GEI Consultants

Geotechnical
Environmental
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Third Party Due-Diligence Review
Investigations and Design of Left Abutment
Calaveras Dam Replacement Project
Santa Clara and Alameda Counties, CA

Gentlemen,

GEI Consultants, Inc. (GEI) is pleased to submit this report to the San Francisco Public Utilities Commission (SFPUC) regarding engineering services provided by GEI for the Calaveras Dam Replacement Project (CDRP) in Santa Clara and Alameda Counties, CA. In general, the work consisted of a due-diligence review of the URS Corporation Design Team's (hereinafter referred to as Design Team) investigations and design of the Left Abutment for the replacement dam project. The GEI Review Team consisted of Messrs. Alberto Pujol, P.E, G.E., Steve Verigin, P.E, G.E., and Jeffrey Brown, P.G., C.E.G.

1.0 PURPOSE AND SCOPE

Unanticipated ground conditions were revealed during excavation for the Left Abutment. The impacted area included areas of the Left Abutment and the Spillway Cut Slope that extend up the northeastern and eastern flanks of Observation Hill. These unforeseen conditions have resulted in significant increases in the construction cost and schedule of the project. GEI was requested by SFPUC to provide a third party review of pre-construction investigations and the design of the Left Abutment to evaluate the Design Team's services with respect to site exploration and foundation characterization of the Left Abutment relative to standard practice in the industry for a major dam project in California.

GEI's scope of work for this project included the following tasks:

- A site visit to view the Left Abutment excavations;
- A review of geologic literature and available project documents, including boring logs, summary reports, memoranda, and Quality Assurance/Quality Control documentation;
- A review of selected core from Left Abutment borings;
- Interviewing members of the Design Team;
- Preparation of this letter report rendering opinions regarding the Design Team's due-diligence during pre-construction investigations.

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The project documents initially provided by SFPUC included electronic copies of a variety of project reports, memoranda, and plans and specifications. A listing of project documents relevant to exploration for, and design of, the Left Abutment that were initially provided by SFPUC for GEI's review is provided on Table 1. To maintain the independence of our review, documentation prepared by other reviewers in the course of the CDRP design development, such as review information prepared by the Calaveras Technical Advisory Panel (CTAP) and the California Division of Safety of Dams (DSOD), was not included in the scope of GEI's analysis.

As we proceeded with our reviews, we requested additional project documents from SFPUC. The additional project documents that GEI received are listed in Table 2. In addition, to assist in evaluation of Quality Assurance/ Quality Control (QA/QC) policy compliance, we requested further QA/QC documentation from the Design Team. The QA/QC records reviewed are listed in Table 3.

As part of our evaluation, GEI also obtained and reviewed geologic reports and maps of the local and regional area not referenced in the project documents. A list of the references cited in this letter report is included in Table 4. We also requested from SFPUC access to the stereographic aerial photographs of the Left Abutment used in the Design Team's analyses as referenced in the GDR. A list of the aerial photographs reviewed by GEI for this study is included in Table 5.

Messrs. Pujol, Verigin, and Brown visited the site on June 25, 2013, in the company of John White, Daniel Wade and Susan Hou, representing SFPUC. After site and project orientations, the group collectively viewed excavations at the Left Abutment. Mr. Brown returned to the site on September 10 and 11, 2013, in the company of Ken Yoder of the Construction Management Team, to review selected boxes of rock core recovered during the project's field investigations. Questions on methodology, interpretations, and analyses generated by the review of documents and rock core were presented to the Design Team and discussed during a meeting with the Design Team and SFPUC on November 22, 2013.

Based on the review of project documents and interviews, GEI performed an evaluation of the due-diligence of Design Team during the planning, investigation and design phases of the project. In particular, GEI intended to address the specific questions posed by SFPUC regarding the Design Team's pre-construction performance. These questions included the following:

- Were geologic/geotechnical investigations planned and implemented prudently and in accordance with standard practice in the industry?
- Were reasonable/sufficient geotechnical data obtained?
- Were data properly evaluated and in accordance with standard practice?
- Were analyses done properly?
- Was proper senior oversight and QA/QC performed on the data collection, geologic interpretation and analyses?
- Were conclusions and recommendations prudent and within standard practice in the industry?

Our evaluation focused on developing opinions about the Design Team's approach and completeness during site characterization and dam design relative to the nature of the project and current practice. Our evaluation also considered the recognized general limitations of subsurface exploration, that is, that there are professional judgments and risks involved in extrapolating localized, small samplings made in exploratory borings to the broad areas between the borings.

2.0 CONCLUSIONS ON DUE DILIGENCE EMPLOYED DURING PROJECT DESIGN

The six questions posed by SFPUC relating to the due diligence employed by the Design Team in their investigations for the CDRP are indicated below with GEI's responses.

Question 1: Were geologic/geotechnical investigations planned and implemented prudently and in accordance with standard practice in the industry?

Response: Yes, an extensive exploration program was conducted consistent with standard practice for the design of major dams in California. The exploration program included review of geologic literature, aerial photographs, surface mapping, trenching, seismic refraction surveys, exploratory borings, and in-situ and laboratory testing. The phasing of the investigations and the various components of the studies followed a typical approach for this type of project. Issues, such as highly fractured rock, steep, inaccessible topography, compressed field investigation schedules, and the desire to accelerate environmental review, may have influenced the Design Team's investigations to some degree, but the need to manage such matters is not unusual on large dam projects. The Design Team developed reasonable workarounds, such as use of limited-access drill rigs and accelerated field mobilizations, and conducted explorations in alternate areas without compromising the objectives of their field investigations.

Question 2: Were reasonable/sufficient geotechnical data obtained?

Response: Yes, the Design Team recovered data from an extensive review of geologic literature and aerial photographs, and from field studies performed in most site areas that were accessible for exploration equipment. The investigation used common methods to recover data that are standard for this type of project with the prevailing ground and topographic conditions. The number and depth of exploratory borings was appropriate for a major dam project. The drilling subcontractor used on the majority of the pre-construction exploration, Ruen Drilling, is highly regarded in the geotechnical exploration business. There were small data losses due to zones of No Recovery from the core borings, but this would be expected when coring in the broken, weathered rock that exists in the Left Abutment.

Question 3: Were data properly evaluated and in accordance with standard practice?

Response: Yes, the Design Team appears to have been reasonably thorough in their review and evaluation of the available data. The Design Team looked at all manner of data from geologic literature, aerial photographs, surface mapping, trenching, seismic refraction surveys, borings and televiewer surveys to form the basis for their site characterization.

A preliminary report by Nilsen et al (1975) that was reviewed by the Design Team (URS, 2008) and was based on analysis of aerial photographs, mapped a landslide adjacent to the western edge of the designed Left Abutment excavation. This feature was not mentioned in any of the Design Team's reports; however, this is not unusual considering that this report was labeled preliminary, and subsequent, more detailed, reports by the same author, and others, did not map a landslide at this location or in other areas of the Left Abutment. In addition, our review of the available historical aerial photographs suggests that the Nilsen et al (1975) preliminary conclusion of a landslide origin for the area along the Left Abutment was likely based on the prominent hillside bench located above the existing spillway in this area. While such a benched feature can be evidence for the presence of a landslide, an alternate, more plausible, interpretation is that this landform was likely constructed during the extensive site grading for the original dam and spillway in this area. Indeed, we note that a pre-grading topographic map (USGS, 1899), having a 25-foot contour interval, appears to indicate that this bench did not exist prior to dam construction. It is thus reasonable that the 1975 preliminary mapping, which was later discounted, would not have provided sufficient incentive on its own for the Design Team to initiate a focused landslide investigation within the footprint of the Left Abutment excavation area, especially considering the difficult access conditions.

The two possible landslides mapped on the flanks of Observation Hill during our aerial photograph review appear to be comparatively surficial or only marginally encroach into the Left Abutment area. Based on the Geologic Map and Exploration Plan shown on Figure 2-1 of the GDR (URS, 2008), exploratory borings and/or outcrop mapping were performed in both these areas, suggesting that these field explorations would have discounted the presence of landslides at these locations.

The Design Team's Geotechnical Interpretive Report (GIR) {URS, 2008a} appears to provide a comprehensive discussion of their site characterization and analysis of the properties of the materials forming the Left Abutment. The Design Team developed a coherent "no-landslide" interpretation for the Left Abutment that was consistent with a comprehensive body of geologic and geotechnical data. Reasons for not suspecting a landslide were many:

- The existing Left Abutment slope was significantly altered by construction activities for the original dam, but remained apparently stable at a very steep angle for the last 90 years.
- There was no surface indication of landslide failure.
- The deep weathering in the Left Abutment was attributed primarily to disturbance relating to the local faulting and folding.
- A basal slide surface was not detected in the various explorations that intersected the slope.
- There were small data losses due to zones of No Recovery from the core borings, but this would be expected when coring in the broken, weathered rock that exists in the Left Abutment.
- The rock materials of the Left Abutment were interpreted to be highly weathered, in place rock, as they appeared to generally fit together in a fractured, but intact, rock mass.

Question 4: Were analyses done properly?

Response: Yes, based on the stated interpretations of site conditions. The strength parameters for the rock mass in the Left Abutment were derived using procedures that are broadly accepted by the dam design community. The values adopted for the rock mass shear strength parameters appear reasonable for the interpreted condition of the foundation as an in-place rock mass devoid of pre-existing, large-scale planes of weakness having unfavorable orientations. The stability analyses were also conducted using procedures that are broadly accepted by the dam design community. The geometry of the excavations and the stability analysis results appear reasonable for the interpreted foundation conditions.

Question 5: Was proper senior oversight and QA/QC performed on the data collection, geologic interpretation and analyses?

Response: The QA/QC procedures described in the Work Plans (URS, 2004, 2005) required peer review of all data and interpretations. The Design Team formally documented the review process by means of Calculation Cover Sheets (CCSs), Detail Checking Reports (DCRs), and Independent Technical Review Reports (ITRs). GEI was provided with at least 114 of such QA/QC documents prepared for many calculations, drawings and reports for the project. Based on our review of the QA/QC records, it is our opinion that a rigorous and comprehensive peer review process was in-place throughout the Design Team's work.

Question 6: Were conclusions and recommendations prudent and within standard practice in the industry?

Response: Based on their responses to the interview questions and the discussions in their reports, the Design Team had confidence in their interpretation of the subsurface conditions. The foundation design included excavations to remove most of the weathered brown sandstone within the core contact area of dam foundation, and an extensive grouting program to strengthen and seal the rock mass under the core foundation. Considering the Design Team's interpretations of subsurface conditions in the Left Abutment, their design of the Left Abutment and methods for mitigation of the foundation materials appear appropriate, prudent and within standard practice in the industry.

3.0 APPROACH TO PROJECT REVIEW

GEI's experience on numerous dam projects, both as prime consultant and third-party reviewer, suggests that different teams of consultants and designers may have differing approaches to exploration and design for a large dam. Such differences may stem from variations in the training, experience, and conservatism of the members of the design team, either as individuals or as a group. However, in all cases, the ultimate goal of the subsurface exploration is to adequately characterize the site conditions relative to the design of a safe dam structure.

GEI began the project review at a point when significant abutment excavation had been performed in response to the unforeseen conditions in the Left Abutment area. Therefore, we did not have the perspective of viewing the site as it existed during the replacement dam pre-construction exploration and design phase. Nonetheless, GEI's approach to the project review was to generally follow and assess the Design Team's rationale through the investigation and design of the Left Abutment of the dam. This approach was facilitated by site visits, review of documents related to the area and the project, and discussions with members of the Design Team, including inquiries regarding their rationale for certain conclusions that were developed based on the acquired subsurface data.

As requested by SFPUC, GEI's review was specific to the Left Abutment area. In general, GEI had access to most formal documents related to the project and some other background information provided by the Design Team. However, GEI did not review unpublished internal memoranda, emails, or records of undocumented conversations that may also have been important in establishing the interpretations and conclusions developed by the Design Team.

We conducted our review to the extent needed to facilitate our understanding of the subsurface conditions as expressed on boring logs and in summary reports.

4.0 RESULTS OF GEI REVIEW

The general results of our review of project-related literature, aerial photographs, documents, and rock core are discussed by in the following sections. Each section presents an overview of the materials reviewed, summarizes the results of the review, and provides general conclusions drawn from the review.

4.1 Agency Guidelines for Site Investigations

An examination of regulatory agency guidelines and technical manuals was conducted to assess requirements and/or guidelines on recommended scopes of work for field investigations in support of a large embankment dam similar to Calaveras Dam. Documents relating to dam construction from the following agencies were reviewed:

- U.S. Army Corps of Engineers (USACE)
- U.S. Bureau of Reclamation (USBR)
- Federal Energy Regulatory Commission (FERC)
- California Department of Water Resources, Division of Safety of Dams (DSOD)
- U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS)

Pertinent text regarding the scope of field investigations for dams cited from agency publications is summarized in the following paragraphs.

4.1.1 U.S. Army Corps of Engineers (USACE)

An USACE engineering manual applicable to Calaveras Dam is "General Design and Construction Considerations for Earth and Rock-Fill Dams" (USACE, 2004). While no specific direction regarding number and spacing of explorations is offered, the manual provides the following general statements:

> "Geological and subsurface investigations at the sites of structures and possible borrow areas must be adequate to determine suitability of the foundation and abutments, required foundation treatment, excavation slopes, and availability and characteristics of the embankment materials." (Section 3.1. Geological and Subsurface Explorations and Field Tests, a. General Requirements, Item (1))
>
> "The magnitude of the foundation exploration program is governed principally by the complexity of the foundation problem and the size of the project." (Section 3.1. Geological and Subsurface Explorations and Field Tests, a. General Requirements, Item (3))

In the USACE engineering manual entitled "Geotechnical Investigations" (USACE, 2001), the frequency and depth of explorations for pre-construction investigations at a project site is also generalized:

> "Areal extent of the investigations is determined by the size and nature of the project…. Major projects, such as dams and reservoirs, electrical generating plants, and locks and dams, require comprehensive field programs." (Section 2-2 Reconnaissance and Feasibility Studies, c. Investigation steps, (2) Initial field investigations)
>
> "The (design) investigation is an extension of previous studies but focuses on the area surrounding the structure under study. These studies are expanded by close-order subsurface investigations which may include large-diameter borings, cone penetrometer or standard penetrometer tests, test excavations, fills, and grouting programs, detailed laboratory testing, pile driving and load tests, and any other method of investigations which will resolve issues or problems that came to light during the Preconstruction Engineering and Design studies." (Section 2-3 Preconstruction Engineering and Design Studies, d. Design investigations, (2) Data Collection, (B) Feature design data collection)

4.1.2 U.S. Bureau of Reclamation (USBR)

Guidelines for investigations at small (typically ≤ 50 feet in height) dam sites from the USBR, which have typically also been applied to larger dams like Calaveras, include the following as found in their publication "Design of Small Dams" (USBR, 1987):

> "Investigations for a potential dam primarily consist of three stages, or levels, of study. These stages, ranked in progressive order of complexity, consist of appraisal, feasibility, and design investigations. Each level of study uses the results obtained from previous investigations as a starting point for further investigations." (Chapter 5, Foundations and Construction Materials, A. Scope of Investigations)

Regarding frequency and depth of borings for the dam foundation, the USBR publication presents the following guidelines:

> "The number of drill holes required for foundation exploration of small dams should be determined by the complexity of geologic conditions, but the depth of the drill holes should be greater than the height of the dam." (Chapter 5, Foundations and Construction Materials, A. Scope of Investigations)

Similar generalities on the scope of site investigations for dams are included in the USBR publication "Design Data Collection Guidelines" (USBR, 2007):

> "The geologic investigations program must be based on site conditions and type of structure. The complexity of the site will determine the detail of the investigation." (Chapter 4 - Specifications Designs, 1. Dams, D. Foundation Data, (1) General Engineering Requirements)

> "Conduct specific foundation exploration at the site of all dams and appurtenant structures, diversion or outlet works, spillways, pumping or generating plants. Furnish data adequate for preparing bedrock contour maps, geologic cross sections or other illustrations required to demonstrate foundation conditions." (Chapter 4 - Specifications Designs, 1. Dams, D. Foundation Data, (2) Geologic Data)

4.1.3 Federal Energy Regulatory Commission (FERC)

General comments regarding dam exploration and investigation contained in Chapter 5 Geotechnical Investigations and Studies of FERC's "Engineering Guidelines for the Evaluation of Hydropower Projects" (FERC, 1991) include the following:

> "Adequate information about foundation properties and characteristics is critical to a full understanding of the adequacy of any design or in the evaluation of an existing structure. Therefore, explorations should be adequately distributed over the dam site, including abutments and dam foundation, and in special cases at appurtenant structures, including penstocks, tunnels, spillways, intakes and outlets, at the powerhouse site (whether surface or subsurface), along the reservoir rim, and at the borrow sites." (Section 5-3 Methods of Investigations, 5-8.2.2 Locations of Explorations, Page 5-8)

The FERC website also deferred to a Federal Emergency Management Agency (FEMA) publication entitled "Federal Guidelines for Dam Safety" (FEMA, 1979). This document contained the following text:

> "After a site is selected, a program for the geotechnical exploration, design, and analysis of that specific site is required. No checklist can be made which would cover all eventualities at all sites, or any one site, and attempts to formulate such a list would be counterproductive to the intent to insure dam safety" (Section 3. Geotechnics, a.General, (1) Site Specifics, Page 24)

"Geotechnical explorations generally proceed from wide-spaced borings and geophysical surveys to determine the general geological conditions, to additional explorations assigned in an ongoing sequence to develop the geologic correlations and to determine the type of dams suitable for the site. The extent, depth, and type of exploration depend on the complexity of the geology and size and type of dam." (Section 3. Geotechnics, b. Exploration and Identification of Geotechnical Problems, Page 25)

4.1.4 California Division of Safety of Dams (DSOD)

Practices of the DSOD are governed by the California Water Code. The DSOD has published general guidelines for dam design entitled "Guidelines for the Design and Construction of Small Embankment Dams," but these guidelines apply to minimal-hazard dams, as noted below:

"In general, the guidelines are intended for small earthfill dams located in rural type settings, with heights ranging up to 50 feet, with no unique foundation or embankment problems, and with minimal potential for downstream damage." (Introduction, General)

For dams under DSOD jurisdiction, the Water Code allows the DSOD to require explorations for investigation of new or enlarged dams or reservoir sites, as stated in Division 3 Dams and Reservoirs of the Code. However, the frequency or type/depth of exploration is not specified:

"For the purpose of enabling it to make decisions compatible with economy and public safety as possible the department shall make or cause to be made such investigations and shall gather or cause to be gathered such data as may be needed for a proper review and study of the various features of the design of dams, reservoirs, and appurtenances." (Part 1 Supervision of Dams and Reservoirs, Chapter 4 Powers of the Department, Article 4 Investigations and Studies, Paragraph 6120)

4.1.5 National Resource Conservation Service (NCRS)

The National Engineering Handbook (NEH), Part 631-Geology from the NRCS (NRCS, 2012) contains guidelines regarding frequency and depth of borings for Group A (largest classification) dam structures as indicated by the following:

"Detailed subsurface investigations must be of sufficient intensity to determine all conditions that may influence the design, construction, and functioning of the structure. The extent of geologic investigation required for a particular site depends on the complexity of site conditions, size of the structure, potential damage upon failure, and purpose and function of the structure." (Chapter 2-Engineering Geologic Investigations, Section 631.0205 Detailed Site Investigation)

"The depth of investigation under the footprint of the structure must be equivalent to the proposed height of the structure unless hard, massive, or otherwise unaltered impervious rock is encountered at a shallower depth. Borings must extend far enough into rock to determine its character and condition and whether it is in-place. For all concrete dams, the depth of borings will be no less than 1.5 times the height of the controlled head of the dam. … All borings must be sufficiently deep and closely spaced to establish reliable correlation of strata under the entire base of the structure. The number, depth, and spacing of holes needed depend on the regularity, continuity, and attitude of strata and character of geologic structures." (Chapter 2-Engineering Geologic Investigations, Section 631.0205 Detailed Site Investigation, (a) Group A Structure Sites, (2) Test Hole Locations and Depths)

Evaluation – Agency Guidelines for Site Investigations

The agency guidelines cited above are all interpreted to concur in the intent that exploration programs for dam sites provide adequate characterization of the subsurface conditions for proper design of the dam. Regulatory agencies recognize that the scope and methodology of surface exploration will vary between sites in keeping with the nature and complexity of the subsurface conditions and the size and importance of the dam. The general criteria of exploration depths being at least equal to the height of the embankment is a common guideline within the regulatory community. Other numerical guidelines are typically not provided.

For the CDRP, an extensive pre-construction exploration program was conducted, including review of geologic literature, aerial photographs, surface mapping, trenching, seismic refraction surveys, exploratory borings, and in-situ and laboratory testing. As described in the GDR (URS, 2008), the pre-construction exploration for the dam site included approximately 77 exploratory borings[1] totaling about 10,300 linear feet of exploratory hole length, of which at least eight borings extended to depths greater than the dam height (most of them located on the Left Abutment) and another 16 borings extended to depths that equaled or exceeded 90 percent of the dam height. Based on our experience with design of dams, it is our opinion that the pre-construction exploration program for the CDRP was consistent with agency guidelines for the design of major dams in California.

It is beneficial for project success, and often required, to keep regulatory agency(s) with jurisdictional power over a dam actively involved during all phases of a project, including field exploration planning and execution. During review of exploration plans, Agency professionals typically express their concerns for the project and render opinions on the adequacy of the scope of work planned for each phase of site investigation. This regulatory guidance was performed for the CDRP by DSOD, who monitored the plans and execution of site investigations, reviewed the formal reports prepared for the project, and provided correspondence transmitting review comments and concurrence.

4.2 General Geological Literature

Geologic maps and reports covering the Calaveras reservoir area from the U.S. Geological Survey (USGS), California Department of Water Resources (DWR) and academia were reviewed by the Design Team during pre-construction activities; the documents reviewed were listed in Section 9 - References of the project GDR (URS, 2008). GEI's review included most of these documents and an updated version (2005) of the Dibblee geologic map for the Calaveras

[1] Numbers and length of borings provided include core, rotary wash, bucket auger and percussion borings made for geology and design investigations within or adjacent to the proposed dam area, and do not include six borings totaling about 1,000 linear feet made specifically for borrow site investigations.

Dam quadrangle (Dibblee, 1973). Of these, the Nilsen et al (1975) preliminary study, which was based on analysis of aerial photographs, mapped a landslide on the southeast flanks of Observation Hill, along the left abutment for the existing dam. The northeastern limits of this landslide are difficult to project onto the CDRP map because of the scale differences; however, the northeast edge appears to extend slightly into Left Abutment excavation slope. Nilsen et al (1975) also mapped a questionable, elongated landslide mass existing between the base of the northeast flank of Observation Hill and the southwest base of Hill 1000.

Later, Nilsen et al (1979) indicated the Temblor Sandstone portions of Observation Hill were classed as "Generally Stable to Marginally Stable." Kintzer (1980) noted that surficial slope failures, primarily debris slides, are present on the eastern slopes of Observation Hill, but no distinct landslides were mapped. Kintzer also indicated the east and south flanks of Observation Hill to be Class III – Very Stable in regard to slope stability; the northeast flank was designated Class V – Moderately Stable to Unstable, Depending on Dip.

Other local and regional geologic reports, including Cotton (1972), Dibblee (2005), and the recent California Geological Survey-sponsored Landslide Inventory Map of Calaveras Reservoir Quadrangle (Wiegers, 2011), did not indicate mappable slides in the immediate area of the Left Abutment of the proposed dam on quadrangle-scale geologic maps.

<u>Summary – General Geological Literature Review</u>

An early reconnaissance-level study that was primarily developed through analysis of aerial photographs indicated possible slope instability in the Left Abutment area. More recent studies did not map deep-seated landslides in this immediate area.

4.3 Aerial Photographs

The project GDR (URS, 2008) indicates that nine sets of aerial photographs, dated from 1957 to 2006 as listed in Section 9 - References, were reviewed and interpreted during the Design Team's studies for the Calaveras Dam project area. GEI pursued acquiring these same aerial photographs to conduct an independent review. Further research indicated that two of the nine listed flights did not have stereo coverage of the Left Abutment area and two others were incorrectly cited. Ultimately, GEI reviewed photographs from five of the nine listed flights plus other stereographic flights in the vendor's library that covered the Left Abutment area (16 additional flights). The dates of the flight series reviewed by GEI ranged from years 1957 to 2006 (Table 5); no aerial photographs were available from dates prior to the construction of the original Calaveras Dam. These aerial photographs were reviewed by Senior Geologist Jeffrey Brown using a magnifying stereoscope to aid in identifying landforms in the Left Abutment area that may be indicators of mass wasting.

<u>Conclusions – Aerial Photograph Review</u>

The review of aerial photographs indicates that much of the Left Abutment and other nearby areas have been significantly disturbed by past dam construction. There are numerous scars on the landscape resulting from past exploration, borrow pit development and quarrying. Such man-made alterations coupled with the variable geology caused by movement on local faults presented challenges in interpretation of site landforms on the aerial photographs.

The Design Team's GDR (URS, 2008) and Geotechnical Interpretive Report (URS, 2008a) specifically address site landslides and devote extensive text to landslides on the Right Abutment. In their responses to specific questions at the interview (see Section 5.0), the Design Team indicated that during their studies, which included a review of aerial photographs, they uncovered no evidence of a landslide in the Left Abutment.

During GEI's review of aerial photographs, two adjacent, relatively small landforms possibly representing shallow to moderate depth (less than ~30 feet) landslides were interpreted to be on the northeastern flank and base of Observation Hill. The lower, northern landform appears to have been dissected by grading and its nature is particularly questionable. Based on Figure 2-1 of the GDR (URS, 2008), a quarry exists in this general area. This northern landform exists along the southern half of the questionable landslide area mapped between Observation Hill and Hill 1000 by Nilsen et al (1975). Current field-checking of these features would not be possible because of contemporary site grading, which has removed all of the southern landform and the eastern half of the northern landform. Neither of these two landforms were mapped or discussed in the reviewed project documents. However, outcrops of Temblor Sandstone, presumably intact, are mapped in both these areas on the Geologic Map and Exploration Plan (Figure 2-1) of the GDR (URS, 2008), suggesting that the areas were field-checked during the project's field exploration phase. No other landforms were observed during GEI's review that would appear to be indicative of deep-seated landslides on the eastern, northeastern and southeastern flanks of Observation Hill (including the Left Abutment area).

The Nilsen et al (1975) preliminary conclusion of a landslide origin for the area upslope of the existing dam's left abutment during photometric mapping was likely based on the prominent hillside bench located above the existing spillway in this area. While such a benched feature can be evidence for the presence of a landslide, an alternate, more plausible, interpretation is that this landform was likely constructed during the extensive site grading for the original dam and spillway in this area. Indeed, our review of a pre-grading topographic map (USGS, 1899), having a 25-foot contour interval, appears to indicate that this bench did not exist prior to original dam construction. The benched feature was not delineated on more detailed landslide maps in subsequent publications. It is thus reasonable that the 1975 preliminary mapping, which was later discounted, would not have provided sufficient incentive on its own for the Design Team to initiate a focused landslide investigation within the footprint of the Left Abutment excavation area, especially considering the difficult access conditions. No test explorations were made within the limits of this area during contemporary or previous investigations of the existing dam.

4.4 Design Team Documents

4.4.1 Pre-Exploration Phase Documents

To help understand the Design Team's approach to the project and their effort to perform studies consistent with industry practices for major dam projects, GEI reviewed the pre-exploration project documents for the conceptual and detailed design phases of work. These included the 2004 Conceptual Phase (URS, 2004) and 2005 Design Phase (URS, 2005) Geotechnical Investigation Work Plans that described the general purpose, location, and type of explorations for the field investigations. The associated Project Management and Quality Assurance Plans

(2003, 2005a) contained general procedures that described methodology, requirements, and quality control checks for ensuring consistency in field and analytical products from the site investigations.

Quality Assurance/Quality Control - The 2004 Work Plan (URS, 2004) and/or the 2005 Work Plan (URS, 2005) indicated the following Quality Assurance/Quality Control (QA/QC) requirements for the various types of investigation:

1) Aerial Photograph Review

   "Interpretation of remote sensing imagery should be conducted by geologists experienced in interpreting the various types of imagery that will be used on the project…. At least two geologists should interpret individual images and stereo-pairs." (2004 Work Plan, Section 5.1.3.1 Remote Sensing Interpretation)

2) Field Mapping

   "The field mapping task should be completed by trained field geologists under the supervision of the Project Geologist, or his designated representatives." (2004 Work Plan, Section 5.1.3.2 Mapping of Surficial Exposures)

3) Boring Exploration

   "The rig supervisor reports daily to the Project Geologist or his designated representative. The Project Geologist shall audit the work products (logs, notes, samples) of the rig supervisor and will make suggestions for improvements, if warranted." (2004 Work Plan, Section 5.3.7 Supervision)

On the finalized boring logs in the GDR (URS, 2008), in addition to the rig supervisor, a person is listed as being a reviewer or checker. This listing provides formal documentation that the logs were reviewed by someone in addition to the original logger.

4) Trench Exploration

   "The trench supervisor reports daily to the Project Geologist or his designated representative. The Project Geologist shall audit the work products (logs, notes, samples) of the trench supervisor and will make suggestions for improvements, if warranted." (2004 Work Plan, Section 5.5.6 Supervision)

The test pit logs provided in the GDR (URS, 2008) only have provisions for naming one geologist/engineer (assumed to be the field logger) in the heading. Therefore, the test pit logs provide no indication as to whether they were reviewed by someone other than the original logger. However, a review of the Design Team's QA/QC Detail Checking Reports indicates that logs for test pits were reviewed by a senior geologist.

5) General Field Work Products

> "Field quality control measures will be provided through senior engineering geologist oversight of the field activities throughout the duration of the geotechnical investigations." (2005 Work Plan, Section 4.5 Quality Control)

In addition, the companion Project Management and Quality Assurance Plan (URS, 2005a) indicates the following directive in Section 8.0 Project Quality Assurance Plan:

> "Project Team members are responsible for checking their own work before submittal for review. All deliverables, including those from subcontractors and SFPUC (see scope of work in Appendix A), will have the QA documentation in place. Specifically, Independent Technical Review (ITR) forms will be completed and be submitted to the Project Manager and Engineering Manager for signoff."

A review of the Design Team's QA/QC documentation indicates that Detail Checking Reports and Independent Technical Reviews were conducted for field investigation work products, such as the Geotechnical Data Report, in accordance with the QA/QC procedures.

Environmental Clearance - In preparing for the collection of geotechnical data, URS was scoped and planned for the acquisition of environmental permits, if needed, for potential impacts resulting from a range of field investigation activities (URS, 2003a, 2005, and 2005a). In developing their field investigation approach, however, the Design Team identified field investigation locations that met their data collection objectives and avoided environmental impacts, thereby eliminating their need to pursue permits and completing work in a manner consistent with the project schedule.

The Design Team's approach to streamlining environmental review required the avoidance of impacts to sensitive habitats, as noted in the 2004 Work Plan (URS, 2004):

> "Several elements of the geotechnical work plan and the site selection were developed in order to avoid or minimize disturbance to habitat…. No new access roads will be created; drilling equipment will be transported by helicopter in three locations where access roads would otherwise be required." (Section 6.1.4 Avoidance Measures for Biological Resources)

Regarding the exploration sites proposed in the work plans, GEI's review indicated that five borings (four on the Left Abutment) were moved because of the need to avoid environmental impacts (URS, 2005). The displacement of these borings was a maximum of about 50 feet from the sites originally proposed in the 2005 Work Plan, as indicated below:

> "Core boring sites CB-27, 29, 30, 31 and 33 were moved after the initial field survey. … The core boring locations are being moved approximately 30 to 50 feet from the original mapped locations …." (Appendix D Identification of Sensitive Biological Resources in the Study Area, Section D.2.2, Page D-4)

Conclusions – Pre-Exploration Phase Documents

In GEI's opinion, the pre-exploration work plans reviewed were general in nature and represent the typical phased approach to site explorations. The Design Team's choice to avoid environmental impacts and eliminate the need for environmental permits in order to facilitate mobilization to the field is not an unusual workaround on large dam projects with challenging project schedules, nor was it discussed as a constraint in the reviewed reports.

The quality control documents have provisions dictating comprehensive quality control of field data, analyses and reporting. As compared with industry standards, these documents appear adequate for the project. Based on our review of various QA/QC documents provided to GEI, it is our opinion that the Design Team adhered to the provisions of their QA/QC policies for the project.

4.4.2 Exploration and Design Documents

The exploration and design documents summarize the exploration program, the geotechnical data, geotechnical interpretations and analyses, and conclusions for the project. The content of these documents, relative to the subsurface materials of the Left Abutment and the geotechnical parameters assigned to these materials for analysis and design, is briefly discussed by document below.

Geotechnical Data Report (URS, 2008)

Ground Conditions - The Design Team's Geotechnical Data Report GDR) appears thorough in presenting the data acquired in the geotechnical investigations. The text and the boring logs describe distinct differences between Temblor Sandstone above and below specific deep horizons in the borings:

> "Below a depth of about 100 feet, geotechnical data show that the sandstone quality improves markedly." (Section 5.2.1.1 Description of Formation and Weathering, Page 5-5)

In many borings, zones of No Recovery (core materials not recovered from specific depth intervals) or distinct shear zones were logged near the interface between the upper brown, highly weathered sandstone and the lower gray, slightly weathered sandstone.

The report describes landslides as underlying the Right Abutment; these landslide features were identified in previous geologic reports and further defined during this site investigation. The report also describes debris flows in surficial colluvial soils as existing on the Left Abutment slopes. However, there is no mention of the possibility of deep-seated landslides underlying the Left Abutment area because the body of geologic and field data available to the Design Team did not point to the existence of such features.

The GDR presents the field and laboratory data only and does not contain any discussion of geotechnical parameters or analyses for design.

Geotechnical Interpretive Report (URS, 2008a)

Ground Conditions - The Design Team's Geotechnical Interpretive Report (GIR) presents an interpretation of the data presented in the GDR (URS, 2008). As in the GDR, the GIR text notes two distinct horizons in the Temblor Sandstone:

> "The results of core borings drilled in the left abutment show that the Temblor Sandstone can be divided into two units. … Where used in this report, brown Temblor Sandstone refers to the unit of highly weathered to moderately weathered, yellowish to olive-brown colored, extremely to very weak rock and gray Temblor Sandstone refers to the unit of slightly weathered to fresh, moderately strong to strong and moderately to slightly fractured rock." (Section 3.2.1 Temblor Sandstone, Page 3-2)

The Design Team recognized a distinct difference between Temblor Sandstone above and below specific deep horizons in the borings, and that this depth varied across the site:

> "Within the dam foundation area, the depth to the gray Temblor Sandstone ranged from about 54 feet in CB-30 to 148 feet in CB-52 with an average of about 80 feet for all core borings. Within the spillway cut in Observation Hill, the depth of the gray Temblor Sandstone was found to be up to 158 feet below the ground surface at CB-16A." (Section 3.2.1 Temblor Sandstone, Page 3-2)

The GIR also notes that the depth of the weathering in the Temblor Sandstone is significantly less beneath the nearby Hill 1000:

> "Based on core boring CB-18, the Temblor Sandstone in Hill 1000 is less deeply weathered than in Observation Hill, with slightly weathered to fresh, moderately strong rock underlying about 30 feet of highly to moderately weathered brown Temblor Sandstone." (Page 4.1, Section 4.1.1 Rock Conditions)

The GIR discussions of landslides in the site area do not mention the possibility that the highly weathered and locally sheared materials underlying the Left Abutment area could have resulted from downslope displacement. The interpretation presented in the GIR is based on the conclusion that the materials underlying the Left Abutment are weak and weathered, but essentially intact, and accordingly, the rock materials are not described as downslope-displaced materials. As described further in Section 5, Design Team Interviews, the Design Team based their no-landslide interpretation on several factors including 1) the lack of geomorphic or topographic expression of landslides in the area, 2) the lack of previously-mapped landslides in the geologic literature, 3) the observation that rock outcrops appeared to be stable, in-place rock, 4) the observation that the core recovered from exploratory borings was of rock that typically retained its internal structure and did not appear unusually disturbed or disrupted, and 5) the lack of a continuous clay seam that could represent a potential sliding surface. It is our opinion that this was a reasonable interpretation based on the extensive body of geologic information and subsurface data that the Design Team had collected at the time the design was prepared.

Geotechnical Parameters – The GIR documents the selection of geotechnical parameters for the Temblor Sandstone that forms the Left Abutment foundation and spillway excavations, for use in subsequent analyses. Most structural features were interpreted as extending continuously 10 feet or less. Because the planned cut slopes were up to 450 feet in height and in relatively weak and fractured rock masses, the rock mass strength was seen as being more significant to the stability of the excavated slopes than the strength along structural weakness planes. The strength parameters for the rock mass in the Left Abutment were derived using procedures (the Geological Strength Index Classification used with the Hoek-Brown failure criterion) that are broadly accepted by the dam design community. The values adopted for the rock mass shear strength parameters appear reasonable for the interpreted condition of the foundation as an in-place rock mass devoid of pre-existing, large-scale planes of weakness having unfavorable orientations.

A separate set of strength parameters was developed for individual discontinuities or planes of weakness. It appears that these parameters were envisioned for use in analyzing the stability of individual rock blocks or wedges that may be uncovered in the excavated slope and require stabilization by bolting and shotcrete. As is to be expected, the strength parameters for discontinuities were significantly lower than those adopted for the rock mass, but these also appear to be reasonable.

Final Design Report (URS, 2011)

Ground Conditions - The Design Team's Final Design Report (FDR) essentially copies the text of the GIR in relation to the condition of the sandstone underlying the Left Abutment. The text notes that brown weathered sandstone is not an acceptable foundation material for the dam core. The core foundation will need to be in the gray, slightly weathered sandstone:

> "In the Temblor Sandstone, the core trench excavation will be extended through the brown highly to moderately weathered rock to the gray, slightly weathered or fresh rock that is groutable for the reasons described in Section 9.5. The top of the gray rock is 46 feet below top of rock at CB-30 and deepens to about 133 feet below the top of rock at CB-52 located about 70 feet west of the left end of the replacement dam." (Page 9.2, Section 9.2.2 Depth of Excavation-Core Foundation Level)

This text also mentions that the thickness of brown sandstone is very irregular from base of slope (CB-30) to mid-height slope area (CB-52). There is no discussion of possible landslides affecting the Left Abutment.

Geotechnical Analyses – The FDR documents the design configuration and geotechnical analyses of the Left Abutment. The proposed high cut on the eastern flank of Observation Hill above the emergency spillway and Left Abutment consists of an excavation up to 450 feet in height with overall slope of 1.25 horizontal to 1 vertical. The design configuration for the high cut was developed based on observations of the apparently stable existing natural and excavated slopes in the Temblor Sandstone forming the eastern flank of Observation Hill, observed at inclinations steeper than 1 horizontal to 1 vertical. The stability of the excavation was analyzed using the strength parameters that were developed and documented in the GIR (URS, 2008a). The stability analyses were conducted using procedures that are broadly accepted by the dam design community. The geometry of the cut and the stability analysis results appear reasonable for the interpreted condition of the foundation as an in-place rock mass devoid of pre-existing, large-scale planes of weakness having unfavorable orientations. The north-south trending Spillway Fault was represented as a vertical plane that crossed the upper part of the excavation, and was deemed not to have an adverse impact on excavation slope stability.

Geotechnical Data Report Supplement 1 (URS, 2013)

Ground Conditions - The work performed during the Supplemental Investigation was focused on developing additional data to characterize the conditions and stability of the Left Abutment and Spillway Cut Slope. This work was undertaken after initiation of the construction phase wherein subsurface conditions in the Left Abutment were being exposed by the required excavations. Additional core borings were made 1) near previous boring sites that had No Recovery intervals at depths near the brown/gray sandstone interface (e.g. CB-2 and LA2012-05); 2) to reduce spacing of the borings made in the pre-construction phase; and 3) to investigate a new area (northeast base of Observation Hill). In addition to the core borings, a bucket auger boring (LA2012-05BA) was made adjacent to the LA2012-05 to enable direct viewing of the interface between the brown and gray sandstone. There are no discussions in the report text about geology or interpretation of subsurface conditions in the Left Abutment area.

Left Abutment Excavation Slope Technical Memorandum (URS, 2012)

Ground Conditions – This report was also prepared after initiation of the construction phase. This is an interpretive report of the new and previous data from the Left Abutment that provides a more comprehensive discussion of the conditions in the sandstones of the Left Abutment. This document highlights the significance that rupture on the Spillway Fault must have had on the conditions seen in the sandstone underlying the Left Abutment slope:

> "The left abutment area is transected by the Spillway fault zone, which influences the overall geologic conditions in the left abutment area." (Section 2.3.1 Generalized Geologic Domains, Page 2-2)

The report further provides revisions to the conclusions rendered in the pre-construction documents as to the impact that displacements on the Spillway Fault had on slope stability in the Left Abutment area:

> "The Spillway fault zone impact on the stability of Observation Hill was assumed to be minimal in URS (2006), as surface mapping evidence indicated its trace as a fault plane behaving as a discontinuity (URS, 2008b). Current assessment indicates that the Spillway fault has an associated shear zone up to 300 feet wide. The size of the shear zone makes it a significant part of the rock mass of Observation Hill and thus will have a significant impact on stability." (Section 3.3.1.2 Spillway Fault Zone, Page 3-3)

The additional explorations performed in the supplemental phase proved to be instrumental in determining that the rock conditions in the Spillway Fault Zone could have a substantial effect on the stability of the proposed cut slope:

> "Based on the results of 25 supplemental geotechnical core borings drilled between June and September 2012, the Spillway Fault Zone is located further to the east and is wider than was previously known prior to construction. This fault zone is now understood to intersect the spillway cut slope and would be exposed at the surface in a significant portion of the new cut slope surface." (Section 5.1 Area A, Page 5-2)

The report provides a thorough discussion of the difficulties in determining the origin of material conditions in the Left Abutment, due in-part to the effects of the nearby Spillway Fault:

> "The interpretation of the origin of these materials is critical to the development of a reasonable geologic model of the Left Abutment area; a distinction must be made to interpret whether materials exposed in boreholes and excavations are (a) weathered in-place bedrock, (b) weathered transported bedrock blocks, or (c) weathered and fractured fault zone materials. Uncertainties in differentiating such materials can be large, and often the only diagnostic criteria for differentiating between "weathered," "landslide," and "faulted" materials are the overall geometry of the deposits and the geologic setting of the site." (Section 2.3.3 Weathered Bedrock, Surficial Deposits and/or Fault-Zone Materials, Page 2-4)

In general, the text indicates that the new data appeared to provide further clarification of geologic conditions seen in some pre-construction borings in the Left Abutment:

> "Observations in bucket auger boring LA2012-05BA of breccia and with east-dipping clayey shears, directly overlying a moderately east-dipping abrupt contact with unfractured gray Tts sandstone, are consistent with similar geologic relationships at similar elevations in the nearby borings CB-2, CB-45, CB-28, CB-29, and LA2012-09 (as described above)." (Section 2.4.2 Area B, Page 2-10)

Data from additional borings and geologic mapping, coupled with a reevaluation of previous data, led to the delineation and characterization of Areas A and B, which influence the stability of the Left Abutment excavation slope. The subsurface character of Area A was summarized as such:

> "Considering the entire set of surface and subsurface geologic evidence in Area A, including the overall geometry of the material, the most reasonable interpretation is that the weathered material in Area A along the northeastern flank of Observation Hill is a deep-seated landslide complex." (Section 2.4.1 Area A, Page 2-10)

At the time the report was prepared, the origin of Area B was difficult to discern as described below:

> "This material can be characterized as a deformed zone of variable weathered and fractured sandstone blocks under the influence of mass wasting. The absence of a

> continuous, ubiquitous low-strength remolded clay seam at the base of the material indicates that the mechanism of transport is not a classic transitional or rotational landslide, or that the limited observations are along basal surfaces that have moved by mechanisms other than large-scale sliding (as required to develop a remolded clay seam). The steepness of the terrain and the highly fractured source material suggest that a basal clay seam is not required for the jumbled transport of material down the east-facing sidewall of the incised Calaveras Creek Valley" (Section 2.4.2 Area B, Page 2-11)

Based on the Design Team's interpretation of the subsurface information, the origin of the Area B landform (major portion of the Left Abutment) was still in doubt after performance of the Supplemental Exploration Phase.

> "This material may represent a zone of deep weathering, perhaps related to the highly deformed rocks of within the Spillway fault zone, or it may have been transported downslope along the Calaveras Creek valley margin. It appears possible that transport may have taken place as a mass of large, coherent to partially articulated blocks of weathered material, moving as a result of the steep valley sidewall and varied mass wasting processes." (Section 2.5 Summary of Geologic Findings, Page 2-12)

Although there was uncertainty about Area B at the time of the 2012 supplemental investigation, we understand that substantial additional field explorations (32 additional borings and numerous test pits) were performed in Area B during 2013 and early 2014, and that the additional data provide indisputable evidence that Area B is a landslide. This conclusion will be presented in a forthcoming report now under preparation (SFPUC, personal communication).

Geotechnical Parameters and Analyses – The report models a large-scale geologic structure, the Spillway Fault Zone, crossing the excavated slope with a width of up to 300 feet in the cross-sections that are analyzed for slope stability. From construction exposures, the fault zone is described as intensely to highly fractured sandstone. Strength parameters for the fault zone material were back-calculated from a slope failure that occurred in a temporary cut during construction. The re-evaluated strength of the material is significantly lower than originally estimated for the highly weathered, brown sandstone materials.

Conclusions – Exploration and Design Documents

The Design Team's post-exploration reports can be separated into pre-construction and construction documents. The pre-construction documents discuss the contrast between the brown, weathered sandstone and the gray slightly weathered sandstone, and the variable, but deep, interface between these two horizons in the Left Abutment area. From the lack of discussion of deep-seated landslides in the Left Abutment area in the pre-construction reports, and the Design Team's responses to interview questions (see Section 5.0), it is clear that the Design Team considered that the deep weathering in the bedrock was not related to landsliding, but primarily associated with the disruptive effects of movement on nearby faults. That interpretation was carried through in the design of the dam, with the acknowledgment that the brown sandstone was poor foundation material for the core and would need to be removed below the dam core trench.

Once construction commenced, more of the subsurface materials were exposed, and the performance of the temporary excavations led to the necessity for a reevaluation of the nature of the deep weathering, particularly in connection with the safety of the excavations. Additional surface mapping and subsurface exploration led to the conclusion that the materials underlying the Left Abutment may have been weakened as a result of displacement downslope in addition to disturbance caused by the nearby faults.

Based on our review of the project documents and the Design Team's responses to our questions (see Section 5.0), it is our opinion that the Design Team was methodical and thorough in their attempts to characterize the materials underlying the Left Abutment. The slopes of the Left Abutment area were very steep and mostly inaccessible for exploration equipment. The Design Team's choice to avoid environmental impacts and associated permitting processes may have reduced their options when optimizing exploration sites. However, the Design Team indicated that acceptable exploration sites were available and the objectives of their investigations were not compromised by this approach.

Notwithstanding these factors, an extensive amount of subsurface data was generated that resulted in a coherent interpretation of the subsurface conditions at the site that was consistent with the body of data assembled. Multiple shear and brecciated zones were logged in many borings, but with the lack of local clay seams typical of slide planes near the brown/gray sandstone interface, and an apparent lack of a continuous basal slide surface across the area, it would have been speculative to characterize the Left Abutment slope as being underlain by a massive landslide. The strength parameters and stability analysis methods used to evaluate the design of the dam and spillway appear reasonable for the interpreted conditions. Ultimately, additional exposure of the bedrock and additional borings during the construction phase were necessary to develop a reasonable alternative explanation for the conditions seen in the subsurface. Even with this additional data and analysis, a displacement mechanism that would account for the weak rock conditions underlying the Left Abutment could not be determined with certainty in 2012 during the initial phases of the Left Abutment excavation. Another extensive phase of field exploration in 2013 and early 2014 was necessary to confirm that a major portion of the Left Abutment excavation is underlain by a landslide.

4.4.3 Design Team Report Limitations

The Design Team's FDR (2011) contains the following advisory in Section 7 Limitations; similar text is provided in other technical documents from the Design Team:

> "The analyses presented in this report are based on subsurface conditions disclosed by a limited number of exploratory locations. The subsurface conditions have been assumed to not deviate significantly from those disclosed at the locations of the site-

specific explorations. … URS represents that the services and geotechnical design recommendations were conducted in a manner that is consistent with the standard of care ordinarily applied as the state of practice in the practice within the limits prescribed by our client. No other warranties, either expressed or implied, are included or intended in this FDR."

Conclusions – Design Team Report Limitations

This advisory is common to the industry and highlights the dependence on extrapolation of data from small samplings to larger areas.

4.4.4.Rock Core Review

As part of the review process, Mr. Jeffrey Brown, a Senior Geologist with GEI, visited the project area to review selected boxes of the core recovered from borings made primarily in the Left Abutment area. The intent of this review was to assist in an evaluation of the appropriateness and consistency of the descriptions in the boring logs prepared by the Design Team. The core boxes reviewed were selected based on depth intervals near the brown/gray sandstone interface, near potentially important features, such as shear zones, no recovery zones, and the suspected basal landslide plane based on the current subsurface model. Core from both pre-construction (CB Series) and construction (LA2012 Series) explorations were viewed to assess whether similar standards of logging were used during both phases of work.

The vast majority of the core viewed originated from the Temblor Sandstone, the predominant bedrock in the excavations of the Left Abutment. The Temblor Sandstone is a sedimentary rock formation that is typically very dense and moderately indurated (rock-like) in a fresh state. Because of the clastic nature of the sandstone, there is typically a small degree of porosity to the rock structure. Calcite cementation may be present in the rock, which locally provides varying degrees of binder to the clastic structure.

Upon recovery and storage, core from clastic rock can be negatively affected by desiccation and handling of the core. The porous nature of the sedimentary rock comprising the core allows it to dry out significantly over the months to years kept in storage. Where cementation is absent, desiccation removes the binding effects of moisture in sandstone having little plastic fines content, allowing the core to easily crumble. Similarly, fractures in the rock mass can open up significantly when subjected to drying. Where the sedimentary rock contains a significant content of plastic fines, desiccation typically causes the rock mass to harden as the clays loose excess water. In summary, with desiccation, sandy portions of the core crumble, fractures typically open, and clayey portions harden in the soft rock materials. The crumbling and opening of fractures in the core is typically exacerbated by the handling of the core during placement in the core box, transportation to the core storage area, and subsequent core review.

Comparison between the core box photos and the current state of the core indicate that desiccation and handling have produced significant changes to the core. Colors have faded, fractures have opened and most of the core appears to have hardened considerably. As such, the common log descriptions of extremely to very weak rock were seldom evident in the core during our review, although the addition of water often caused the core to weaken significantly.

Conclusions – Rock Core Review

Based on GEI's review of select core, the descriptions on the boring logs provided in the project documents generally appeared to be representative of the materials viewed in the core boxes. During our core review, it was noted, however, that a few intervals of the core were described on the logs as "shear zones," apparently because of the presence of a few angular fragments (breccia) of local sandstones within a clayey matrix. In our opinion, the origin of the breccia may in some cases (e.g. Boring LA-2012-24, 30.5 – 31.6 feet) be synsedimentary, or related to sedimentation rather than a post-lithic shearing process, particularly in those zones where no evidence of shear planes was observed. In another case, a feature described as a "shear plane" (Boring LA-2012-9 at 75.8 feet) appeared to possibly be drill cuttings mashed onto pieces of mechanically-broken rock as a result of the drilling process, rather than by natural shearing.

In general, core logging of borings in the Left Abutment during the construction-phase supplemental investigations appeared to be somewhat less exacting than that seen in the pre-construction phase borings. Labeling of runs, core depths and core loss appeared to be less consistent in presentation during this phase of work. For example, in Boring LA-2012-5, start-of-run depths for Runs 19 through 21 are not consistent between the core box and log, and a zone of No Recovery was marked in the core box from 88.3 to 90.5 feet, although core is described at this depth interval on the log. These and other minor inconsistencies possibly reflect a reduced oversight resulting from the fast-track nature of the supplemental investigation field work.

For the most part, the logs prepared by the Design Team for the rock core reviewed by GEI appeared to have appropriate descriptions of the core. The detail provided on the logs is commensurate with that typically produced by experienced field personnel on a significant project. However, because of the effects of handling and desiccation, in-situ descriptions on the logs of certain features, such as fracturing, rock strength and shear zones, which were likely used by the Design Team to develop the subsurface model, could not always be confirmed during our review.

5.0 DESIGN TEAM INTERVIEW

During GEI's review of project documents, questions were developed regarding the Design Team's approach to the exploration program, conclusions developed from the field data, and analysis of the project data. The questions were submitted to the Design Team by the SFPUC on October 22, 2013.

On November 22, 2103, a meeting was held in GEI's Oakland office during which the Design Team presented responses to the questions, and a dialog was held in follow-up discussions. In addition to the three members of the GEI Review Team, the following URS and SFPUC personnel attended the meeting:

URS Corporation	SFPUC[2]
Noel Wong – Principal In-Charge	Daniel Wade

[2] Members of the SFPUC were observers at the interview meeting and did not participate in discussions between GEI and the Design Team.

Mike Forrest – Project Manager | Gilbert Tang

John Roadifer – Project Engineer | David Tsztoo

Phil Respess – Project Geologist | Susan Hou

Mark Schmoll – Project Geologist (until 2006)

The responses to the questions were delivered orally at the meeting by the Design Team. During the meeting, the GEI attendees recorded notes on the Design Team's responses. Major themes from the Design Team's responses are summarized below. A listing of the questions and the complete set of GEI notes on the Design Team's responses is provided in Attachment A.

Field Investigation Access

As described earlier, the selection of exploration sites and access to those locations was a consideration in the development of the Design Team's approach to the geotechnical investigations of the Left Abutment. To accelerate mobilization to the field, the Design Team elected to not pursue environmental permits and complete the work under sequential CEQA Categorical Exemptions.

Likewise, the steep topography of the disturbed, east-facing slope of Observation Hill did not allow exploration by drilling within the southern half of the Left Abutment above the existing spillway. The drilling contractors that were consulted advised that borings could not be made on this slope without extensive slope cutting, which would have been very difficult, potentially dangerous, and would have been expected to trigger the need for environmental permitting. These factors prompted the Design Team to relocate Boring CB-50 to a position about 200 feet farther west and angle the boring into the slope in order to investigate the Spillway Fault zone.

Similarly, the Design Team relocated trenches FT-4 and FT-5, which were used to investigate the Spillway Fault, from preferred locations higher on the north side of Observation Hill to locations downslope to avoid environmental impacts and the need for additional permits. The Design Team understood that a process to permit exploration disturbance in environmentally-sensitive areas existed, and that such permitting would have required up to 12 months for approval. The Design Team did not elect to pursue such environmental permits for any exploration site. In the Design Team's opinion, the objectives of their investigations were not compromised by the environmental regulations governing access to field exploration sites.

Geologic Interpretations of Left Abutment

The deep weathering profile in the Temblor Sandstone was interpreted by the Design Team in pre-construction reports to result from increased fracturing in the rock mass because of periodic, intense shaking along the Spillway Fault (and the Calaveras Fault), the topographic effects that amplified the shaking (e.g. ridgetop shattering), and folding of the rock mass. The steep, three-sided nature of the ridgetop also allowed the weathering profile to extend to a greater depth into the core of the hill. The steeply-dipping joints along the rock bedding planes likely allowed deeper penetration of surface waters into the rock mass, thereby accelerating the weathering processes. The same deep weathering effects were not seen in Hill 1000 because the hill is not as tall or steep-sided, the rock bedding has a shallower dip, and it is farther away from the Spillway and Calaveras Faults. A landslide cause for the deep weathering on the eastern flanks of Observation Hill was discounted because:

- No ubiquitous basal clay seam appeared to be present in his area.
- Most of the rock core was composed of pieces that could be fit back together rather than being disjointed as expected in a large landslide mass.
- Surface outcrops on the eastern flanks of Observation Hill were fractured, but appeared to be in-place rock that did not display the chaotic appearance that is typical of landslide material.
- These observations suggested that the rock mass had retained most of its internal structure, and was not involved in a deep-seated landslide.

Interpretation of Exploration Data

The Left Abutment Excavation Slope Technical Memorandum (URS, 2012) discussed in detail the many types of data from surface and subsurface explorations that were assessed by the Design Team in the development of their geologic model of the Left Abutment. Although this methodology was not articulated in such detail within previous site reports, these types of assessments are standard during complex site investigations such as were performed for the project. The Design Team's response to a question on procedures (see Attachment 1, Question 5) indicated that the data assessment and evaluation methodology that occurred during the Supplemental Phase was also used during earlier phases of study.

After evaluation of the data acquired from explorations, and literature and photograph review, and considering the structure of the rock formations, the proximity to faults and the topography of Observation Hill, the Design Team concluded that the observed conditions resulted from a complex series of processes that resulted in a fractured rock mass and deep weathering profile on Observation Hill. The possibility that the observed conditions in the Left Abutment could be the result of landsliding processes was not considered during the design phase for the previously itemized reasons and the following:

- Lack of previously-mapped landslides in the geologic literature.
- Historical photography appeared to indicate uniform bedding on the east slope of Observation Hill.
- Aerial photographs did not have compelling geomorphic or topographic expressions of landslides in this area.
- Essential absence of weak claystone or shale layers in the Temblor Sandstone and lack of unusually disturbed appearance.
- The very steep east slope of Observation Hill appeared to remain stable in the 90 years since construction of the existing dam.

Even with the more focused exploration that occurred during the 2012 Supplemental Phase, the origin of the disturbance and deep weathering seen in the Left Abutment could not be definitively attributed to the common mechanisms of mass wasting. However, the redesign of the Left Abutment excavation was prompted by the Design Team's acknowledgement that a differing site condition existed at the Left Abutment, and subsurface conditions were less stable for the required steep excavations than what was assumed in their previous design analyses.

Exploration With Large-Diameter Borings

Large-diameter borings were used to investigate landslide features existing on the Right Abutment during the pre-construction phase. The Left Abutment was not investigated by this type of boring because:

- No landslides were being considered as underlying the Left Abutment.
- Televiewer surveys, which allowed imaging of the rock discontinuities and brown/gray sandstone interface, were performed in several Left Abutment core borings.
- The large size of the drilling equipment and footprint required for a bucket auger boring would present extremely difficult access issues within most portions of the Left Abutment area.

The Design Team used a large-diameter bucket auger boring to investigate the subsurface conditions of the Left Abutment during the 2012 Supplemental Phase of work when, as a result of the ongoing construction activities, access became available for this size of drill rig. Downhole observations revealed the contact between the brown and gray sandstone as a non-planar, discontinuous contact with minor clay that did not extend around the circumference of the boring. The materials viewed in this boring were useful in understanding the nature of the brown/gray sandstone interface, but were not convincing evidence that a landslide plane existed at this depth.

Zones of No Recovery at Brown/Gray Sandstone Interface

The majority of core borings drilled in the Left Abutment area were logged with zones of No Recovery (up to three feet in thickness) very near the brown/gray sandstone interface. The Design Team indicated that in their experience, zones of No Recovery are typical when drilling is performed in weathered, weak sandstones; the sandier content tends to be washed out by the circulating drill fluids. The Design Team also noted that fat clays, such as would constitute a basal slide plane or a fault, are typically more recoverable during coring. This results from the cohesiveness of the clayey material. Accordingly, if the fat clay that typically constitutes a basal slide plane was present at the depths of No Recovery logged in the core borings, it is expected that some indications of the clay material would have been recovered. Additionally, the Design Team noted that, in some cases, borings located nearby to those having No Recovery zones at the interface had complete recovery of core across the interface without indications of a basal slide surface.

6.0 CONCLUDING COMMENTS

Although different teams of consultants and designers may have differing overall approaches to the exploration and design of a large dam, most of their field programs will have common elements or methodologies that are used to discern the subsurface character of the site. One common methodology is to develop “working hypotheses” of the site geology based on review of available data and experience. With these hypotheses in mind, an exploration program is designed and implemented to confirm or modify the initial understanding of site conditions. This is often an iterative process, involving multiple phases of data gathering to arrive at the detailed understanding of subsurface conditions required for the project design. Even at the conclusion of a comprehensive pre-construction exploration program, the understanding of subsurface conditions usually remains limited, as it commonly involves extrapolating the findings from small samplings and observations made in localized exploratory borings to broad areas between the borings. Typically, it is not until construction excavations fully expose the actual foundation conditions that a final understanding of the subsurface character can be developed. Finding unforeseen conditions is more the rule than the exception for large projects that are located on sites having complex geology, such as the Calaveras Dam site.

At Calaveras Dam, as is the case at most dam sites, access limitations likely influenced development of the exploration program. A factor in exploration coverage appears to have been the steep site topography. Possible exploration sites in the northeastern and southeastern flanks of Observation Hill were limited to those accessible from existing roads because of the very steep slopes or hillside areas with natural benches that would allow drill setup and helicopter access. Other than a few sites that were accessed by helicopter, the steepest portions of the slope between existing roads were not explorable by borings until access was made possible during the Construction Phase. Consequently, the Design Team was limited to interpreting data gathered from accessible boring sites, from surficial mapping, and from other sources to characterize parts of the Left Abutment during the pre-construction field investigations.

The exploratory boring data gathered during pre-construction investigations indicated a deep and typically distinct weathering profile in the Temblor Sandstone of Observation Hill. The Design Team reviewed this data together with information from aerial photographs, surface mapping, trenching, and past site history in their analysis of the subsurface conditions. Noting the absence of surface expression of ground movements, the apparent stability of the steep slopes, the irregular depths of weathering, and the absence of a pervasive basal slide plane in the Left Abutment, the Design Team interpreted the deep weathering to be related to disturbance caused by movement on the nearby faults. Considering the information available at that time, this appears to be a reasonable conclusion. It was not until the subsurface was exposed during construction that the degree of rock fracturing and weakness, and its implications to worker safety, could be realistically evaluated.

Poor core recovery near the brown/gray sandstone interface was common in borings made in the Left Abutment area. In their responses to the questions posed by GEI, the Design Team expressed confidence that the lack of core recovery near the interface in some borings was not a hindrance in their development of the site characterization. Nonetheless, it stands to reason that recovery of this core might have aided the Design Team in their development of conclusions about the character of this contact. Could another drilling company have been able to recover these zones during the pre-construction exploration? Possibly, but based on our experience with field investigations, we consider the drilling subcontractor used for most of the pre-construction exploration, Ruen Drilling, to be among the best in the geotechnical exploration business.

In summary, based on our review of the project documents made available to us, it is GEI’s opinion that the Design Team’s work conformed to the standard practice in the industry for major dam projects in California. The characterization of the Left Abutment subsurface conditions would have been a formidable task for any design team given the complex and irregular subsurface conditions resulting from faulting, folding and seismic activity, the access for exploration equipment restricted by the steep topography, and the disturbance caused by past dam construction. While the Design Team's pre-construction subsurface characterization did not fully capture the actual physical conditions or geologic processes involved in forming the materials and geologic hazards of the Left Abutment, the obstacles for doing so were extraordinary.

We have appreciated the opportunity to be of service on this vital dam replacement project. Please call me at 510-350-2908 with any questions or comments.

Sincerely,
GEI Consultants, Inc.

Alberto Pujol, P.E., G.E
Vice President

C: Daniel Wade and Susan Hou (SFPUC)
Steve Verigin and Jeff Brown (GEI)

Tables:

Table 1 – Key Documents Provided Initially by SFPUC for GEI Review
Table 2 – Documents Subsequently Provided by SFPUC for GEI Review
Table 3 – Quality Assurance/Quality Control Documentation Provided by SFPUC
Table 4 – References
Table 5 – Listing of Aerial Photographs Reviewed

Attachments:

Attachment A – GEI Notes of Design Team Responses to Interview Questions

TABLE 1

KEY DOCUMENTS PROVIDED INITIALLY BY SFPUC FOR GEI REVIEW

Department of Water Resources, Division of Safety of Dams. 2013. New Calaveras Dam No 10-27, Alameda County. Memorandum addressed to Daniel Wade. Received February 13.

Carlin, Michael, Wong, Jackson and Labonte, Julie. 2012. WSIP Calaveras Dam Replacement Project - Response to Commission Questions Regarding Unexpected Geologic Conditions in Observation Hill. Prepared for the San Francisco Public Utilities Commission. Dated Nov. 7.

URS Corporation. 2005. Calaveras Dam Conceptual Engineering, Contract No. CS-716, Calaveras Dam Replacement Project, Final Conceptual Engineering Report, Dam and Appurtenant Structures, File: 4110 (Task14). Prepared for the San Francisco Public Utilities Commission. Dated October 31.

URS Corporation. 2008. Calaveras Dam Replacement Project, Project No. CUW 37401, Final Geotechnical Interpretive Report (Task B.10), File: 4110. Prepared for the San Francisco Public Utilities Commission. Dated August 15.

URS Corporation. 2008. Final Geotechnical Data Report (Task B.9), Calaveras Dam Replacement Project, Project No. CUW 37401, Contract No. WD-2551. Prepared for the San Francisco Public Utilities Commission. Dated August 5, 2008; reissued January 4, 2011.

URS Corporation. 2010. Calaveras Dam Replacement, Contract No. WD-2551 (Conformed Construction Drawings). Prepared for the San Francisco Public Utilities Commission. Dated December 17.

URS Corporation. 2011. Specifications, Volume 1 of 2, Divisions 0 and 1, Calaveras Dam Replacement Project, Contract No. WD-2551, Project No. CUW 37401. Prepared for the San Francisco Public Utilities Commission. Dated January.

URS Corporation. 2011. Specifications, Volume 2 of 2, Divisions 2 through 16, Calaveras Dam Replacement Project, Contract No. WD-2551, Project No. CUW 37401. Prepared for the San Francisco Public Utilities Commission. Dated January.

URS Corporation. 2011. Calaveras Dam Replacement Project, Project No. CUW 37401, Final Design Report, File: 4110. Prepared for the San Francisco Public Utilities Commission. Dated April 25.

URS Corporation. 2012. Calaveras Dam Replacement Project, Project No. CUW 37401, Evaluation of Left Abutment Excavation Slope, Revised Technical Memorandum. Prepared for the San Francisco Public Utilities Commission. Dated December 18.

URS Corporation. 2013. Geotechnical Data Report Supplement 1, Calaveras Dam Replacement Project, Project No. CUW 37401, Contract No. WD-2551. Prepared for the San Francisco Public Utilities Commission. Dated January.

Wade, Daniel L. 2012. CUW37401 - Calaveras Dam Replacement Project – Rationale for Directing Contractor to: (1) Implement Full Slope Layback of Observation Hill; and (2) Proceed with Revised Construction Schedule that Adds 25 Months to Project Schedule. Memorandum to Julie Labonte. Dated November 5.

TABLE 2

DOCUMENTS SUBSEQUENTLY PROVIDED BY SFPUC FOR GEI REVIEW

Branner, J.C, 1918, Geology in the Vicinity of Calaveras Dam. Memorandum to Allen Hazen, Spring Valley Water Company. Dated April 20.

Geomatrix. 2002. Geologic Mapping and Fault Evaluation, Calaveras Dam Seismic Evaluation Study. Prepared for Olivia Chen Consultants. Dated October 9.

Kintzer, Fredrick C. 1980. Geology and Landslides at Calaveras Reservoir, Alameda and Santa Clara Counties, California. M.S. Thesis, California State University, Hayward. Dated August.

Marliave, Chester. 1935. Geological Report on Calaveras Dam Situated on Calaveras Creek Tributary to Alameda Creek in Alameda County. Unpublished report, State of California Department of Public Works, Division of Water Resources. Dated October.

San Francisco Public Utilities Commission. Agreement CS-716, Calaveras Dam Replacement Project, Task Order No. 1, Amendment 1, Appendix C - Terms and Conditions, Protection of Biological and Cultural Resources, SFPUC Alameda Watershed.

URS Corporation. 2003. Calaveras Dam Conceptual Engineering, Contract No. CS-716, Task 1.1 – Draft Compilation of Background Information, File: 4110. Prepared for the San Francisco Public Utilities Commission. Dated November 3.

URS Corporation. 2003a. Calaveras Dam Conceptual Engineering, San Francisco Public Utilities Commission, Agreement No. CS-716, Project Management and Quality Assurance Plan. Prepared for the San Francisco Public Utilities Commission. Dated October 27. (Copy provided did not include appendices).

URS Corporation. 2004. Calaveras Dam Conceptual Engineering, Contract No. CS-716, Task 4.1 - Final Geotechnical Investigation Work Plan, File: 4110. Prepared for the San Francisco Public Utilities Commission. Dated January 14.

URS Corporation. 2005. Calaveras Dam Replacement Project, Contract No. CS-716, Task 5.6 - Final Geotechnical Investigation Work Plan, File: 4110. Prepared for the San Francisco Public Utilities Commission. Dated November 9.

URS Corporation. 2005a. Draft Project Management and Quality Assurance Plan, Calaveras Dam Replacement Project. Prepared for the San Francisco Public Utilities Commission. Dated November 29.

URS Corporation. 2006. Calaveras Dam Replacement Project, Project No. CUW 37401, Draft Technical Memorandum - Spillway Excavation Slope Stability (Task C5), File: 4110. Prepared for the San Francisco Public Utilities Commission. Dated November 21.

URS Corporation. 2010. Project Execution and Quality Assurance Plan, Revision 0, Calaveras Dam Replacement Project, Final Design (CUW 32401), Agreement No. CS-716. Prepared for the San Francisco Public Utilities Commission. Dated February 1.

URS Corporation. 2011. Project Execution and Quality Assurance Plan, Revision 0, Calaveras Dam Replacement Project, Engineering Support Services During Construction (CUW 32401), Agreement No. CS-716. Prepared for the San Francisco Public Utilities Commission. Dated November 15.

URS Corporation. 2012. CS-716, Calaveras Dam Replacement Project, Proposed Geotechnical Explorations, Revision 5 (table listing only). Dated August 28.

URS Corporation. 2013. Project Execution and Quality Assurance Plan, Revision 1, Calaveras Dam Replacement Project, Engineering Support Services During Construction (CUW 32401), Agreement No. CS-716. Prepared for the San Francisco Public Utilities Commission. Dated March 22.

URS Corporation/William Lettis & Associates, Inc. 2005. Calaveras Dam Conceptual Engineering, Contract No. CS-716, Task 6.2 Final Technical Memorandum on Investigation of Fault Rupture Potential. Prepared for the San Francisco Public Utilities Commission. Dated February 25.

TABLE 3
QUALITY ASSURANCE / QUALITY CONTROL
DOCUMENTATION PROVIDED BY SFPUC

PM or EM Approval Date	Checker	Checker Approval Date	Title
URS CALCULATION COVER SHEETS (CCSs)			
07/06/04	G. Reichert/ T. McDonald	06/25/04	Wind Wave Analysis
07/06/04	T. McDonald/ G. Reichert	03/17/04	Probable Maximum Precipitation (PMP)
11/01/06	J. Hudson	09/18/06	HEC-RAS Model of Calaveras Spillway Channel Modification
04/16/07	C. Gillan	03/27/07	Intake Tower Platform Structural Design
05/15/07	S. Leung	05/15/07	Spillway - Dam Crest Elevation
10/15/07	S. Logeswaran	09/28/07	Estimation of Core Settlement
12/13/07	S. Gambino	12/13/07	Seepage Collection Drain Design
01/16/08	P. Mineart	01/15/08	Calaveras Disposal Site #3 Riprap Size
01/16/08	N. Kawamura	01/16/08	Design of Rock Anchors for Spillway Wall
01/16/08	N. Kawamura	01/15/08	Design of Rock Anchors for Spillway Base Slab
01/17/08	N. Kawamura	01/16/08	Design of Rock Anchors to Resist Spillway Wall Overturning (Right Wall)
NS*	C.S. Doo	01/30/08	Spillway Wall Anchor Design
09/15/08	P. Mineart	09/15/08	Riprap Design Check
10/08/08	J. Roadifier	10/08/08	Riprap Gradation
12/05/10	P. Humphrey	05/03/10	PY-Wall Analysis (Main Section)
12/15/10	T. Kanagalingam	04/30/10	UTexas Runs: Landslide Slope Stability
12/15/10	T. Kanagalingam	06/08/10	PY Wall Analysis for Section B
12/15/10	P. Humphrey	05/03/10	Analysis of Block Failure - Tie Back Wall at Right Abutment
12/15/10	S. Gambino	05/03/10	Tieback Design
12/15/10	P. Humphrey	06/16/10	Tieback Design Check
12/15/10	T. Kanagalingam	05/03/10	Hand Calc Check of Rt. Abut Wall Design
12/15/10	W. Ku	ND	Spillway Anchorage (95%)
12/15/10	C. Jaramillo	08/15/08	Design of Rock Anchors - Global Stability (Incl. Buoyancy and Cohesion)
12/15/10	P. Smith	ND	Spillway Wall Design
12/15/10	M. Monaghan	03/06/07	Retaining Wall Along Spillway
12/15/10	C. Gong	03/04/08	78" Pipeline Encasement, Static Analysis
12/15/10	C. Gong	01/05/09	Outlet Conduit Concrete Encasement - Reinforcement Design
12/15/10	M. Monaghan	Mar-09	Outlet Conduit Extension
12/15/10	M. Monaghan	11/8/11**	Concrete Encasement Thrust Resistance
12/15/10	S. Jones	12/16/07	New Tower Standpipe Structural Analysis
12/15/10	S. Jones	12/17/07	Fixed Cone Valve Vault Structural Design

PM or EM Approval Date	Checker	Checker Approval Date	Title
12/15/10	S. Jones	12/17/07	Fixed Cone Valve Vault Slab Structural Design
12/15/10	S. Jones	07/20/10	Tower Interior Platform Design Modification
12/15/10	S. Jones	12/17/07	Intake Tower Exterior Platform Structural Design
12/15/10	S. Gambino	01/30/07	Outlet Works - New Tower and Shaft - Shaft Excavation and Support
12/15/10	N. Kawamura	01/10/08	Retaining Wall Design (Tower and Shaft Retaining Wall)
04/27/11	P. Smith	04/27/11	Thrust Reinforcement
URS DETAIL CHECKING REPORTS (DCRs)			
04/29/04	M Schmoll	04/21/04	GDR - Bucket Auger and Core Boring Logs App A1 & A3 - App. A
04/29/04	P. Respess	04/28/04	GDR - Generalized Geologic Sections
04/29/04	P. Respess	04/28/04	GDR -Geologic & Exploration Location Plan
04/29/04	M. Schmoll	04/22/04	GDR - NORCAL Geophysical Report Appendix C
04/29/04	P. Respess	03/25/04	GDR - Packer Test Summary Tables B-1 through B-11 (Spreadsheets - App. B)
04/29/04	J. Benton	04/28/04	GDR - Summary Tables for Soil & Rock Data in App. D
04/29/04	P. Respess	04/20/04	GDR - Test Pit Figures - App. A
01/25/06	J. Wu	01/19/06	Summary of Geo. Testing on Soil Table and Test Pit Summary Logs
04/03/06	K. Wolfe	03/06/06	Packer Tests Excel Calc Summary Sheets CB-27, -28, -29, -30, -31, -32, -33, -35, -36, -45, -51, -52
06/28/06	S. Leung	06/27/06	Packer Tests for CB-65
07/27/06	S. Leung	07/27/06	Test Fill Program (Task B7.2) CDRP - Draft
08/18/06	S. Leung	07/05/06	CDRP - Results of Packer Tests for Boring CB-45A
08/18/06	S. Leung	08/11/06	Packer Tests CB-66
09/13/06	J. Wu	09/05/06	Packer Tests (Table B-1) for Targeted Investigations Only (Previous Tests Detail Checked for Interim Geo. Data Package
04/02/07	S. Logeswaran	03/13/07	Task C2 Report Embankment Seismic Def'n
04/16/07	C. Gillan	04/16/07	Intake Tower Platform Structural Design
05/15/07	P. Respess	10/04/06	Figure 2 Geologic Map /Exploration Plan
05/15/07	S. Leung	09/30/06	Summary of Lab Test Results on 8-21 (Table D-3)
05/15/07	S. Leung	10/02/06	Summary of Laboratory Tests on Rock (CB-27 thru CB-76)
05/15/07	P. Respess	10/05/06	Test Pit Logs TP-20 & TP-21
05/15/07	P. Respess	10/04/06	Test Pit Logs TP-22 through TP-58
05/21/07	W. Ku	05/11/07	Draft Technical Memorandum (Spillway Structural Design)
06/14/07	J. Roadifier	06/14/07	Signet (Hayward Office) Triaxial Test Results (CB-38A, 47.1-47.4 and TP-37-2)
01/07/08	M. Forrest	10/29/07	Revised Draft Tech Memo - Embankment Filter and Drain Design (Task C2)
01/16/08	N. Kawamura	01/16/08	Design of Rock Anchors for Spillway Wall
01/16/08	N. Kawamura	01/16/08	Design of Rock Anchors for Spillway Base Slab
NS	A. Dufeur	01/16/08	Disposal Site #3 Riprap
01/17/08	N. Kawamura	01/17/08	Design of Rock Anchors to Resist Spillway Wall Overturning
08/05/08	J. Roadifier	07/28/08	Final GDR Drawings
08/05/08	J. Pietrzak	07/27/08	GDR Figures & Appendices
08/18/08	J. Pietrzak	08/12/08	GIR Checked Tables and Numbers in Report / Also Figure(s) & References

PM or EM Approval Date	Checker	Checker Approval Date	Title
06/24/10	G. Reichert	06/23/10	Fish Screen Head Loss Calculations
12/07/10	J. Pietrzak	12/07/10	Verification of Incorporation of CM Comments on 100% Draft Dwgs
12/08/10	J. Pietrzak	12/08/10	Incorporation of Responses to CM Comments on 100% Draft Specs
12/15/10	C.S. Doo	02/01/08	Spillway Wall Anchor Design
12/15/10	C. Gong	03/04/08	78" Pipeline Encasement, Static Analysis
12/15/10	C. Gong	03/04/08	Outlet Conduit Concrete Encasement - Reinforcement Design Calculations Book
12/15/10	N. Kawamura	01/10/08	Retaining Wall Design (Tower and Shaft Retaining Wall)
01/20/11	Y. Yiadom	10/18/10	Calaveras Fish Screen Pile Cap and Pile Demand Calculations
URS INDEPENDENT TECHNICAL REVIEW REPORTS (ITRs)			
03/29/04	D. Garner	03/29/04	Calaveras Test Site Hazardous Waste Evaluation - Tech Memo 5.2 (Draft)
09/14/05	M. Forrest	09/14/05	Draft Geotechnical Work Plan (Final Design)
02/21/06	D. Hughes	02/20/06	Draft Test Fill Plan
04/06/06	L. Mejia	04/06/06	Draft Tech Memo - Left Abutment Seepage Control Alts. Evaluation (Task C3.1)
04/10/06	C. Jaramillo	04/10/06	Draft Tech Memo - Left Abutment Seepage Control Alts. Evaluation (Task C3.1)
08/17/06	L. Mejia	08/17/06	Test Fill Program (Task B7.2) - Tech Memo - Draft
11/13/06	N. Wong	11/13/06	Revised Draft Tech Memo - Right Abutment Landslide Treatment (Task C4) - ITR#2
12/06/06	L. Mejia	12/06/06	Draft Tech memo - Embankment Stability (Task C2)
12/06/06	L. Mejia	12/06/06	Revised Draft Tech Memo - Right Abutment Landslide Treatment (Task C4)
01/10/07	M. Forrest	01/10/07	Spillway Model Test Technical Memorandum
01/26/07	B. Moler	11/21/06	Tech Memo C5 (Spillway Excavation Slope Stability)
02/29/07	L. Mejia	03/28/07	Draft TM - Spillway Excavation Slope Seismic Deformation (Task C5)
03/06/07	G. Reichert	03/06/07	Appendix C, Appendix to Hydraulic Model Study
04/02/07	R. Dillon	03/13/07	Draft TM - Embankment Seismic Deformation (Task C2)
05/14/07	L Mejia	05/14/07	Draft Addendum - Initial Landslide Treatment
05/15/07	G. Reichert	01/17/07	Inspection of Outlet System
05/21/07	S. Hom	05/16/07	Spillway Structural Design Structural TM - Draft
07/06/07	L. Mejia	07/06/07	Draft TM Addendum - Embankment Seismic Deformation (Task C2)
07/09/07	M. Forrest	06/27/07	Draft TM Addendum - Embankment Stability Analysis (Task C2) Analysis of Replacement Dam at Stations 11+560 and 18+00 and Disposal Site 2
NS***	M. Forrest	10/29/07	Revised Draft Tech Memo - Embankment Filter and Drain Design
11/13/07	L. Mejia	11/13/07	Evaluation of Melange Shear Strength Parameters Based on Additional Field and Laboratory Data Memorandum
11/20/07	L. Mejia	11/20/07	Draft Addendum - Evaluation of Effect of Seismically-Induced Deformation of Existing Dam on Intake Adits and Drain
12/21/07	M. Forrest	12/21/07	Geotechnical Evaluation Disposal Sites 3 and 7
12/21/07	A. Rajendram	12/20/07	Geotechnical Evaluation Disposal Sites 3 and 7 - Material Properties, Slope Stability and Simplified Deformation Analysis
03/13/08	L. Mejia	03/13/08	Draft Tech Memo (Spillway Gravity Wall Stability)
07/31/08	M. Forrest	07/31/08	Final Geotechnical Data Report
08/14/08	L. Mejia	08/13/08	Final Geotechnical Interpretive Report (Task B.10)
10/30/08	M. Forrest	10/30/08	Final Design Report - Draft: 11/4/08

PM or EM Approval Date	Checker	Checker Approval Date	Title
06/26/09	J. Bricker	06/26/09	Calaveras Seich(e) Runup Memo
06/25/10	C. Jaramillo	06/23/10	Draft Grouting Manual
06/25/10	M. Forrest	06/25/10	Technical Memorandum: Phase 1 Concept design for Intake Adit Fish Screens
06/28/10	C. Jaramillo	06/28/10	Draft Engineering Considerations and Instructions for Field Personnel (ECIFP)
07/15/10	C. Jaramillo	07/15/10	Right Abutment L/S Treatment Memorandum
07/15/10	M. Smith	07/15/10	URS Prepared Draft 100 Percent Drawings and Technical Specifications (Div 2, 3, 5, 13)
11/12/10	G. Reichert	11/10/10	Fish Screens Draft Final Tech Memo
11/12/10	G. Reichert	11/10/10	Fish Screens Draft Final Tech Memo
01/20/11	C. Gong	10/18/10	Calaveras Fish Screen Pile Cap Calcs & Pile Demands
04/13/11	G. Reichert	04/06/11	Spec 03300, Cast-in-place Concrete, and Addenda 5 and 6

PM: Project Manager   EM: Engineering Manager   NS: Not Signed   ND: Not Dated

* Not signed on CCS. However, a DCR with this title was submitted with C.S. Doo as checker and M. Forrest as the signed Approver.

** Assumed incorrect date

*** No Approver signature on ITR. However, a DCR with this title was submitted with M. Forrest as checker and Approver.

TABLE 4

REFERENCES

Dibblee, T.W. 1973. Preliminary Geologic Map of the Calaveras Reservoir Quadrangle, Alameda and Santa Clara Counties, California. U.S. Geological Survey Open File Map 73-58.

Dibblee, T.W. 2005. Geologic Map of the Calaveras Reservoir Quadrangle, Alameda and Santa Clara Counties, California. Dibblee Geology Center Map DF-154.

Cotton, W.R. 1972. Preliminary Geologic Map of the Franciscan Rocks in the Central Part of the Diablo Range, Santa Clara and Alameda Counties, California. U.S. Geological Survey Miscellaneous Investigations Map I-343.

Federal Emergency Management Agency, U.S. Department of Homeland Security. 1979. Federal Guidelines for Dam Safety. Prepared by the Interagency Committee on Dam Safety. Reprinted April 2004.

Federal Energy Regulatory Commission. 1991. Engineering Guidelines for the Evaluation of Hydropower Projects, Chapter 5 Geotechnical Investigations and Studies. Dated April.

Geomatrix Consultants. 2002. Geologic Mapping and Fault Evaluation, Calaveras Dam Seismic Evaluation Study. Unpublished report to Olivia Chen Consultants. Dated October 9.

Kintzer, Fredrick C. 1980. Geology and Landslides at Calaveras Reservoir, Alameda and Santa Clara Counties, California. M.S. Thesis, California State University, Hayward.

Nilsen, T.H, Bartow, J.A., Frizzell, V.A., Jr., and Sims, J.D. 1975. Preliminary Photointerpretation maps of Landslides and other Surficial Deposits of 56 7.5-minute Quadrangles in Southeastern San Francisco Bay Region, Alameda, Contra Costa, and Santa Clara Counties, California. U.S. Geological Survey Open File Report 75-277.

Nilsen, T.H, Wright, R.H., Vlasic, T.C., and Spangle, W. E. 1979. Relative Slope Stability and Land-Use Planning in the San Francisco Bay Region, California. U.S. Geological Survey Professional Paper 944.

National Resources Conservation Service, U.S. Department of Agriculture. 2012. Title 210 National Engineering Handbook, Part 631 Geology, Chapter 2 Engineering Geologic Investigations. Amendment 55. Dated January.

URS Corporation. 2004. Calaveras Dam Conceptual Engineering, Contract No. CS-716, Task 4.1 - Final Geotechnical Investigation Work Plan, File: 4110. Prepared for the San Francisco Public Utilities Commission. Dated January 14.

URS Corporation. 2005. Calaveras Dam Replacement Project, Contract No. CS-716, Task 5.6 - Final Geotechnical Investigation Work Plan, File: 4110. Prepared for the San Francisco Public Utilities Commission. Dated November 9.

URS Corporation. 2005a. Draft Project Management and Quality Assurance Plan, Calaveras Dam Replacement Project. Prepared for the San Francisco Public Utilities Commission. Dated November 29.

URS Corporation. 2008. Final Geotechnical Data Report (Task B.9), Calaveras Dam Replacement Project, Project No. CUW 37401, Contract No. WD-2551. Prepared for the San Francisco Public Utilities Commission. Dated August 5, 2008; reissued January 4, 2011.

URS Corporation. 2008a. Calaveras Dam Replacement Project, Project No. CUW 37401, Final Geotechnical Interpretive Report (Task B.10), File: 4110. Prepared for the San Francisco Public Utilities Commission. Dated August 15.

URS Corporation. 2011. Calaveras Dam Replacement Project, Project No. CUW 37401, Final Design Report, File: 4110. Prepared for the San Francisco Public Utilities Commission. Dated April 25.

URS Corporation. 2012. Calaveras Dam Replacement Project, Project No. CUW 37401, Evaluation of Left Abutment Excavation Slope, Revised Technical Memorandum. Prepared for the San Francisco Public Utilities Commission. Dated December 18.

URS Corporation. 2013. Geotechnical Data Report Supplement 1, Calaveras Dam Replacement Project, Project No. CUW 37401, Contract No. WD-2551. Prepared for the San Francisco Public Utilities Commission. Dated January.

U.S. Army Corps of Engineers. 2001. Geotechnical Investigations. Manual EM-1110-1-1804.

U.S. Army Corps of Engineers. 2004. General Design and Construction Considerations for Earth and Rock-Fill Dams. Engineering and Design Manual EM-1110-2-2300.

U.S. Bureau of Reclamation. 1987. Design of Small Dams, Third Edition.

U.S. Bureau of Reclamation. 2007. Data Design Collection Guidelines.

U.S. Geological Survey, (1899), San Jose 15-Minute Quadrangle. Reprinted June 1913.

Wiegers, M.O. 2011. Landslide Inventory Map of the Calaveras Reservoir Quadrangle, Alameda and Santa Clara Counties, California. California Geological Survey Landslide Inventory Map Series.

TABLE 5

LISTING OF AERIAL PHOTOGRAPHS REVIEWED BY GEI

Date	Flight No.	Line	Photo No.	Scale
02-06-06	AV 9308	02	06, 07, 08	1:7,200
08-20-99	AV 6100	30	56, 57	1:12,000
08-20-99	AV 6100	231	8, 9	1:12,000
07-31-96	AV 5200	30	60, 61, 62	1:12,000
06-02-94	KAV 4664	12	30, 31	1:36,000
06-02-94	AV 4625	30	59, 60, 61	1:12,000
07-22-92	AV 4230	0130	56, 57	1:12,000
10-07-91	KAV 4122	12	1, 2	1:36,000
07-23-90	AV 3845	28	62, 63	1:12,000
05-02-90	KAV3817	10	13, 14	1:36,000
05-23-88	AV 3292	12	15, 16	1:36,000
06-30-86	AV 2881	08	20, 21	1:33,600
10-10-85	AV 2664	12	1, 2	1:36,000
06-11-85	AV 2655	13	28, 29	1:36,000
04-24-85	AV 2600	13	20, 21	1:63,360
07-01-84	AV 2485	16	01, 02	1:12,000
07-01-84	AV 2485	17	01	1:12,000
02-04-82	AV 2050	13	30, 31	1:54,000
10-13-71	AV 1277	16	01, 02	1:12,000
10-13-71	AV 1277	17	01	1:12,000
10-12-71	AV 1006	16	01, 02	1:12,000
10-12-71	AV 1006	17	01, 02	1:12,000
05-07-68	AV844	22	53, 54	1:30,000
08-23-60	AV 385	03	04, 05	1:30,000
05-16-57	AV 253	29	58, 59	1:12,000

ATTACHMENT A

CALAVERAS DAM REPLACEMENT PROJECT
GEI NOTES OF
DESIGN TEAM RESPONSES TO INTERVIEW QUESTIONS

MEETING DATE: NOVEMBER 22, 2013

CALAVERAS DAM REPLACEMENT PROJECT

GEI NOTES OF DESIGN TEAM RESPONSES TO INTERVIEW QUESTIONS

Meeting Date: November 22, 2013
Location: GEI Oakland Office
Attendees:

URS Corporation	SFPUC	GEI Consultants
Noel Wong	Daniel Wade	Steve Verigin
Mike Forrest	Gilbert Tang	
John Roadifer	David Tsztoo	Jeff Brown
Phil Respess	Susan Hou	
Mark Schmoll		

Note: The Design Team noted during the meeting that in the text of the questions the Temblor Sandstone was incorrectly referred to as the Tremblor Sandstone. The spelling has been corrected in the text of the questions below. The spelling of report titles and minor typos have been corrected as well.

QUESTION 1: *We note that the January 2004 Geotechnical Investigation Work Plan for Conceptual Engineering indicates that no new roads are planned for the geotechnical investigation. Did this decision prevent drilling of borings at locations considered to most likely yield useful subsurface information? If so, please provide details.*

NOTES ON RESPONSE TO QUESTION 1:

- The 2004 investigation plan was intended as a Conceptual Engineering Phase that was a broad assessment of a wide range of project alternatives. Repairing or replacement of the existing dam, and type and location of dam and type of spillway for a new dam, were considered.

- The 2004 studies were considered a first phase of study after deficiencies in the existing dam were identified. These studies were not directed toward detail.

- This phase of the geotechnical investigation was completed under a CEQA Categorical Exemption and was consistent with applicable requirements of the SFPUC Alameda Watershed Management Plan and the Alameda Watershed Management Plan, Final Environmental Impact Report (SFPUC 2000).

- To accelerate mobilization to the field, the investigation was designed to avoid environmental impacts in order to allow use of a CEQA Categorical Exemption, which requires impact avoidance, but has a short review and approval duration. Accordingly, this investigation had to avoid significant environmental impacts, including those that would result from access road construction and removal of sensitive habitats and special status vegetation communities, such as oak woodlands. Off-road access was only allowed in grassland after sites were reviewed and approved.

- During the 2004 investigation, four core borings were drilled to investigate the Left Abutment area. Of these, Boring CB-2 would have been drilled higher up the slope instead of on the road if allowed. However, the preferred location was on a very steep slope (about 1:1 inclination) and access would have been very difficult. Boring CB-24 would have been drilled at a higher elevation on the slope below the spillway, instead of on an existing road, in order to drill through the Temblor Sandstone and into the Franciscan Complex. The excluded areas were explored during subsequent phases of investigation.

- The areas that could not be readily explored included areas too steep for safe construction of drill pads or platforms. These areas included the east facing slope of Observation Hill and the east facing slope above Calaveras Creek.

- The east slope of Observation Hill has a height of about 400 feet and cutting a pad on the steep slope would be a safety hazard. Excavation would primarily be in rock because most of soil was removed and used for hydraulic fill during original dam construction.

FOLLOW-UP INQUIRY TO QUESTION 1: *Was the Left Abutment slope too steep for safe access?*

NOTES ON RESPONSE TO FOLLOW-UP INQUIRY TO QUESTION 1:

- The slope was too steep to walk on safely.

QUESTION 2: *The location of Core Boring CB-50 was changed from the 2005 Work Plan site (mid-slope on southeast face of Observation Hill – east of Spillway Fault) to upper slope on south face of Observation Hill – west of Spillway Fault. What was the reason for relocating CB-50?*

NOTES ON RESPONSE TO QUESTION 2:

- Boring CB-50 was planned as a helicopter-access boring in the 2005 Work Plan to fill a data gap. The intention was to build a platform for the rig, but upon inspection, the driller thought the slope was too steep for safe platform construction. The location was changed to a small level area about 200 feet west of the original location. This level spot was likely associated with the original dam construction.

- At the alternate location for CB-50, the boring was angled into the hill to intercept the Spillway Fault zone, which was to be investigated anyway. This boring was intended to provide data on the width and characteristics of the Spillway Fault zone.

FOLLOW-UP INQUIRY TO QUESTION 2: *Could the Design Team find a contractor that would attempt to drill at the original CB-50 location?*

NOTES ON RESPONSE TO FOLLOW-UP INQUIRY TO QUESTION 2:

- The Design Team thought that a platform with helicopter access would allow drilling at the original CB-50 location, but they could not find a driller that would build the platform. To access that location the contractors wanted to cut a road to the site, but because this phase of the field investigation had been cleared under a CEQA Categorical Exemption, road construction could not be conducted because it could have potentially significant environmental impacts..

- Boring CB-27 on the north side of the Left Abutment was drilled off a platform by Crux Subsurface. This contractor had poor performance and poor recovery from this boring and was discharged. However, Crux did look at the original CB-50 site and determined that it was too steep for platform construction. After construction began, there was another attempt to drill a boring at the original CB-50 location. Once again, a contractor could not be located that would drill at this site.

QUESTION 3: *The project data and design report acknowledge that the upper 100 feet or so of the Temblor Formation in borings was notably different than that below:*

> *"The results of core borings drilled in the left abutment below about elevation 800 feet show that the upper 100 feet of the Temblor Sandstone is yellow-brown, generally extremely to very weak, completely to highly weathered, and intensely to highly fractured (fracture spacing <2 inches to 1 foot) with zones of moderately strong, slightly weathered rock. RQD (rock quality designation) values are mostly zero, with occasional values up to 50 percent. Many of the joints are filled with clayey materials."*
>
> *"Below a depth of about 100 feet, geotechnical data show that the sandstone quality improves markedly. The sandstone is gray, generally moderately strong to strong, slightly weathered to fresh, and moderately to slightly fractured, and occasionally massive (fracture spacing from 1 to 3 feet or more). RQD values are mostly 100 percent, with occasional values down to about 50 percent." (Geotechnical Data Report, Section 5.2.1.1, Description of Formation and Weathering - Page 5-5)*

In addition, there was an acknowledgement that the pattern of deep weathering in the left abutment area was considerably deeper than the nearby Hill 1000:

> *"Based on core boring CB-18, the Temblor Sandstone in Hill 1000 is less deeply weathered than in Observation Hill, with slightly weathered to fresh, moderately strong rock underlying about 30 feet of highly to moderately weathered brown Temblor Sandstone." (Geotechnical Interpretive Report, Section 4.1.1 Rock Conditions, Page 4.1)*

and

> *"The results of core borings drilled in the left abutment show that in the area of Observation Hill, the upper 100 feet of the Temblor Sandstone is completely weathered to highly weathered, brown, extremely to very weak, and intensely to highly fractured rock. Below a depth of about 100 feet, the sandstone is slightly weathered to fresh, gray, moderately strong to strong, and moderately to slightly fractured, and occasionally massive. Hill 1000, which is north (downstream) of Observation Hill, and flanks the stilling basin, presents shallower weathering, and below about 30 feet, the highly weathered sandstone gives way to the less weathered and stronger gray sandstone." (Draft TM: Spillway Excavation Slope Stability, Section 2.1.1, Temblor Sandstone, Page 2-1)*

Our review of field data in the area of Area B indicate that most boring logs indicate zones of sheared materials, weaker and more weathered rock, or intervals of No Recovery very near to the general horizon between the brown and gray sandstone. Please explain the Design Team's pre-construction interpretations of this data, the geologic characterization of the left abutment, and the rationale for arriving at that interpretation.

NOTES ON RESPONSE TO QUESTION 3:

- The pre-construction interpretations of these data were that the brown/gray horizon represented the leading edge of a deep weathering profile that terminated at an abrupt transition between underlying parent rock and overlying regolith (Phil Respess displayed a photo of a sharp weathering contact from a site in Panama).

- The deeper weathering profile and relatively abrupt horizon in Observation Hill were interpreted to be the result of the following factors:

    - ➢ The Spillway fault contributed to increased fracturing of the rock mass and create the breccia seen in the rock core.
    - ➢ The nearby Calaveras fault subjected the Observation Hill rock mass to seismic

shaking and ridgetop shattering (amplification or focusing of seismic energy due to the narrow ridge and steep peak of Observation Hill). This effect is more pronounced on the upper and outer boundaries of the hill and less within the core of the hill.
    - ➢ The more steeply dipping joint set along bedding (about 63 degrees) on the upper portion of Observation Hill channeled meteoric water deeper into the fractured rock mass, promoting deeper weathering.

- The short and squat topography, and the shallower bedding in Hill 1000 (almost flatlying to 30 degrees dip) resulted in the shallower weathering profile at Hill 1000. The effects of the Quarry Fault were considered in the evaluation of weathering within Hill 1000.

- The geologic characterization of the Left Abutment was that:

    - ➢ The upper 100 feet was generally composed of highly weathered, sandstone that was deeply jointed and brecciated throughout due to the ridgetop shattering effect. Fracturing and shearing were also present in the underlying gray sandstone.
    - ➢ At the leading edge of the weathering front, the parent rock was under high attack and undergoing accelerated deterioration.
    - ➢ The condition of the rock was an explanation for the poor core recovery.
    - ➢ The observed rock structure was interpreted to be characteristic of an intact rock mass subjected to jointing and weathering.

- The rationale for this interpretation is that:

    - ➢ Most of the core was composed of pieces that could be fit back together.
    - ➢ The joint infillings appeared to be associated with weathering.
    - ➢ The limited rock outcrops on slope were fractured, but did not display a tumbled, displaced or disturbed appearance that would indicate a massive landslide. This led to the belief that this was an intact rock mass. (The general structure of the site area was indicated in a broad view photograph displayed during the meeting. The photograph showed the Left Abutment and was taken on November 20, 2013.)
    - ➢ The intense fracturing was interpreted to be caused by the nearby seismic activity and in part by the folding associated with the plunging synclinal structure of the area.
    - ➢ The farther distance from the main faults and the lower bedding angles in Hill 1000 resulted in less fracturing and less penetration of weathering in that area.

QUESTION 4: *Borings CB-16 and CB-16A, located on the top of Observation Hill and west of the Spillway Fault have an uncharacteristically deep weathering profile compared to borings* *made east of the Spillway Fault (LA2012-11 and LA2012-12 of the Supplemental Phase do also). In CB-16, the log indicates primarily highly to moderately weathered, brown sandstone to the final boring depth of 150 feet. The adjacent CB-16A, which was logged beginning at 148 feet, was described as having brown, moderately weathered sandstones to the final boring depth of 250.2 feet, excepting for gray, slightly weathered zones from about 158 to 167 and about 178 to 197 feet. In borings made on the east face of Observation Hill, except in the Spillway Fault Zone, once the gray, slightly weathered or fresh sandstone was encountered, the rock was typically described as maintaining this non-weathered condition to the final boring depth. What was the Design Team's interpretation for the comparatively deep weathering and alternating weathering horizons observed in the borings on the top of Observation Hill?*

NOTES ON RESPONSE TO QUESTION 4:

- The alternating weathered and non-weathered zones in the Temblor sandstone were not unusual. This was interpreted as caused by more resistant zones or bands of rock (corestones) within the larger rock mass that was disturbed by faulting and folding.

- The weathering pattern generally went from more to less weathering with depth, i.e. less brown sandstone layers with depth. This was attributed to natural in-place processes rather than disturbance caused by landsliding.

- The deep weathering profile on Observation Hill would be expected due to the following factors:

  - The high ground shaking from the Calaveras and Spillway faults and multiple splay faults resulting in deep rock fracturing and weathering due to ridgetop shattering.

  - The deeper level of rock weathering typically observed on Observation Hill is partially due to steep slopes on three sides that allowed the weathering profile to extend to a greater depth into the rock.

  - Regional uplift and folding of the rock mass and resulting fracturing allowed the weathering profile to extend deeper along fractures and the moderately to steeply inclined bedding present at the top of Observation Hill.

  - The alternating weathered (brown) and unweathered (gray) zones in borings at the top of Observation Hill, and in borings on the east side of the hill (CB-1, CB-45, CB-51) were interpreted to be the result of differential weathering, with corestones of less fractured rock still present within the more weathered rock mass.

QUESTION 5: *The report "Evaluation of Left Abutment Excavation Slope" (December 18, 2012) provides extensive text on the difficulty of interpreting the origin of the deep* *weathering seen in borings made on the Left Abutment (eastern flanks of Observation Hill):*

> *"The interpretation of the origin of these materials is critical to the development of a reasonable geologic model of the Left Abutment area; a distinction must be made to interpret whether materials exposed in boreholes and excavations are (a) weathered in-place bedrock, (b) weathered transported bedrock blocks, or (c) weathered and fractured fault zone materials. Uncertainties in differentiating such materials can be large, and often the only diagnostic criteria for differentiating between "weathered," "landslide," and "faulted" materials are the overall geometry of the deposits and the geologic setting of the site." (Section 2.3.3 – Weathered Bedrock, Surficial Deposits and/or Fault-Zone Materials, Page 2-4)*

This statement was followed by a listing of 15 sets of data from the borings that were analyzed along with excavation exposures, historical maps and photography. Was the same methodology used (excepting for the abutment excavation exposures that did not exist) to assess the condition of the slope during the design phase? During the design phase, were there difficulties in determining the origin of the materials that were similar to those discussed in the supplemental phase report? If so, was the possibility considered during the design phase that the deep weathering seen in the Left Abutment and Spillway Cut borings could be attributed to landsliding? The possibility of deep-seated landslides underlying the Left Abutment was not discussed in the GDR, GIR, or FDR.

NOTES ON RESPONSE TO QUESTION 5:

- The GDR (Geotechnical Data Report) provides the field and lab data without interpretations.

- The GIR (Geotechnical Interpretive Report) is the report where the data is interpreted and evaluated, and where site conditions are characterized for use in analyses performed for design. The actual analyses are reported in different technical memoranda and the Final Design Report.

- The FDR (Final Design Report) is the report where the design parameters are reported that support the plans and specifications.

Question 5 - Part A: *Was the same methodology used (excepting for the abutment excavation exposures that did not exist) to assess the condition of the slope during the design phase?*

Notes On Response To Question 5 - Part A:

- The same methodology was used during the Design Phase.

- The design investigations were conducted without indications of a deep-seated slide in the Left Abutment (see response to Question 5 – Part C for amplification). There was a different focus in the 2012 studies as the slope was investigated in the context that a landslide may be present based on the observation of abutment excavation exposures during construction.

- The same techniques were used to evaluate data, and characterize and analyze site conditions in all phases of site work (e.g., differences in RQD, weathering, jointing).

- A remolded clay slide plane that could be correlated across multiple borings was not encountered during the design phase of work.

- The data from the design borings was considered in context with the proximity of faults and the structure and slopes of Observation Hill.

- Similar criteria were used throughout all phases of the investigation in the geological assessment of the subsurface conditions.

Question 5 - Part B: *During the design phase, were there difficulties in determining the origin of the materials that were similar to those discussed in the supplemental phase report?*

Notes On Response To Question 5 - Part B:

- No notable difficulties were encountered in determination of conditions of the Left Abutment during the Design Phase. The Design Team was satisfied that the observed conditions were the result of a complex series of processes that resulted in the deep weathering profile and fractured rock mass on Observation Hill.

Question 5- Part C: *If so, was the possibility considered during the design phase that the deep weathering seen in the Left Abutment and Spillway Cut borings could be attributed to landsliding?*

Notes On Response To Question 5 - Part C:

- The possibility that the deep weathering profile was a result of landsliding processes was not considered during the design investigation for the following reasons:

  - Previous geologic and landslide maps of the site (Marliave; Dibblee; Nilsen, Kintzer, and Geomatrix) do not show landslides mapped in the vicinity of Observation Hill.

  - A review of historic construction photographs obtained from the DSOD files showed no indications of deep-seated landsliding on the Left Abutment. The photos indicated uniform bedding dipping to the north on east slope of Observation Hill indicative of an intact rock mass.

  - A review of stereographic aerial photographs showed no geomorphic evidence or topographic expression of a landslide (other than surficial slumping and small breaks in slope) such as backscarps, hummocky topography or displaced stream at the toe.

  - Observations of the Temblor Sandstone in outcrop and the core borings indicated it is uniform, monolithic and contained no shale interbeds and that generally the bedding has a favorable angle into the slope.

  - No remolded fat clay seams were observed nor were any indications of continuous slip plane surfaces between borings observed. Thin clays here and there were observed, but no layers that could line up across the area.

  - Most of the core was composed of pieces that could be fit back together suggesting the rock mass had maintained its internal structure.

  - The 400-foot high east slope of Observation Hill, at 1:1 slope, appeared to be stable, other than surficial debris flows, since construction of the existing dam. If this steep slope was underlain by a landslide, it would not be expected to remain in-place during this time interval.

- Design Team's interpretation was a dilated, but in-place rock mass in the Left Abutment.

FOLLOW-UP INQUIRY TO QUESTION 5: *Did the Design Team use the 15 criteria (zones of No Recovery, RQD, etc.) reportedly used to evaluate the exploration data during* *the Supplemental Phase during the Design Phase also?*

NOTES ON RESPONSE TO FOLLOW-UP INQUIRY TO QUESTION 5:

- The evaluation criteria used during the Design Phase were the same as those used during the Supplemental Phase. The criteria were tools for evaluation and did not lead the Design Team to consider a landslide interpretation for the Left Abutment. There was no compelling evidence for a landslide interpretation; rather, there was considerable evidence for the opposite, that the slope was intact.

QUESTION 6: *Essentially, all borings (LA2012-01 to -04 and LA2012-06 to -08) drilled to characterize the existence and limits of Area A on the northern flanks of Observation Hill were made in the supplemental phase of work. Considering that the Spillway Cut Slope would encroach on a significant portion of the eastern and northeastern ends of Observation Hill, why wasn't this area investigated by borings during pre-construction investigation phases?*

N**OTES ON RESPONSE TO QUESTION 6**:

- During the Design Phase, it was the Design Team's opinion that CB-2, -16, -16A, -27, -28, 45, - 45A, -51, -52, and -53, all drilled between from about the mid-point to the northern third point of the proposed cut, provided sufficient data of the conditions in the northern half of Observation Hill.

- The Design Team did not consider other borings on the northeastern end of Observation Hill because:

  - ➢ The area lacked geomorphic evidence of different conditions as compared to adjacent areas that had already been investigated.

  - ➢ There were no access roads to the northeastern end of Observation Hill.

  - ➢ Trenches FT-4 and FT-5 for the Spillway Fault investigation were originally planned to be located up the hill but were made downslope of Observation Hill to avoid the need for environmental permits.

  - ➢ Borings in the southern half of Observation Hill were limited (CB-1 and CB-50) due to the steepness of the existing slope.

- Despite the limitations the Design Team felt that the objectives of their investigations were not compromised.

- Borings were made in areas of restricted access in later phases of work during construction once road construction was allowed.

- The Design Team could have pursued permission to drill at these sites during the design phase, but there was no apparent need and the process to complete a CEQA Mitigated Negative Declaration and acquire applicable federal and state environmental permits would have required up to 12 months. Since alternative drilling and trenching locations were available, URS did not recommend pursuit of the more complex and time consuming environmental clearances.

QUESTION 7: *The Left Abutment Excavation Slope Memo (Dec. 18, 2012) indicates:*

> *"Observations in bucket auger boring LA2012-05BA of breccia and with east-dipping clayey shears, directly overlying a moderately east-dipping abrupt contact with unfractured gray Tts sandstone, are consistent with similar geologic relationships at similar elevations in the nearby borings CB-2, CB-45, CB-28, CB- 29, and LA2012-09 (as described above). The characteristics of the basal material and the overall geometry and location of the entire mass suggest that this is a large complex of transported material" (Section 2.4.2 Area B, Page 2-10, Paragraph 4, Line 13-20)*

If "similar geologic relationships at similar elevations" existed in the pre-construction CB borings, was the possibility of a "large complex of transported material "underlying the Left Abutment area considered in the pre-construction geological characterization? Should that possibility have been presented in the GIR?

NOTES ON RESPONSE TO QUESTION 7:

- The term similar "geologic relationships" referred to similar degrees and depths of weathering.
- A landslide was not considered because the Design Team interpreted the highly fractured and weathered nature of the rock to be caused by the factors discussed in the responses to previous questions, such as local folding, faulting, shearing and ground shaking.
- The weathering profile and amount of rock fracturing would not be expected to be at similar elevations in adjacent borings if underlain by a deep-seated landslide.
- No fat remolded clay seams that are indicative of a large landslide basal slip plane surface were observed in the CB borings.
- The possible slide feature observed in LA2012-5BA is a thin, irregular clay seam. The seam is not continuous in the area around the borehole.

- Cut slope observations during construction indicate that a clay seam cannot be mapped as continuous across the site.

QUESTION 8: *Zones of No Recovery (NR) were logged very near the brown/gray sandstone interface in many Left Abutment pre-construction borings:*

CB-2 (88.5-91.6 feet)

CB-29 (70.0-72.4 feet and 74.2-75.0 feet)*

CB-30 (49.6-51.2 feet and 57.3-58.6 feet)*

CB-31 (67.1-68.3 feet)*

CB-45 (96.3-96.5 feet – 2 feet below shear zone)*

CB-51 (136.2-137.7 feet)*

CB-53 (45.7-46.5 feet)

Televiewer survey performed

No Recovery is frequently a consequence of coring through weak and/or broken materials that are washed away by the circulating fluids. Most of these NR zones correspond with brecciated zones seen on the televiewer logs. Was the possibility that a basal slide plane could exist at these depths of No Recovery considered during the pre-construction phase?

NOTES ON RESPONSE TO QUESTION 8:

- The evaluation of the geotechnical data provided no reason to suspect a landslide to underlay the Left Abutment.

- The intervals of No Recovery were interpreted in the context of the weathering profile and the tectonic setting.

- In the Design Team's experience, when drilling core borings in weathered, weak sandstone, the weak, sandier materials tend to wash out and result in No Recovery.

- The remolded fat clay from a basal slide plane will frequently plug the bit and be recovered in the core.

- While rock core with numerous joints that contained clayey sand infilling was recovered in the weathered upper portion of the rock mass, the Design Team did not observe a consistent layer of remolded clay at the brown/gray weathering horizon that could be correlated across multiple borings.

- Four other borings (CB-1, -27, -28, and -52) that were drilled in the Left Abutment did not have NR zones near the change from brown Temblor Sandstone to gray Temblor Sandstone.

- The televiewer data for CB-28 includes measurements of bedding above and below the basal plane of Area B that have similar orientations. These orientations are consistent with surface measurements made on outcrops in the Left Abutment.

- Borings CB-51 and CB-52 are near each other on the Left Abutment slope but explorations indicate differences between them. CB-51 indicated a zone of No Recovery and brecciated material at the transition from brown to gray sandstone. Other zones of No Recovery, brecciation and shearing were observed in this boring. CB-52 did have a brecciated zone at 120 feet, but the core was recovered. CB-52 did not have NR zones near the change from brown to gray sandstone.

- CB-51 indicated rock that was more broken than in CB-52, and thereby could be more readily washed out during coring. The zones of No Recovery were due to the broken structure, not to a possible landslide plane. Taking all the data together, the non-landslide characterization was a rational explanation for the Design Team.

QUESTION 9: *As indicated by the data recovered from Boring LA2012-05BA, clay seams and disturbed materials are better viewed in large-diameter borings rather than 2.5-inch diameter cores recovered from the nearby CB-2 and LA2012-05. Considering the irregular and deep weathering seen in the Temblor Formation beneath the Left Abutment, the zones of No Recovery logged at critical depths in the core borings, and the shallow weathering seen in other portions of the Temblor Formation, why were large-diameter borings and downhole logging not performed in this area during the pre-construction exploration phase?*

NOTES ON RESPONSE TO QUESTION 9:

- The Design Team did not see the need for bucket auger borings and downhole logging in the Left Abutment area because there were no indications of a landslide in this area. Televiewer logging in core borings was used for downhole imaging.

- Zones of No Recovery in core borings are not unexpected in weathered and fractured rock, and are not a conclusive reason for performing bucket auger borings.

- On the right abutment, where a landslide was known to be present, bucket auger holes were drilled.

- Because of the large size of bucket auger rigs and the large area needed for drilling, it would have been very difficult to locate meaningful areas in the Left Abutment where this type of exploration could be performed within the applicable topographic constraints.

QUESTION 10: *Table 5-3, Summary of Discontinuity Data: Temblor Sandstone in the GDR (Page 5-7) does not list the prominent secondary joint set (N33E, 30NW) for the gray Temblor Sandstone that dips obliquely into the hill, even though this secondary joint set is highlighted by a great circle in a stereoplot on Figure 5-18. In Figure 5-18, the orientation data for this joint set is well concentrated in the gray sandstone plot (right stereoplot) and contrasts with the sparse plotting for this joint set within the brown Temblor Sandstone (left stereoplot), even though the brown sandstone plot contains 79% more data points. Did this trend for a much lower percentage of into-slope dips in the brown sandstone (i.e. more out-of-slope dips) suggest that some downslope rotation and displacement could have occurred in the brown sandstone?*

Both stereoplots (brown and grey sandstone) on Figure 5-18 include data from two borings located west of (CB-16A) or in the Spillway Fault zone (CB-50). These plots contain the influences of data from a different domain (CB-16A) and a fault zone (CB-50). Were composite stereoplots developed for discontinuities in the brown and gray sandstones not including data from these borings to allow a clearer representation of the contrast between joint patterns in the brown and gray sandstones in the primary sub-unit of the Left Abutment excavation?

NOTES ON RESPONSE TO QUESTION 10:

- The stereoplots show the combined joint and bedding data from the televiewer logs. The concentration of data in this area (N33E, 30NW) on the gray sandstone plot results from bedding orientations. Because of weathering, few bedding attitudes were discernible in the brown sandstone on the televiewer logs.

- The orientation of the bedding (N33E, 30 NW) in the gray sandstone is similar to the few bedding orientations that the Design Team measured in surface outcrops.

- The Design Team attributed the increased scatter of poles on the brown sandstone stereoplot to the ridge-top shattering effects in the weathered, brown rock.

- The removal of the CB-16 and CB-50 data from the stereoplots was not considered during the Design Phase. However, the joint and bedding data was separated for analysis during the Design Phase.

- For this meeting, the Design Team prepared additional stereoplots without the data from these two borings and found that the overall pattern of the pole concentrations did not change significantly.