The Resources Agency
DEPARTMENT OF WATER RESOURCES
Division of Safety of Dams

FILE

Memorandum of Conference

Mill Pond Dam and Reservoir, No. 2381
Mendocino County
March 17, 2015

By Dean W. Smith, Jr. DWS 3/25/15

Reference:

1. ARCADIS, "DRAFT Mill Pond Dam Supplemental Site Investigation", March 2015.

Background

This dam was built in 1885, is 33 feet high and impounds 72 acre-feet. Most of the storage capacity contains silt. The dam is located on a coastal bluff next to the Pacific Ocean. The federal hazard classification is low. The Department of Toxic Substances Control also has jurisdiction. This facility functions as a wetland by providing contaminant mitigation before water flowing through the reservoir discharges into the ocean. Safety deficiencies at this dam include: spillway capacity, absence of low level outlet, and seismic stability of dam embankment and foundation. The owner has restricted public access because of the safety deficiencies. By letter of August 11, 2010, DSOD directed the owner to remove the dam by 2015. During a conference with DSOD staff on October 9, 2012, Dave Massengill of Georgia-Pacific Corporation stated they are now considering rehabilitation of the dam as an alternative to removal of the dam.

Introduction

Mr. Roth requested this meeting to present the results of the recent field exploration and to discuss design concepts to remediate seismic and hydrologic deficiencies at this dam. This information is presented in Reference 1.

Participants

Georgia Pacific Corporation
[redacted]

ARCADIS U.S., Inc.
[redacted]

Safety of Dams
Wallace Lam, Acting Design Branch Chief
Mutaz Mihyar, Project Engineer
Dean Smith, Design Engineer
Y-Nhi Enzler, Regional Engineer
Lakhbir Singh, Area Engineer
Chris Tracy, Acting Geology Branch Chief

Discussion

[redacted] provided an update since ARCADIS last assessment in 2010 with a PowerPoint® presentation which is attached. The peak ground acceleration is reduced from 0.46 g to 0.36 g because the NGA-14 attenuation equations are used in place of the pre-NGA equations. The M 8.05 earthquake scenario is unchanged. The 2010

assessment was based only on four widely spaced borings. The revised assessment includes the exploration completed in 2014: six SPT borings paired with six CPT soundings, five additional CPT soundings, piezometer measurements, test pits, field mapping, laboratory tests, and geophysical surveys. The SPT and CPT data indicate that portions of the dam embankment and foundation would liquefy during the postulated earthquake (Fig. 14). Based on limit equilibrium analyses, the northern and southern portions of the dam and foundation would be remediated (Figs. 9 and 10). The central section has a wide crest and would require less remediation. These analyses did not model progressive failure and ARCADIS will look into this possibility. ARCADIS is considering deep soil mixing to strengthen the dam embankment and the foundation. The spillway would be relocated or rehabilitated.

The deadline to complete the environmental documentation for the project was extended into next year. The Department of Toxic Substances Control has concluded that there is no need to remove the sediments behind the dam since they found no ecological risk or any risk to the environment by keeping the sediments in the reservoir.

Division staff responded that deep soil mixing has been used at other dams but only for the foundation and that this option has been used when there is limited space for other options such as a stabilizing berm. However, using deep soil mixing for the embankment will probably not be acceptable. In addition, since the sediments inside the reservoir are judged not a risk to the environment, DSOD staff encouraged the owner/ARCADIS to reevaluate the option of constructing interior dikes to compartmentalize the reservoir which would make this facility nonjurisdictional.

The owner/ARCADIS thanked DSOD staff for their comments and will look seriously again into the option of removing this facility from DSOD jurisdiction.

DWSmith:dws
C:Files/20150325.doc

California Natural Resources Agency
Department of Water Resources
Division of Safety of Dams

Meeting in Division Conference Room

Meeting Date: March 17, 2015

Reason for Meeting: Proposed Remediation of Mill Pond Dam #2381

Participants:

Name	Organization	Telephone Number
1. Dean Smith	Safety of Dams	916-227-4623
[redacted]	Georgia-Pacific	[redacted]
	GP	
	~~ARCADIS~~	
	ARCADIS	
6. Mutaz B. Mihyar	DSOD/ Design	916-227-4636
7. LAKHBIR SINGH	DSOD Field Branch	916-227-4603
8. Y Nhi Enzler	id	916-227-4604
[redacted]	ARCADIS	[redacted]
	ARCADIS	
11. CHRIS TRACY	DSOD-GEOLOGY	916-227-5634
12. Wallace Law	DSOD - Design	916-227-4626
13.		
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15.		
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18.		
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20.		
21.		
22.		
23.		
24.		

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Summary of Work to Date

- Original understanding conceptual mitigation
- Field investigation, laboratory testing, and analyses
- Summary of results
  - Geologic and Hydrogeologic Conditions
  - Analysis Methods and Results
- Conceptual mitigation
  - Original concepts
  - Refined concepts
- Next steps

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Original (2010) Site Characteristics and Understanding

- Little data - four widely spaced borings. Presence of sediment behind embankment not considered
  - Liquefaction of entire embankment section below water table
  - Liquefaction of upper several feet of marine terrace deposits
  - Entire dam seismically unstable
- Assumptions guiding conceptual mitigation
  - Crib wall section probably need to be removed and replaced
  - Spillway relocated or rehabilitated
  - Geometry favors stabilization buttress for northern and central sections
- Uncertainties
  - Crib wall configuration and foundation uncertain
  - Spillway foundation uncertain
  - Continuity of dam geology and zones of liquefaction uncertain
  - Need to mitigate thick central section uncertain
  - Limited dam and terrace deposit material property information
  - Conditions at downstream toe of central and northern section unknown
  - Influence of sediment behind dam uncertain
  - Availability of on-site soil borrow uncertain

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Field Investigation, Laboratory Testing, and Analyses

- Geophysical exploration (resistivity, seismic refraction, utility location) along centerline of dam
- Five borings along crest of embankment and one boring at toe of northern section – embankment borings paired with CPTs
- Nine CPTs along crest of embankment and two CPTs at toe of central/northern sections
- Eight piezometers – two rounds of monitoring data
- Test pits in log deck
- Laboratory testing
  - Index properties
  - Shear strength
  - Compaction
- Liquefaction and stability analyses

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Principal Geologic Findings

- Geologic interpretation
  - Generally consistent with previous understanding
  - Marine terrace deposit irregular and pinches out at some locations
  - Fill at toe of embankment relatively thick, contains debris, and saturated
  - Significant amount of sediment behind dam
- Crib wall
  - Relatively well-defined parallel to dam axis
  - Built across former stream channel (Alder Creek)
  - Geophysics and observations indicate cribs span drainage and "socketed" into bedrock
- Spillway
  - Top of bedrock approximately 10 ft below spillway crest
- Log deck will provide on-site source of borrow material if needed

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SEE FIGURES

- I-1: Profile H-H
- I-2: Profile I-I
- I-3: Resistivity and Refraction Profile

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Liquefaction Evaluation

Original evaluation

- Magnitude 8.05 earthquake
- PGA 0.45g (pre-NGA relationships)
- No amplification, some internal attenuation of ground motion
- Evaluation procedures:
  - SPT NCEER (1997) procedures and limited laboratory data
  - Terrace deposit age effects acknowledged but not considered

Current evaluation

- Magnitude 8.05 earthquake
- PGA 0.36g (NGA-14 relationships)
- No amplification, no internal attenuation of ground motion
- Evaluation procedures:
  - SPT Idriss & Boulanger (2008) procedures and limited laboratory data
  - CPT Boulanger & Idriss (2014) procedures
  - Terrace deposit age effects considered
- Sensitivity analyses:
  - Soil behavior (I_c)
  - Fines content (C[FC])
  - Combination of I_c and C[FC]
- CPT results adjusted to SPT/laboratory fines content results

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Principal Liquefaction Findings

- Sensitivity
  - No reasonable variation in methods, parameters, or properties makes liquefaction "go away"
  - No reasonable variation in methods, parameters, or properties significantly changes the interpretation of liquefaction susceptibility
  - Age effect in marine terrace deposit – not significant unless factor is greater than 2.5
- Liquefaction less pervasive than original interpretation
- Generally occurs as discontinuous layers in fill and marine terrace deposits
- Fill liquefaction susceptibility variable from south (less susceptible) to north (more susceptible)
- Marine terrace deposits variably susceptible to liquefaction (including deposits underlying fill downstream of dam)

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SEE FIGURES

- Figure 13 (Sensitivity Analysis)
- Figure 14 (Liquefaction Profile)
- Figure 15 (Liquefaction Crib Wall Section)
- Figure 16 (Liquefaction Central & Northern Section)

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Principal Stability Findings

- With no liquefaction:
  - Static stability generally acceptable if crib wall not neglected in analysis
  - Seismic deformation less than 6 inches
- With liquefaction assumed:
  - Back-sliding into the sediment and water behind the dam not significant
  - Mitigation of crib wall and northern sections still warranted
  - Mitigation of central section not necessary due to width of section

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SEE STABILITY ANALYSIS FIGURES

- Post Earthquake
  - Section A-A'
  - Section F-F' – including inboard edge of dam
  - Section G-G'

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Original Mitigation Concept

- Objectives:
  - Stabilize northern section and central section (if necessary) with earthfill buttress
  - Replace spillway due to uncertain foundation conditions
  - Replace crib wall section with concrete gravity structure due to uncertain foundation and construction conditions
- Concepts remain valid
- Northern buttress:
  - Foundation/key deeper than originally estimated due to fill thickness
  - Water inflow and management during construction
- Crib wall excavation and replacement
  - Crib wider (~70 ft) than initial estimates (~40 ft)
  - Overall dimension of replacement structure similar
  - Irregular bedrock surface – increased foundation preparation costs
  - Construction challenges and constraints due to location

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SEE CONCEPTUAL MITIGATION FIGURES

- Northern Buttress
- Excavate and Replace Crib Wall

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Refined Concept

- Northern section
  - Ground improvement to mitigate liquefaction in fill and terrace deposits
  - Slope dressing and erosion protection on outboard side of embankment as necessary
- Central section
  - Slope dressing and drainage control on outboard side of embankment
  - Spot or targeted ground improvement in fill and/or terrace deposits if necessary based on analysis
- Crib wall/spillway section
  - Leave crib wall in place and protect from wave action/erosion
  - Ground improvement and/or stabilizing rock buttress (crib wall area) to mitigate liquefaction
  - Relocate or rehabilitate existing spillway

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Next Steps

- Select final concept
  - Contractor site visit and input
  - Identification of permit constraints with respect to location
  - Cost/effectiveness assessment
- Final evaluation and design
- Alteration Application submittal
- Address DSOD comments
- Implement project

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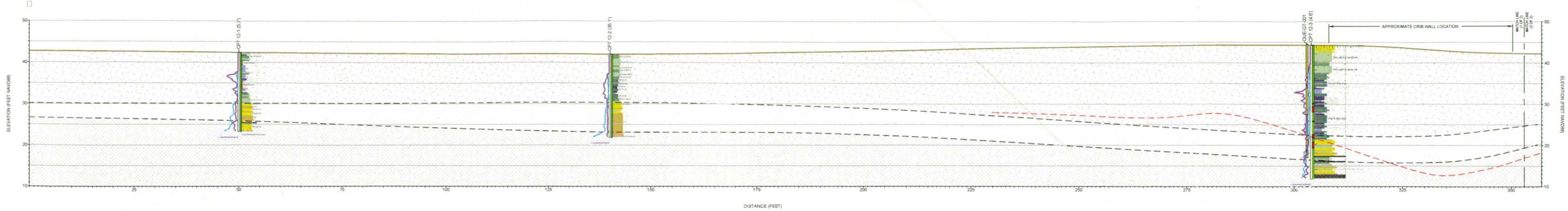
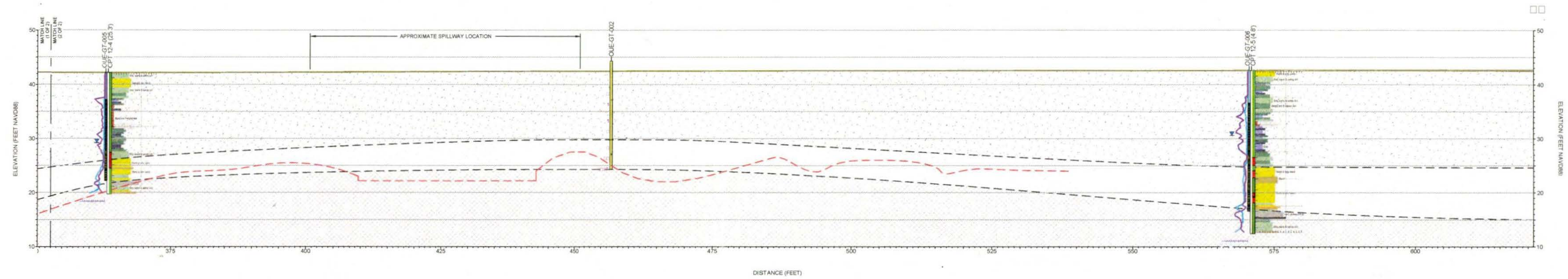




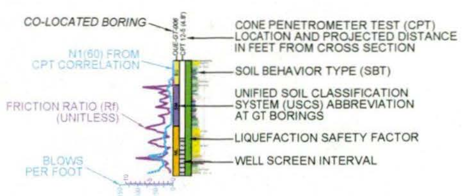
0 6' 12' 18' 24'
HORIZONTAL SCALE

0 6' 12' 18' 24'
VERTICAL SCALE

LEGEND

SOIL BEHAVIOR TYPE:
- SENSITIVE, FINE GRAINED
- ORGANIC MATERIALS
- CLAY
- SILTY CLAY TO CLAY
- CLAYEY SILT TO SILTY CLAY
- SANDY SILT TO CLAYEY SILT
- SILTY SAND TO SANDY SILT
- SAND TO SILTY SAND
- SAND
- GRAVELY SAND TO SAND
- VERY STIFF FINE GRAINED
- SAND TO CLAYEY SAND

- FILL MATERIAL
- MARINE TERRACE DEPOSITS
- BEDROCK
- LIQUEFACTION SAFETY FACTOR ≤1
- LIQUEFACTION SAFETY FACTOR >1
- GROUNDWATER ELEVATION ON 2/5/15 (FEET NAVD88)
- SPT BLOW COUNT
- BEDROCK OUTCROPPING SURVEY



USCS ABBREVIATIONS:
- SM
- SP
- SW
- ML
- GP

NOTES:
1. CPT BORINGS CLEARED TO 5 FEET BELOW GROUND SURFACE WITH A HAND AUGER.
2. CONTACTS INFERRED BETWEEN BORING LOCATIONS.
3. THE BEDROCK OUTCROPPING SURVEY WAS PERFORMED ON THE FACE (OCEAN SIDE) OF THE DAM. THE OFFSET FROM THE BEDROCK OUTCROPPING SURVEY TO THE SECTION LINE IS APPROXIMATELY 40 FEET.

FORMER GEORGIA-PACIFIC WOOD PRODUCTS FACILITY
FORT BRAGG, CALIFORNIA

GEOLOGIC CROSS SECTION H-H'
CRIB WALL AND SPILLWAY

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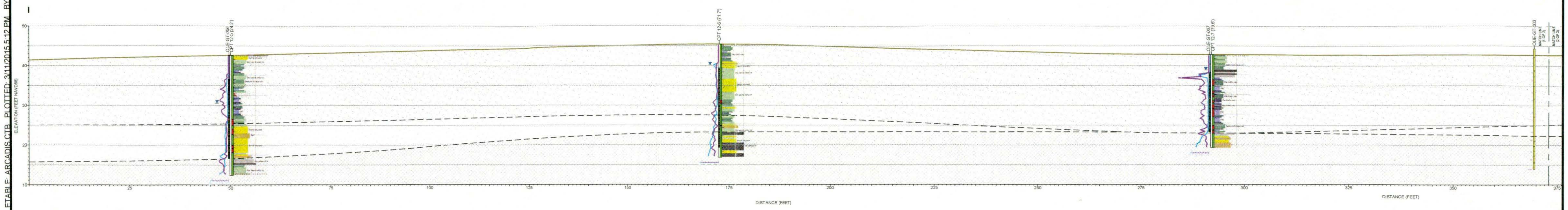
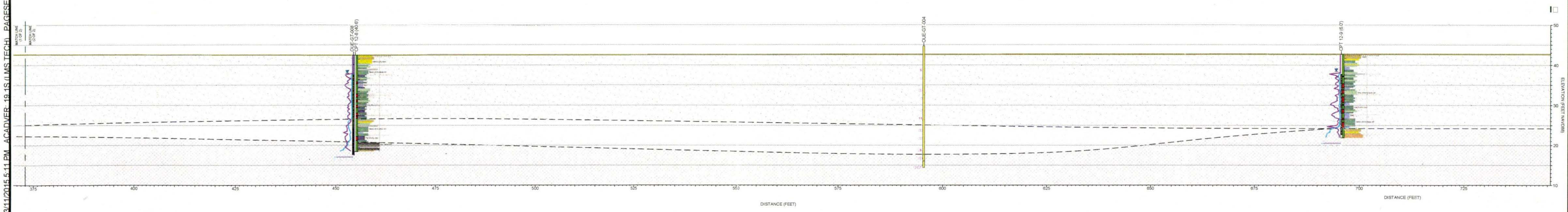
FIGURE
I-1





0 4' 8' 12' 16'
HORIZONTAL SCALE

0 4' 8' 12' 16'
VERTICAL SCALE

LEGEND

SOIL BEHAVIOR TYPE:
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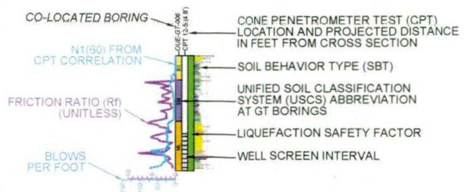

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FORT BRAGG, CALIFORNIA

GEOLOGIC CROSS SECTION I-I' NORTHERN EMBANKMENT

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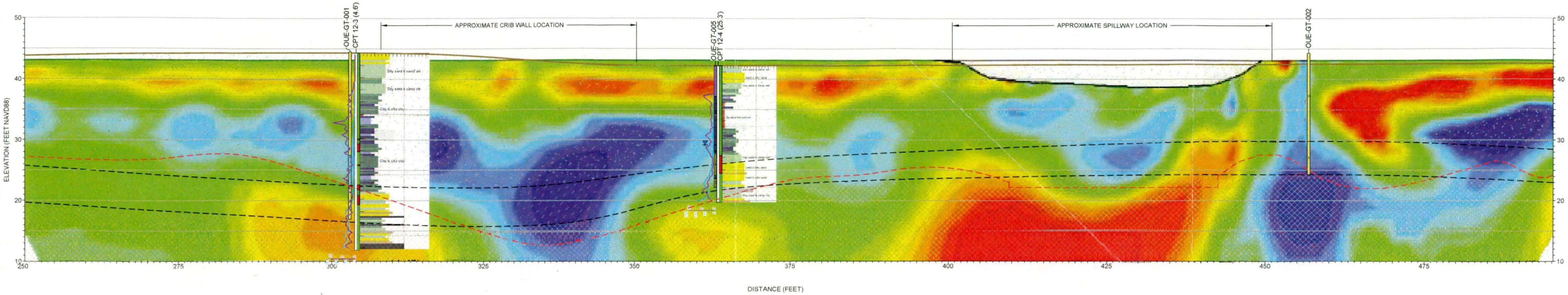
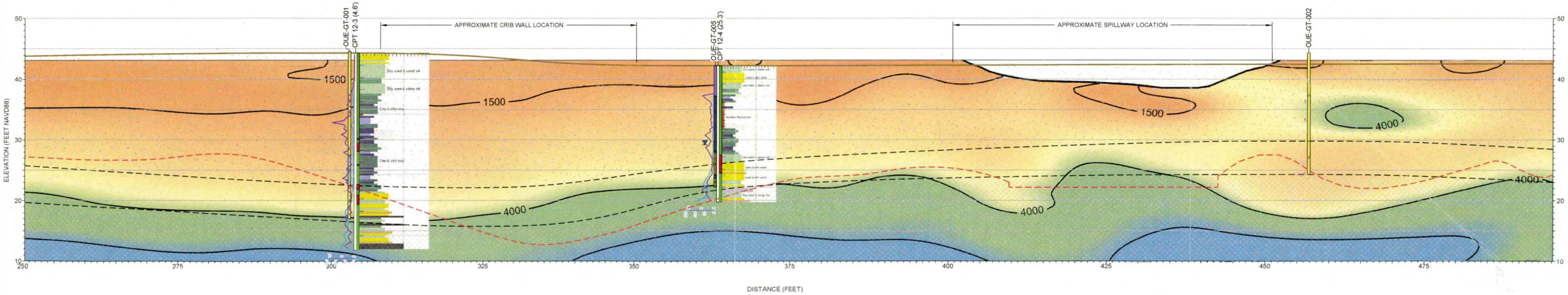
FIGURE
I-2





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VERTICAL SCALE

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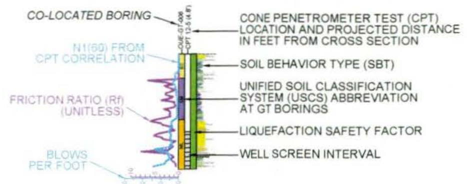

USCS ABBREVIATIONS:
- SM
- SP
- SW
- ML
- GP

ELECTRICAL RESISTIVITY PROFILE

5 10 19 36 71 100 266 515 1,000

ELECTRICAL RESISTIVITY (OHM-FT)

SEISMIC REFRACTION PROFILE

2,000 4,000 6,000 8,000 10,000 12,000

VELOCITY (FEET PER SECOND)

NOTES:

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FORT BRAGG, CALIFORNIA

GEOLOGIC CROSS SECTION H-H' CRIB WALL AND SPILLWAY ER AND SM PROFILES

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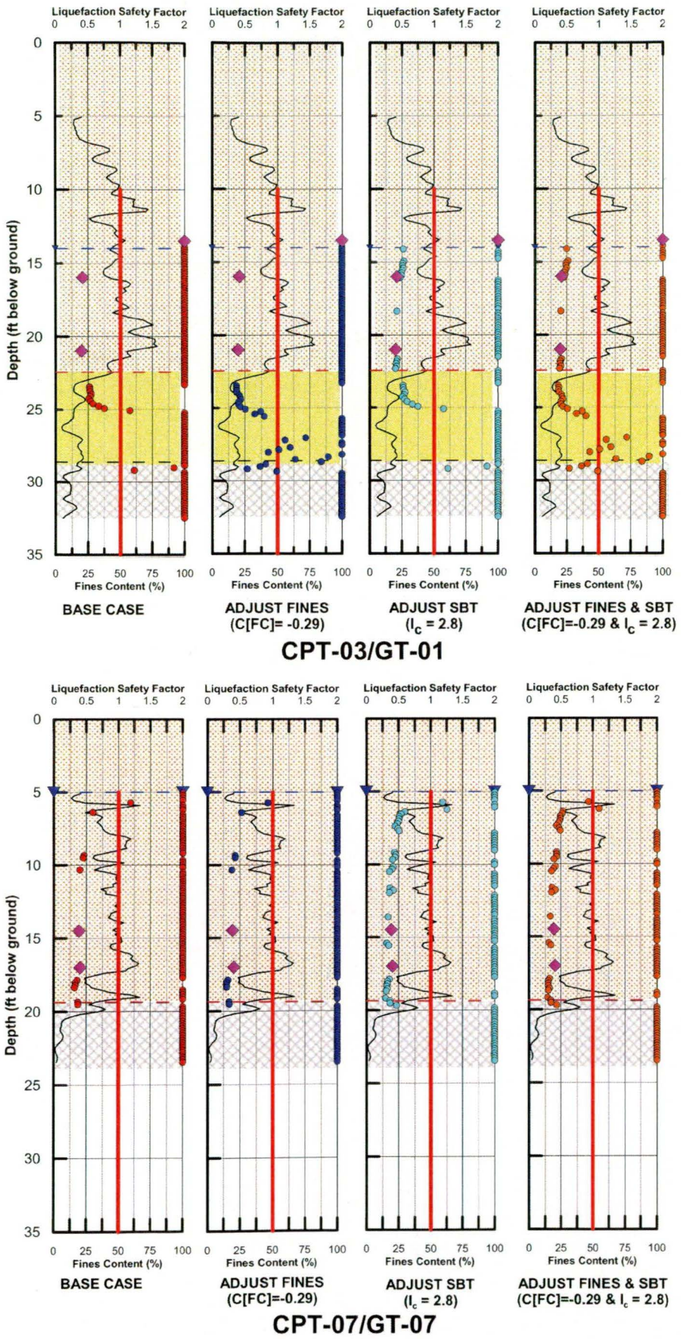
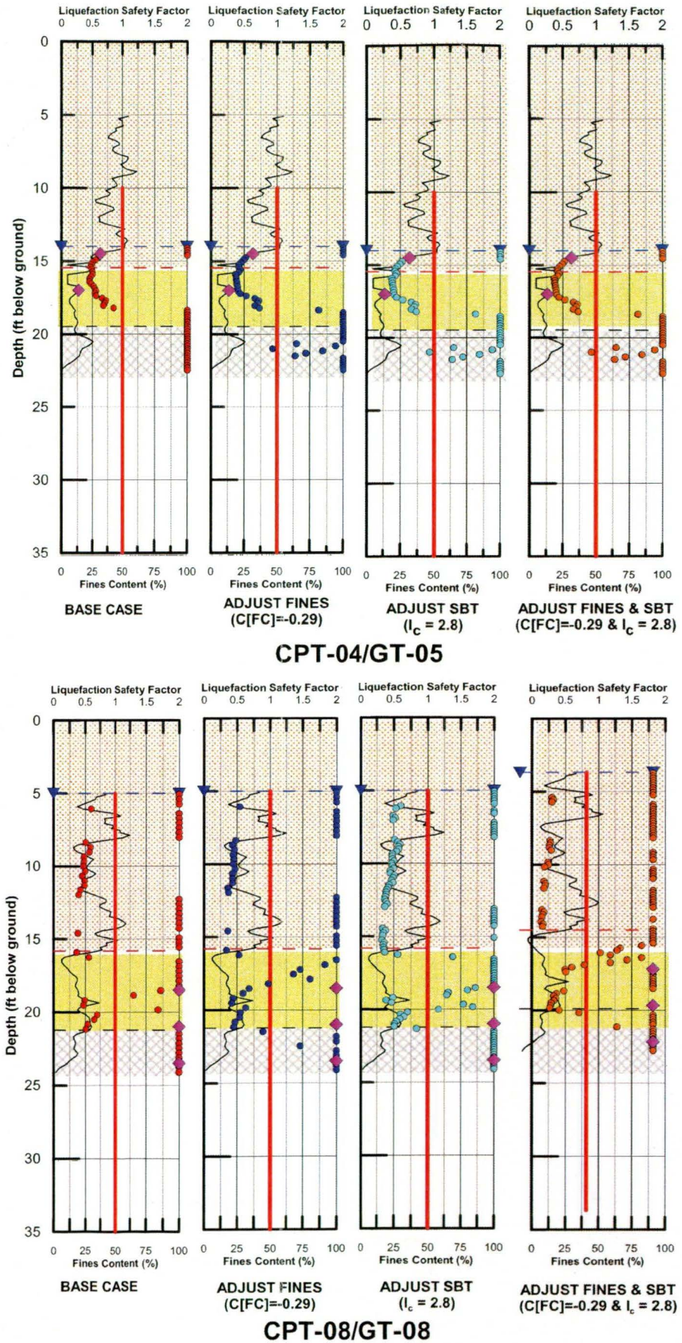
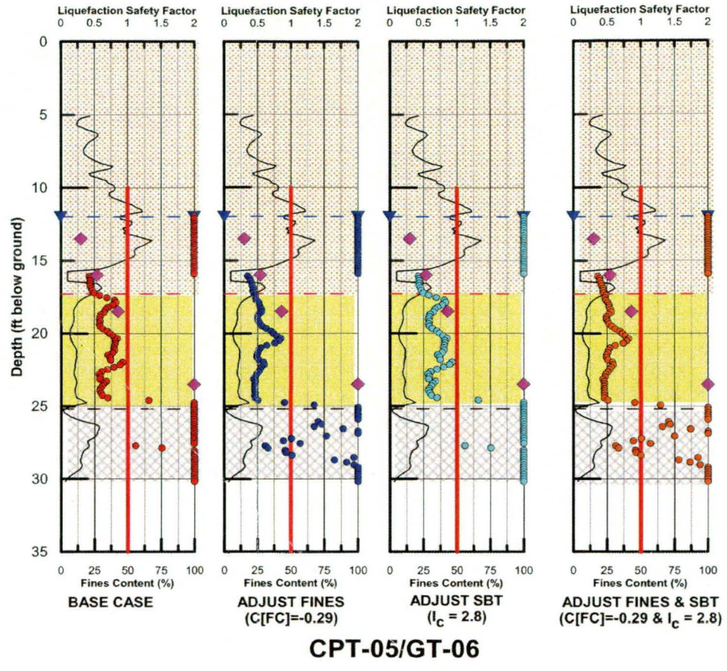
FIGURE
I-3



CPT-03/GT-01



CPT-04/GT-05



CPT-05/GT-06

CPT-07/GT-07

CPT-08/GT-08

Explanation

- CPT Fines Content
- Groundwater
- Bottom Fill
- Bottom Terrace Deposits
- Liquefaction Safety Factor = 1.0
- Liquefaction Safety Factor (SPT and Lab Data)
- Liquefaction Safety Factor - Base Case (C[FC]=0; I_c=2.6)
- Liquefaction Safety Factor - Adjust Fines Content (C[FC]=-0.29)
- Liquefaction Safety Factor - Adjust Soil Behavior Type (I_c=2.8)
- Liquefaction Safety Factor - Adjust Fines and SBT

FORMER GEORGIA-PACIFIC WOOD PRODUCTS FACILITY
FORT BRAGG, CALIFORNIA

RESULTS OF LIQUEFACTION SENSITIVITY ANALYSES

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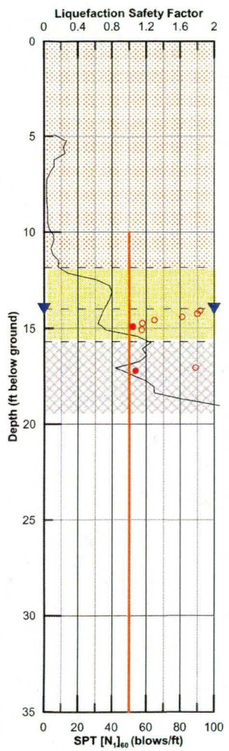
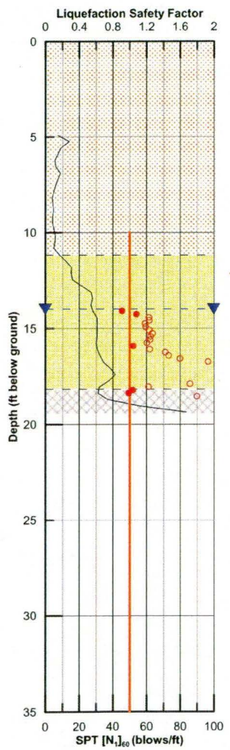
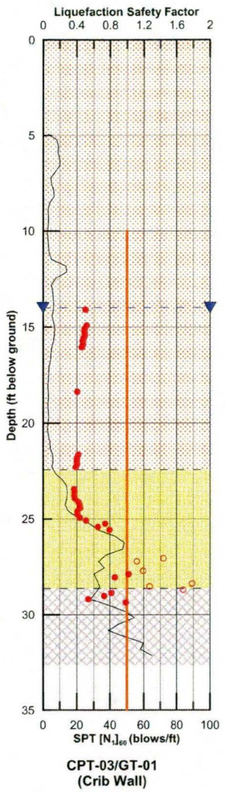
FIGURE 13



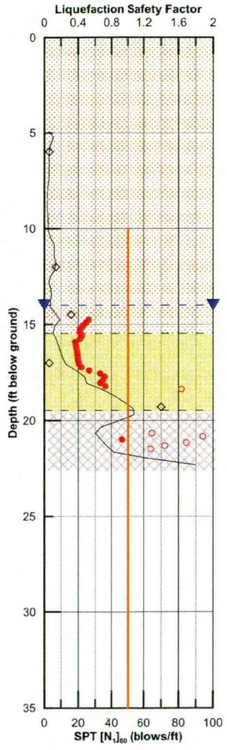
CPT-01
(SW End of Alignment)



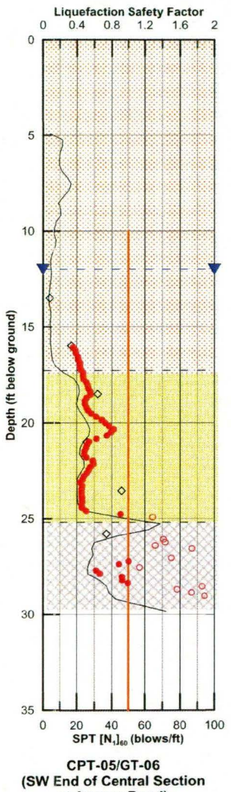
CPT-02
(SW End of Alignment)



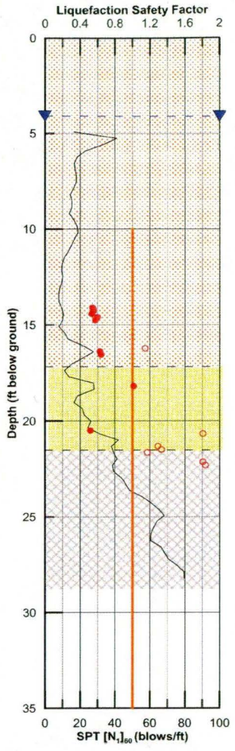
CPT-03/GT-01
(Crib Wall)



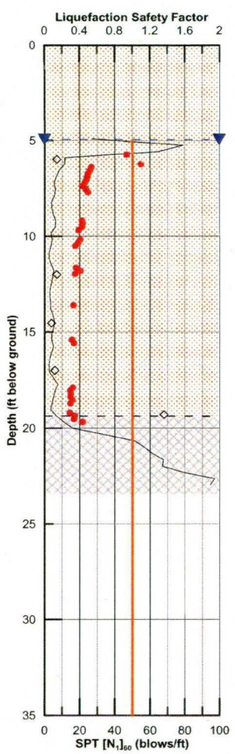
CPT-04/GT-05
(Between Crib Wall and Spillway)



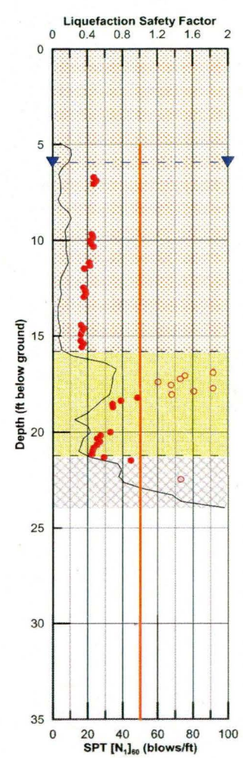
CPT-05/GT-06
(SW End of Central Section at Access Road)



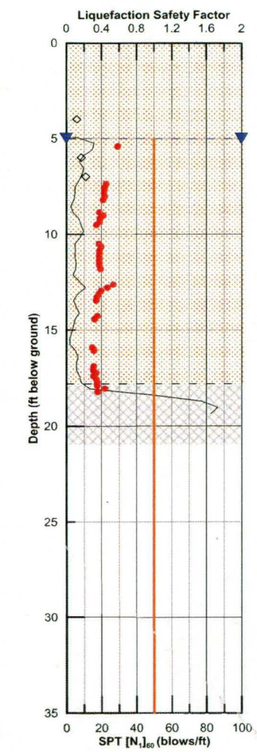
CPT-06
(Middle of Central Section)



CPT-07/GT-07
(NE End of Central Section)



CPT-08/GT-08
(Middle of Northern Section)



CPT-09
(NE End of Northern Section)

FORMER GEORGIA-PACIFIC WOOD
PRODUCTS FACILITY
FORT BRAGG, CALIFORNIA

RESULTS OF LIQUEFACTION ANALYSES

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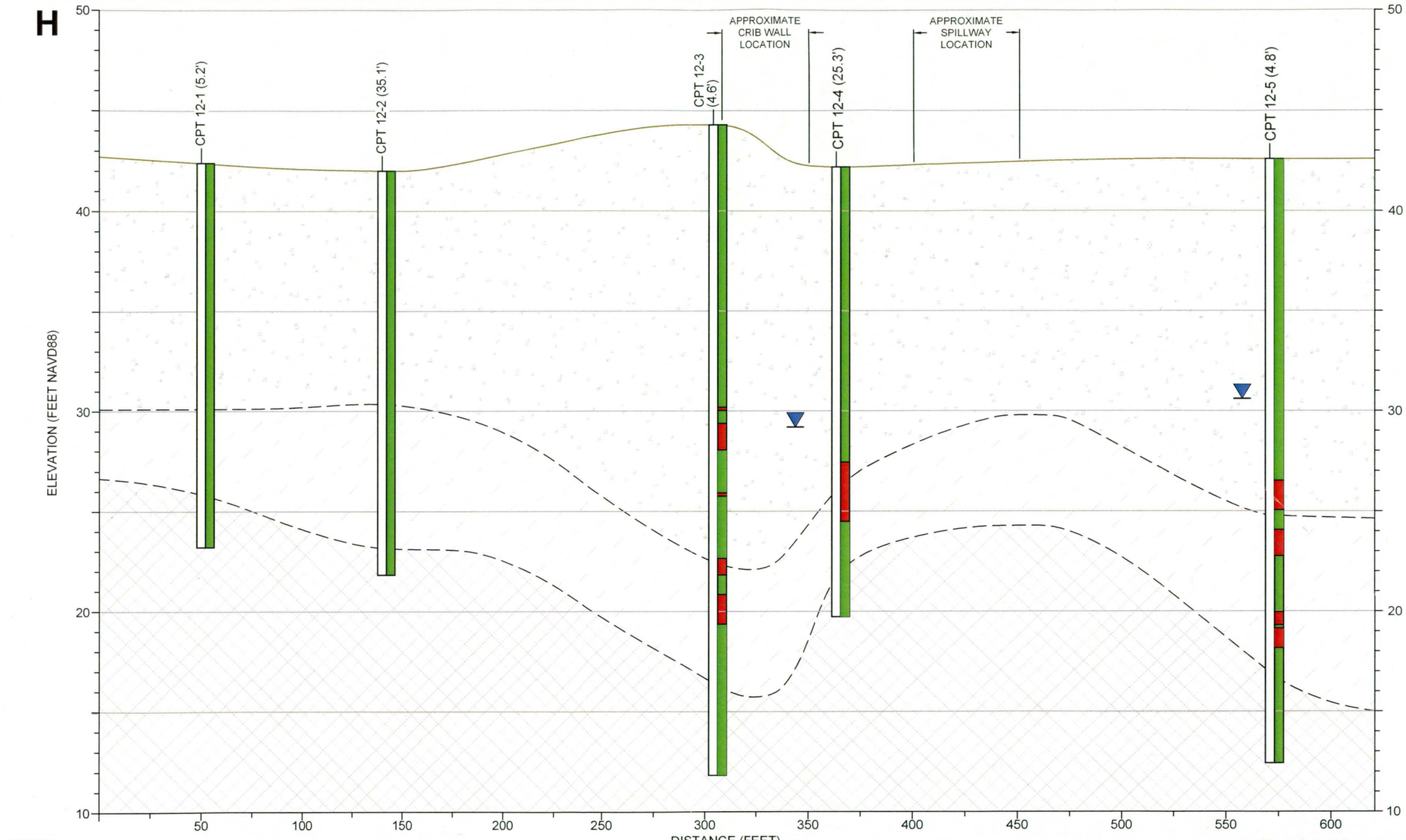
FIGURE
14



LEGEND

- FILL MATERIAL
- MARINE TERRACE DEPOSITS
- BEDROCK
- LIQUEFACTION SAFETY FACTOR ≤1
- LIQUEFACTION SAFETY FACTOR >1
- GROUNDWATER ELEVATION ON 2/5/15 (FEET NAVD88)

CONE PENETROMETER TEST (CPT) LOCATION AND PROJECTED DISTANCE IN FEET FROM CROSS SECTION

LIQUEFACTION SAFETY FACTOR

NOTES:

1. CPT BORINGS CLEARED TO 5 FEET BELOW GROUND SURFACE WITH A HAND AUGER.
2. CONTACTS INFERRED BETWEEN BORING LOCATIONS.

0 50'
HORIZONTAL SCALE

0 5'
VERTICAL SCALE

FORMER GEORGIA-PACIFIC WOOD PRODUCTS FACILITY
FORT BRAGG, CALIFORNIA

GEOLOGIC CROSS SECTION H-H'
CRIB WALL AND SPILLWAY
LIQUEFACTION POTENTIAL

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FIGURE
15

CITY: SAN RAFAEL, CA (PETALUMA) DIV/GROUP: ENV/CAD DB: J. HARRIS
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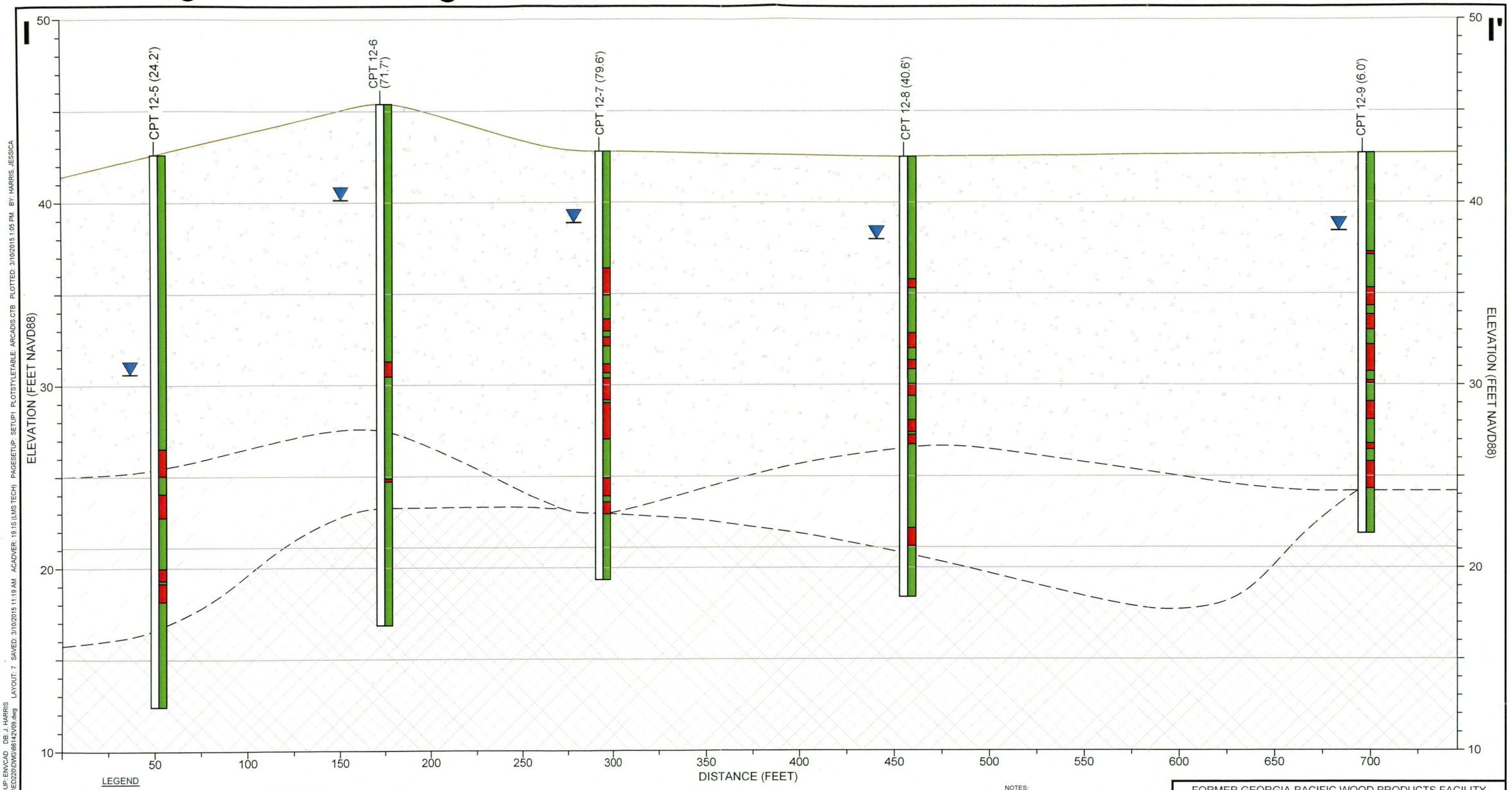

LEGEND

- FILL MATERIAL
- MARINE TERRACE DEPOSITS
- BEDROCK
- LIQUEFACTION SAFETY FACTOR ≤1
- LIQUEFACTION SAFETY FACTOR >1
- GROUNDWATER ELEVATION ON 2/5/15 (FEET NAVD88)

CPT 12-5 (4.6')
CONE PENETROMETER TEST (CPT) LOCATION AND PROJECTED DISTANCE IN FEET FROM CROSS SECTION

LIQUEFACTION SAFETY FACTOR

NOTES:

1. CPT BORINGS CLEARED TO 5 FEET BELOW GROUND SURFACE WITH A HAND AUGER.
2. CONTACTS INFERRED BETWEEN BORING LOCATIONS.

0 50'
HORIZONTAL SCALE

0 5'
VERTICAL SCALE

FORMER GEORGIA-PACIFIC WOOD PRODUCTS FACILITY
FORT BRAGG, CALIFORNIA

GEOLOGIC CROSS SECTION I-I'
NORTHERN EMBANKMENT
LIQUEFACTION POTENTIAL

ARCADIS

FIGURE
16

CITY: SAN RAFAEL, CA (PETALUMA) DIVGROUP: ENVCAD DB: J. HARRIS
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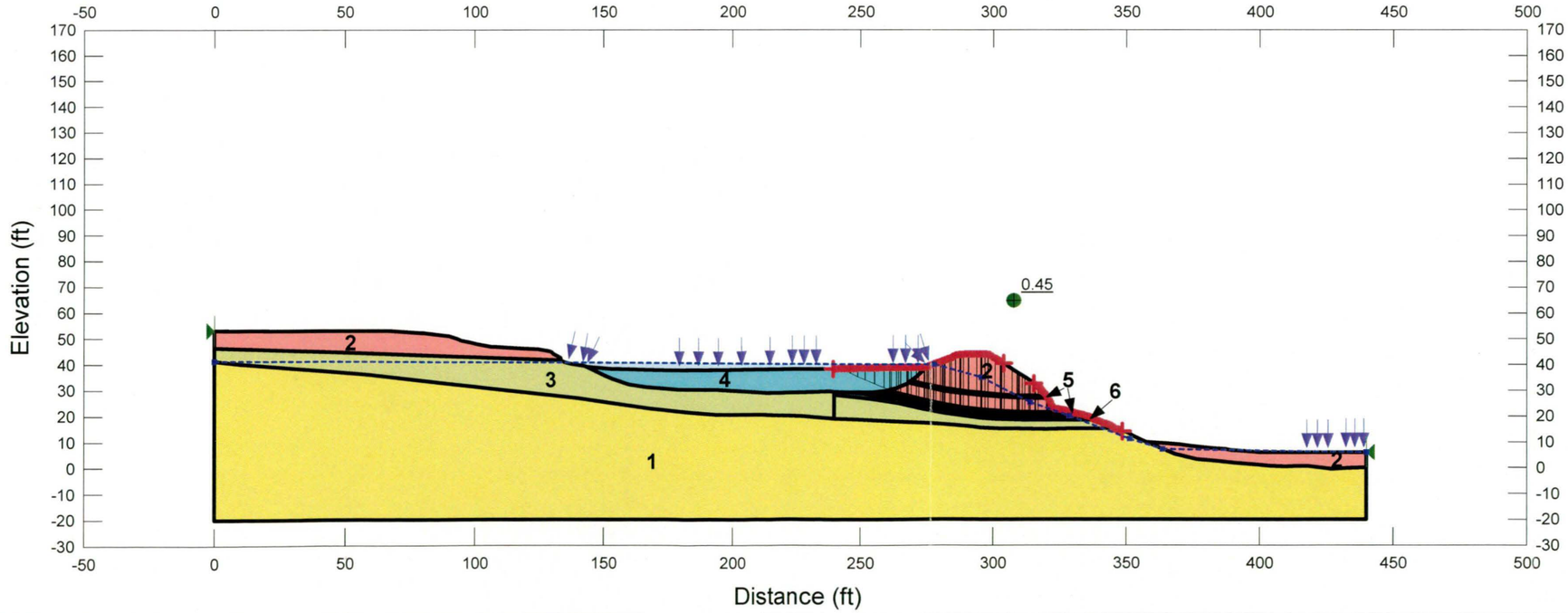
File Name: A-A'_post-earthquake.gsz
Last Saved Date: 3/5/2015
Analysis Type: Spencer
Cross Section A-A'
Seismic Load: 0g
Analysis View: 2D

Material Number, Description, Unit Weight, Cohesion, Friction Angle
Material #1: Bedrock; [redacted])
Material #2: Fill; [redacted]
Material #3: Marine Deposit; [redacted]
Material #4: Sediment; [redacted]
Material #5: Fill_Liquefied; [redacted]
Material #6: Marine Deposit_Liquefied; [redacted]

A

A'



Directory: C:\Users\Jhu\Desktop\Mill Pond Dam\SlopeStability\ A-A'_post-earthquake.gsz Date: 3/5/2015 Time: 1:35:50 PM Last Edited By: Hu, Jian

ARCADIS
Infrastructure · Water · Environment · Buildings

Scale	Project Number	Analyzed
1 inch = 50 feet	B0066142.2015	J. Hu
	Date	Checked
	3/5/2015	N. Trimble

Mill Pond Dam
Fort Bragg, California

Cross Section A-A'

Slope Stability Analysis Result

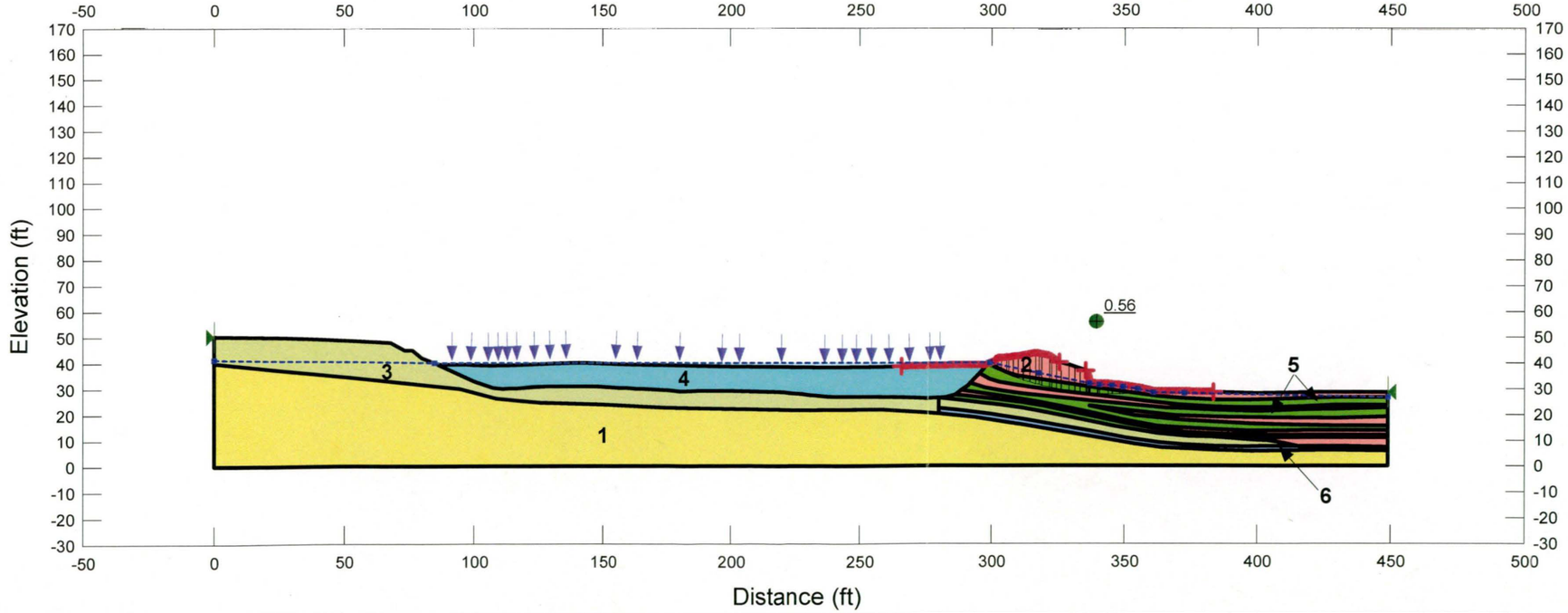
Attachment 1
Figure 7

File Name: F-F'_post-earthquake.gsz
Last Saved Date: 3/5/2015
Analysis Type: Spencer
Cross Section F-F'
Seismic Load: 0g
Analysis View: 2D

Material Number, Description, Unit Weight, Cohesion, Friction Angle
Material #1: Bedrock; Model: [redacted])
Material #2: Fill; [redacted]
Material #3: Marine Deposit; [redacted]
Material #4: Sediment; Unit Weight: [redacted]
Material #5: Fill_Liquefied; Unit Weight: [redacted]
Material #6: Marine Deposit_Liquefied; [redacted]

F

F'



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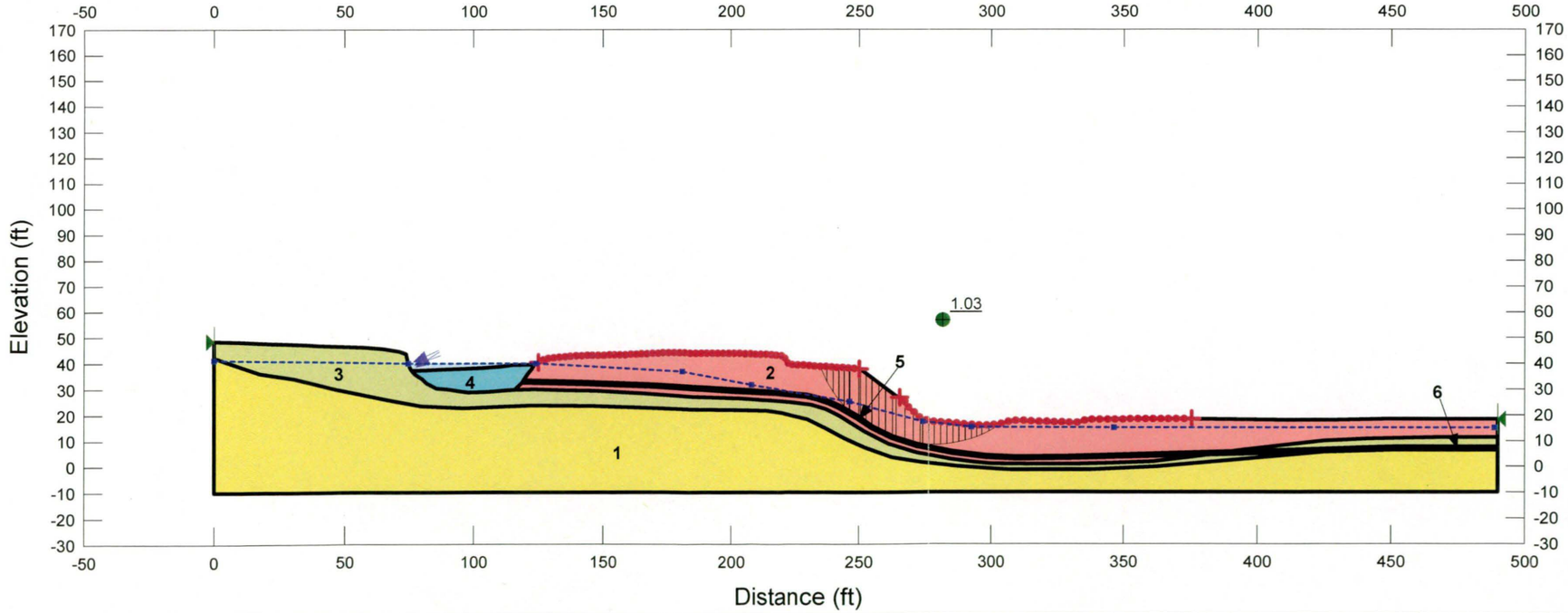
ARCADIS Infrastructure · Water · Environment · Buildings	Scale: 1 inch = 50 feet	Project Number: B0066142.2015	Analyzed: J. Hu	Mill Pond Dam Fort Bragg, California	Cross Section F-F'	**Slope Stability Analysis Result**	**Attachment 1** **Figure 8**
		Date: 3/5/2015	Checked: N. Trimble				

File Name: G-G'_post-earthquake.gsz
Last Saved Date: 3/5/2015
Analysis Type: Spencer
Cross Section G-G'
Seismic Load: 0g
Analysis View: 2D

Material Number, Description, Unit Weight, Cohesion, Friction Angle
Material #1: Bedrock; Model: [redacted]
Material #2: Fill; [redacted]
Material #3: Marine Deposit; [redacted]
Material #4: Sediment; Unit Weight: [redacted]
Material #5: Fill_Liquefied; Unit Weight: [redacted]
Material #6: Marine Deposit_Liquefied; [redacted]

G

G'



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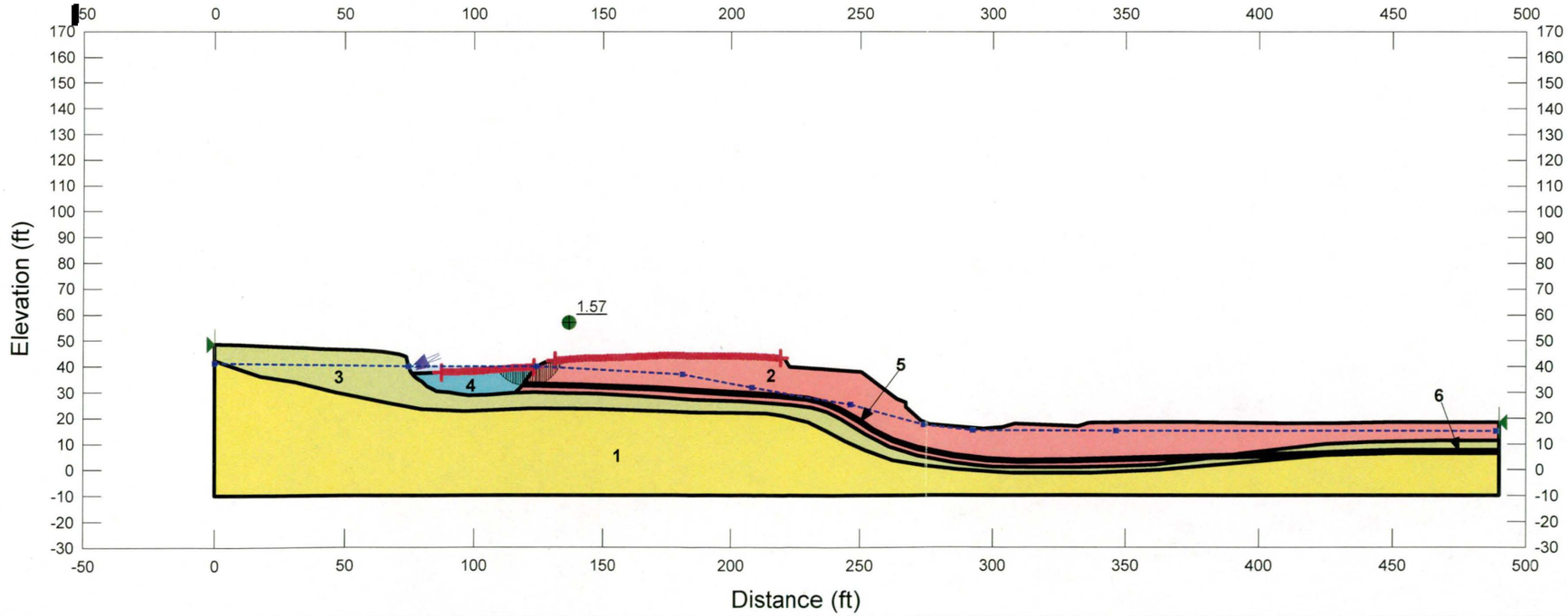
ARCADIS Infrastructure · Water · Environment · Buildings	**Scale** 1 inch = 50 feet	Project Number B0066142.2015 / Date 3/5/2015	Analyzed J. Hu / Checked N. Trimble	**Mill Pond Dam Fort Bragg, California**	Cross Section G-G'	**Slope Stability Analysis Result**	**Attachment 1 Figure 9**

File Name: G-G'_post-earthquake - reservoir.gsz
Last Saved Date: 3/11/2015
Analysis Type: Spencer
Cross Section G-G'
Seismic Load: 0g
Analysis View: 2D

Material Number, Description, Unit Weight, Cohesion, Friction Angle
Material #1: Bedrock; Model: [redacted])
Material #2: Fill; Unit Weight: [redacted]
Material #3: Marine Deposit; [redacted]
Material #4: Sediment; [redacted]
Material #5: Fill_Liquefied; [redacted]
Material #6: Marine Deposit_Liquefied; [redacted]

G G'



Directory: C:\Users\Jhu\Desktop\Mill Pond Dam\SlopeStability\ G-G'_post-earthquake - reservoir.gsz Date: 3/11/2015 Time: 2:05:52 PM Last Edited By: Hu, Jian

ARCADIS Infrastructure · Water · Environment · Buildings	Scale: 1 inch = 50 feet	Project Number: B0066142.2015	Analyzed: J. Hu	Mill Pond Dam Fort Bragg, California	Cross Section G-G'	Slope Stability Analysis Result	Attachment 1 Figure 12
		Date: 3/11/2015	Checked: N. Trimble				

NOTE: Design of buttress and the extent and nature of the keyway will depend largely on jurisdiction and associated design requirements.

Figure 10
NORTHERN EMBANKMENT SECTION
CONCEPTUAL MITIGATION

Figure 9
CRIB WALL CONCEPTUAL REMEDIATION
(DAM REMAINS IN JURISDICTION)