# SEISMIC STABILITY EVALUATIONS OF CHESBRO, LENIHAN, STEVENS CREEK, AND UVAS DAMS (SSE2)

## PHASE A: STEVENS CREEK AND LENIHAN DAMS

# SITE INVESTIGATIONS AND LABORATORY TESTING AT STEVENS CREEK DAM

# ADDENDUM TO WORK PLAN

Prepared for

**SANTA CLARA VALLEY WATER DISTRICT**
5750 Almaden Expressway
San Jose, CA 95118

January 2011

TERRA / GeoPentech
a Joint Venture

# TABLE OF CONTENTS

1.0 Introduction .......... 1

2.0 Evaluation of Key Findings from Phase 1 Investigations .......... 1

- 2.1 Groundwater Levels within the Alluvium .......... 2
- 2.2 Need for Becker Penetration Testing Based on Gravel Content of Alluvium .......... 3
- 2.3 Results of CPT Trial Program .......... 4

3.0 Recommended Modifications to Work Plan .......... 4

- 3.1 Types and Locations of Investigations .......... 4
- 3.2 Procedures not Included in Work Plan .......... 5
  - 3.2.1 Becker Borings .......... 5
  - 3.2.2 Installation of Sealed Observation Wells .......... 6
  - 3.2.3 Cone Penetrometer Tests .......... 7
- 3.3 Specialty Contractors .......... 7

## Tables

A-1 Results of Gradation Tests in Alluvium

## Figures

A-1 Saturated Alluvium above Santa Clara Formation – Stevens Creek Dam

A-2 Results of Gradation Tests in Alluvium – Stevens Creek Dam

9R Final Subsurface Explorations – Plan – Stevens Creek Dam

10R Final Subsurface Explorations – Sections – Stevens Creek Dam

# 1.0 INTRODUCTION

The scope of the site investigations and laboratory testing at Stevens Creek Dam being completed as part of the SSE2 project is described in the Work Plan dated November 2010[1]. The Work Plan describes a phased approach in which sonic borings, piezometers, and physical and index property tests on samples from the sonic borings are completed and evaluated before proceeding with the remaining part of the work. The purpose of this interim evaluation is to check that the work planned for the second phase of the investigation is still appropriate given the results of the Phase 1 work and, in consultation with the District and DSOD, to modify the plan for Phase 2 work as necessary and appropriate.

This addendum to the Work Plan summarizes our evaluation of the key findings from the Phase 1 investigations and recommends modifications to the Phase 2 investigations. The recommended modifications are based on our evaluation of the results of the Phase 1 investigations and on discussions with the District and DSOD during a teleconference held on December 22, 2010. In addition, subsequent discussions on January 4 and 5, 2011 regarding the possible addition of Cone Penetrometer Tests (CPTs) to the Phase 2 work led to a trial program on January 24, 2011. This trial program showed that the embankment and foundation materials could be successfully penetrated by the cone and is also discussed hereinafter.

It should be noted that this addendum is intended to be used in conjunction with the Work Plan. Details of the proposed Phase 2 investigations already in the Work Plan are not repeated herein as only recommended changes in the Phase 2 work are discussed. The field boring logs, piezometer installation reports, and laboratory test results from the Phase 1 Investigations, as well as the preliminary logs from the CPT trial program, have been provided to the District and DSOD and final versions of this information will be included in the Site Characterization Report for Stevens Creek Dam that will be prepared after all the site investigations and laboratory testing are completed.

# 2.0 EVALUATION OF KEY FINDINGS FROM PHASE 1 INVESTIGATIONS

The key findings from the Phase 1 work are related to the groundwater levels within the alluvium and the need for Becker Penetration Testing based on the gravel content of the alluvium. As discussed in the Work Plan, the location of the piezometric surface within the alluvium is critical because, if the alluvium is susceptible to liquefaction and is saturated to some elevation, it will likely liquefy due to the high seismic ground motions. Therefore, the focus of the work effort continues to be the evaluation of the liquefaction potential of the alluvium and the development of residual strength for these materials, if indeed they are judged to be liquefiable.

[1] TERRA/GeoPentech, a Joint Venture, 2010 (November), Seismic Stability Evaluations of Chesbro, Lenihan, Stevens Creek, and Uvas Dams, Phase A: Stevens Creek and Lenihan Dams, Site Investigations and Laboratory Testing at Stevens Creek Dam, Work Plan, prepared for Santa Clara Valley Water District.

## 2.1 Groundwater Levels within the Alluvium

Casagrande piezometers were installed at the base of the alluvium layer in all five of the sonic borings completed during the Phase 1 investigations. The installation procedure typically included backfilling the portion of the borehole that penetrated the Santa Clara Formation with bentonite chips to the top of the formation, installing a porous plastic piezometer tip in a 3-ft thick sand collection zone within the borehole that extended up from the top of the Santa Clara Formation, placing a 3- to 12-foot thick layer of bentonite chips from the top of the 3-ft thick collection zone, and grouting the borehole using cement-bentonite grout above that. The bottom of the 1-foot long piezometer tip was typically placed approximately 0.5 feet above the top of the Santa Clara Formation so that piezometric levels as low as 0.5 feet above the top of the Santa Clara Formation could be measured. However, the bottom of the piezometer tip for boring SC-101S was actually installed 0.2 feet above the top of the Santa Clara Formation.

The saturated thickness of the alluvium and piezometric level at the piezometers are tabulated below based on measurements made on December 16, 2010; these data were discussed with the District and DSOD during the teleconference on December 22, 2010.

| Piezometer Number | Groundwater Head, ft | Saturated Thickness of Alluvium, ft | Nominal Location and Formation |
|---|---|---|---|
| SC-101 | 420.6 | 0.2 | Sta 7+50 10' D/S Younger Alluvium |
| SC-102 | 419.8 | 0.6 | Sta 7+50 100' D/S Younger Alluvium |
| SC-103 | 419.2 | 2.0 | Sta 7+50 200' D/S Younger Alluvium |
| SC-104 | 418.5 | 5.9 | Sta 7+50 350' D/S Younger Alluvium |
| SC-105 | 495.0 | 5.7 | Sta 4+00 10' D/S Older Alluvium |

The borings show that the thickness of the alluvial soils left in place beneath the dam varied from 11 to 14 feet. The borings also found that the Santa Clara Formation beneath the alluvium was cemented and essentially dry. The piezometer data tabulated above show that the saturated thickness of the Younger Alluvium at Station 7+50 varies from 0.2 to 2.0 feet beneath the embankment and increases to 5.9 feet at the toe, and that the gradient of horizontal flow within the Younger Alluvium is relatively constant and equal to 0.006 on average. It should also be noted that the groundwater head at the toe of the dam in the vicinity of the outlet structure may be controlled by the elevation of the water in Stevens Creek at the outlet structure that appears to be higher than the measured groundwater elevation at the toe of the dam.

The saturated thickness of the Older Alluvium at Sta 4+00 is 5.7 feet and the groundwater head is at elevation 495 feet, indicating that water within the Older Alluvium is perched on top of the relatively impervious Santa Clara Formation.

Figure A-1 summarizes the data on the thickness of the saturated alluvium measured in the Casagrande piezometers from the time they were installed though January 24, 2010. Also shown on this figure is the reservoir level during the same period. Review of this figure suggests that the saturated thickness of Older Alluvium at the right abutment (SC-105S) is somewhat influenced by the reservoir level: it appears to have increased by about 6 inches in response to a rise in reservoir level of about 10 feet. On the other hand, the saturated thickness of Younger Alluvium appears to be much more affected by the level in Stevens Creek downstream of the dam because it increased by about 1 foot to 2 feet under the embankment but by almost 2.5 feet in the vicinity of the toe of the dam. Also, the reservoir level remained essentially constant in the last two weeks of the monitoring period but the saturated thickness started decreasing again as the water level in Stevens Creek at the outlet structure decreased.

The data collected from the Casagrande piezometers clearly show that the Younger Alluvium at Station 7+50 is acting as a horizontal drainage blanket beneath the downstream shell of the dam, that the amount of seepage through the dam embankment is relatively small compared to the hydraulic capacity of the alluvium to convey water horizontally. As a result, the saturated thickness of the Younger Alluvium is typically 2 feet or less except in the vicinity of the toe of the dam where the saturated layer is as much as 8 feet thick and where the groundwater head is probably controlled by the elevation of the water in Stevens Creek at the outlet structure and thus could be even thicker. From this it follows that the portion of the alluvium above the saturated thickness should be partially saturated, with zero or negative pore pressures within the partially saturated zone.

As a result, we have concluded that the piezometers originally planned for installation within the Santa Clara Formation during the Phase 2 investigations are not necessary and that the number of piezometers within the upper portion of the Younger Alluvium can be reduced from two to one. The purpose of the piezometer in the upper portion of the Younger Alluvium is to verify that the pore water pressures in the partially saturated alluvium are zero or negative. The specific implications of this conclusion are discussed in Section 3 of this Addendum.

## 2.2 Need for Becker Penetration Testing Based on Gravel Content of Alluvium

As shown in Table A-1, the thickness of the alluvium in the sonic borings was found to vary from 11 to 14 feet. Table A-1 also lists the amount of gravel and fines within the alluvial soils based on laboratory gradation tests on recovered samples. Figure A-2 contains a plot of percent gravel and percent fines vs. depth below the top of the alluvium. The range and median value of percent gravel and percent fines are as follows:

| Particle Size | Range in % by Weight | Median % by Weight |
|---|---|---|
| Gravel | 12 to 63 | 47 |
| Fines (Silt and Clay) | 7 to 32 | 13 |

Given the high gravel content, it is clear that gravels will have a significant effect on the results of Standard Penetration Tests (SPTs). It may be possible to obtain some representative SPT data by monitoring the blows per inch required to advance the split-spoon sampler but it is likely that most of the SPT data will be found to be “corrupted” by the high gravel content. As a result, and in consultation with the District and DSOD, it was concluded that Becker Penetration Tests will provide data to aid in the characterization of the liquefaction potential of the alluvium. However, we believe SPTs should continue to be performed in the alluvium in mud rotary borings because it is important that the results of the Becker Penetration Tests be compared with the limited SPT data that may be obtained from these mud rotary borings and, as discussed below, with the relatively large amount of data that will be provided by the CPTs.

## 2.3 Results of CPT Trial Program

Based on further review of the characteristics of the materials comprising Stevens Creek Dam, we came to the conclusion that serious consideration should be given to the addition of Cone Penetrometer Tests (CPTs) to the Phase 2 investigations. The results of the CPTs could be very useful in the characterization of the embankment materials for the seismic stability analyses because they would provide a profile of resistance through the embankment and alluvium, supplement the results of the sonic and OYO profiling, and allow us to “tie together” the information at discrete depths available from previous investigations and from the additional borings already planned. Also, the results of CPTs in the alluvium may help in the evaluation of the results of the planned BPTs, OYO shear wave measurements, and SPTs, and possibly allow us to justify more reliable values of residual strength in the alluvium than would be derived from the BPTs alone. However, there was a concern that the cone would not be able to penetrate the embankment materials and/or the underlying alluvium because of the high gravel content of these materials. Thus, we recommended that CPTs be attempted on a trial basis in areas easily accessible by the heavy CPT rig to confirm that penetration could be achieved and to check on the reasonableness of the test results before formally adding CPTs to the Phase 2 investigations. This approach was recommended to the District and the trial program was authorized. The program was also discussed with DSOD personnel who expressed concern about the usefulness of CPTs but had no objections to our approach provided the CPTs and SPTs were not the primary tools used for evaluating the liquefaction potential or residual strength of the alluvium.

The program was completed on January 24, 2011 using a 20-ton capacity cone with a tip area of 15 $cm^2$ and a friction sleeve area of 225 $cm^2$. A total of 3 CPTs were successfully completed through the embankment materials and alluvium: two from the crest of the dam (one each 8 to 9 feet upstream of SC-101S and SC-105S) and 1 at the toe, 8 feet downstream of SC-104S. The test produced continuous logs for the full depth of the test at each location, extending through the embankment/alluvium soils and into the underlying rock. Preliminary logs have been provided to the District and DSOD. Although processing of the data is still pending we believe it is appropriate to add a program of CPTs in the Phase 2 investigations for the reasons discussed above.

# 3.0 RECOMMENDED MODIFICATIONS TO WORK PLAN

## 3.1 Types and Locations of Investigations

Based on the evaluations and conclusions presented above, we recommend the following modifications to the Work Plan for the Phase 2 work as shown on Figures 9R and 10R which have been revised from the Work Plan:

1. Delete mud rotary borings SC-102MR, and SC-103MR.

2. Focus the attention of the remaining mud rotary borings on:
   a. obtaining at least ten 4-inch diameter Pitcher Barrel samples of the original embankment materials for engineering property testing,
   b. conducting Standard Penetration Tests (while measuring blows per inch of penetration) on samples at 5-ft intervals within the original embankment materials,
   c. conducting Standard Penetration Tests (while measuring blows per inch of penetration) on samples within the alluvium that are nearly continuous while allowing for a minimum of 1 foot of spacing (i.e., clean-out) between consecutive Standard Penetration Tests,
   d. measuring shear wave velocities of the original embankment, alluvium and Santa Clara Formation using OYO downhole suspension logging.
3. Add five Becker Penetration Test borings, one each at the location of borings SC-102, SC-103, and SC-104, and two additional Becker borings located 50 feet on either side of Boring SC-104.
4. Install four grouted-in-place vibrating wire piezometers in Becker Boring SC-102 as shown on Figure 10R.
5. Install two sealed 2-inch diameter observation wells within the Becker borings SC-106BB and SC-107BB that are located 50 feet on either side of Boring SC-104BB.
6. Install a staff gage on the Stevens Creek outlet structure to allow monitoring of the level of Stevens Creek at the outlet structure.
7. Complete up to 13 additional CPTs with the following anticipated distribution: 5 CPTs along the dam crest, 4 CPTs on the two temporary benches on the downstream slope (2 on each bench), and 4 CPTs at the downstream toe. The exact locations of these CPT probes will be determined in the field.

## 3.2 Procedures not Included in Work Plan

### *3.2.1 Becker Borings*

The Becker borings will be drilled using a truck-mounted AP1000 Drill Systems Becker Hammer Drill equipped with an ICE -180 diesel hammer that will be used to drive a 6.6-inch diameter crowd-plugged bit with the turbocharger turned on. The number of hammer blows required to advance the bit every foot will be monitored and recorded. In addition, the bounce chamber pressure will be measured and recorded during each and every foot of penetration. Borings SC-103BB and SC-104BB will be grouted upon completion. The grout mix will be the same as that used for grouting the sonic and mud rotary borings as described in the Work Plan.

Boring SC-102BB will be completed by installing 4 multi-level vibrating wire (VW) piezometers as shown on Figure 10R. The procedure for installing these piezometers is described in Section 11.2 of the Work Plan, except that the installation procedure will be modified so that the string of vibrating wire piezometers (and associated placement pipe) is installed inside the Becker drill casing after the plug at the bottom of the casing has been removed or knocked out.

Sealed observation wells will be installed upon completion of Borings SC-106BB and SC-107BB, as shown on Figure 9R. The procedure for installing the observation wells is described in the following subsection.

### *3.2.2 Installation of Sealed Observation Wells*

The observation wells will be constructed using 2-inch diameter threaded flush joint PVC solid riser casing connected to a 2-foot long slotted well screen with 0.020-inch wide machine-cut slots. A threaded screw-on cap will be provided at the bottom of the well screen. The sand filter to be installed around the well screen will be a commercially available well pack suitable for use with a 0.020-inch slotted well screen. Typical gradation requirements for the sand filter are listed below:

| Sieve Number | Size, inches | % Finer by Weight |
|---|---|---|
| 16 | 0.047 | 98 |
| 18 | 0.039 | 87 |
| 20 | 0.033 | 65 |
| 25 | 0.027 | 34 |
| 30 | 0.023 | 8 |
| 35 | 0.020 | 2 |

The installation procedure for the sealed observations wells will be as follows:

1. Backfill the bottom portion of the borehole to within 6 inches below the top of the Santa Clara Formation using HOLEPLUG ¾-inch Bentonite Chips or approved equivalent product.
2. Place 18 inches of sand filter material on top of the bentonite chips.
3. Assemble well screen and riser pipe and lower assembly into the borehole so that it rests on the top of the one foot of sand installed in step 2. Check that the bottom of the well screen is 12 inches above the top of the Santa Clara Formation.
4. Backfill the annular space around the well with sand filter material so that the top of the sand is 1 foot above the top of the well-screen slots and 4 feet above the top of the Santa Clara Formation.
5. Backfill the annular space around the well riser with 10 feet of bentonite chips.
6. Grout the annular space around the well riser so that the top of the grout is 1 foot below the ground surface. The grout mix will be the same as that used to backfill the sonic and mud rotary borings, as described in the Work Plan.

7. After the grout sets, cutoff the well riser pipe so that it is 3 inches below the ground surface and install a removable pipe cap with a ¼-inch diameter hole drilled in the cap to allow venting of the well. Then install an 8-inch diameter, 12 inch deep, monitoring well vault, flush with the ground surface and supported on a concrete pad, to protect the top of the well. The cover of the vaults will be a Morrison Well Cover marked with the words Monitoring Well and secured by two steel bolts.

### *3.2.3 Cone Penetrometer Tests*

The CPTs will be completed using a 20-ton capacity truck-mounted cone rig on the dam crest and at the toe of the dam. CPTs on the temporary benches will be performed using a track-mounted rig that has the ability to auger into the ground to provide the necessary reactive force to push the cone.

In addition to measuring tip resistance and side friction, we will conduct 25 pore pressure dissipation tests at various depths within the embankment and alluvium in order to obtain field data on soil permeability and we will also measure shear wave velocity using the seismic cone at 5-foot intervals adjacent to borings SC-101MR, SC-104MR, and SC-105MR in which OYO downhole suspension logging is planned. Shear wave velocity will also be measured within the alluvium at all other CPT locations.

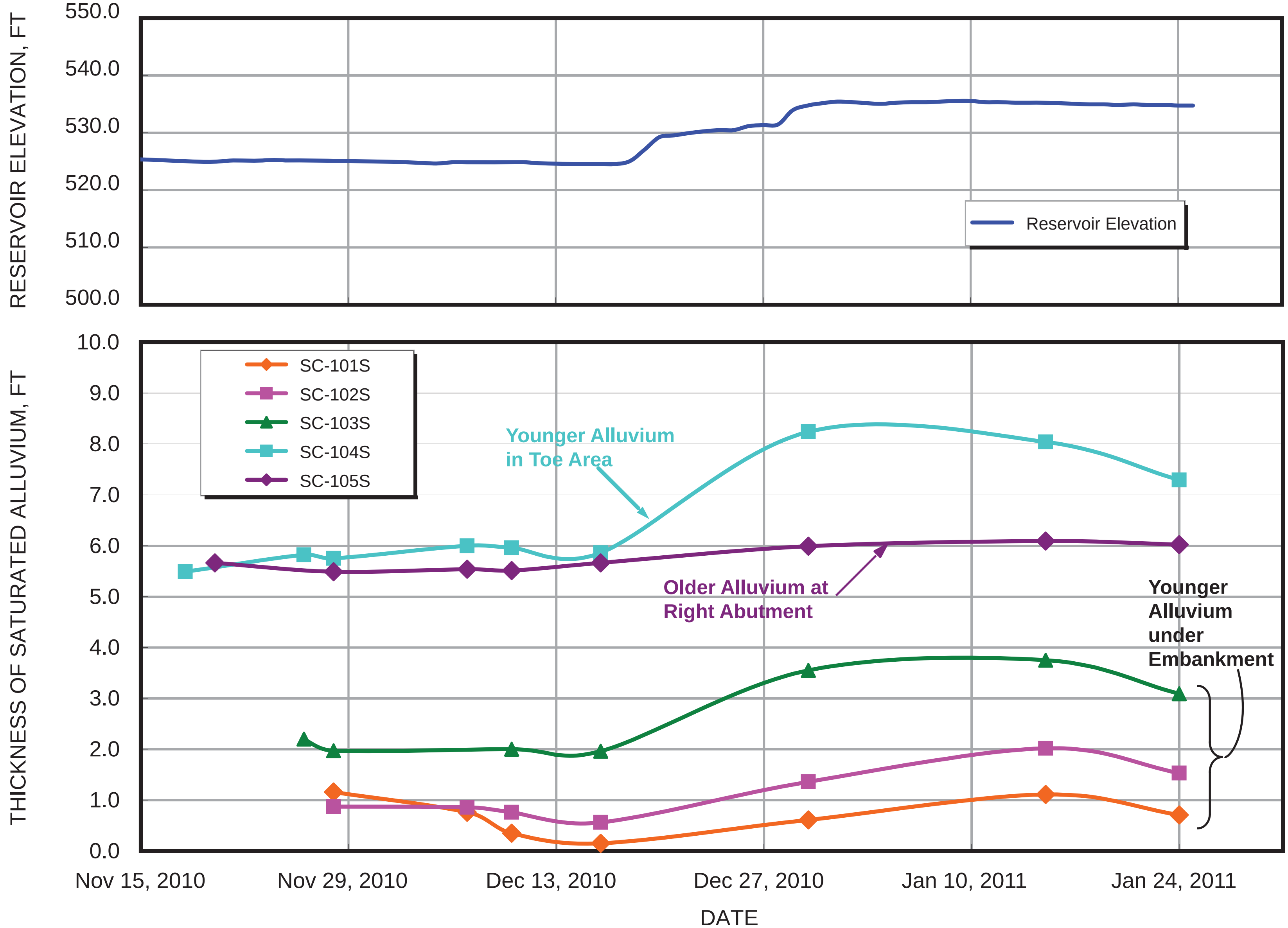
## 3.3 Specialty Contractors

In addition to those listed in the Work Plan, the following specialty contractors will participate in the Phase 2 investigations:

1. Great West Drilling will complete the Becker borings and install the vibrating wire piezometers and the observation wells. The drill rig will be operated by an experienced driller and two experienced helpers.
2. Gregg Drilling and Testing will perform the CPTs. They completed the trial program on January 24, 2011.

# TABLE A-1
# RESULTS OF GRADATION TESTS IN ALLUVIUM

| Boring No. | SC-101S | SC-102S | SC-103S | SC104-S | SC-105S |
|---|---|---|---|---|---|
| Ground Surface Elevation, ft | 557.0 | 527.5 | 490.2 | 442.4 | 553.4 |
| Elevation of Top of Alluvium, ft | 432.0 | 433.5 | 431.2 | 427.4 | 500.4 |
| Thickness of Alluvium, ft | 11 | 14 | 14 | 14 | 11 |
| | | | | | |
| Depth Below Top of Alluvium, ft | | | | 1 | |
| Elevation, Ft | | | | 426.4 | |
| Percent Gravel | | | | 48 | |
| Percent Fines | | | | 13 | |
| Unified Soil Classification | | | | GC | |
| | | | | | |
| Depth Below Top of Alluvium, ft | 7 | 4 | 4 | 5 | 5 |
| Elevation, Ft | 425.0 | 429.5 | 427.2 | 421.4 | 495.4 |
| Percent Gravel | 63 | 12 | 28 | 47 | 26 |
| Percent Fines | 9 | 30 | 32 | 9 | 25 |
| Unified Soil Classification | GP | SM | SM | GW | SC |
| | | | | | |
| Depth Below Top of Alluvium, ft | 10 | 9 | 10 | 10 | 9 |
| Elevation, Ft | 422.0 | 424.5 | 421.2 | 416.4 | 491.4 |
| Percent Gravel | 35 | 58 | 21 | 63 | 47 |
| Percent Fines | 15 | 8 | 15 | 7 | 15 |
| Unified Soil Classification | SC | GW | SM | GP | GC |
| | | | | | |
| Depth Below Top of Alluvium, ft | | 11 | 12 | | |
| Elevation, Ft | | 422.5 | 419.2 | | |
| Percent Gravel | | 14 | 63 | | |
| Percent Fines | | 8 | 8 | | |
| Unified Soil Classification | | SW-SC | GP | | |



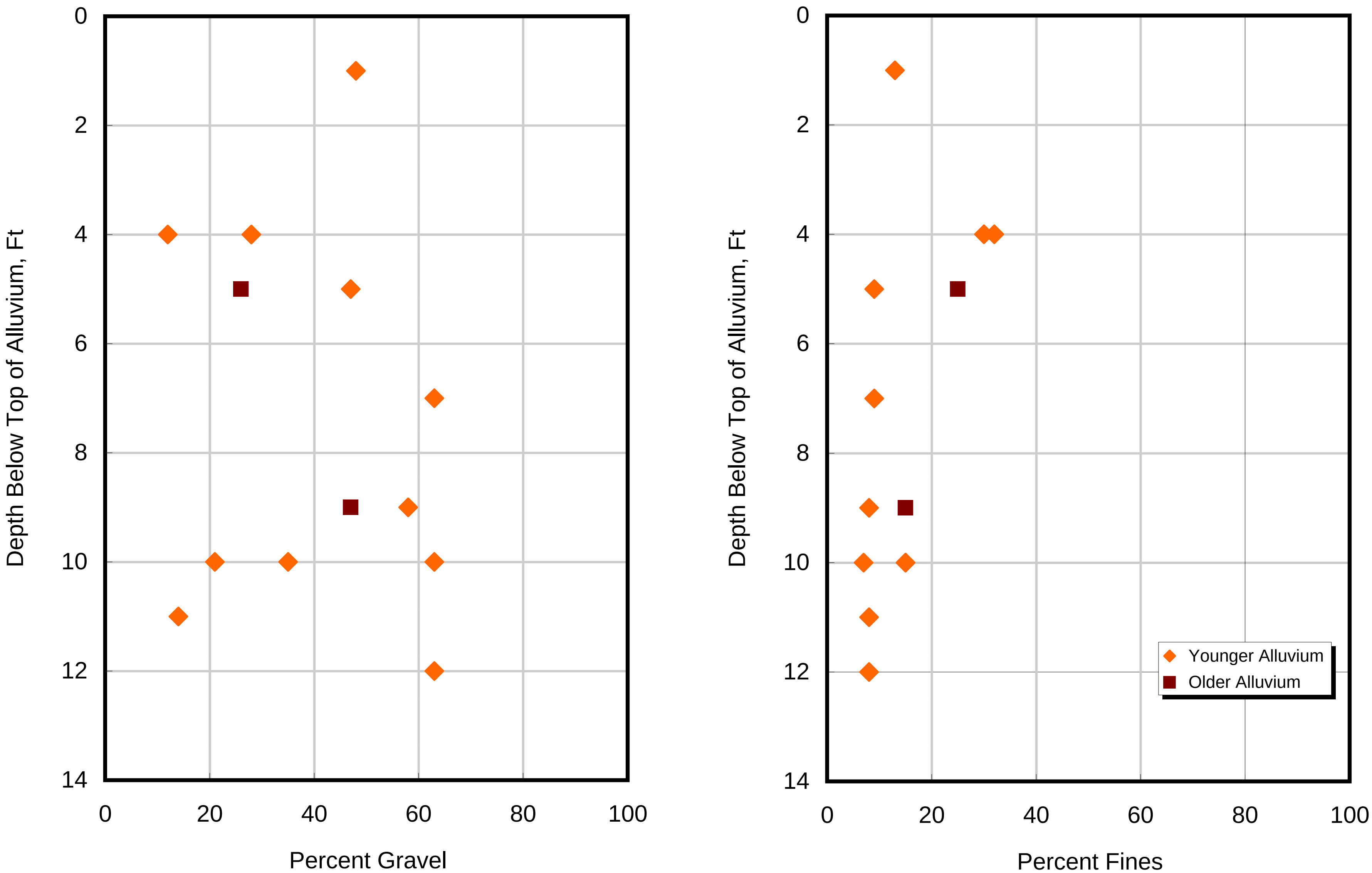

Note: Thickness of saturated alluvium as measured in Casagrande piezometers installed in sonic borings.

TERRA / GeoPentech
a Joint Venture

SATURATED ALLUVIUM ABOVE SANTA CLARA FORMATION - STEVENS CREEK DAM

SEISMIC STABILITY EVALUATIONS (SSE2)

Figure A-1




TERRA / GeoPentech
a Joint Venture

RESULTS OF GRADATION TESTS IN ALLUVIUM
STEVENS CREEK DAM
SEISMIC STABILITY EVALUATIONS (SSE2)

Figure A-2

Rev. 0 12/21/2010 SSE2-WP-1ASC


SC-102 S/MR/BB

EXPLORATION LOCATION AND NUMBER

| S = Sonic Boring | MR = Mud-Rotary Boring | BB = Becker Boring |
|---|---|---|
| 1 Casagrande Piezometer in Alluvium (All Locations) | Downhole Geophysical Logging (SC-101, SC-104, SC-105) | 4 Vibrating Wire Piezometers at SC-102 BB (See Figure 10R) |
| Field Permability Test (All Casagrande Piezometers) | | Sealed Observations Wells at SC-106 BB and SC-107 BB |

Sonic, Mud-Rotary, and/or Becker Borings at the same nominal location are drilled 10 feet apart.

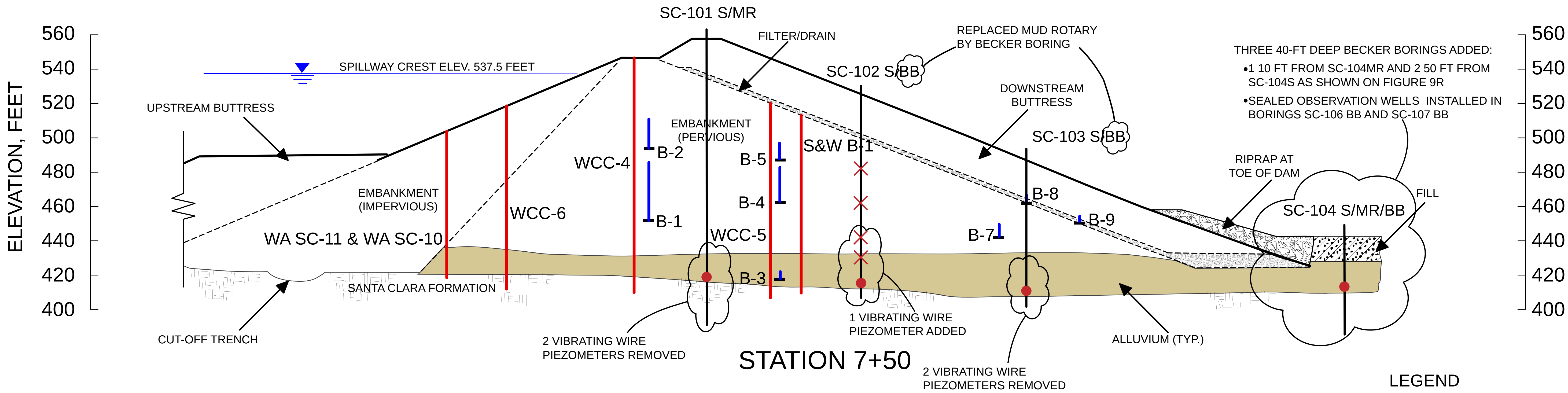
Note: See Figure 11 for sections and details of access road.

TERRA / GeoPentech
a Joint Venture

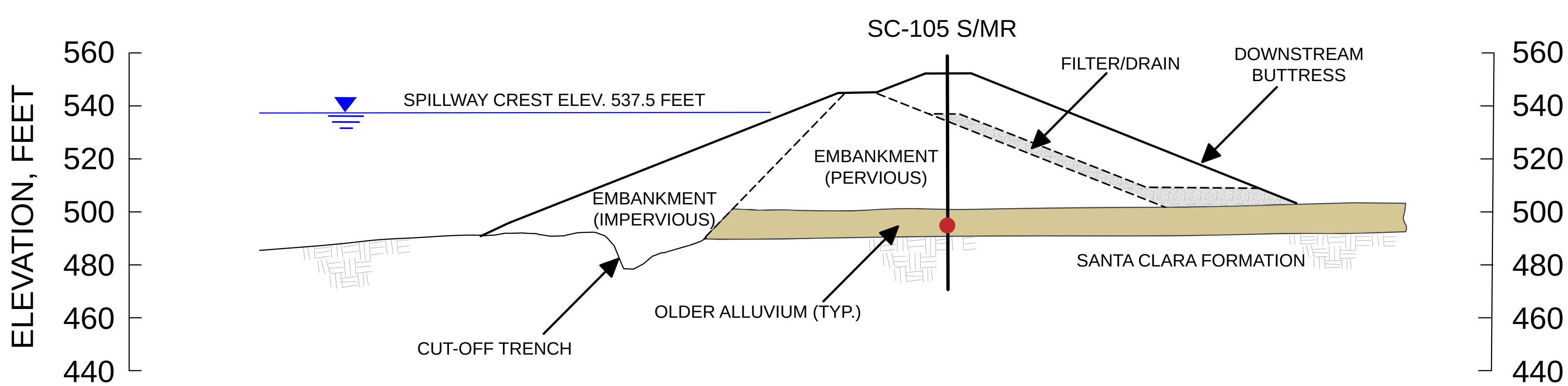
FINAL SUBSURFACE EXPLORATION PLAN
STEVENS CREEK DAM
SEISMIC STABILITY EVALUATIONS (SSE2)

Figure 9R

Rev. 7 01/31/2011 SSE2-WP-1SC

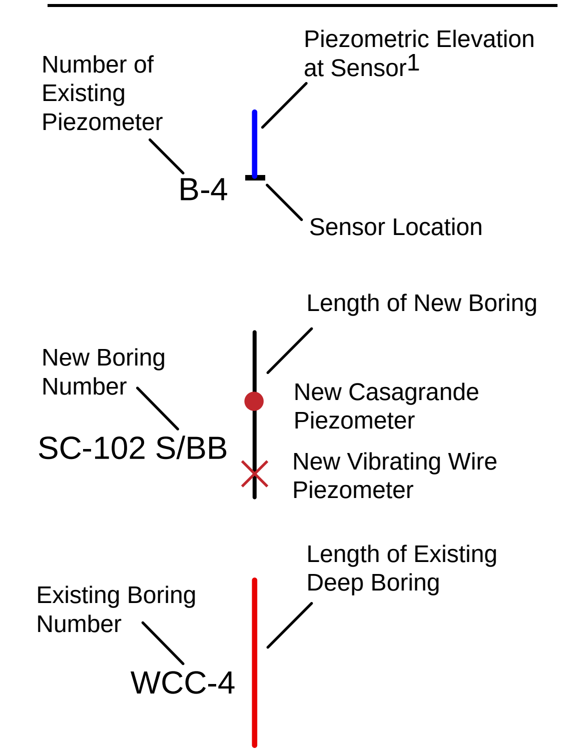


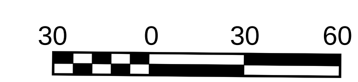

STATION 7+50




STATION 4+00

LEGEND




APPROXIMATE SCALE IN FEET

Notes:

1. Piezometric Elevations from Figure 3 of 2010 Surveillance Report.
2. Elevations of top of Santa Clara Formation and base of dam embankment and buttresses from geologic model developed by TGP.
3. Piezometer B-6 at station 9+70 is screened approximately 25 ft. below top of the Santa Clara Formation.

TERRA / GeoPentech
a Joint Venture

PROPOSED EXPLORATIONS
STEVENS CREEK DAM
SEISMIC STABILITY EVALUATIONS (SSE2)

Figure
10R

Rev. 7 01/31/2011 SSE2-WP-1SC