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# FOUNDATION INVESTIGATION

Ellis Creek Bridge
Rubicon Trail at Ellis Creek
El Dorado County, California

County of El Dorado
Owner

2009-0151
39120-A3:083N:158W

December 2009

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## Introduction

We have completed a geologic/geotechnical investigation of the subject site and are providing geologic and foundation information for design of foundation elements for the proposed vehicular bridge across Ellis Creek. A site visit was made with the County on June 17, 2009 and site investigation was performed on October 27, 2009.

## Project and Site Description

The site of the proposed bridge is downstream of an existing unimproved stream crossing along the Rubicon Trail. This location was selected by the County during the June 17, 2009 site visit. It is understood that the purpose of the proposed bridge is to move traffic out of the creek bed and to allow for restoration of the stream channel in the location of the existing crossing.

Ellis Creek at the proposed bridge location flows generally northwest to southeast. The banks of the creek at the bridge abutment locations was observed to be composed of a mantle of soil and tree litter with exposed igneous rock along portions of the stream thread. The banks immediately next to the stream are steep to vertical of approximately 5-ft height. Above the near vertical bank section the slopes become flatter with approximately 3H:1V or less gradient in the areas of the two proposed abutments. Observed stream bed materials consisted of cobble to boulder size clasts of igneous rock.

The area immediately southwest of the proposed southern abutment is mostly level and covered by brush, with some large rock outcroppings protruding from the ground. The land to the north slopes upward away from the proposed northern abutment location with a gradient of 3H:1V or flatter. The Rubicon Trail currently passes approximately 20-ft to the north of the proposed northern abutment. Outcroppings of intensely weathered to decomposed igneous rock was observed along the alignment of

the Rubicon Trail north of the proposed bridge location and along the portion of the Rubicon Trail that passes through the creek.

Tentatively, the proposed bridge crossing is to be a one lane single span structure of approximately 65-ft length supported on reinforced concrete abutments. Approach roadway embankments are assumed to be minimal and to closely match existing grades when constructed. Approach roadway is assumed to consist of gravel, with no paving. Bridge type selection has yet to be performed. Site layout and proposed bridge alignment were provided by the County on an untitled site plan (Figure 2).

## Geologic Conditions

The site is shown on published geologic mapping ("Geologic Map of the Chico Quadrangle" CDMG, 1991 1:250,000) as underlain by Cretaceous age plutonic rocks of granite to granodiorite composition. Channel alluvium consists of sand, gravel, cobbles, and scattered boulders.

No faults are indicated to pass through the project site on published mapping. Several un-named faults are mapped nearby, with the nearest approximately 2 miles north of the project location. These faults are listed as not active during the Holocene by the California Geological Survey and are not included in the faults shown on the Caltrans "Seismic Hazard Map". The nearest active fault is West Tahoe - Dollar Point fault which is approximately 11.3 miles to the east of the site.

## Exploration and Testing

Information on the nature and distribution of subsurface materials and conditions for this foundation investigation was obtained by means of two double ended refraction seismic soundings. The soundings were made in the area designated by the County as the likely location of the proposed abutments. No excavation was permitted during our site evaluation and no samples were taken for laboratory testing.

The sounding locations and velocity profile are shown on Figure-2 and Figure-3. David Kitzmann, C.E.G., was the field engineering geologist for this project. Locations are referenced to site features as provided on an untitled topographic map provided by the El Dorado County Department of Transportation.

## Seismic Refraction Profiling

Refraction seismic profiling indicates primary wave (compression wave) velocities ranging from 400 fps to as much as 13000 fps. Seismic lines were approximately 30 to 35±feet in length and would represent materials to depths of 15-17±feet.

Interpreted results/details of the seismic refraction profiles are summarized in the following table:

| Refraction Seismic Profiles | | | |
|---|---|---|---|
| **Seismic Line** | **Estimated Depth to Bottom of Layer (ft)** | **Layer Velocity (fps)** | **Materials Description*** |
| S1-S2 | 5-7 | 400-1,200 | Topsoil / Alluvium |
| | | 4,600-13,000 | Intensely Weathered to Slightly Weathered rock |
| S3-S4 | 5-7 | 750-1,600 | Topsoil / Alluvium |
| | | 10,000-10,300 | Slightly Weathered Rock |

* Materials description is interpreted, based on site observations and layer velocities.

Location of the seismic profile is shown in Figure-2. Time-distance graphs for refraction seismic profiles are shown on Figure-3.

## Earth Materials and Conditions

Two geotechnically important units exist at this location consisting of an upper topsoil/alluvium unit and a lower weathered rock unit.

Rock observed in the vicinity of the proposed abutments is consistent with published mapping. The nearest rock outcropping observed to the proposed abutments was within 20 feet of the project boundaries. It can be expected that the rock observed surrounding the project site is representative of the rock underlying the Topsoil/Alluvium in the general vicinity.

### Topsoil/Alluvium

Topsoil/Alluvium was encountered at each sounding location and is interpreted to be on the order of 5 to 7±ft in thickness. Surface materials generally consist of tree litter including bark, needles, and branches forming a spongy surface layer on the order of 1±ft thick underlain by sandy soil. Exposed soil ranged from light gray to light orange in color and was damp to dry and semicompact. Some cobble to boulder size clasts were found scattered across the project site. It is likely that cobble and boulder size clasts also exist within the Topsoil / Alluvium unit.

### Rock

At the proposed abutment locations weathered rock is interpreted as beginning at approximately 5 to 7.5±ft depth at both abutment locations. Based on recorded shear wave velocities recorded the weathered rock is interpreted as being similar to that exposed along the adjacent Rubicon Trail, which is moderately weathered to decomposed igneous rock with zones of slightly weathered to fresh igneous rock. The rock surface is interpreted as being variable in depth with the possibility of distinct steps in elevation.

The highly weathered to decomposed rock is capable of generating support for heavy concentrated foundation loads, however upper 1-3 ft of the decomposed rock is not considered erosion/scour resistant.

**Corrosivity**

Removal of soil from the site was not permitted and therefore no corrosion testing was performed for this investigation. Soil mapping and data provided by the USDA (http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx) lists surface soils in the area as possessing moderate corrosion potential for steel and concrete. It is anticipated that foundations will be established in rock with engineered fill backfill behind the abutment walls. It is recommended that site soils be tested prior to construction to verify the corrosivity potential of the site soils.

**Groundwater**

In general, all of the Topsoil / Alluvium below channel water surface is expected to be saturated and capable of transmitting seepage to open excavations. Seepage through rock is expected to be considerably less than in upper unit soils and concentrated along zones with more open fractures / weathering, particularly in the upper part of the rock where fractures are more likely to have hydraulic continuity with the overlying alluvium.

**Seismic Conditions**

The site is located approximately 11.3±miles (18.3 km) west of the trace of the West Tahoe - Dollar Point fault; the style of this fault is listed as normal (per Caltrans ARS Online site, http://dap3.dot.ca.gov/shake_stable). Based on available data, the site can be assigned a soils profile Type-C (per Table B.1, Caltrans "Seismic Design Criteria" (SDC) Appendix B Rev. 8/12/2009). Caltrans structure design practice requires certain

increases in SDC response curves due to fault proximity and type. The controlling fault is within 25 km of the site and fault proximity adjustments are required.

Based on the above information, structure design is recommended to be based on the following SDC parameters:

- Soil Type C
- Deterministic Controlling Fault: West Tahoe – Dollar Point fault
- Maximum Magnitude: 7.0
- $R_{rup}$: 18.3 km

An ARS curve and seismic design parameters incorporating near field effects as generated by the Caltrans online tool can be found in Appendix A.

**Conclusions and Discussion**

No over-riding geologic hazards (e.g., faulting, landslides, severe erosion, subsidence, etc.), are identified at this site.

Local scour is considered possible within the soil and decomposed rock, the evidence of such scour was observed at the site. Evidence of scour at the site include deeply incised channel near the proposed bridge location, however larger clasts / boulders of igneous rock found along the channel appear to be providing at least some nominal scour protection to the banks.

The ground appears adequately stable and capable of providing foundation support for the proposed bridge. Access and conditions at support locations would allow for spread footing foundations in weathered rock and we expect that spread footings would be the most straight-forward and recommended bridge foundation type. We anticipate that exposed weathered rock will not be "scour resistant" and that spread footing foundations established within rock should be protected from scour.

Driven pipe piles and concrete piles are not recommended due to hard driving conditions evident at the site, cobbles/boulders in upper unit soils, and shallow bedrock. CIDH piles, while feasible, are not recommended for this site due to the potential for oversize materials and difficult installation and availability of foundation support near-surface. Saturated soil at the support locations would also likely require "wet" construction and special inspection of CIDH piles.

## Abutments

At bridge abutments, spread footings appear to be the most straightforward foundation type. For design purposes, allowable bearing pressures of 3 tons per square foot for footing excavations of 24-inches or deeper into competent weathered rock appear appropriate. Variations in rock surface elevation and rock condition are expected to be accommodated with the use of plain concrete fill below the reinforced concrete footings. Plain concrete fill of up to 2±ft is acceptable without considering the need to widen footing excavation. It can be expected that depth to competent weathered rock will vary across the abutment footprint and deviations of 2±ft should be expected. An engineering geologist from this office should review the completed footing excavations for general compliance with the conclusions and recommendations in this report and to provide supplementary recommendations if needed.

Expected base of footing depths are summarized in the following table.

Table 2

Spread Footing Data Table

| Support Location | Minimum Footing Width | Bottom of Footing Elevation | Recommended Soil Bearing Pressure | |
|---|---|---|---|---|
| | | | WSD[1] | LFD[2] |
| | | | Gross Allowable Soil Bearing Pressure ($q_{all}$) | Ultimate Soil Bearing Pressure ($q_u$) |
| N Abut | 3-ft | 6517.00 | 3 tsf | N/A |
| S Abut | 3-ft | 6518.00 | 3 tsf | N/A |

Notes:

1) Working Stress Design, (WSD), the Maximum Contact Pressure, ($q_{max}$), is not to exceed the recommended Gross Allowable Soil Bearing Pressure, ($q_{all}$). The Ultimate Soil Bearing Capacity, ($q_{ult}$), will equal or exceed 3 times the recommended Gross Allowable Soil Bearing Pressure, ($q_{all}$).

2) Load Factor Design, (LFD), The Maximum Contact Pressure ($q_{max}$) divided by the Strength Reduction Factor ($\phi$) is not to exceed the recommended Ultimate Soil Bearing Pressure ($q_u$). The Ultimate Soil Bearing Capacity, ($q_{ult}$), will equal or exceed the recommended Ultimate Soil Bearing Pressure, ($q_u$).

For resistance to lateral loads, concrete footings poured neat against clean weathered rock may be assigned an ultimate base friction coefficient of 0.50. Additional resistance to sliding can be obtained by doweling into the weathered rock. For transient overturning loads and Working Stress Design, a 1/3 increase in allowable bearing capacity is permissible. Higher bearing pressures could be considered for seismic loading conditions.

If groundwater is encountered in open excavations it is expected to be controlled with diking, diversion and pumping. Temporary construction backslopes should be reviewed during construction in evaluation of stability and for possible supplemental support (e.g., local shoring in areas of soft/weak materials). It is expected that construction backslopes should be stable at configurations of 2H:1V or flatter. All excavations should conform to CalOSHA standards.

If seepage cannot be controlled the use of cofferdams may be necessary at the abutment footing locations. It is expected that sheet piles can be at least partially driven into decomposed/intensely weathered rock to facilitate footing construction. Hard driving conditions should be considered with sheet pile and hammer selection. Substantial variation in sheet-pile penetration could result from changes in the depth and thickness of the decomposed rock across the footings and in the consistency of the decomposed rock, possibly including local zones of fresher rock. The surface of rock bearing materials is likely to be irregular.

The decomposed rock materials are expected to have relatively low permeability and the depth to bottom of footings is expected to be above summer channel level. It is expected that seepage if present will be minimal and can be controlled by pumping. Dewatering an excavation penetrating into the rock bearing materials is permissible and is not expected to result in bottom heave. If seepage amounts can not be adequately controlled by pumping for a neat pour against the completed excavation it is recommended that the foundation be doweled into rock.

*Earth Pressures*

With use of standard Caltrans "Structure Backfill" materials and details, an active soil pressure of 36 pcf is considered appropriate for use in abutment wall design. Seismic loading will apply additional soil pressure to abutment walls. The resultant of incremental lateral soil pressure due to seismic loading will act at 0.6 times the wall height (above the base of the wall) and the magnitude of resultant may be calculated on the basis of an additional equivalent fluid pressure of 17 pcf. For seismic loading into abutments, passive soil resistance of up to 5.0 ksf is available – to be reduced for effective wall height less than 5.5 ft in accordance with Caltrans SDC (v.1.4).

*Earthwork*

All earthwork should be performed in accordance with Caltrans "Standard Specifications" supplemented by the recommendations below.

The area to be graded should be stripped of all debris, vegetation, and other organic materials. Where woody vegetation is removed, all substantial roots should be excavated and removed. Debris, organic material, and otherwise unsuitable materials should be disposed to an approved location.

The surfaces to receive fill should be scarified to 6-inch depth, moisture conditioned to at least optimum-moisture content, and compacted to at least 95% relative compaction (per CTM 216). Inability to achieve the required compaction on the scarified materials may be used as a field criterion to identify areas requiring additional removal and/or compaction (locally soft / loose soils).

Embankment fill slopes of 2H:1V or flatter are considered acceptable. Where new fill is to be placed onto fill or natural slopes exceeding 5H:1V, it should be placed on discrete benches cut fully into the slope and below any loose/soft or otherwise unsuitable materials (per Section 19 of Caltrans "Standard Specifications"). The benches (usually 1 ft or so in height) are typically cut during fill placement activities and, per Section 19-6.01, are a minimum of 6-ft in width. These recommendations can be modified by the Resident Engineer in charge of the project based on soil exposures and grading operations during earthwork activities.

On-site soils (less debris or organic material, oversized material, or other deleterious material) are considered generally acceptable for use as compacted embankment fill and, except as described below, should be placed to at least 90% relative compaction at or above optimum moisture per CTM 216. Considering the use of

the proposed bridge and the anticipated roadway materials, native materials up to 6-inches in diameter can be used as backfill. Imported embankment fill should be approved by the Engineer and have "low" expansion potential (Expansion Index less than 25 or Plasticity Index less than 20).

An expansive soil exclusion zone shall be used for bridge embankment construction as described in Caltrans "Guidelines for Structures Foundation Reports" Version 2.0 (March 2006).

## Scour Protection

It is understood that the placement of the proposed abutments is above the anticipated high water level of Ellis Creek, however abutment footings will be below the likely high water level and portions of the weathered rock may be susceptible to scour if significant bank erosion were to take place. It is recommended that a grout apron be poured after completion of the footing which should extend a minimum of 2-ft horizontally from the edge of footing. Alternatively rock slope protection (RSP) can be used to provide this protection. RSP should be placed in accordance with Caltrans standard practice.

## Construction Considerations

Relatively fresh igneous rock is expected within footing excavations (at least in part) and is expected to be difficult to excavate. Airtools or blasting may be required to penetrate fresher rock materials. Groundwater is not expected to be a major consideration in abutment excavations during low / no flow conditions and encountered seepage is expected to be controllable by means of sump pumping, as necessary. Within the channel, adequate construction de-watering is expected to be achievable (at low channel flow) by means of diking/diversion of surface water and sump pumping, but could require heavy pumping.

## Roadway Earthwork

It appears from field observations that roadway earthwork can be generally accomplished using typical earthmoving equipment. Boulders were observed within the site boundaries and may be encountered within the upper portions of the site soils. During construction some loose/soft subgrade may be encountered and construction would require sub-excavation down to firm intact soils. It is understood that the approach roadway will be a gravel road and pavement structural sections were therefore not part of this scope.

## Supplemental Services

The conclusions and recommendations provided in this report are dependent on several supplementary services. We highly recommend ridge plans be provided for review by this office prior to bid. In addition, since no subsurface investigation was possible the conclusions and recommendations are based on surface observations and inferred from geophysical means. It is therefore critical that footing excavations be reviewed by this office to confirm our conclusions and to provide additional or alternate recommendations when actual subsurface conditions are observed.

REGISTERED PROFESSIONAL ENGINEER RONALD ERIC LOUTZENHISER NO. 64089 Exp. 9/30/10 CIVIL STATE OF CALIFORNIA

TABER CONSULTANTS

REGISTERED GEOLOGIST DAVID KITZMANN NO. 2412 CERTIFIED ENGINEERING GEOLOGIST STATE OF CALIFORNIA

Reviewed by: Ronald E. Loutzenhiser
R.C.E. 64089

David A. Kitzmann
C.E.G. 2412

Attachments:

| | |
|---|---|
| | "General Conditions" |
| Figure-1 | "Vicinity Map" |
| Figure-2 | "Location of Field Tests" |
| Figure-3 | "Refraction Seismic Record" |
| Appendix-A | "Seismic Design Parameters" |

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## GENERAL CONDITIONS

The conclusions and recommendations of this study are professional opinion based upon the indicated project criteria and the limited data described herein. It is recognized there is potential for sufficient variation in subsurface conditions that modification of conclusions and recommendations might emerge from further, more detailed study.

This report is intended only for the purpose, site location and project description indicated and assumes design and construction in accordance with Caltrans practice.

As changes in appropriate standards, site conditions and technical knowledge cannot be adequately predicted, review of recommendations by this office for use after a period of two years is a condition of this report.

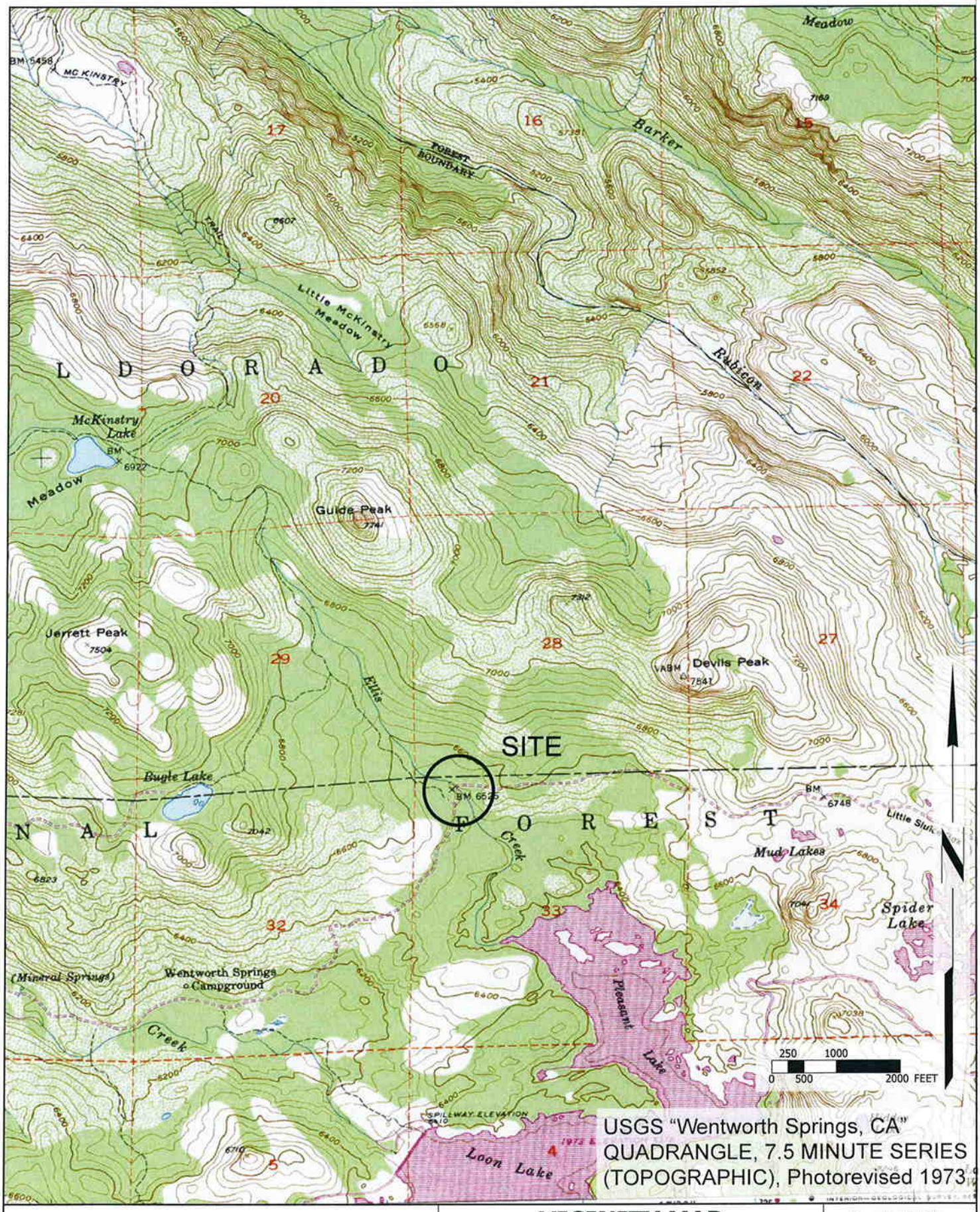
A review by this office of any foundation and/or grading plans and specifications or other work product insofar as they rely upon or implement the content of this report, together with the opportunity to make supplemental recommendations as indicated therefrom is considered an integral part of this study and a condition of recommendations.

Subsequently defined construction observation procedures and/or agencies are an element of work that may affect supplementary recommendations.

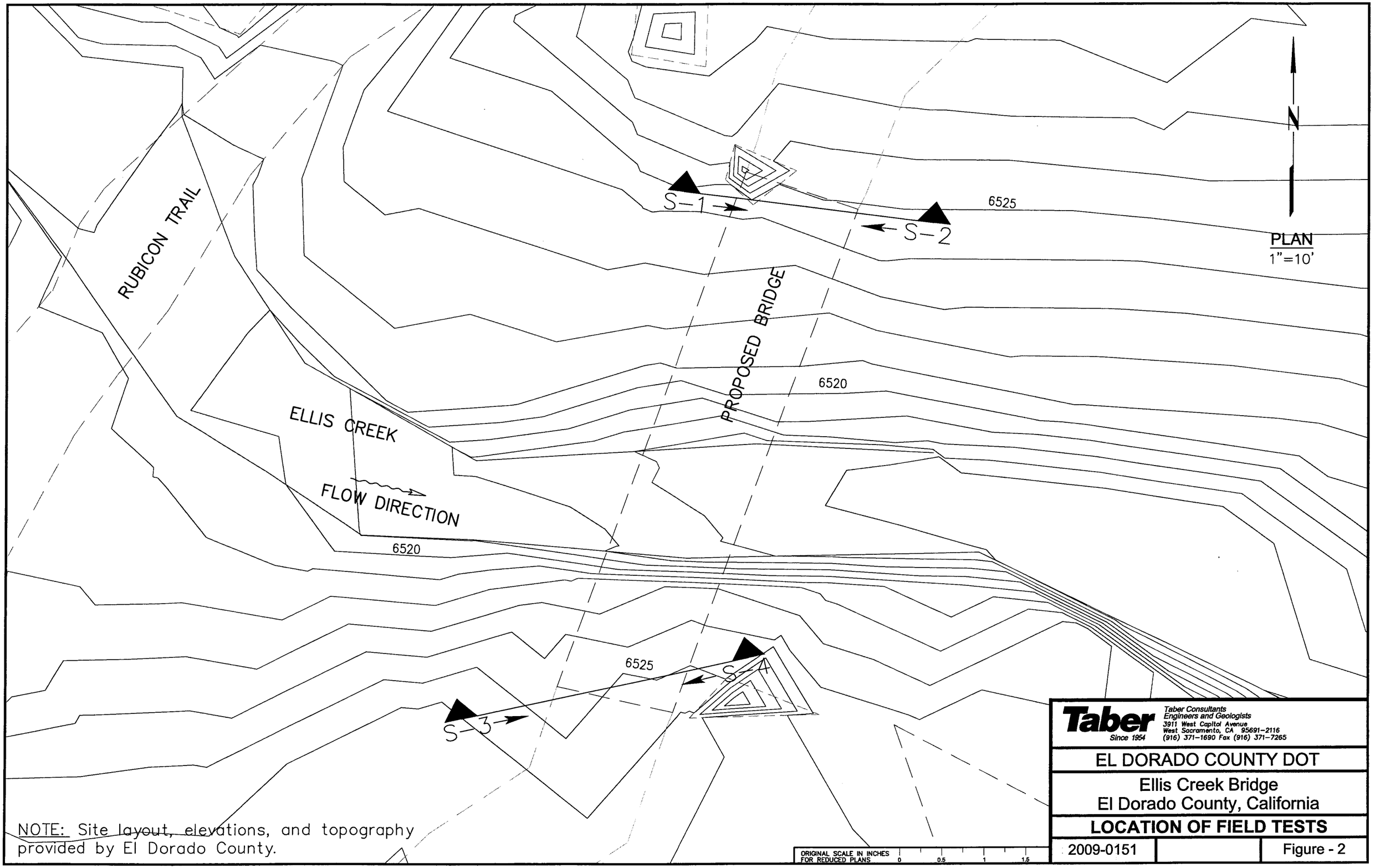
Should there be significant change in the project, or should earth materials or conditions different from those described in this report be encountered during construction, this office should be notified for evaluation and supplemental recommendations as necessary or appropriate.

Opinions and recommendations apply to current site conditions and those reasonably foreseeable for the described development--which includes appropriate operation and maintenance thereof. They cannot apply to site changes occurring, made, or induced, of which this office is not aware and has not had opportunity to evaluate.

The scope of this study specifically excluded sampling and/or testing for, or evaluation of the occurrence and distribution of, hazardous substances. No opinion is intended regarding the presence or distribution of any hazardous substances at this or nearby sites.




| | | |
|---|---|---|
| Taber Since 1954<br>*Taber Consultants*<br>*Engineers and Geologists*<br>3911 West Capitol Avenue<br>West Sacramento, CA 95691-2116<br>916-371-1690 Fax: 916-371-7265<br>www.taberconsultants.com | **VICINITY MAP**<br>El Dorado County<br>Ellis Creek Bridge<br>El Dorado County, California | Project No.<br>2009-0151<br>December 2009<br>**FIGURE-1** |




NOTE: Site layout, elevations, and topography provided by El Dorado County.

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EL DORADO COUNTY DOT

Ellis Creek Bridge
El Dorado County, California

**LOCATION OF FIELD TESTS**

| 2009-0151 | | Figure - 2 |
|---|---|---|

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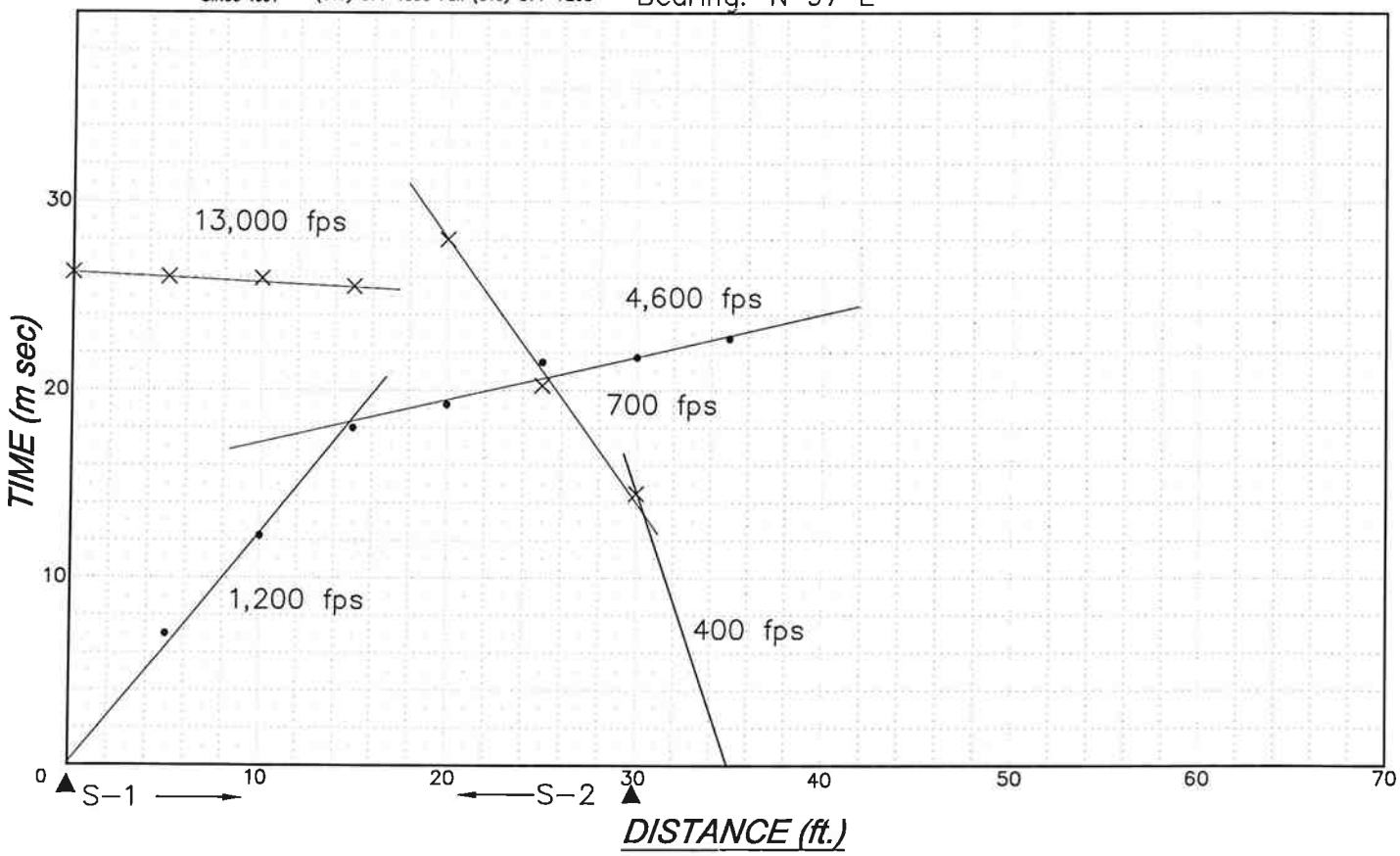
Location: Ellis Creek North Abutment Location
Bearing: N 97° E




Location: Ellis Creek South Abutment
Bearing: N 78° E

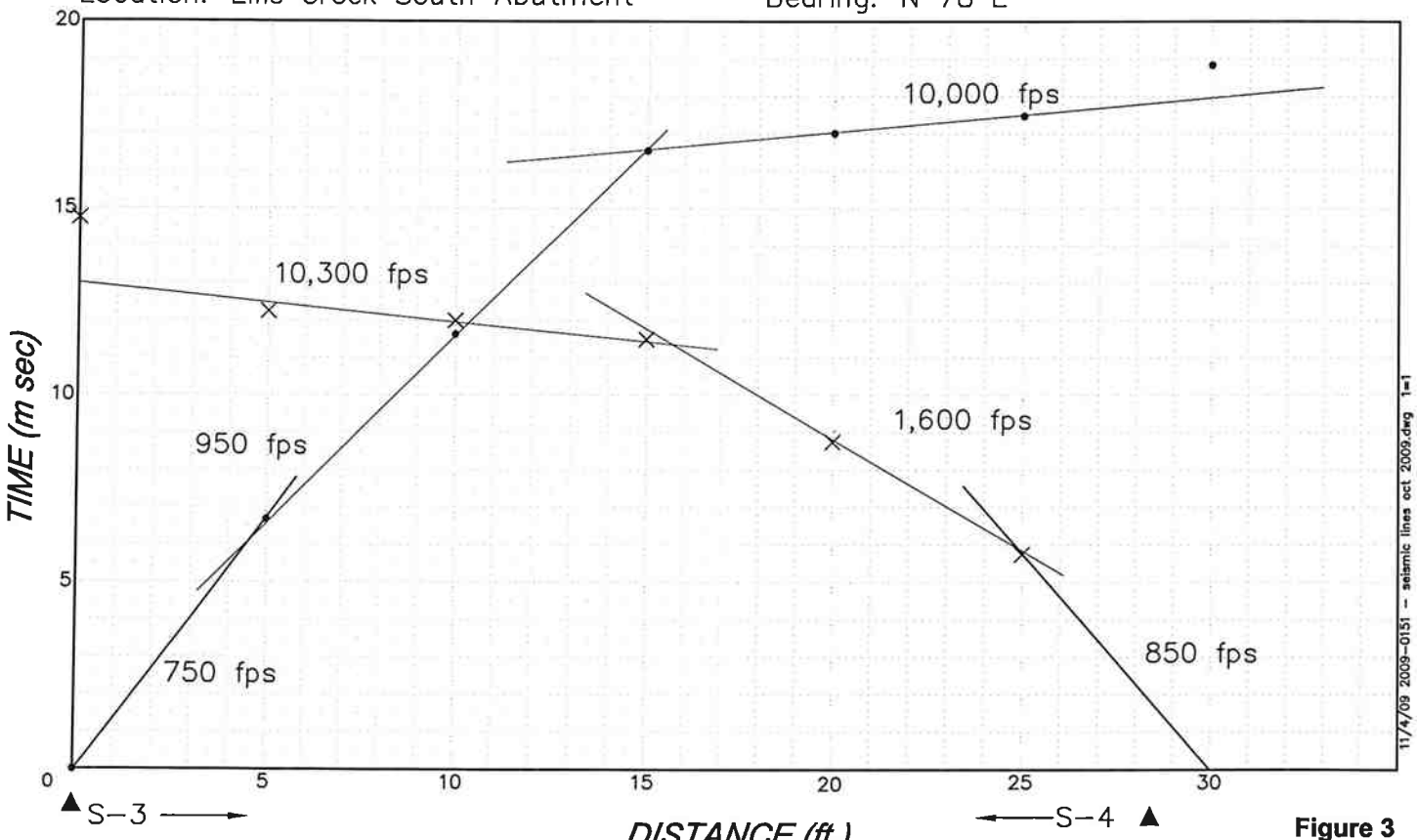



**Figure 3**
**Page 1 of 1**

## REFRACTION SEISMIC RECORD

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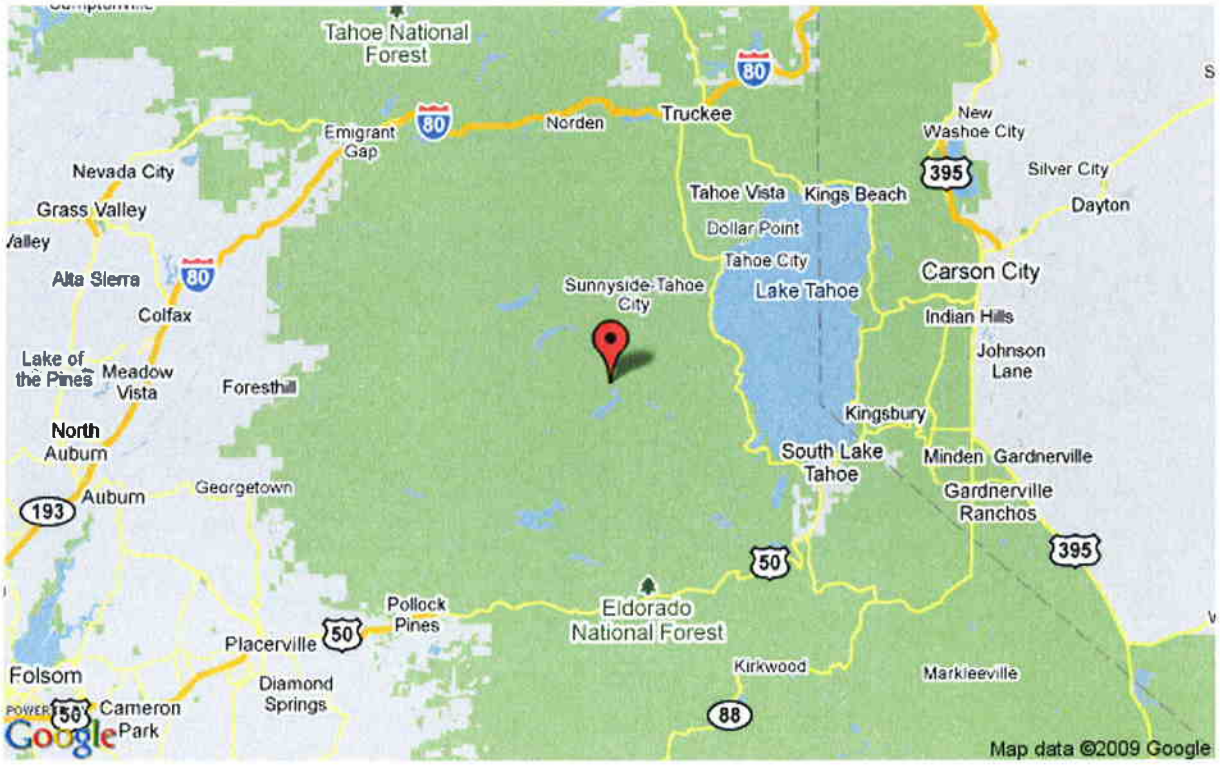
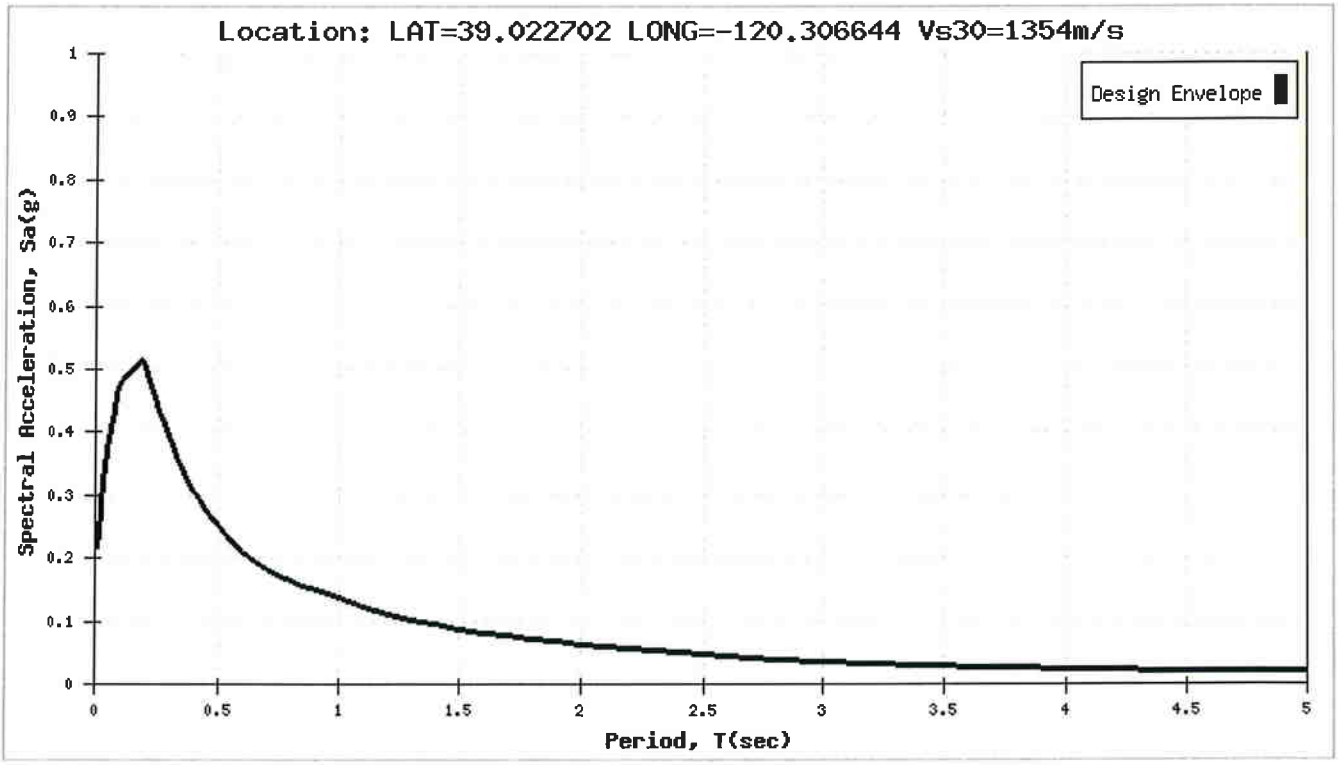
# Appendix A

## Seismic Design Parameters

## SELECT SITE LOCATION




## CALCULATED SPECTRA




## SITE DATA

| | |
|---|---|
| **Shear Wave Velocity, $Vs_{30}$:** | 1354 m/s |
| **Latitude:** | 39.022702 |
| **Longitude:** | -120.306644 |
| **Depth to Vs = 1.0 km/s:** | 3 m |
| **Depth to Vs = 2.5 km/s:** | 2.00 km |

## DETERMINISTIC

### West Tahoe - Dollar Point fault

| | |
|---|---|
| **Fault ID:** | 84 |
| **Maximum Magnitude (MMax):** | 7 |
| **Fault Type:** | N |
| **Fault Dip:** | 60 Deg |
| **Dip Direction:** | e |
| **Bottom of Rupture Plane:** | 13.00 km |
| **Top of Rupture Plane(Ztor):** | 0.00 km |
| **Rrup** | 18.30 km |
| **Rjb:** | 18.30 km |
| **Rx:** | 18.29 km |
| **Fnorm:** | 1 |
| **Frev:** | 0 |

| Period | SA(Base Spectrum) | Basin Factor | Near Fault Factor(Applied) | SA(Final Spectrum) |
|---|---|---|---|---|
| **0.01** | 0.115 | 1.000 | 1.000 | 0.115 |
| **0.02** | 0.117 | 1.000 | 1.000 | 0.117 |
| **0.022** | 0.119 | 1.000 | 1.000 | 0.119 |
| **0.025** | 0.122 | 1.000 | 1.000 | 0.122 |
| **0.029** | 0.126 | 1.000 | 1.000 | 0.126 |
| **0.03** | 0.127 | 1.000 | 1.000 | 0.127 |
| **0.032** | 0.130 | 1.000 | 1.000 | 0.130 |
| **0.035** | 0.135 | 1.000 | 1.000 | 0.135 |
| **0.036** | 0.136 | 1.000 | 1.000 | 0.136 |
| **0.04** | 0.142 | 1.000 | 1.000 | 0.142 |
| **0.042** | 0.146 | 1.000 | 1.000 | 0.146 |
| **0.044** | 0.149 | 1.000 | 1.000 | 0.149 |
| **0.045** | 0.151 | 1.000 | 1.000 | 0.151 |
| **0.046** | 0.152 | 1.000 | 1.000 | 0.152 |
| **0.048** | 0.156 | 1.000 | 1.000 | 0.156 |
| **0.05** | 0.159 | 1.000 | 1.000 | 0.159 |
| **0.055** | 0.169 | 1.000 | 1.000 | 0.169 |
| **0.06** | 0.179 | 1.000 | 1.000 | 0.179 |

| | | | | |
|---|---|---|---|---|
| **0.065** | 0.189 | 1.000 | 1.000 | 0.189 |
| **0.067** | 0.193 | 1.000 | 1.000 | 0.193 |
| **0.07** | 0.199 | 1.000 | 1.000 | 0.199 |
| **0.075** | 0.208 | 1.000 | 1.000 | 0.208 |
| **0.08** | 0.216 | 1.000 | 1.000 | 0.216 |
| **0.085** | 0.224 | 1.000 | 1.000 | 0.224 |
| **0.09** | 0.232 | 1.000 | 1.000 | 0.232 |
| **0.095** | 0.239 | 1.000 | 1.000 | 0.239 |
| **0.1** | 0.246 | 1.000 | 1.000 | 0.246 |
| **0.11** | 0.256 | 1.000 | 1.000 | 0.256 |
| **0.12** | 0.264 | 1.000 | 1.000 | 0.264 |
| **0.13** | 0.271 | 1.000 | 1.000 | 0.271 |
| **0.133** | 0.273 | 1.000 | 1.000 | 0.273 |
| **0.14** | 0.277 | 1.000 | 1.000 | 0.277 |
| **0.15** | 0.281 | 1.000 | 1.000 | 0.281 |
| **0.16** | 0.280 | 1.000 | 1.000 | 0.280 |
| **0.17** | 0.278 | 1.000 | 1.000 | 0.278 |
| **0.18** | 0.276 | 1.000 | 1.000 | 0.276 |
| **0.19** | 0.273 | 1.000 | 1.000 | 0.273 |
| **0.2** | 0.270 | 1.000 | 1.000 | 0.270 |
| **0.22** | 0.255 | 1.000 | 1.000 | 0.255 |
| **0.24** | 0.241 | 1.000 | 1.000 | 0.241 |
| **0.25** | 0.234 | 1.000 | 1.000 | 0.234 |
| **0.26** | 0.228 | 1.000 | 1.000 | 0.228 |
| **0.28** | 0.216 | 1.000 | 1.000 | 0.216 |
| **0.29** | 0.211 | 1.000 | 1.000 | 0.211 |
| **0.3** | 0.206 | 1.000 | 1.000 | 0.206 |
| **0.32** | 0.197 | 1.000 | 1.000 | 0.197 |
| **0.34** | 0.189 | 1.000 | 1.000 | 0.189 |
| **0.35** | 0.185 | 1.000 | 1.000 | 0.185 |
| **0.36** | 0.181 | 1.000 | 1.000 | 0.181 |
| **0.38** | 0.174 | 1.000 | 1.000 | 0.174 |
| **0.4** | 0.168 | 1.000 | 1.000 | 0.168 |
| **0.42** | 0.161 | 1.000 | 1.000 | 0.161 |
| **0.44** | 0.155 | 1.000 | 1.000 | 0.155 |
| **0.45** | 0.152 | 1.000 | 1.000 | 0.152 |
| **0.46** | 0.149 | 1.000 | 1.000 | 0.149 |
| **0.48** | 0.144 | 1.000 | 1.000 | 0.144 |
| **0.5** | 0.139 | 1.000 | 1.000 | 0.139 |
| **0.55** | 0.126 | 1.000 | 1.013 | 0.128 |
| **0.6** | 0.115 | 1.000 | 1.027 | 0.118 |
| **0.65** | 0.106 | 1.000 | 1.040 | 0.111 |
| **0.667** | 0.104 | 1.000 | 1.045 | 0.108 |
| **0.7** | 0.099 | 1.000 | 1.054 | 0.104 |
| **0.75** | 0.092 | 1.000 | 1.067 | 0.099 |
| **0.8** | 0.087 | 1.000 | 1.080 | 0.094 |

| | | | | |
|---|---|---|---|---|
| **0.85** | 0.082 | 1.000 | 1.094 | 0.090 |
| **0.9** | 0.078 | 1.000 | 1.107 | 0.086 |
| **0.95** | 0.074 | 1.000 | 1.121 | 0.083 |
| **1** | 0.071 | 1.000 | 1.134 | 0.080 |
| **1.1** | 0.064 | 1.000 | 1.134 | 0.072 |
| **1.2** | 0.058 | 1.000 | 1.134 | 0.066 |
| **1.3** | 0.053 | 1.000 | 1.134 | 0.060 |
| **1.4** | 0.049 | 1.000 | 1.134 | 0.055 |
| **1.5** | 0.045 | 1.000 | 1.134 | 0.051 |
| **1.6** | 0.042 | 1.000 | 1.134 | 0.047 |
| **1.7** | 0.039 | 1.000 | 1.134 | 0.044 |
| **1.8** | 0.036 | 1.000 | 1.134 | 0.041 |
| **1.9** | 0.034 | 1.000 | 1.134 | 0.039 |
| **2** | 0.032 | 1.000 | 1.134 | 0.036 |
| **2.2** | 0.028 | 1.000 | 1.134 | 0.032 |
| **2.4** | 0.026 | 1.000 | 1.134 | 0.029 |
| **2.5** | 0.024 | 1.000 | 1.134 | 0.028 |
| **2.6** | 0.023 | 1.000 | 1.134 | 0.026 |
| **2.8** | 0.021 | 1.000 | 1.134 | 0.024 |
| **3** | 0.019 | 1.000 | 1.134 | 0.022 |
| **3.2** | 0.018 | 1.000 | 1.134 | 0.020 |
| **3.4** | 0.017 | 1.000 | 1.134 | 0.019 |
| **3.5** | 0.016 | 1.000 | 1.134 | 0.018 |
| **3.6** | 0.016 | 1.000 | 1.134 | 0.018 |
| **3.8** | 0.015 | 1.000 | 1.134 | 0.017 |
| **4** | 0.014 | 1.000 | 1.134 | 0.016 |
| **4.2** | 0.013 | 1.000 | 1.134 | 0.015 |
| **4.4** | 0.012 | 1.000 | 1.134 | 0.014 |
| **4.6** | 0.012 | 1.000 | 1.134 | 0.013 |
| **4.8** | 0.011 | 1.000 | 1.134 | 0.013 |
| **5** | 0.011 | 1.000 | 1.134 | 0.012 |

## PROBABILISTIC

**Probabilistic Model**
**USGS Seismic Hazard Map(2008) 975 Year Return Period**

| Period | SA(Base Spectrum) | Basin Factor | Near Fault Factor(Applied) | SA(Final Spectrum) |
|---|---|---|---|---|
| **0.01** | 0.215 | 1.000 | 1.000 | 0.215 |
| **0.02** | 0.273 | 1.000 | 1.000 | 0.273 |
| **0.022** | 0.283 | 1.000 | 1.000 | 0.283 |
| **0.025** | 0.295 | 1.000 | 1.000 | 0.295 |
| **0.029** | 0.311 | 1.000 | 1.000 | 0.311 |
| **0.03** | 0.315 | 1.000 | 1.000 | 0.315 |
| **0.032** | 0.322 | 1.000 | 1.000 | 0.322 |

| | | | | |
|---|---|---|---|---|
| **0.035** | 0.332 | 1.000 | 1.000 | 0.332 |
| **0.036** | 0.335 | 1.000 | 1.000 | 0.335 |
| **0.04** | 0.348 | 1.000 | 1.000 | 0.348 |
| **0.042** | 0.353 | 1.000 | 1.000 | 0.353 |
| **0.044** | 0.359 | 1.000 | 1.000 | 0.359 |
| **0.045** | 0.362 | 1.000 | 1.000 | 0.362 |
| **0.046** | 0.365 | 1.000 | 1.000 | 0.365 |
| **0.048** | 0.370 | 1.000 | 1.000 | 0.370 |
| **0.05** | 0.375 | 1.000 | 1.000 | 0.375 |
| **0.055** | 0.388 | 1.000 | 1.000 | 0.388 |
| **0.06** | 0.400 | 1.000 | 1.000 | 0.400 |
| **0.065** | 0.411 | 1.000 | 1.000 | 0.411 |
| **0.067** | 0.415 | 1.000 | 1.000 | 0.415 |
| **0.07** | 0.422 | 1.000 | 1.000 | 0.422 |
| **0.075** | 0.432 | 1.000 | 1.000 | 0.432 |
| **0.08** | 0.442 | 1.000 | 1.000 | 0.442 |
| **0.085** | 0.451 | 1.000 | 1.000 | 0.451 |
| **0.09** | 0.460 | 1.000 | 1.000 | 0.460 |
| **0.095** | 0.469 | 1.000 | 1.000 | 0.469 |
| **0.1** | 0.477 | 1.000 | 1.000 | 0.477 |
| **0.11** | 0.482 | 1.000 | 1.000 | 0.482 |
| **0.12** | 0.486 | 1.000 | 1.000 | 0.486 |
| **0.13** | 0.491 | 1.000 | 1.000 | 0.491 |
| **0.133** | 0.492 | 1.000 | 1.000 | 0.492 |
| **0.14** | 0.494 | 1.000 | 1.000 | 0.494 |
| **0.15** | 0.498 | 1.000 | 1.000 | 0.498 |
| **0.16** | 0.501 | 1.000 | 1.000 | 0.501 |
| **0.17** | 0.505 | 1.000 | 1.000 | 0.505 |
| **0.18** | 0.508 | 1.000 | 1.000 | 0.508 |
| **0.19** | 0.511 | 1.000 | 1.000 | 0.511 |
| **0.2** | 0.513 | 1.000 | 1.000 | 0.513 |
| **0.22** | 0.483 | 1.000 | 1.000 | 0.483 |
| **0.24** | 0.456 | 1.000 | 1.000 | 0.456 |
| **0.25** | 0.444 | 1.000 | 1.000 | 0.444 |
| **0.26** | 0.433 | 1.000 | 1.000 | 0.433 |
| **0.28** | 0.413 | 1.000 | 1.000 | 0.413 |
| **0.29** | 0.403 | 1.000 | 1.000 | 0.403 |
| **0.3** | 0.394 | 1.000 | 1.000 | 0.394 |
| **0.32** | 0.372 | 1.000 | 1.000 | 0.372 |
| **0.34** | 0.353 | 1.000 | 1.000 | 0.353 |
| **0.35** | 0.344 | 1.000 | 1.000 | 0.344 |
| **0.36** | 0.335 | 1.000 | 1.000 | 0.335 |
| **0.38** | 0.319 | 1.000 | 1.000 | 0.319 |
| **0.4** | 0.305 | 1.000 | 1.000 | 0.305 |
| **0.42** | 0.292 | 1.000 | 1.000 | 0.292 |
| **0.44** | 0.280 | 1.000 | 1.000 | 0.280 |

| | | | | |
|---|---|---|---|---|
| **0.45** | 0.275 | 1.000 | 1.000 | 0.275 |
| **0.46** | 0.269 | 1.000 | 1.000 | 0.269 |
| **0.48** | 0.259 | 1.000 | 1.000 | 0.259 |
| **0.5** | 0.250 | 1.000 | 1.000 | 0.250 |
| **0.55** | 0.226 | 1.000 | 1.020 | 0.230 |
| **0.6** | 0.205 | 1.000 | 1.040 | 0.213 |
| **0.65** | 0.188 | 1.000 | 1.060 | 0.199 |
| **0.667** | 0.183 | 1.000 | 1.067 | 0.195 |
| **0.7** | 0.174 | 1.000 | 1.080 | 0.188 |
| **0.75** | 0.161 | 1.000 | 1.100 | 0.177 |
| **0.8** | 0.151 | 1.000 | 1.120 | 0.169 |
| **0.85** | 0.142 | 1.000 | 1.140 | 0.162 |
| **0.9** | 0.134 | 1.000 | 1.160 | 0.156 |
| **0.95** | 0.127 | 1.000 | 1.180 | 0.150 |
| **1** | 0.121 | 1.000 | 1.200 | 0.145 |
| **1.1** | 0.109 | 1.000 | 1.200 | 0.131 |
| **1.2** | 0.099 | 1.000 | 1.200 | 0.119 |
| **1.3** | 0.091 | 1.000 | 1.200 | 0.109 |
| **1.4** | 0.083 | 1.000 | 1.200 | 0.100 |
| **1.5** | 0.077 | 1.000 | 1.200 | 0.093 |
| **1.6** | 0.072 | 1.000 | 1.200 | 0.086 |
| **1.7** | 0.067 | 1.000 | 1.200 | 0.081 |
| **1.8** | 0.063 | 1.000 | 1.200 | 0.076 |
| **1.9** | 0.060 | 1.000 | 1.200 | 0.072 |
| **2** | 0.056 | 1.000 | 1.200 | 0.068 |
| **2.2** | 0.049 | 1.000 | 1.200 | 0.059 |
| **2.4** | 0.044 | 1.000 | 1.200 | 0.053 |
| **2.5** | 0.041 | 1.000 | 1.200 | 0.050 |
| **2.6** | 0.039 | 1.000 | 1.200 | 0.047 |
| **2.8** | 0.035 | 1.000 | 1.200 | 0.042 |
| **3** | 0.032 | 1.000 | 1.200 | 0.039 |
| **3.2** | 0.029 | 1.000 | 1.200 | 0.035 |
| **3.4** | 0.027 | 1.000 | 1.200 | 0.032 |
| **3.5** | 0.026 | 1.000 | 1.200 | 0.031 |
| **3.6** | 0.025 | 1.000 | 1.200 | 0.030 |
| **3.8** | 0.023 | 1.000 | 1.200 | 0.028 |
| **4** | 0.021 | 1.000 | 1.200 | 0.026 |
| **4.2** | 0.020 | 1.000 | 1.200 | 0.024 |
| **4.4** | 0.019 | 1.000 | 1.200 | 0.023 |
| **4.6** | 0.019 | 1.000 | 1.200 | 0.022 |
| **4.8** | 0.018 | 1.000 | 1.200 | 0.022 |
| **5** | 0.017 | 1.000 | 1.200 | 0.021 |

**MINIMUM DETERMINISTIC SPECTRUM**

| Period | SA |
|---|---|
| **0.01** | 0.168 |
| **0.02** | 0.172 |
| **0.022** | 0.175 |
| **0.025** | 0.179 |
| **0.029** | 0.185 |
| **0.03** | 0.187 |
| **0.032** | 0.192 |
| **0.035** | 0.199 |
| **0.036** | 0.202 |
| **0.04** | 0.211 |
| **0.042** | 0.217 |
| **0.044** | 0.222 |
| **0.045** | 0.224 |
| **0.046** | 0.227 |
| **0.048** | 0.232 |
| **0.05** | 0.237 |
| **0.055** | 0.253 |
| **0.06** | 0.269 |
| **0.065** | 0.284 |
| **0.067** | 0.290 |
| **0.07** | 0.299 |
| **0.075** | 0.313 |
| **0.08** | 0.325 |
| **0.085** | 0.337 |
| **0.09** | 0.347 |
| **0.095** | 0.358 |
| **0.1** | 0.367 |
| **0.11** | 0.379 |
| **0.12** | 0.388 |
| **0.13** | 0.395 |
| **0.133** | 0.397 |
| **0.14** | 0.400 |
| **0.15** | 0.403 |
| **0.16** | 0.399 |
| **0.17** | 0.393 |
| **0.18** | 0.388 |
| **0.19** | 0.381 |
| **0.2** | 0.375 |
| **0.22** | 0.351 |
| **0.24** | 0.329 |
| **0.25** | 0.319 |
| **0.26** | 0.309 |
| **0.28** | 0.292 |
| **0.29** | 0.284 |
| **0.3** | 0.276 |

| | |
|---|---|
| **0.32** | 0.263 |
| **0.34** | 0.251 |
| **0.35** | 0.246 |
| **0.36** | 0.241 |
| **0.38** | 0.230 |
| **0.4** | 0.221 |
| **0.42** | 0.211 |
| **0.44** | 0.201 |
| **0.45** | 0.196 |
| **0.46** | 0.192 |
| **0.48** | 0.184 |
| **0.5** | 0.176 |
| **0.55** | 0.157 |
| **0.6** | 0.142 |
| **0.65** | 0.129 |
| **0.667** | 0.125 |
| **0.7** | 0.118 |
| **0.75** | 0.109 |
| **0.8** | 0.101 |
| **0.85** | 0.095 |
| **0.9** | 0.089 |
| **0.95** | 0.084 |
| **1** | 0.079 |
| **1.1** | 0.070 |
| **1.2** | 0.063 |
| **1.3** | 0.057 |
| **1.4** | 0.052 |
| **1.5** | 0.047 |
| **1.6** | 0.043 |
| **1.7** | 0.040 |
| **1.8** | 0.037 |
| **1.9** | 0.034 |
| **2** | 0.032 |
| **2.2** | 0.028 |
| **2.4** | 0.025 |
| **2.5** | 0.024 |
| **2.6** | 0.022 |
| **2.8** | 0.020 |
| **3** | 0.018 |
| **3.2** | 0.017 |
| **3.4** | 0.016 |
| **3.5** | 0.015 |
| **3.6** | 0.015 |
| **3.8** | 0.014 |
| **4** | 0.013 |
| **4.2** | 0.012 |

| | |
|---|---|
| **4.4** | 0.011 |
| **4.6** | 0.011 |
| **4.8** | 0.010 |
| **5** | 0.010 |

**Envelope Data**

| Period | SA |
|---|---|
| **0.01** | 0.215 |
| **0.02** | 0.273 |
| **0.022** | 0.283 |
| **0.025** | 0.295 |
| **0.029** | 0.311 |
| **0.03** | 0.315 |
| **0.032** | 0.322 |
| **0.035** | 0.332 |
| **0.036** | 0.335 |
| **0.04** | 0.348 |
| **0.042** | 0.353 |
| **0.044** | 0.359 |
| **0.045** | 0.362 |
| **0.046** | 0.365 |
| **0.048** | 0.370 |
| **0.05** | 0.375 |
| **0.055** | 0.388 |
| **0.06** | 0.400 |
| **0.065** | 0.411 |
| **0.067** | 0.415 |
| **0.07** | 0.422 |
| **0.075** | 0.432 |
| **0.08** | 0.442 |
| **0.085** | 0.451 |
| **0.09** | 0.460 |
| **0.095** | 0.469 |
| **0.1** | 0.477 |
| **0.11** | 0.482 |
| **0.12** | 0.486 |
| **0.13** | 0.491 |
| **0.133** | 0.492 |
| **0.14** | 0.494 |
| **0.15** | 0.498 |
| **0.16** | 0.501 |
| **0.17** | 0.505 |
| **0.18** | 0.508 |
| **0.19** | 0.511 |
| **0.2** | 0.513 |
| **0.22** | 0.483 |

| | |
|---|---|
| **0.24** | 0.456 |
| **0.25** | 0.444 |
| **0.26** | 0.433 |
| **0.28** | 0.413 |
| **0.29** | 0.403 |
| **0.3** | 0.394 |
| **0.32** | 0.372 |
| **0.34** | 0.353 |
| **0.35** | 0.344 |
| **0.36** | 0.335 |
| **0.38** | 0.319 |
| **0.4** | 0.305 |
| **0.42** | 0.292 |
| **0.44** | 0.280 |
| **0.45** | 0.275 |
| **0.46** | 0.269 |
| **0.48** | 0.259 |
| **0.5** | 0.250 |
| **0.55** | 0.230 |
| **0.6** | 0.213 |
| **0.65** | 0.199 |
| **0.667** | 0.195 |
| **0.7** | 0.188 |
| **0.75** | 0.177 |
| **0.8** | 0.169 |
| **0.85** | 0.162 |
| **0.9** | 0.156 |
| **0.95** | 0.150 |
| **1** | 0.145 |
| **1.1** | 0.131 |
| **1.2** | 0.119 |
| **1.3** | 0.109 |
| **1.4** | 0.100 |
| **1.5** | 0.093 |
| **1.6** | 0.086 |
| **1.7** | 0.081 |
| **1.8** | 0.076 |
| **1.9** | 0.072 |
| **2** | 0.068 |
| **2.2** | 0.059 |
| **2.4** | 0.053 |
| **2.5** | 0.050 |
| **2.6** | 0.047 |
| **2.8** | 0.042 |
| **3** | 0.039 |
| **3.2** | 0.035 |

| | |
|---|---|
| **3.4** | 0.032 |
| **3.5** | 0.031 |
| **3.6** | 0.030 |
| **3.8** | 0.028 |
| **4** | 0.026 |
| **4.2** | 0.024 |
| **4.4** | 0.023 |
| **4.6** | 0.022 |
| **4.8** | 0.022 |
| **5** | 0.021 |