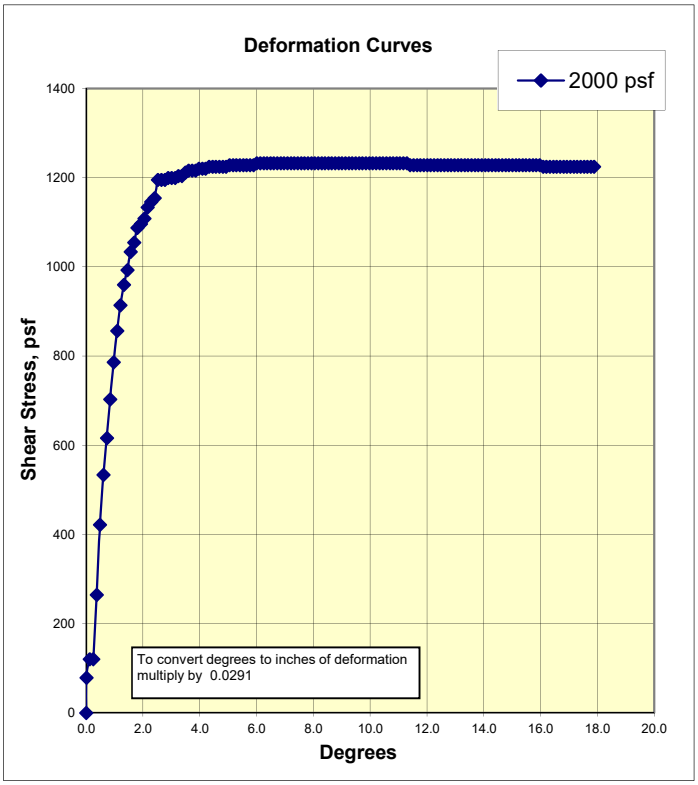
Drained Fully Softened Peak Torsional Shear Strength (ASTM D7608)

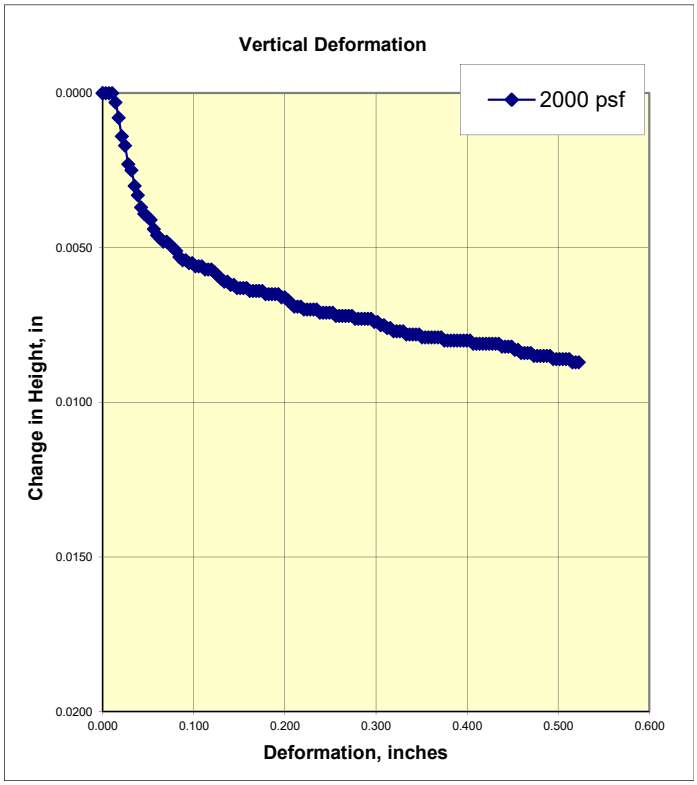
CTL Job No.:	026-608	**Boring:**	UB B-7	**Date:**	7/8/2016	**Clay, %:**	16.4
Client:	Cotton, Shires & Associates, Inc.	**Sample:**		**By:**	PJ	**LL:**	40
Project Name:	Eagle Canyon	**Depth (ft):**	Upper Barrier	**Checked:**	DC	**PL:**	33
Project Number:	E5285	**Test Type:**	Fully Softened Peak				
Soil Type:	Strong Brown SILT w/ Sand						
Normal Stress, psf:	2000						
Secant Phi, deg.:	32						

Remarks: Due to the granular nature of the soil a clearly defined peak could not be attained.





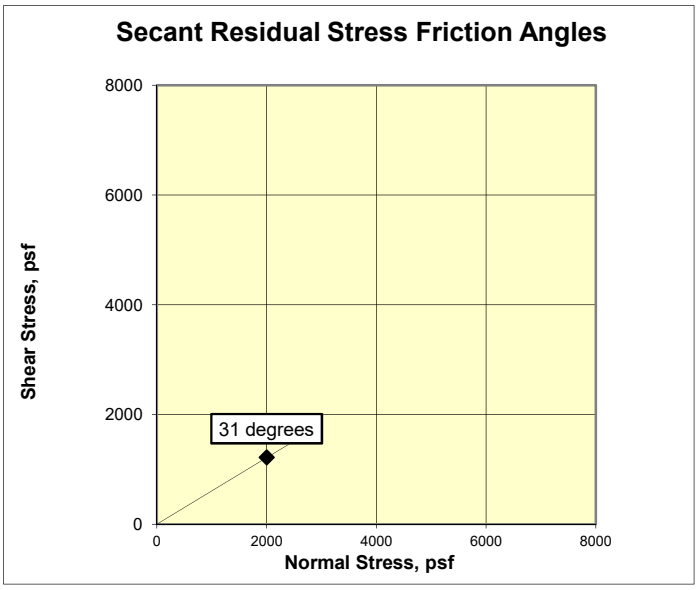


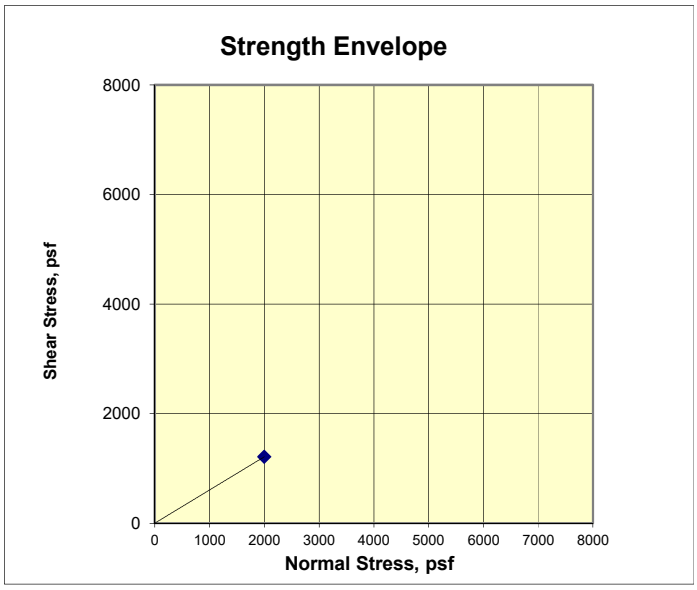


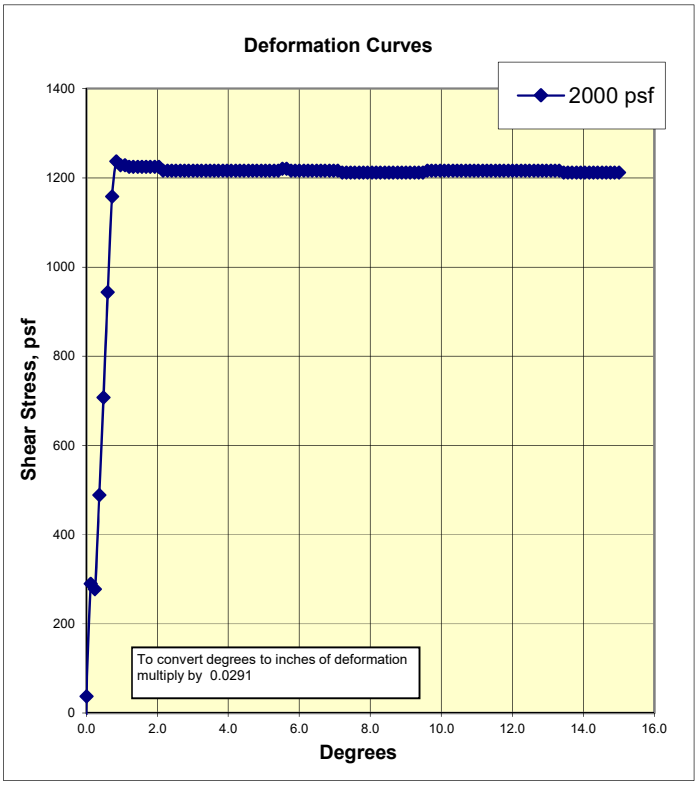
Drained Residual Torsional Shear Strength (ASTM D6467)

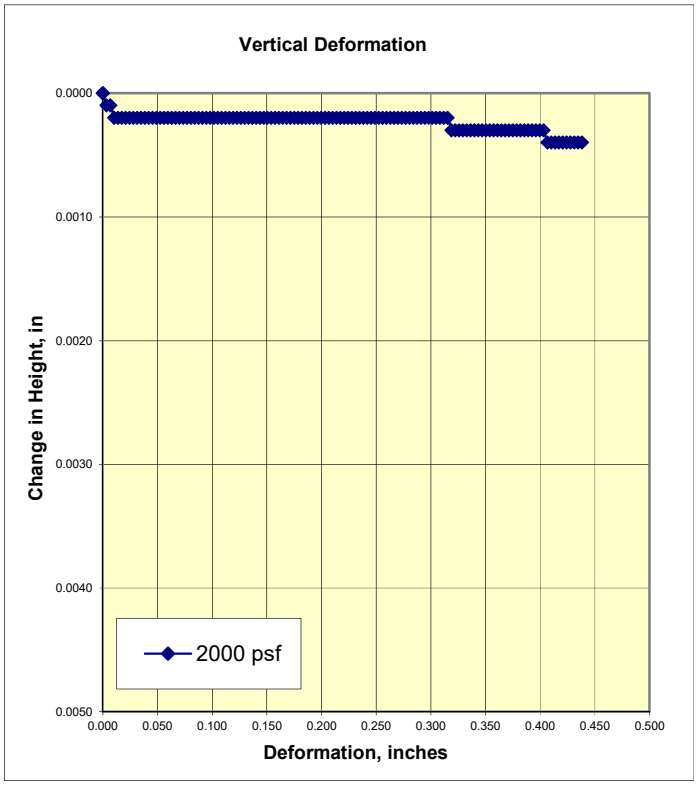
CTL Job No.:	026-608	**Boring:**	UB B-7	**Date:**	7/8/2016	**Clay, %:**	16.4
Client:	Cotton, Shires & Associates, Inc.	**Sample:**		**By:**	PJ	**LL:**	40
Project Name:	Eagle Canyon	**Depth (ft):**	Upper Barrier	**Checked:**	DC	**PL:**	33
Project Number:	E5285	**Test Type:**	Fully Softened Residual				
Soil Type:	Strong Brown SILT w/ Sand						
Normal Stress, psf:	2000						
Secant Phi, deg.:	31						

Remarks: A small friction correction was applied to the point.





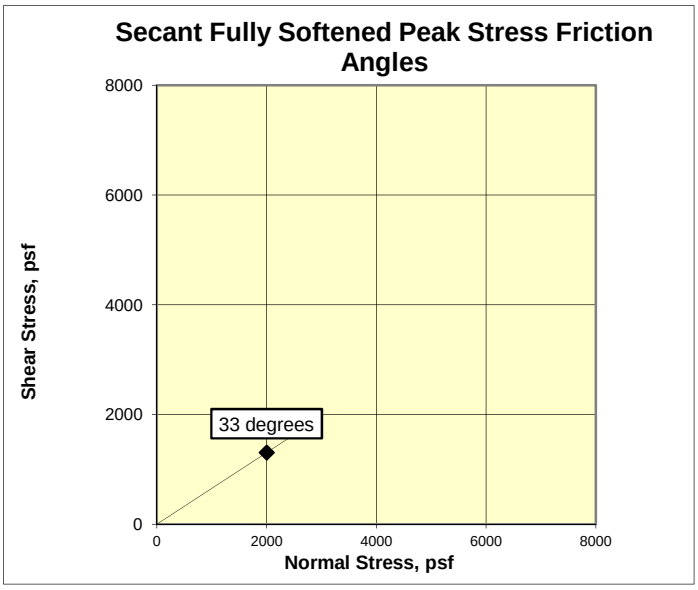


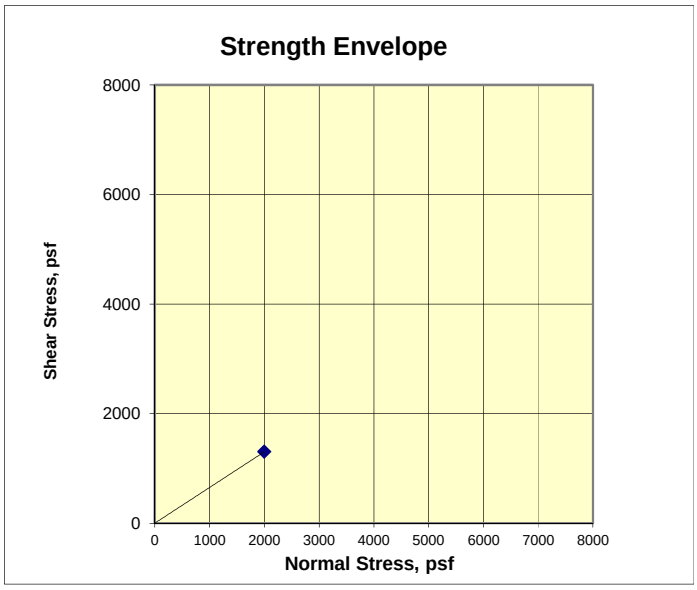


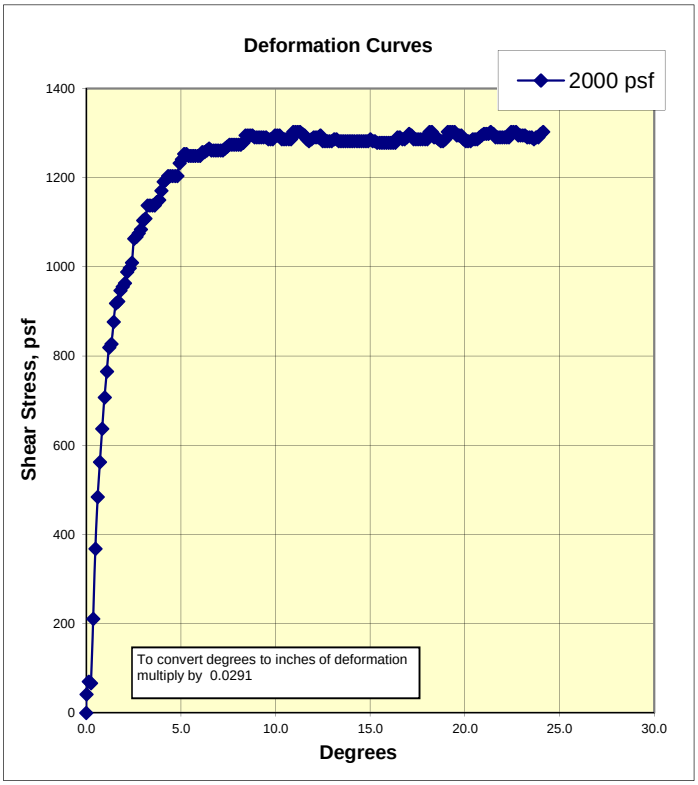
Drained Fully Softened Peak Torsional Shear Strength (ASTM D7608)

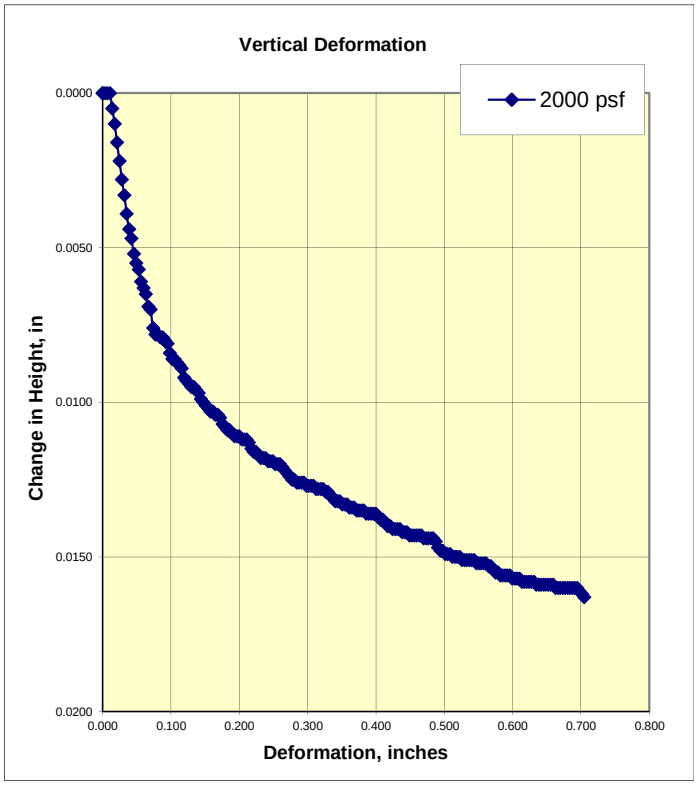
CTL Job No.:	026-608	**Boring:**	LB B-2	**Date:**	7/6/2016	**Clay, %:**	3.2
Client:	Cotton, Shires & Associates, Inc.	**Sample:**		**By:**	PJ	**LL:**	
Project Name:	Eagle Canyon	**Depth (ft):**	Lower Barrier	**Checked:**	DC	**PL:**	
Project Number:	E5285	**Test Type:**	Fully Softened Peak				
Soil Type:	Strong Brown Silty SAND w/ organics						
Normal Stress, psf:	2000						
Secant Phi, deg.:	33						

Remarks: Due to the granular nature of the soil a clearly defined peak could not be attained.





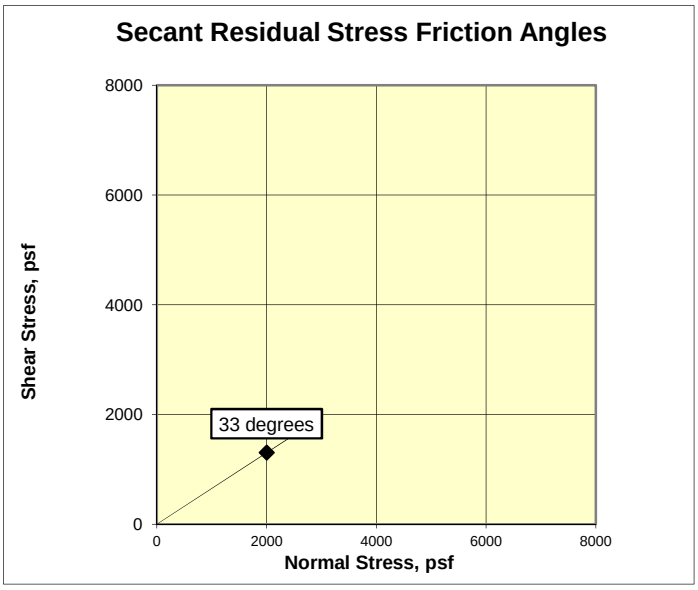


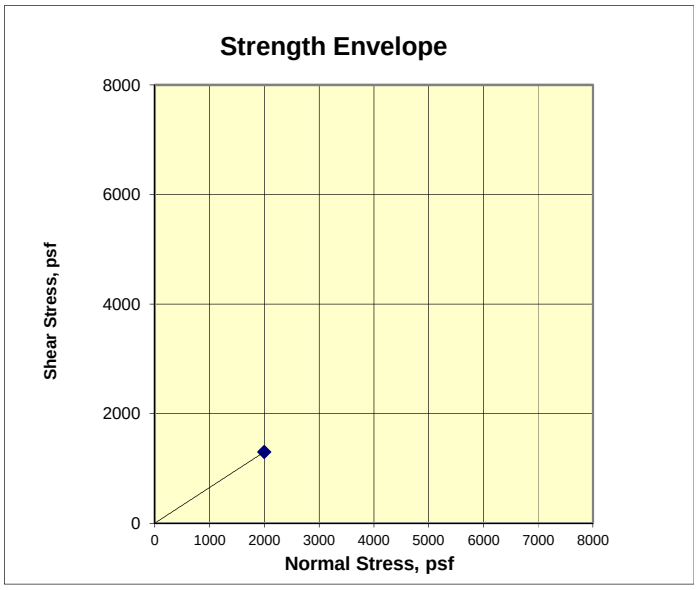


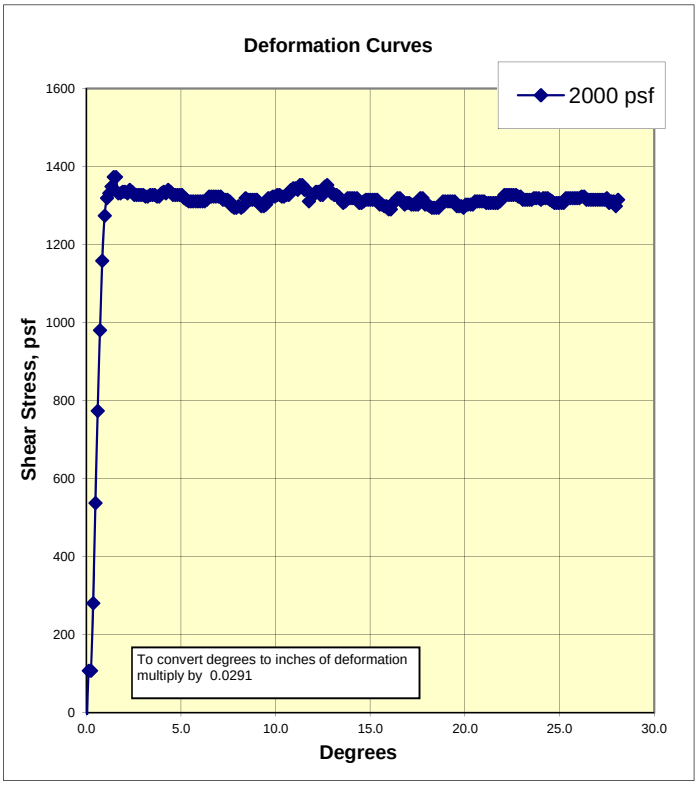
Drained Residual Torsional Shear Strength (ASTM D6467)

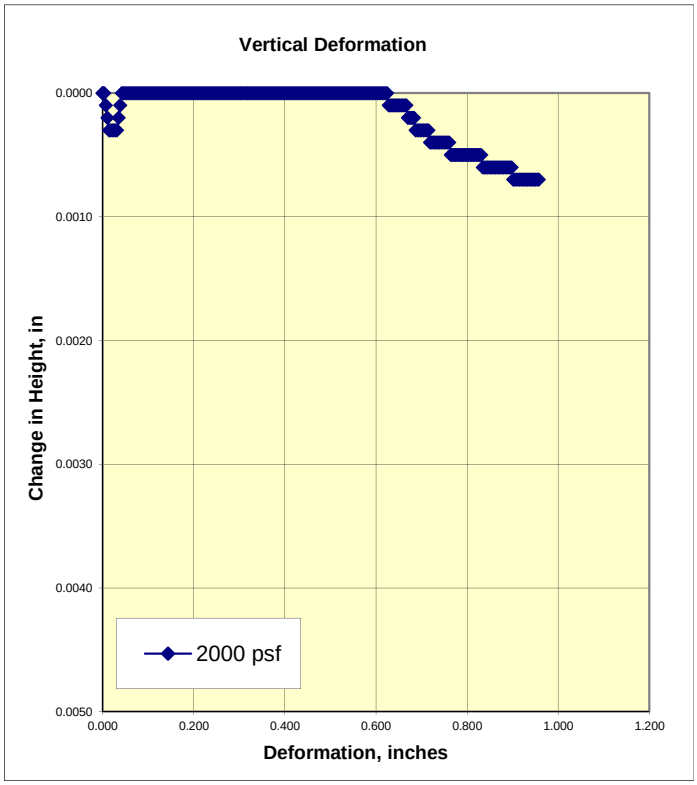
CTL Job No.:	026-608	**Boring:**	LB B-2	**Date:**	7/6/2016	**Clay, %:**	3.2
Client:	Cotton, Shires & Associates, Inc.	**Sample:**		**By:**	PJ	**LL:**	
Project Name:	Eagle Canyon	**Depth (ft):**	Lower Barrier	**Checked:**	DC	**PL:**	
Project Number:	E5285	**Test Type:**	Fully Softened Residual				
Soil Type:	Strong Brown Silty SAND w/ organics						
Normal Stress, psf:	2000						
Secant Phi, deg.:	33						

Remarks: A small friction correction was applied to the point.









Corrosivity Test Summary

CTL # 026-608 **Date:** 6/2/2016 **Tested By:** PJ **Checked:** PJ

Client: Cotton, Shires & Associates **Project:** Eagle Canyon **Proj. No:** E5285

Remarks:

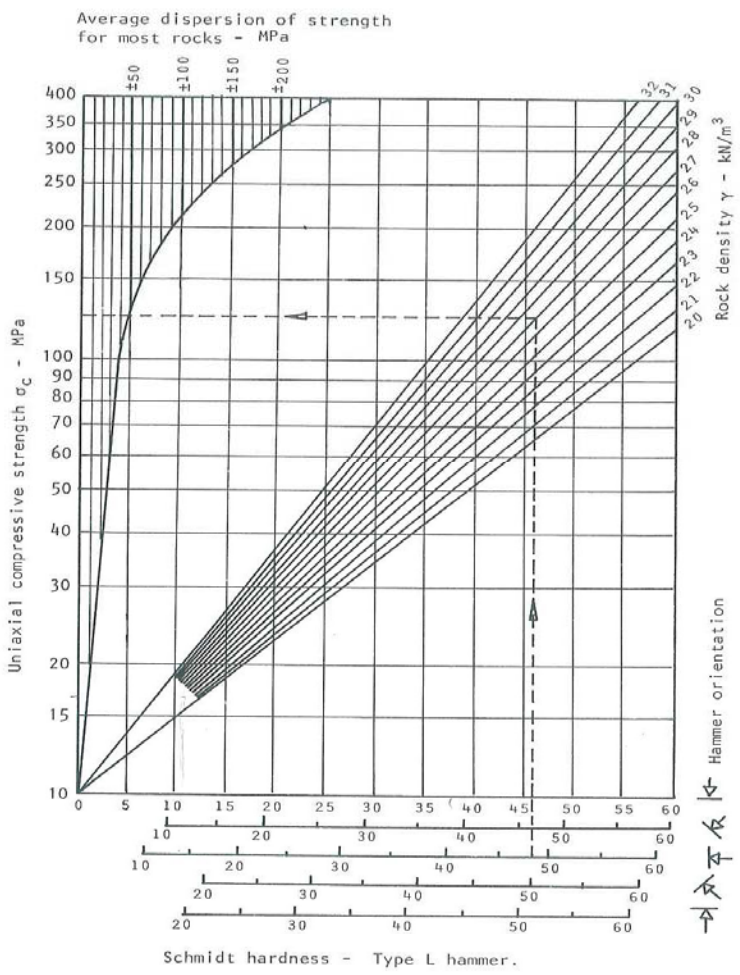
Sample Location or ID			Resistivity @ 15.5 °C (Ohm-cm)			Chloride	Sulfate		pH	ORP	Moisture	Soil Visual Description
Boring	Sample, No.	Depth, ft.	As Rec.	Minimum	Saturated	mg/kg	mg/kg	%		(Redox)	At Test	
						Dry Wt.	Dry Wt.	Dry Wt.		mv	%	
			ASTM G57	Cal 643	ASTM G57	Cal 422-mod.	Cal 417-mod.	Cal 417-mod.	Cal 643	SM 2580B	ASTM D2216	
UB B-6	-	-	-	5095	-	<2	54	0.0054	7.4	-	40.7	Gray Silty SAND
LB B-1	-	-	-	16366	-	2	45	0.0045	7.3	-	26.0	Olive Brown Silty SAND

APPENDIX C

Schmidt Hammer Testing, Rock Mass and Joint Strengths

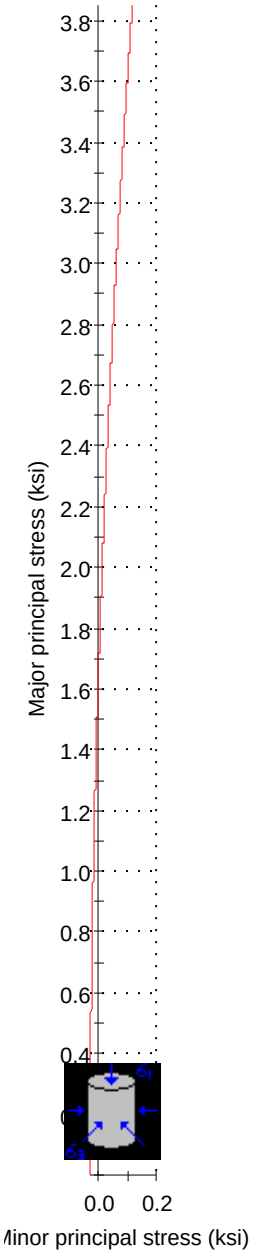
UPPER BARRIER													
		pdf	kn/m^3										
	Unit Weight:	165	25.9										
Schmidt Hammer Readings													
				Reading									
Boulder	**Boulder Side**	**Side Location**	**Direction**	1	2	3	4	5	6	7	8	9	10
SHB5	North	Middle	Horizontal	54	56	54	55	56	56				
	East	Middle	Horizontal	60	58	60	62	58	58				
SHB6	Top	Middle	Vertical	54	56	60	60	59	60				
	North	Middle	Horizontal	58	60	64	62	58	60				
SHB7	Top	Middle	Vertical	53	58	56	58	58	59	56	60	58	59
SHB8	Top	Middle	Vertical	52	54	55	57	55	56	52	56	56	53
SHB9	Top	Middle	Vertical	57	58	62	60	61	61	58	63	63	60
SHB10	Top	Middle	Vertical	54	57	59	57	55	54	55	58	59	58
SHB11	Top	Middle	Vertical	70	69	62	71	71	64	72	66	66	70
Canyon Wall	**Side of Cyn**		**Direction**										
SHW1	West		Horizontal	56	56	60	62	58	56	60	62	56	59
	West		Horizontal	62	64	64	59	60	62	64	62	60	53
SHW2	West		Horizontal	52	57	55	57	60	56	57	58	60	58
SHW3	West		Horizontal	54	57	55	56	56	56	59	60	58	57
SHW4	West		Horizontal	54	54	58	58	52	54	55	52	56	56
SHW5	West		Horizontal	58	61	62	64	62	59	64	65	63	60
SHW6	West		Horizontal	62	62	64	63	62	63	62	63	63	66
Schmidt Hammer Correlations With Unconfined Compressive Strength													
	Schmidt Reading			Mpa *1			Psi						
Location	Low	Average	High	Low	Average	High	Low	Average	High				
Boulder													
SH-B5 (Horiz)	54	57	62	172	207	272	24,961	30,071	39,477				
SH-B6 (Vert)	54	58	60	193	242	268	27,967	35,140	38,854				
SH-B6 (Horiz)	58	60	64	216	247	305	31,391	35,882	44,271				
SH-B7 (Vert)	53	58	60	183	234	268	26,475	33,880	38,854				
SH-B8 (Vert)	52	55	57	173	199	227	25,064	28,902	32,964				
SH-B9 (Vert)	57	60	63	227	272	316	32,964	39,498	45,797				
SH-B10 (Vert)	54	57	59	193	222	254	27,967	32,249	36,782				
SH-B11 (Vert	62	68	72	299	418	517	43,355	60,564	74,995				
Canyon Wall						Averages:	30,018	37,023	43,999				
SH-W1 (Horiz)	53	60	64	163	239	305	23,571	34,702	44,271				
SH-W2 (Horiz)	52	57	60	153	204	243	22,259	29,643	35,203				
SH-W3 (Horiz)	54	57	60	172	202	243	24,961	29,305	35,203				
SH-W4 (Horiz)	52	55	58	153	181	216	22,259	26,282	31,391				
SH-W5 (Horiz)	58	62	65	216	269	323	31,391	39,027	46,882				
SH-W6 (Horiz)	62	63	66	272	288	342	39,477	41,805	49,646				
1 - From Hoek and Bray Rock Slope Engineering, 1997 (Deere and Miller, 1966)						Averages:	27,320	33,461	40,433				

LOWER BARRIER									
		pdf	kn/m^3						
	Unit Weight:	**165**	25.9						
Schmidt Readings									
Boulder	**Boulder Side**	**Side Location**	**Direction**	**Reading**					
				1	2	3	4	5	6
SHB1	South East	South West	Horizontal	58	56	62	56	61	58
		Middle	Horizontal	56	55	61	56	58	62
		North East	Horizontal	52	54	53	58	62	61
	North East	Middle	Horizontal	60	58	57	60	59	60
SHB2	Top	South West	Vertical	68	66	66	67		
		Middle	Vertical	58	60	60	64	60	60
		North East	Vertical	64	64	64	58		
SHB3	South East	West	Horizontal	50	52	54	50	52	52
		Middle	Horizontal	52	55	56	57	55	
		East	Horizontal	51	54	59	52	57	52
SHB4	North West	North	Horizontal	62	58	62	64		
		Middle	Horizontal	62	60	56	59		
		South	Horizontal	64	58	59	60	58	57
	Schmidt Reading			Mpa *1			Psi		
Location	Low	Average	High	Low	Average	High	Low	Average	High
SH-B1 (Horiz)	52	58	62	153	217	272	22,259	31,466	39,477
SH-B2 (Vert)	58	63	68	240	312	415	34,821	45,262	60,233
SH-B3 (Horiz)	50	54	59	137	168	229	19,848	24,297	33,242
SH-B4 (Horiz)	56	60	64	193	242	305	27,992	35,059	44,271
1 - From Hoek and Bray Rock Slope Engineering (Deere and Miller, 1966)						Averages:	26,230	34,021	44,306



From Hoek and Bray Rock Slope Engineering (Deere and Miller, 1966)

Analysis of Rock Strength using RocLab



Hoek-Brown Classification

intact uniaxial comp. strength (sigci) = 16 ksi
GSI = 60 mi = 25 Disturbance factor (D) = 0
intact modulus (Ei) = 1600 ksi

Hoek-Brown Criterion

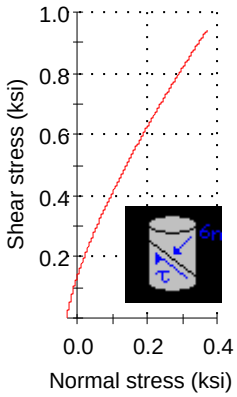
mb = 5.991 s = 0.0117 a = 0.503

Mohr-Coulomb Fit

cohesion = 0.176 ksi friction angle = 65.52 deg

Rock Mass Parameters

tensile strength = -0.031 ksi
uniaxial compressive strength = 1.712 ksi
global strength = 5.326 ksi
deformation modulus = 832.00 ksi

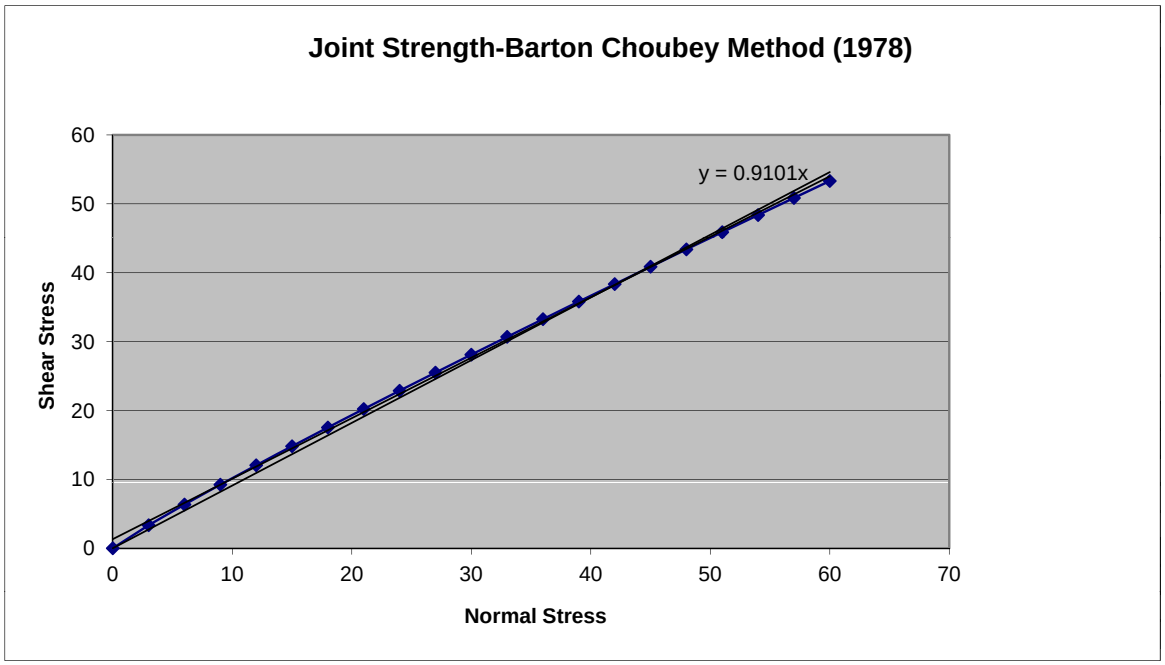


Barton-Choubey Method (1978) - Joint Shear Strength

Tau = SigmaN tan[JRC log(JCS/SigmaN) + Friction]

		User Input	*Variable Name*
Tau	Shear Strength	None	
SigmaN	Normal Stress	None	
JRC	Joint Roughness Coefficient	5	*JRC*
JCS	Joint Compressive Strength	8000	*JCS*
Friction	Base or Residual Friction	31	*Friction*
Maximum Normal Stress		60	*Max*

								Instant Ø	**Instant c**	**Secant Ø**
	SigmaN	**Tau**	JRC*Log(JCS/SigmaN)+Friction	(JRC*PI)/(180*(ln(10))		A^2 + 1	A+B*C	atan(D)	Tau-SigmaNtanE	
	0	0	A	B		C	D	E		
1	3	3.35	1.116	0.038		2.245	1.031	45.9	0.3	48.1
2	6	6.35	1.058	0.038		2.120	0.978	44.4	0.5	46.6
3	9	9.24	1.026	0.038		2.053	0.949	43.5	0.7	45.7
4	12	12.05	1.004	0.038		2.008	0.928	42.9	0.9	45.1
5	15	14.81	0.987	0.038		1.975	0.912	42.4	1.1	44.6
6	18	17.53	0.974	0.038		1.948	0.900	42.0	1.3	44.2
7	21	20.21	0.962	0.038		1.926	0.889	41.7	1.5	43.9
8	24	22.87	0.953	0.038		1.908	0.880	41.4	1.7	43.6
9	27	25.50	0.944	0.038		1.892	0.873	41.1	1.9	43.4
10	30	28.10	0.937	0.038		1.878	0.866	40.9	2.1	43.1
11	33	30.69	0.930	0.038		1.865	0.859	40.7	2.3	42.9
12	36	33.26	0.924	0.038		1.854	0.854	40.5	2.5	42.7
13	39	35.81	0.918	0.038		1.843	0.848	40.3	2.7	42.6
14	42	38.35	0.913	0.038		1.834	0.844	40.2	2.9	42.4
15	45	40.87	0.908	0.038		1.825	0.839	40.0	3.1	42.2
16	48	43.39	0.904	0.038		1.817	0.835	39.9	3.3	42.1
17	51	45.88	0.900	0.038		1.809	0.831	39.7	3.5	42.0
18	54	48.37	0.896	0.038		1.802	0.827	39.6	3.7	41.9
19	57	50.85	0.892	0.038		1.796	0.824	39.5	3.9	41.7
20	60	53.32	0.889	0.038		1.790	0.821	39.4	4.1	41.6



APPENDIX D

Seismicity

PSH Deaggregation on NEHRP BC rock
Unnamed 121.917º W, 40.425 N.

Peak Horiz. Ground Accel.>=0.4030 g
Ann. Exceedance Rate .404E-03. Mean Return Time 2475 years
Mean (R,M,ε_0) 16.4 km, 6.55, 0.37
Modal (R,M,ε_0) = 3.6 km, 6.47, -0.05 (from peak R,M bin)
Modal (R,M,ε*) = 3.6 km, 6.47, 0 to 1 sigma (from peak R,M,ε bin)
Binning: DeltaR 10. km, deltaM=0.2, Deltaε=1.0

