



# Technical Memorandum

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**Prepared For** Mike Inamine, PE  
SBFCA  
Christopher Krivanec, PE, GE  
HDR Engineering, Inc.

**Project** Feather River West Levee

**Date** May 6, 2013

**Subject** Additional Explorations for Project Phase C

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Michael Hughes, PE

**Reviewed By** Khaled Chowdhury, PE, GE

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## 1.0 INTRODUCTION

The HDR team is providing design services to the Sutter Butte Flood Control Agency (SBFCA) for the Feather River West Levee (FRWL) Project. URS Corporation (URS), as a member of the HDR team, has been providing geotechnical engineering services for the FRWL Project.

Based on review comments from DWR, discussions with SBFCA, and evaluation of the existing plans and stick log profiles, the need for three (3) additional explorations in the section of levee within Project Phase C was identified. The purpose of these explorations was to explore the continuity of aquiclude landward of the levee. The location of the three explorations is presented below.

Boring ID	Reach	Station
SM0016_001B	22	1499+00
SM0016_002B	23	1517+00
SM0016_003B	24	1615+00

This memorandum presents the findings of the explorations and presents an interpretation of the data.

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## 2.0 FIELDWORK AND FINDINGS

Explorations were performed in February of 2013 using a truck mounted hollow stem auger/mud rotary drilling rig. Details of subsurface conditions encountered at each exploration are discussed below. Finalized boring logs, laboratory test results, and profile sheets are included in Attachment A.

### **SM0016\_001B (Reach 22, Station 1499+00)**

The levee at this location is approximately 10 feet to 12 feet high, with a crown elevation of approximately +91.5 feet (NAVD88) and a landside toe elevation of +80 feet. The proposed remediation measure is a soil bentonite cutoff wall keying into a fine grained aquiclude layer at an elevation of approximately +50 feet to +55 feet. The local geology in this area is mapped as Lower Modesto, which primarily comprises sand and silt with occasional layers of clay (Helley and Harwood, 1985).

Boring SM0016\_001B was drilled at the toe of the levee at Station 1499+00 adjacent to existing crown exploration WM0016\_010C, which identified an approximately 7 feet thick fine grained aquiclude layer between an elevation of +52 feet and +59 feet.

Boring SM0016\_001B was drilled to a depth of 46.5 feet below ground surface (bgs). The boring encountered a 10 feet thick clay layer at the surface overlying approximately 12 feet of sand to an elevation of approximately +58 feet. Beneath this, an approximately 6 feet thick zone of silt and clay was encountered between elevation +52 feet and +58 feet. These silt and clay layers tie-in with where the crown CPT indicated the location of an aquiclude layer and therefore confirms the continuity of the aquiclude landward of the levee.

### **SM0016\_002B (Reach 23, Station 1517+00)**

The levee at this location is approximately 10 feet high, with a crown elevation of approximately +91.5 feet (NAVD88) and a landside toe elevation of +82 feet. The proposed remediation measure is a soil bentonite cutoff wall keying into a fine grained aquiclude layer at an elevation of approximately +60 feet. The local geology in this area is mapped as Lower Modesto, which primarily comprises sand and silt with occasional layers of clay (Helley and Harwood, 1985). The geomorphology map also indicates the presence of a crevasse splay in this area. Crevasse splay deposits tend to be coarser-grained and are formed from breaching of river banks or natural levees during high flood stages and deposition on the floodplain via small distributary channels.

Boring SM0016\_002B was drilled at the toe of the levee at Station 1517+00 adjacent to existing crown exploration WM0016\_012C, which identified an approximately 9 feet thick fine grained aquiclude layer between an elevation of +58 feet and +69 feet.

Boring SM0016\_002B was drilled to a depth of 51.5 bgs. The boring encountered 5 feet of clay at the surface overlying approximately 15 feet of interbedded sand and silty sand to an elevation of approximately +62 feet. Beneath this, an approximately 18 feet thick zone of silt and clay was encountered between elevation +44 feet and +62 feet. These silt and clay layers are thicker and slightly deeper than those encountered in the adjacent crown CPT.

Based on the results of the additional exploration, it is possible that the aquiclude layer identified in the crown CPT is not laterally persistent landward of the proposed cutoff wall and that a silty

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sand/sand layer is present beneath the wall between approximately elevation +53 feet and +58 feet. As such, some sensitivity analyses were run modeling a sand layer beneath the toe of the proposed cutoff wall. A cross section at Station 1522+00 was selected for analysis, because the main channel is closest to the levee at this location. At Station 1522+00, there is a waterside bench approximately 100 feet wide and there is a canal on the landside at a distance of approximately 500 feet. Based on the assumption of pancake layering, the canal penetrates through the blanket layer in this area.

For the ditch present condition, the analysis results show that underseepage meets criteria for both the 200 year + 1 foot WSE and 200 year + 4 foot WSE. Assuming the ditch is not present, the exit gradient at the 200 year + 1 foot WSE meets criteria, while the gradient at the 200 year + 4 foot WSE has a gradient of 0.66. An analysis cross-section and screen shots of the seepage runs are attached in Appendix A4.

Given the results of the sensitivity analysis, the fact that the aquiclude may or may not be laterally persistent on the landside and taking into account there has been no reported distress on the landside of the levee, it is considered that the proposed wall toe elevation of +60 feet is OK.

#### **SM0016\_003B (Reach 24, Station 1615+00)**

The levee at this location is approximately 10 feet high, with a crown elevation of approximately +94 feet (NAVD88) and a landside toe elevation of +84 feet. The proposed remediation measure is a soil bentonite cutoff wall keying into a fine grained aquiclude layer at an elevation of approximately +30 feet. The local geology in this area is mapped as Lower Modesto, which primarily comprises sand and silt with occasional layers of clay (Helley and Harwood, 1985). The geomorphology map also indicates the presence of a crevasse splay in this area. Crevasse splay deposits tend to be coarser-grained and are formed from breaching of river banks or natural levees during high flood stages and deposition on the floodplain via small distributary channels.

Boring SM0016\_003B was drilled at the toe of the levee at Station 1615+00 adjacent to existing crown boring WM0016\_020B, which identified a clay aquiclude layer at a depth of approximately 50 feet below the landside toe (elevation of +32 feet).

Boring SM0016\_003B was drilled to a depth of 72 feet bgs. The boring encountered approximately 40 feet of interbedded silt, clay, silty sand and clayey sand to an elevation of approximately +48 feet overlying approximately 15 feet of gravel to an elevation of +33 feet. Beneath this, an approximately 16 feet thick zone of silt and clay was encountered between elevation +33 feet and the bottom of the boring. Thin interbeds of silty sand and clayey sand, 1.5 feet to 2.5 feet thick, were encountered within this zone. This layer provides a suitable tie-in layer for the cutoff wall and confirms the continuity of the aquiclude landward of the levee.



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## 3.0 RECOMMENDATIONS

Based on the findings of the additional explorations performed in Reach 22, Station 1499+00, and Reach 24, Station 1615+00, in Project Phase C, it is considered that the landward continuity of the aquiclude has been confirmed. Therefore, the existing analyses performed as part of the final GDRR are valid and there is no need for additional analysis or change to the proposed design.

Based on the findings of the additional exploration performed in Reach 23, Station 1517+00, and the sensitivity analyses that were performed, it is considered that the landward continuity of the aquiclude is not critical in this location. Therefore, the existing analyses performed as part of the final GDRR are valid and there is no need for additional analysis or change to the proposed design.

## 4.0 LIMITATIONS

This technical memorandum was prepared in accordance with the standard of care commonly used as the state-of-practice in the engineering profession. Standard of care is defined as the ordinary diligence exercised by fellow practitioners in this area performing the same services under similar circumstances during the same period. The limitations section of the final GDRR for the FRWL is applicable for this technical memorandum also.

This technical memorandum is for the use and benefit of the HDR design team and SBFCA. Use by any other party is at their own discretion and risk.

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**APPENDIX A**

**A1 – Boring Logs**

**A2 – Laboratory Results**

**A3 – Plan and Profiles**

**A4 – Sensitivity Analysis**

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## **APPENDIX A1**

### **Boring Logs**

DATE STARTED 2/11/13	DATE COMPLETED 2/11/13	GROUND ELEVATION 80.0 ft	ELEVATION DATUM NAVD 88	TOTAL DEPTH OF BORING 46.5 ft
DRILLING CONTRACTOR GeoEx	DRILLER'S NAME Tom Scott	HELPER'S NAME Russel Humphreys	TOTAL DEPTH OF FILL 0 ft	
DRILLING METHOD HA/5" Solid Stem Auger/MR	DRILL RIG MAKE AND MODEL CME 75 #101		CONSULTANT COMPANY URS Corporation	
DRILL BIT SIZE AND TYPE (HOLE DIAMETER) 3" Bucket/5.5" CT PC/5" Auger	DRILLING ROD TYPE AND DIAMETER HWT Wireline 4" ID/1.75" OD AWJ		FIELD LOGGER M. Palmer	
<input checked="" type="checkbox"/> VERTICAL <input type="checkbox"/> INCLINED	CASING TYPE, DIAMETER, INSTALLATION DEPTH 6.5" x 6" Steel to 4'		FIELD LOG REVIEWER MM	
SAMPLER TYPE(S) Bag, SPT(1.375')	HAMMER TYPE, MAKE/MODEL, WEIGHT/DROP CME Autohammer		HAMMER EFFICIENCY 70%	
BOREHOLE BACKFILL OR COMPLETION Neat cement grout	GROUNDWATER READING: DURING DRILLING 14 ft		AFTER DRILLING (DATE-TIME) NA	

Elevation, feet	Depth, feet	Material Graphics	CLASSIFICATION OF MATERIALS (Description)	Sample Location	Sample Number	Recovery, %	Blows per 6 in. [Blows per ft]	N <sub>60</sub> (ASTM)	PP or TV, tsf	LABORATORY DATA						REMARKS		
										Water Content, %	Liquid Limit	Plasticity Index	Fines, % < #200	Other Lab Tests				
80	0		LEAN CLAY with Sand (CL); medium stiff; dark yellowish brown (10YR 3/4); moist; 80% very high dry strength, no to slow dilatancy fines; 20% fine to medium sand; micaceous.													1_001_005		
	1																	
	2						1				0.75P							
	3																	
	4																	
75	5		LEAN CLAY with Sand (CL); medium stiff; dark yellowish brown (10YR 3/4); moist; 80% very high dry strength, no to slow dilatancy fines; 20% fine to medium sand; micaceous.													2_005_007		
	6																	
	7																	
	8																	
	9																	
	10		At 9 feet (10YR 3/6); 75% fines; 25% fine to coarse sand.															
70	10		Poorly Graded SAND with Silt (SP-SM); medium dense; dark yellowish brown (10YR 4/6); 90% fine to coarse sand; 10% no plasticity fines; micaceous.													3A_010_011		
	11																3B_011_012	
	12								[10]									
	13				At 12.5 feet (10YR 3/4); wet.													4_013_014
	14								[15]									
	15		A 15 feet very loose; olive brown (2.5Y 4/4); wet; fine to medium sand; no plasticity fines; trace coarse sand.													5_015_017		
	16																	
	17																	
	18																	
	19																	
65	15																	
	16																	
	17																	
	18																	
	19																	
60	20																	

**Final Report Version**



Borehole Location: Landside Toe County: Sutter  
 Coordinates: Northing: 2,223,229.19 Easting: 6,664,776.97  
 Latitude: 39.26639 Longitude: -121.63580  
 Levee Station or Milepost: 1499+00 Levee Mile: \_\_\_\_\_  
 Levee Segment \_\_\_\_\_  
 Survey Method: GPS Coord. System: CA State Plane Zone II  
 Channel / River Name / Feature: Feather River

**LOG OF BORING  
SM0016\_001B**

Sheet 1 of 3

SBFCA Feather River West Levee

SUTTER BUTTE SOIL LOG REV1; GINTSBFCA; SUTTERBUTTELIBRARY201303113.GLB; 3/22/13

Elevation, feet	Depth, feet	Material Graphics	CLASSIFICATION OF MATERIALS (Description)	Sample Location	Sample Number	Recovery, %	Blows per 6 in. [Blows per ft]	N <sub>60</sub> (ASTM)	PP or TV, tsf	LABORATORY DATA					REMARKS
										Water Content, %	Liquid Limit	Plasticity Index	Fines, % < #200	Other Lab Tests	
60	20		At 20 feet medium dense.				4								6_020_022
	21			X	6	100	6	16							
	22						[14]								
	23		SANDY SILT (ML); hard; strong brown (7.5YR 4/6); moist; 55% low plasticity, medium dry strength, slow dilatancy fines; 45% fine to coarse sand; black speckling; micaceous; over consolidated.	X	7	100	29		>4.5P	18	31	7	57		7_023_024
	24						[50/5"]								
55	25		SANDY SILTY CLAY (CL-ML); dark yellowish brown (10YR 4/4); 60% fines; 40% sand; calcium carbonate veining scattered throughout.	X	8	100	17		>4.5P	19	28	6	60		8_025_027
	26						23	79							
	27		At 27 feet (10YR 4/6); stiff to very stiff.				[68]								
	28			X	9A		4								9A_027_028
	29		SILTY SAND (SM); medium dense; dark yellowish brown (10YR 4/4); moist; 80% fine to medium sand; 20% no to low plasticity fines; micaceous.	X	9B	100	8	19	2.0P						9B_028_029
	30						[16]								
50	30			X	10	89	6								10_030_032
	31						6	21					23		
	32						[18]								
	33		Poorly Graded SAND (SP); dense; dark brown (10YR 3/3); wet; 95% fine to coarse sand; 5% no plasticity fines; trace fine gravel.	X	11	89	4								11_032_034
	34						17	40							
	35		At 34.5 feet very dark grayish brown (2.5Y 3/2); fine to medium sand.				[34]								
45	35			X	12A		8								12_035_036
	36		SILTY SAND (SM); dense; olive brown (2.5Y 4/3); wet; 80% fine to medium sand; 20% no plasticity fines; micaceous.	X	12B	100	14	33					4		12_036_037
	37						[28]								
	38														
	39														
40	40		At 40 feet very dense; dark grayish brown (2.5Y 4/2); 60% fine to medium sand; 40% no to low plasticity, rapid dilatancy fines; micaceous.	X	13	83	10								13_040_042
	41						21	83							
	42						[71]								
	43														
	44		LEAN to FAT CLAY with Sand (CL/CH); hard; dark greenish gray (10G 4/1); moist; 85% medium to high plasticity, very high dry strength, no dilatancy fines; 15% fine to coarse sand; trace mica.												
35	45														

**Final Report Version**



**Borehole Location:** Landside Toe      **County:** Sutter  
**Coordinates: Northing:** 2,223,229.19      **Easting:** 6,664,776.97  
**Latitude:** 39.26639      **Longitude:** -121.63580  
**Levee Station or Milepost:** 1499+00      **Levee Mile:** \_\_\_\_\_  
**Levee Segment:** \_\_\_\_\_  
**Survey Method:** GPS      **Coord. System:** CA State Plane Zone II  
**Channel / River Name / Feature:** Feather River


**LOG OF BORING  
SM0016\_001B**

Sheet 2 of 3

SBFCA Feather River West Levee

Elevation, feet	Depth, feet	Material Graphics	CLASSIFICATION OF MATERIALS (Description)	Sample Location	Sample Number	Recovery, %	Blows per 6 in. [Blows per ft]	N <sub>60</sub> (ASTM)	PP or TV, tsf	LABORATORY DATA					REMARKS
										Water Content, %	Liquid Limit	Plasticity Index	Fines, % < #200	Other Lab Tests	
35	45		LEAN CLAY (CL); medium stiff to stiff; light olive brown (2.5Y 5/3); moist; 90% low to medium plasticity, high dry strength, slow dilatancy fines; 10% fine sand; micaceous.	X	14A	100	8	36	4.5P				92	14A_045_046 14B_046_047	
	46	14B			13		18								2.0P
	47		End of boring at 46.5 feet. Backfilled boring with neat cement grout consisting of 40 gallons water and 6-47 lb sacks of portland cement.												
	48														
	49		Field classification percentages are estimates. See boring log legend for ASTM procedures used for field and lab classification.												
30	50		Sample IDs and corresponding depth ranges are noted in the Remarks Column.												
	51														
	52														
	53														
	54														
25	55														
	56														
	57														
	58														
	59														
20	60														
	61														
	62														
	63														
	64														
15	65														
	66														
	67														
	68														
	69														
10	70														

**Final Report Version**

	Borehole Location: <u>Landside Toe</u> County: <u>Sutter</u> Coordinates: Northing: <u>2,223,229.19</u> Easting: <u>6,664,776.97</u> Latitude: <u>39.26639</u> Longitude: <u>-121.63580</u> Levee Station or Milepost: <u>1499+00</u> Levee Mile: _____ Levee Segment _____ Survey Method: <u>GPS</u> Coord. System: <u>CA State Plane Zone II</u> Channel / River Name / Feature: <u>Feather River</u>	<b>LOG OF BORING</b> <b>SM0016_001B</b> Sheet 3 of 3
	<b>SBFCA Feather River West Levee</b>	

DATE STARTED 2/11/13	DATE COMPLETED 2/12/13	GROUND ELEVATION 82.0 ft	ELEVATION DATUM NAVD 88	TOTAL DEPTH OF BORING 51.5 ft
DRILLING CONTRACTOR GeoEx	DRILLER'S NAME Tom Scott	HELPER'S NAME Russel Humphreys	TOTAL DEPTH OF FILL 0 ft	
DRILLING METHOD HA/Solid Stem Auger/MR	DRILL RIG MAKE AND MODEL CME 75		CONSULTANT COMPANY URS Corporation	
DRILL BIT SIZE AND TYPE (HOLE DIAMETER) 3" Bucket/5" Auger/3-3/4" Drag bit	DRILLING ROD TYPE AND DIAMETER 5" Solid Stem Auger/1.75" AWJ		FIELD LOGGER M. Palmer	
<input checked="" type="checkbox"/> VERTICAL <input type="checkbox"/> INCLINED	CASING TYPE, DIAMETER, INSTALLATION DEPTH 6.5" x 6" Steel to 4'		FIELD LOG REVIEWER MM	
SAMPLER TYPE(S) Bag, SPT(1.375")	HAMMER TYPE, MAKE/MODEL, WEIGHT/DROP CME Autohammer		HAMMER EFFICIENCY 70%	
BOREHOLE BACKFILL OR COMPLETION Neat cement grout	GROUNDWATER READING: DURING DRILLING 20 ft		AFTER DRILLING (DATE-TIME) 21 ft on 2/12/13	

Elevation, feet	Depth, feet	Material Graphics	CLASSIFICATION OF MATERIALS (Description)	Sample Location	Sample Number	Recovery, %	Blows per 6 in. [Blows per ft]	N <sub>60</sub> (ASTM)	PP or TV, tsf	LABORATORY DATA						REMARKS
										Water Content, %	Liquid Limit	Plasticity Index	Fines, % < #200	Other Lab Tests		
80	0		SANDY LEAN CLAY (CL); dark yellowish brown (10YR 3/4); moist; 60% medium plasticity, very high dry strength, no dilatancy fines; 40% fine to medium sand.		1										1_001_004	
	1															
	2															
	3															
	4		At 4.5 feet (10YR 4/6).		2					17	30	13	63		2_004_005	
	5		SILTY SAND (SM); loose; dark yellowish brown (10YR 4/6); moist; 55% fine to medium sand; 45% no to low plasticity, slow dilatancy fines; micaceous; trace tree roots.		3	100	2 2 3 [5]	6							3_005_007	
75	6															
	7															
	8															
	9															
	10		Poorly Graded SAND with Silt (SP-SM); medium dense; olive brown (2.5Y 4/3); moist; 90% fine to coarse sand; 10% no plasticity fines; trace fine gravel; micaceous.		4	78	7 5 5 [10]	12							4_010_012	
70	11															
	12															
	13															
	14		SILTY SAND (SM); medium dense; olive brown (2.5Y 4/3); moist; 85% fine to coarse sand; 15% no plasticity fines; micaceous.		5	78	6 7 8 [15]	18							5_012_014	
	15															
	16															
	17															
	18		Poorly Graded SAND (SP); medium dense; dark olive brown (2.5Y 3/3); moist; 95% fine to coarse sand; 5% no plasticity fines; micaceous.		6	78	6 7 9 [16]	19					2		6_015_017	
65	19															
	20															

**Final Report Version**



Borehole Location: Landside Toe County: Sutter  
Coordinates: Northing: 2,225,011.91 Easting: 6,665,202.97  
Latitude: 39.27128 Longitude: -121.63427  
Levee Station or Milepost: 1517+00 Levee Mile: \_\_\_\_\_  
Levee Segment \_\_\_\_\_  
Survey Method: GPS Coord. System: CA State Plane Zone II  
Channel / River Name / Feature: Feather River

**LOG OF BORING  
SM0016\_002B**

Sheet 1 of 3

SBFCA Feather River West Levee

SUTTER BUTTE SOIL LOG REV1; GINTSBFCA; SUTTERBUTTELIBRARY201303113.GLB; 3/22/13

Elevation, feet	Depth, feet	Material Graphics	CLASSIFICATION OF MATERIALS (Description)	Sample Location	Sample Number	Recovery, %	Blows per 6 in. [Blows per ft]	N <sub>60</sub> (ASTM)	PP or TV, tsf	LABORATORY DATA					REMARKS		
										Water Content, %	Liquid Limit	Plasticity Index	Fines, % < #200	Other Lab Tests			
20	21		SANDY SILT (ML); stiff to very stiff; olive brown (2.5Y 4/4); moist; 65% low plasticity, medium dry strength, slow to rapid dilatancy fines; 35% fine to medium sand; white calcium carbonate veining, and black speckles scattered throughout; micaceous.		7	78	6 10 12	26	2.0P					66		7_020_022	
60	22						[22]										
	23																
	24		At 24 feet dark yellowish brown (10YR 4/4); orange and black speckles scattered throughout.														
	25				8A		6 10		2.0P								
	26		ELASTIC SILT (MH); very stiff; light olive brown (2.5Y 5/3); moist; 90% high dry strength, no to slow dilatancy fines; 10% fine to medium sand; orange staining.		8B	100	20	35	3.75P	38 40	44 54	15 14	69 92			8A_025_026 8B_026_027	
55	27						[30]										
	28		SILTY CLAY with Sand (CL/ML); olive brown (2.5Y 4/3); moist; 85% low plasticity, medium to high dry strength, slow to rapid dilatancy fines; 15% fine to medium sand; micaceous.		9	100	9 18 31	57									9_027_029
	29						[49]										
	30																
	31				10	100	5 6 3	11									10_030_032
	32						[9]										
50	33		CLAYEY SILT with Sand (ML/CL); medium stiff to stiff; olive brown (2.5Y 4/3); wet; 80% low plasticity, medium dry strength, rapid dilatancy fines; 20% fine sand; orange iron oxide staining.		11	72	5 6 10	19	1.0P								11_032_034
	34						[16]										
	35		SANDY SILT (ML); dark yellowish brown (10YR 4/4); wet; 50% fine sand; 50% no to low plasticity fines; micaceous.		12	83	5 8 11	22									12_035_037
	36						[19]										
45	37																
	38		Poorly Graded SAND with Silt (SP-SM); dark grayish brown (2.5Y 4/2); wet; 90% fine to medium sand; 10% no plasticity fines; micaceous.														
	39																
	40				13A		10 11										
	41		SILTY SAND (SM); medium dense; olive brown (2.5Y 4/4); moist; 55% fine to medium sand; 45% no plasticity fines; trace mica.		13B	89	15	30					44				13A_040_041 13B_041_042
	42						[26]										
40	43																
	44		SANDY SILT (ML/SM); olive brown (2.5Y 4/3); moist; 50% fine sand; 50% low plasticity, slow to rapid dilatancy fines; micaceous.														
	45																

**Final Report Version**



**Borehole Location:** Landside Toe **County:** Sutter  
**Coordinates:** Northing: 2,225,011.91 **Easting:** 6,665,202.97  
**Latitude:** 39.27128 **Longitude:** -121.63427  
**Levee Station or Milepost:** 1517+00 **Levee Mile:** \_\_\_\_\_  
**Levee Segment:** \_\_\_\_\_  
**Survey Method:** GPS **Coord. System:** CA State Plane Zone II  
**Channel / River Name / Feature:** Feather River

**LOG OF BORING  
SM0016\_002B**

Elevation, feet	Depth, feet	Material Graphics	CLASSIFICATION OF MATERIALS (Description)	Sample Location	Sample Number	Recovery, %	Blows per 6 in. [Blows per ft]	N <sub>60</sub> (ASTM)	PP or TV, tsf	LABORATORY DATA					REMARKS	
										Water Content, %	Liquid Limit	Plasticity Index	Fines, % < #200	Other Lab Tests		
45					14A		6									
46					14B	89	9	30								14A_045_046 14B_046_047
35	47		LEAN CLAY with Sand (CL); very stiff; light yellowish brown (2.5Y 6/3); moist; 75% medium plasticity, no dilatancy fines; 25% fine sand; poorly indurated.				[26]									
	48		CLAYEY SILT (ML/CL); olive brown (2.5Y 4/3); moist; 95% low plasticity, medium dry strength, slow dilatancy fines; 5% fine sand; micaceous; poorly indurated.		15	44	10 20 39	69				94				15_047_049
	49						[59]									
	50		SILTY SAND (SM); dense; olive brown (2.5Y 4/3); moist; 65% fine sand; 35% no to low plasticity, slow to rapid dilatancy fines; micaceous; poorly indurated.		16		10 12 19	36								16_050_052
	51						[31]									
30	52	End of boring at 51.5 feet. Backfilled boring with neat cement grout consisting of 35 gallons water and 5-47 lb sacks of portland cement and 15 lbs of bentonite powder.														
	53															
	54	Field classification percentages are estimates. See boring log legend for ASTM procedures used for field and lab classification.														
	55	Sample IDs and corresponding depth ranges are noted in the Remarks Column.														
	56															
25	57															
	58															
	59															
	60															
	61															
20	62															
	63															
	64															
	65															
	66															
15	67															
	68															
	69															
	70															

**Final Report Version**



**Borehole Location:** Landside Toe **County:** Sutter  
**Coordinates:** **Northing:** 2,225,011.91 **Easting:** 6,665,202.97  
**Latitude:** 39.27128 **Longitude:** -121.63427  
**Levee Station or Milepost:** 1517+00 **Levee Mile:** \_\_\_\_\_  
**Levee Segment:** \_\_\_\_\_  
**Survey Method:** GPS **Coord. System:** CA State Plane Zone II  
**Channel / River Name / Feature:** Feather River

**LOG OF BORING  
SM0016\_002B**

Sheet 3 of 3

**SBFCA Feather River West Levee**

DATE STARTED 2/12/13	DATE COMPLETED 2/13/12	GROUND ELEVATION 84.0 ft	ELEVATION DATUM NAVD 88	TOTAL DEPTH OF BORING 72.0 ft
DRILLING CONTRACTOR GeoEx	DRILLER'S NAME Tom Scott	HELPER'S NAME Russel Humphreys	TOTAL DEPTH OF FILL 4.5 ft	
DRILLING METHOD Solid Stem Auger/Mud Rotary	DRILL RIG MAKE AND MODEL CME 75	CONSULTANT COMPANY URS Corporation		
DRILL BIT SIZE AND TYPE (HOLE DIAMETER) 5" Auger/4-7/8" CT PC Bit	DRILLING ROD TYPE AND DIAMETER 5" Solid Stem Auger/HWT WL 4" OD	FIELD LOGGER T. HULL/M. PALMER		
<input checked="" type="checkbox"/> VERTICAL <input type="checkbox"/> INCLINED	CASING TYPE, DIAMETER, INSTALLATION DEPTH 6.5" x 6" Steel to 4'	FIELD LOG REVIEWER MM		
SAMPLER TYPE(S) MCal(2.5"), PCore(2.5"), SPT(1.375")	HAMMER TYPE, MAKE/MODEL, WEIGHT/DROP CME Autohammer	HAMMER EFFICIENCY 70%		
BOREHOLE BACKFILL OR COMPLETION Neat cement grout	GROUNDWATER READING: DURING DRILLING 23.5 ft	AFTER DRILLING (DATE-TIME) NA		

Elevation, feet	Depth, feet	Material Graphics	CLASSIFICATION OF MATERIALS (Description)	Sample Location	Sample Number	Recovery, %	Blows per 6 in. [Blows per ft]	N <sub>60</sub> (ASTM)	PP or TV, tsf	LABORATORY DATA					REMARKS
										Water Content, %	Liquid Limit	Plasticity Index	Fines, % < #200	Other Lab Tests	
	0		[FILL] SILTY SAND (SM); loose; dark reddish brown (5YR 3/2); 75% fine to medium sand; 25% low plasticity, slow dilatancy fines; trace fine gravel, max. 3/8 in.; trace rootlets.		1	100	2 3 4 [7]	8							1_000_002
	1														
	2														
	3		[FILL] CLAYEY SAND (SC); loose; dark reddish brown (5YR 3/4); moist; 80% fine to coarse sand; 20% low plasticity, no to slow dilatancy fines; trace rootlets.		2	100	2 2 2 [4]	5							2_002_004
	4														
	5		CLAYEY SAND (SC); loose; reddish brown (5YR 4/3); moist; 65% fine to coarse sand; 35% low to medium plasticity, no to slow dilatancy fines; trace rootlets; trace mica.		3	100	2 2 2 [4]	5					37		3_005_007
	6														
	7														
	8														
	9														
	10		At 10 feet dark brown (7.5YR 3/3); low plasticity fines.		4	94	3 3 3 [6]	7							4_010_012
	11														
	12														
	13														
	14		At 14 feet light yellowish brown (10YR 6/4); fine to medium sand; slow dilatancy fines.		5A 5B	100	8 4 4 [8]	9							5A_015_016 5B_016_017
	15														
	16		SILTY SAND (SM); loose; dark yellowish brown (10YR 3/6); 75% fine to coarse sand; 25% no to low plasticity, rapid dilatancy fines; trace mica.												
	17														
	18		CLAYEY SAND (SC); dark yellowish brown (10YR 4/4); 60% fine to medium sand; 40% medium plasticity, no dilatancy fines; trace mica.												
	19														
	20														

**Final Report Version**



**Borehole Location:** Landside Levee Ditch Levee **County:** Sutter  
**Coordinates:** Northing: 2,233,537.02 **Easting:** 6,664,276.07  
**Latitude:** 39.29470 **Longitude:** -121.63742  
**Levee Station or Milepost:** 1615+00 **Levee Mile:** \_\_\_\_\_  
**Levee Segment:** \_\_\_\_\_  
**Survey Method:** GPS **Coord. System:** CA State Plane Zone II  
**Channel / River Name / Feature:** Feather River

**LOG OF BORING**  
**SM0016\_003B**

Sheet 1 of 4

**SBFCA Feather River West Levee**  
**City of Live Oak Property, Sutter**  
**County**

SUTTER BUTTE SOIL LOG REV1; GINTSBFCA; SUTTERBUTTELIBRARY201303113.GLB; 3/27/13



Elevation, feet	Depth, feet	Material Graphics	CLASSIFICATION OF MATERIALS (Description)	Sample Location	Sample Number	Recovery, %	Blows per 6 in. [Blows per ft]	N <sub>60</sub> (ASTM)	PP or TV, tsf	LABORATORY DATA					REMARKS
										Water Content, %	Liquid Limit	Plasticity Index	Fines, % < #200	Other Lab Tests	
45	46					0	13 50/4"								
47	48						[50/4"]								
35	49														
50	51				15		50/6"								15_050_051
52	53		From 52.5 to 53.5 feet clay and gravel interbeds.				[REF]								
55	56		Poorly Graded SAND with Silt (SP-SM); olive brown (2.5Y 4/3); wet; 90% fine to medium sand; 10% no plasticity fines; micaceous.		16A 16B	100	4 8 11	22	2.75P		52	73	35	99	16A_055_056 16B_056_057
57	58		ELASTIC SILT (MH); very stiff; light olive brown (2.5Y 5/3); 100% slow dilatancy fines; trace fine to medium sand.		17A		[19]								17A_058_059
59	60		LEAN CLAY with Sand (CL); very stiff; light olive brown (2.5Y 5/3); 80% slow dilatancy fines; 20% sand.		17B	100							79		17B_059_060
61	62		CLAYEY SAND (SC/SM); medium dense; olive brown (2.5Y 4/3); wet; 70% fine to medium sand; 30% low plasticity, slow dilatancy fines; trace mica.		18	100	8 11 16	32							18_061_062
63	64		SILTY SAND (SM/SC); olive brown (2.5Y 4/3); wet; 80% fine to medium sand; 20% no to low plasticity, slow dilatancy fines; micaceous.		19A 19B	83	[27]		2.0P					32	19A_062_063 19B_063_064
65	66		SANDY LEAN CLAY (CL); very stiff; olive yellow (2.5Y 6/6); dry; medium plasticity, slow dilatancy fines; micaceous; indurated.		19C										19C_064_065
67	68		SILTY SAND (SM); dense; olive brown (2.5Y 4/3); moist; 65% fine sand; 35% no to low plasticity, rapid dilatancy fines; micaceous.		20	100	13 21 30	60						36	20_065_067
69	70		LEAN CLAY with Sand (CL); light olive brown (2.5Y 5/3); moist; 80% medium plasticity, no dilatancy fines; 20% fine sand; trace fine mica; iron oxide speckles scattered throughout.		21	100	[51]								21_067_071

**Final Report Version**



**Borehole Location:** Landside Levee Ditch Levee      **County:** Sutter  
**Coordinates:** Northing: 2,233,537.02      Easting: 6,664,276.07  
 Latitude: 39.29470      Longitude: -121.63742  
**Levee Station or Milepost:** 1615+00      **Levee Mile:** \_\_\_\_\_  
**Levee Segment:** \_\_\_\_\_  
**Survey Method:** GPS      **Coord. System:** CA State Plane Zone II  
**Channel / River Name / Feature:** Feather River


**LOG OF BORING  
SM0016\_003B**

Sheet 3 of 4

**SBFCA Feather River West Levee  
 City of Live Oak Property, Sutter  
 County**

Elevation, feet	Depth, feet	Material Graphics	CLASSIFICATION OF MATERIALS (Description)	Sample Location	Sample Number	Recovery, %	Blows per 6 in. [Blows per ft]	N <sub>60</sub> (ASTM)	PP or TV, tsf	LABORATORY DATA					REMARKS	
										Water Content, %	Liquid Limit	Plasticity Index	Fines, % < #200	Other Lab Tests		
	70				21	100										
	71		SANDY LEAN CLAY (CL); brown (10YR 4/3); moist; 70% medium plasticity, no dilatancy fines; 30% fine sand.		22	100	4 21 36	67								22_071_072
	72						57									
	73		End of boring at 72 feet. Backfilled boring with neat cement grout consisting of 85 gallons water and 13-47 lb sacks of portland cement and 30 lbs of bentonite powder.													
10	74		Field classification percentages are estimates. See boring log legend for ASTM procedures used for field and lab classification.													
	75		Sample IDs and corresponding depth ranges are noted in the Remarks Column.													
	76															
	77															
	78															
5	79															
	80															
	81															
	82															
	83															
0	84															
	85															
	86															
	87															
	88															
-5	89															
	90															
	91															
	92															
	93															
-10	94															
	95															

**Final Report Version**

	Borehole Location: <u>Landside Levee Ditch Levee</u> County: <u>Sutter</u> Coordinates: Northing: <u>2,233,537.02</u> Easting: <u>6,664,276.07</u> Latitude: <u>39.29470</u> Longitude: <u>-121.63742</u> Levee Station or Milepost: <u>1615+00</u> Levee Mile: _____ Levee Segment _____ Survey Method: <u>GPS</u> Coord. System: <u>CA State Plane Zone II</u> Channel / River Name / Feature: <u>Feather River</u>	<b>LOG OF BORING</b> <b>SM0016_003B</b> Sheet 4 of 4
	SBFCA Feather River West Levee City of Live Oak Property, Sutter County	

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## **APPENDIX A2**

### **Laboratory Results**

**TABLE A-15**

Sample Information				USCS Group Symbol	In Situ Water Content, %	In Situ Dry Unit Weight, pcf	Sieve			Atterberg Limits			Other Tests
Boring Number	Sample Number	Depth, feet	Elevation, feet				Gravel, %	Sand, %	<#200, %	LL	PL	PI	
SM0016_001B	2_005_007	5	75.0	CL	18			78.0	31	16	15		
SM0016_001B	5_015_017	15	65.0	SP-SM				9.0				PA	
SM0016_001B	7_023_024	23	57.0	ML	18			57.3	31	24	7		
SM0016_001B	8_025_027	25	55.0	CL-ML	19			59.7	28	22	6		
SM0016_001B	10_030_032	30	50.0	SM				23.4					
SM0016_001B	12A_035_036	35	45.0	SP				3.8					
SM0016_001B	14B_046_047	46	34.0	CL				91.9					

Report SBFCA LAB SUMMARY TEST: GINTSBFCA: 03/22/2013



**SBFCA Feather River West Levee**

**SUMMARY OF SOIL LABORATORY DATA**

**TABLE A-15**

Sample Information				USCS Group Symbol	In Situ Water Content, %	In Situ Dry Unit Weight, pcf	Sieve			Atterberg Limits			Other Tests
Boring Number	Sample Number	Depth, feet	Elevation, feet				Gravel, %	Sand, %	<#200, %	LL	PL	PI	
SM0016_002B	2_004_005	4	78.0	CL	17			63.1	30	17	13		
SM0016_002B	3_005_007	5	77.0	CL				45.9					
SM0016_002B	6_015_017	15	67.0	SP				2.5					
SM0016_002B	7_020_022	20	62.0	SP				66.5					
SM0016_002B	8A_025_026	25	57.0	ML	38			68.9	44	29	15		
SM0016_002B	8B_026_027	26	56.0	MH	40			91.6	54	40	14		
SM0016_002B	13B_041_042	41	41.0	SM				44.0					
SM0016_002B	15_047_049	48	34.0	ML				94.4					

Report SBFCA LAB SUMMARY TEST: GINTSBFCA: 03/22/2013



**SBFCA Feather River West Levee**

**SUMMARY OF SOIL LABORATORY DATA**

**TABLE A-15**

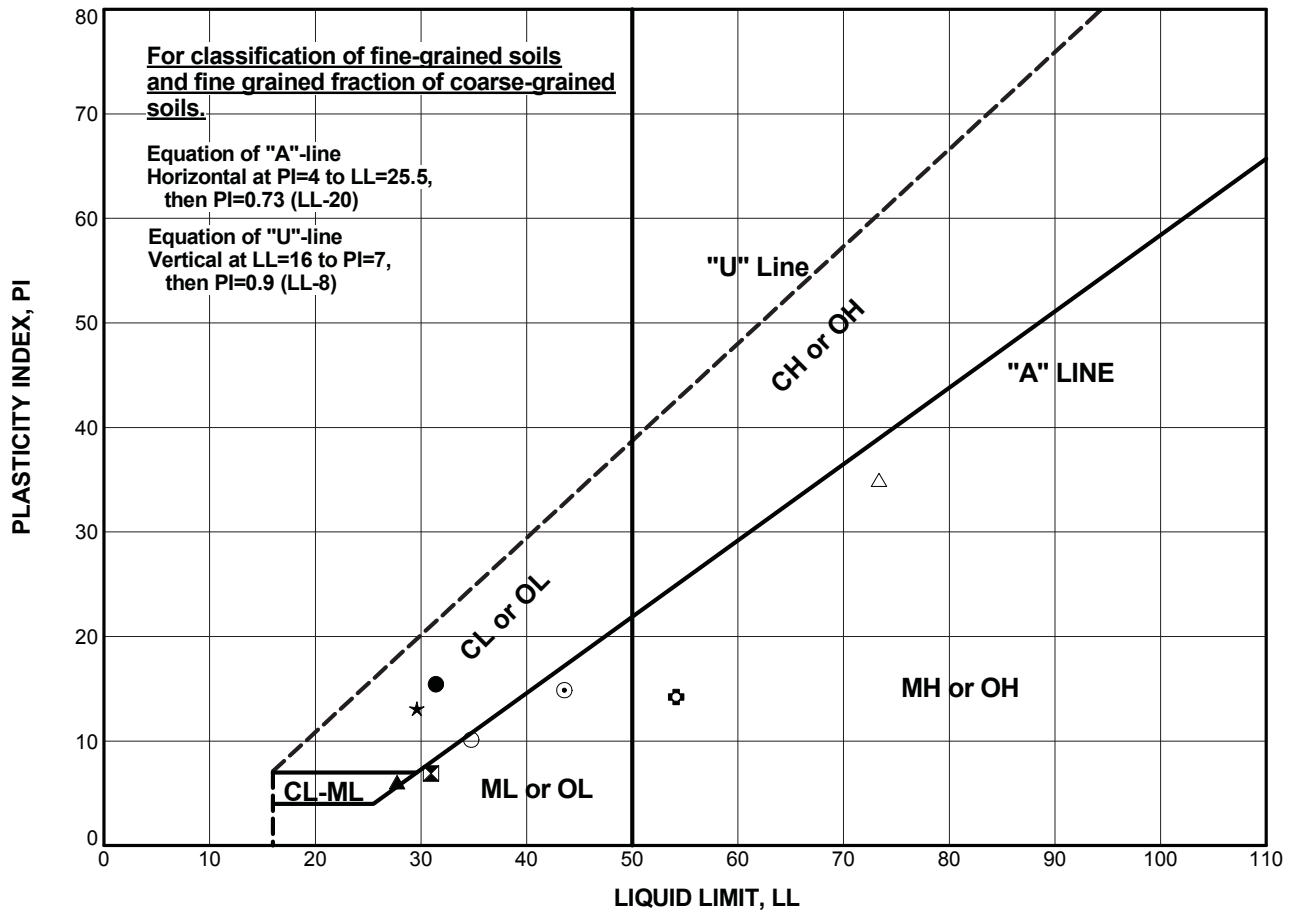
Sample Information				USCS Group Symbol	In Situ Water Content, %	In Situ Dry Unit Weight, pcf	Sieve			Atterberg Limits			Other Tests
Boring Number	Sample Number	Depth, feet	Elevation, feet				Gravel, %	Sand, %	<#200, %	LL	PL	PI	
SM0016_003B	3_005_007	5	83.0	SC			37.5						
SM0016_003B	8A_027_028	27	61.0	ML	31		70.9	35	25	10			
SM0016_003B	10_032_035	32	56.0	SM			68.1						
SM0016_003B	13A_039_039	39	49.0	SM			25.8				PA		
SM0016_003B	14_041_043	41	47.0	GP-GM			6.5						
SM0016_003B	16B_056_057	56	32.0	MH	52		99.0	73	38	35			
SM0016_003B	17B_059_060	59	29.0	CL			78.6						
SM0016_003B	19A_062_063	62.2	25.8	SC			32.1						
SM0016_003B	20_065_067	65	23.0	SM			35.8						

Report SBFCA LAB SUMMARY TEST: GINTSBFCA: 03/22/2013



**SBFCA Feather River West Levee**

**SUMMARY OF  
SOIL LABORATORY DATA**



Boring Number	Sample Number	Depth (feet)	Test Symbol	WC (%)	LL	PL	PI	%Fines <#200	Classification
SM0016_001B	2_005_007	5	●	18.4	31	16	15	78	LEAN CLAY with SAND (CL)
SM0016_001B	7_023_024	23	⊠	18.2	31	24	7	57	SANDY SILT (ML)
SM0016_001B	8_025_027	25	▲	19.4	28	22	6	60	SANDY SILTY CLAY (CL-ML)
SM0016_002B	2_004_005	4	★	17.0	30	17	13	63	SANDY LEAN CLAY (CL)
SM0016_002B	8A_025_026	25	⊙	38.3	44	29	15	69	SANDY SILT (ML)
SM0016_002B	8B_026_027	26	⊕	40.3	54	40	14	92	ELASTIC SILT (MH)
SM0016_003B	8A_027_028	27	○	31.4	35	25	10	71	SILT with SAND (ML)
SM0016_003B	16B_056_057	56	△	52.0	73	38	35	99	ELASTIC SILT (MH)

SBFCA LEVEE ATT. PLOT (U LINE) W/%200; GINTSBFCA; SUTTERBUTTELIBRARY201303113.GLB; 3/22/13



**SBFCA Feather River West Levee**

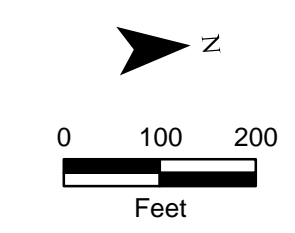
**PLASTICITY CHART**

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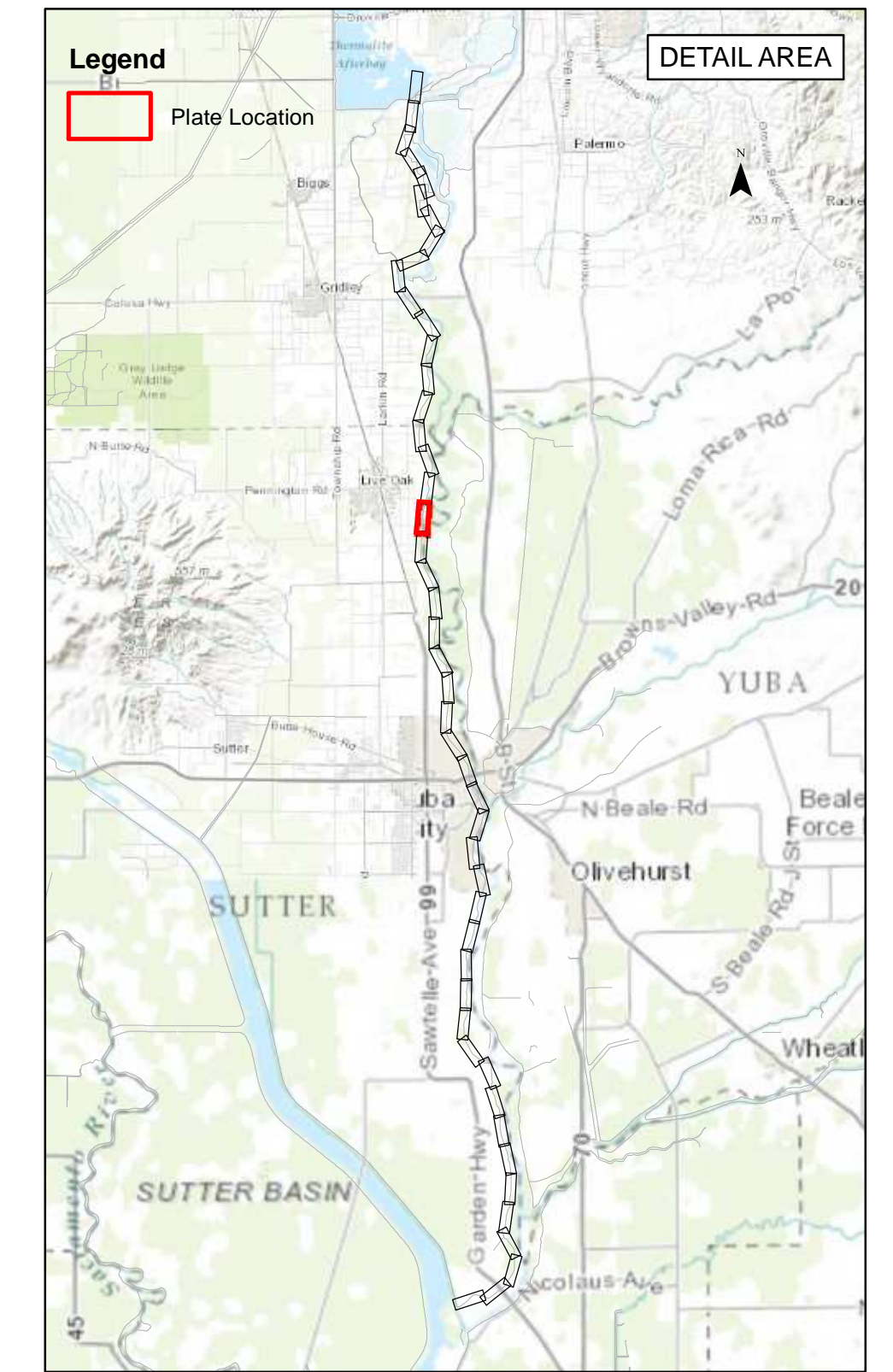
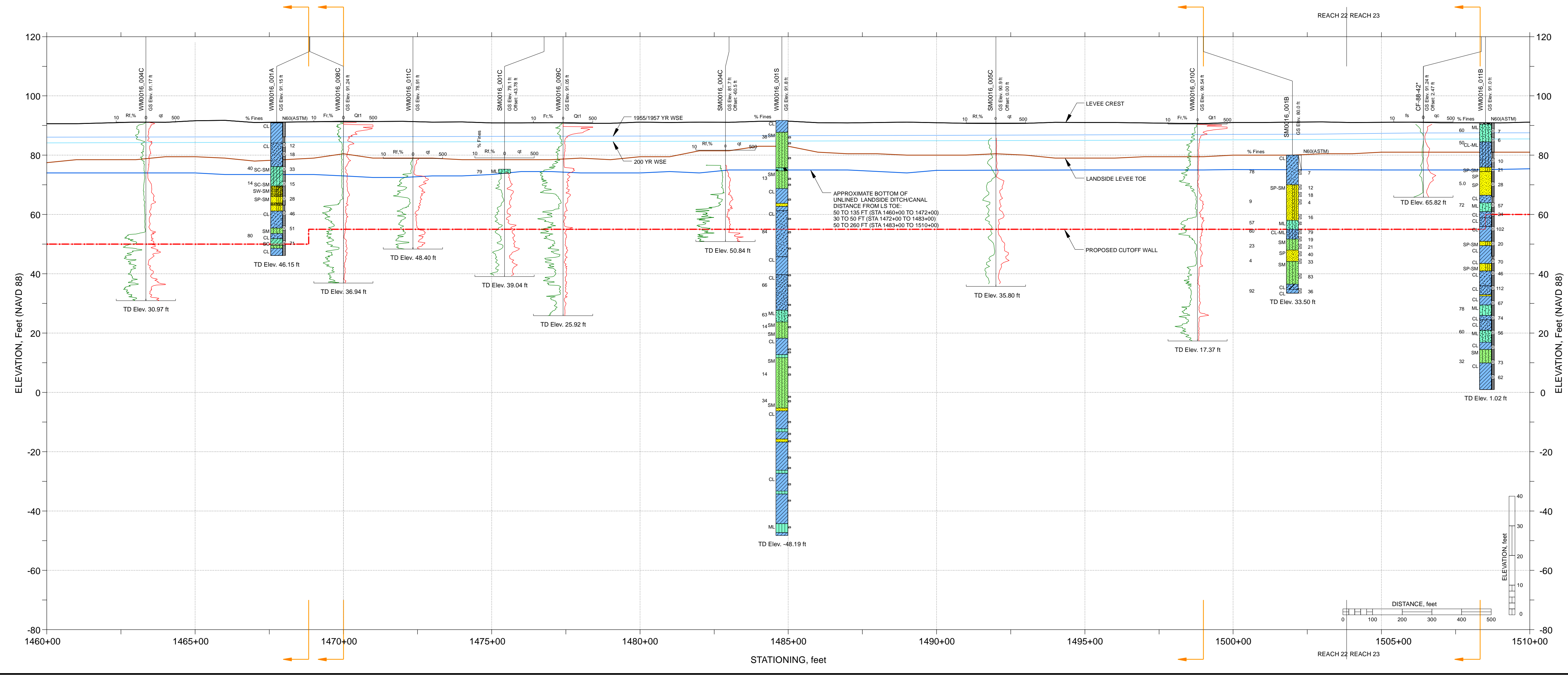
**APPENDIX A3**

**Plan and Profiles**

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- NOTES:
- Elevations of levee crown and landside toe are approximate. These elevations were obtained from DWR CVFED or ULE LIDAR data and used for geotechnical analyses and report purpose only. For detail crown elevation and landside toe information, please refer to the FRWL Project civil drawings.
  - The water surface elevations are based on information provided by Peterson Brustad, Inc. in their July 26, 2012 report entitled "Design Water Surface Profiles for the Feather River West Levee Rehabilitation Project Addendum #1".
  - Locations of explorations are approximate. Stick logs represent general soil conditions encountered at the time of exploration. For more detailed information on the materials encountered, refer to boring and CPT logs in the Geotechnical Data Report for the FRWL Project. No warranty is provided regarding the continuity of soil conditions between individual explorations.
  - When reported,  $N_{60}(ASTM)$  refers to  $N_{60}(ASTM) = N_{60} * \text{Hammer Efficiency } (\%)$ . See Geotechnical Data Report for the FRWL Project for hammer efficiency data for individual borings.
  - These drawings do not include all historical explorations on the profile view. Historical explorations from the DWR ULE project are shown; "other" historical explorations are identified by an asterisk (\*) in the exploration ID. For these "other" historical borings, blow counts are field blow counts (NF) and USCS classifications are visual classifications.
  - USCS classification labels are not presented on the stick logs for soil lenses (thickness less than 1.5 feet).
  - This is a color figure. Black and white reproduction should not be relied upon as data will be lost.
  - To prevent scale distortion, this map should be printed on a "D" size sheet (22x34 inches).
  - Surficial geology was mapped at 1:20,000 scale. (Source: SGRD for DWR ULE Project, URS, 2010).
  - The information provided in these plans and stick-log plates has been compiled from a variety of sources. URS does not attest to the accuracy, completeness, or reliability of geotechnical exploration and other subsurface data by others that are included or referenced in these plates.
  - These plans and stick-log plates are for the use and benefit of HDR, SBFCA, and their consultants in connection with the execution of the FRWL Project. Use by any other party is at their own discretion and risk. These figures should not be used as the sole basis for design, construction, remedial action, or major capital spending decisions.
  - The canal/ditch elevations are approximate. These elevations were estimated from the topography.

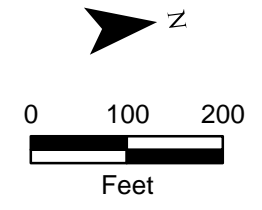
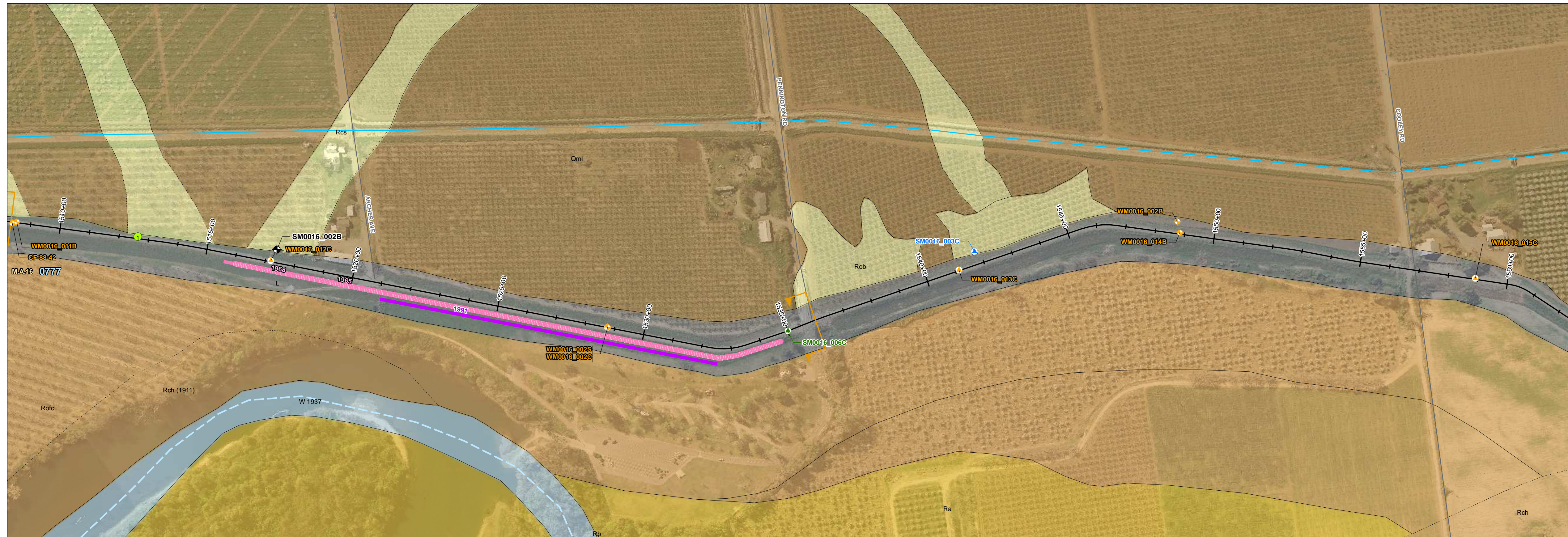


**FRWL Project Plan Views and Stick Log Figures**  
FRWL Project: Station 1460+00 to Station 1510+00

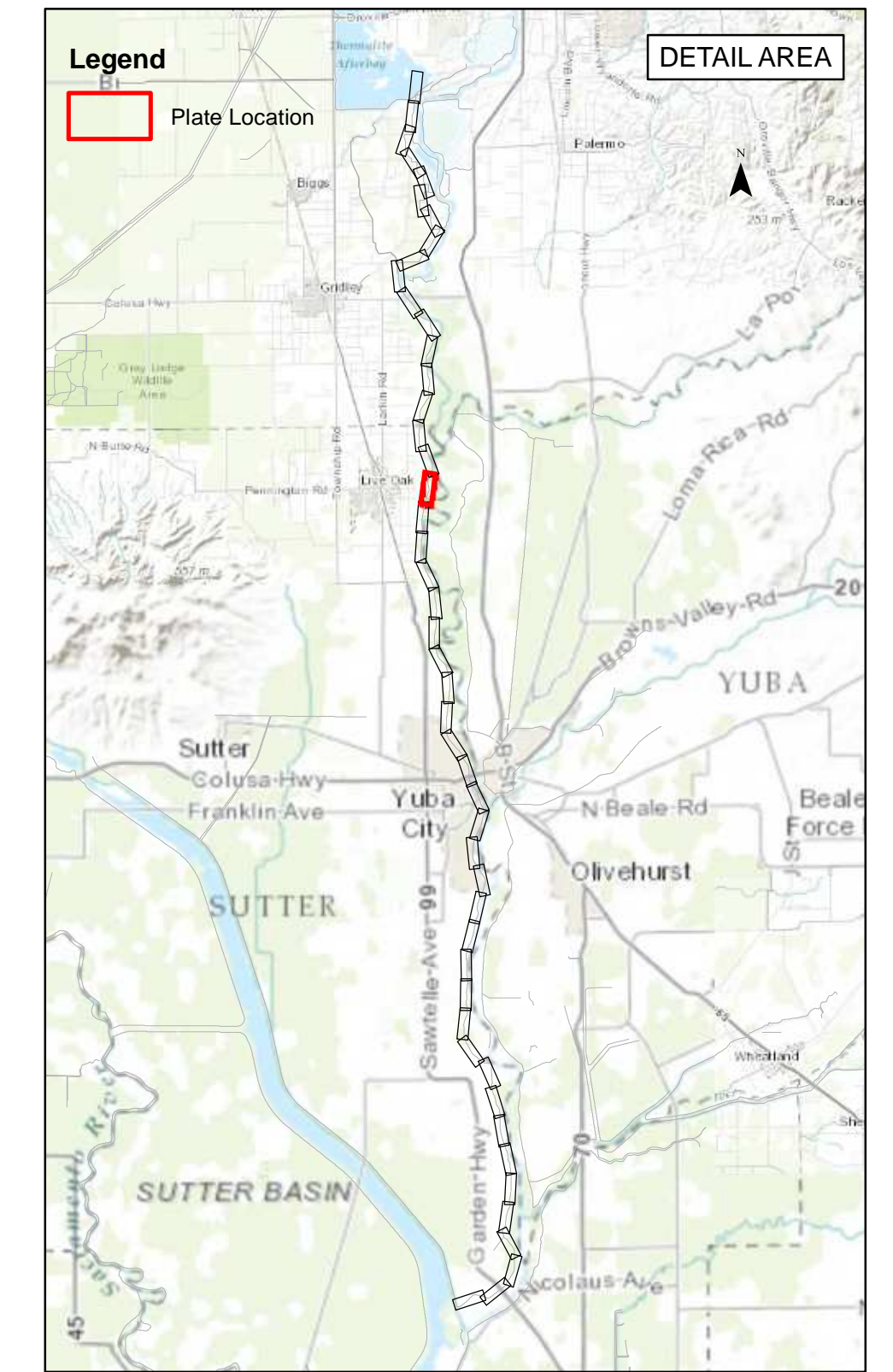
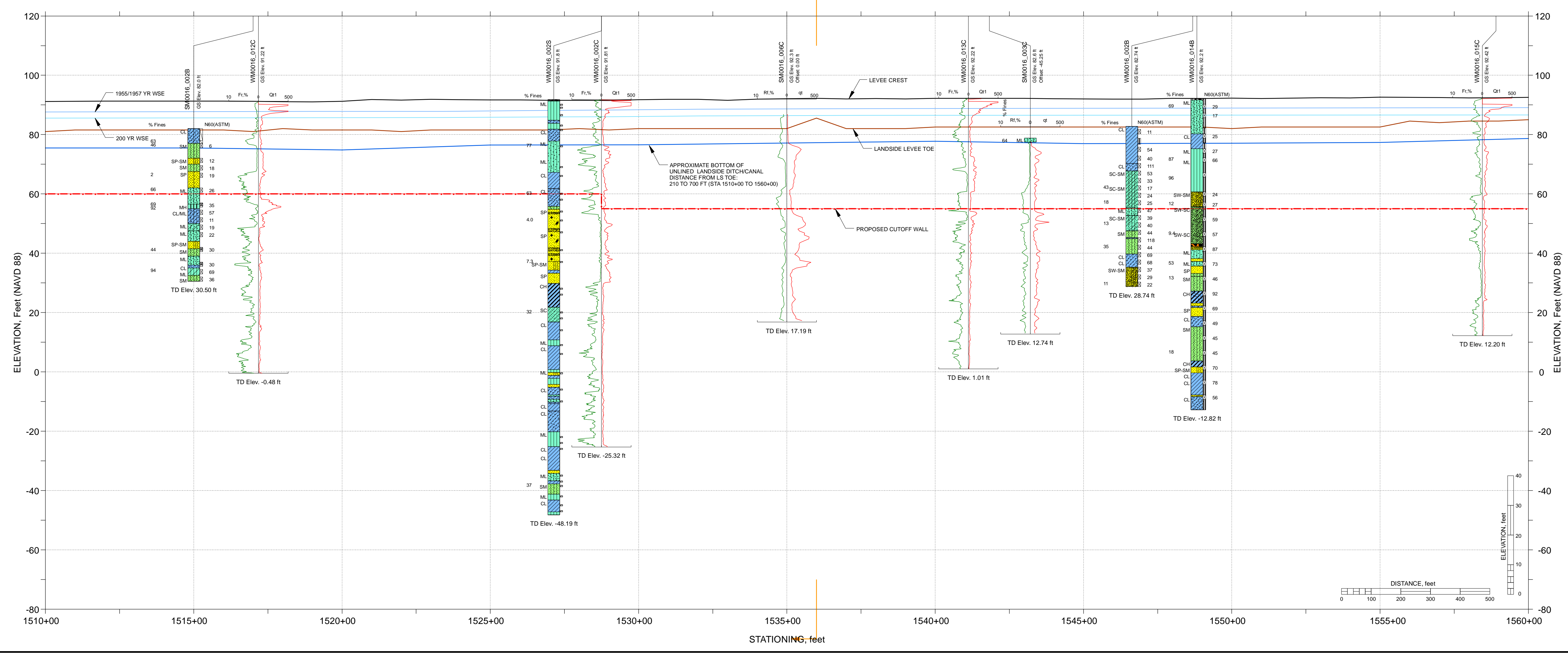
**URS** Geotechnical Design  
Recommendations Report

**Sutter Butte Flood Control Agency**  
FEATHER RIVER WEST LEVEE PROJECT

Appendix  
A32



- NOTES:**
- Elevations of levee crown and landside toe are approximate. These elevations were obtained from DWR CVFED or ULE LIDAR data and used for geotechnical analyses and report purpose only. For detail crown elevation and landside toe information, please refer to the FRWL Project civil drawings.
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  - Locations of explorations are approximate. Stick logs represent general soil conditions encountered at the time of exploration. For more detailed information on the materials encountered, refer to boring and CPT logs in the Geotechnical Data Report for the FRWL Project. No warranty is provided regarding the continuity of soil conditions between individual explorations.
  - When reported,  $N_{60}(ASTM)$  refers to  $N_{60}(ASTM) = N_{60} * \text{Hammer Efficiency} (\%)$ . See Geotechnical Data Report for the FRWL Project for hammer efficiency data for individual borings.
  - These drawings do not include all historical explorations on the profile view. Historical explorations from the DWR ULE project are shown; "other" historical explorations are identified by an asterisk (\*) in the exploration ID. For these "other" historical borings, blow counts are field blow counts (N) and USCS classifications are visual classifications.
  - USCS classification labels are not presented on the stick logs for soil lenses (thickness less than 1.5 feet).
  - This is a color figure. Black and white reproduction should not be relied upon as data will be lost.
  - To prevent scale distortion, this map should be printed on a "D" size sheet (22x34 inches).
  - Surficial geology was mapped at 1:20,000 scale. (Source: SGDR for DWR ULE Project, URS, 2010).
  - The information provided in these plans and stick-log plates has been compiled from a variety of sources. URS does not attest to the accuracy, completeness, or reliability of geotechnical exploration and other subsurface data by others that are included or referenced in these plates.
  - These plans and stick-log plates are for the use and benefit of HDR, SBFCA, and their consultants in connection with the execution of the FRWL Project. Use by any other party is at their own discretion and risk. These figures should not to be used as the sole basis for design, construction, remedial action, or major capital spending decisions.
  - The canal/ditch elevations are approximate. These elevations were estimated from the topography.



**FRWL Project Plan Views and Stick Log Figures**  
FRWL Project: Station 1510+00 to Station 1560+00

**URS** Geotechnical Design  
Recommendations Report

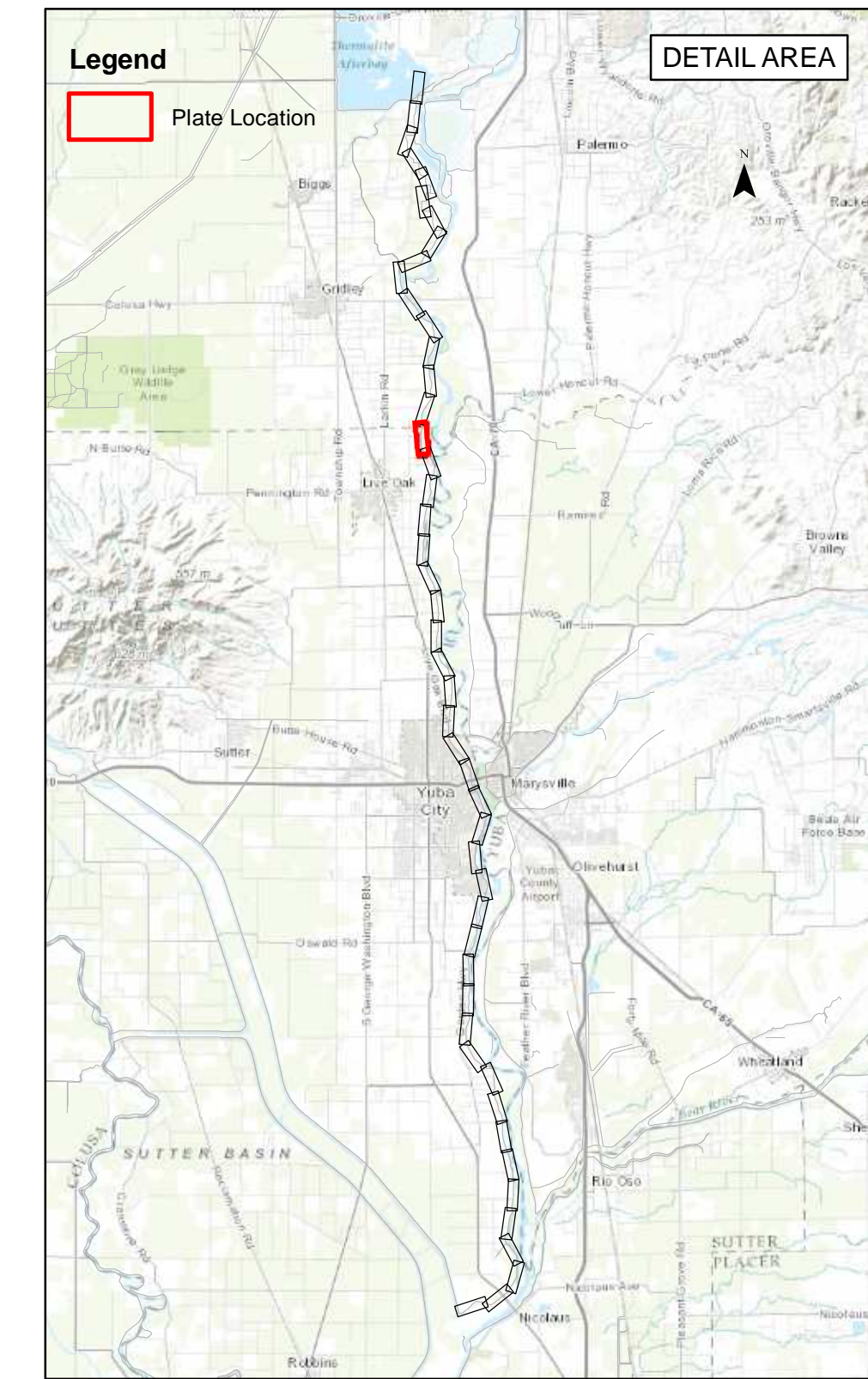
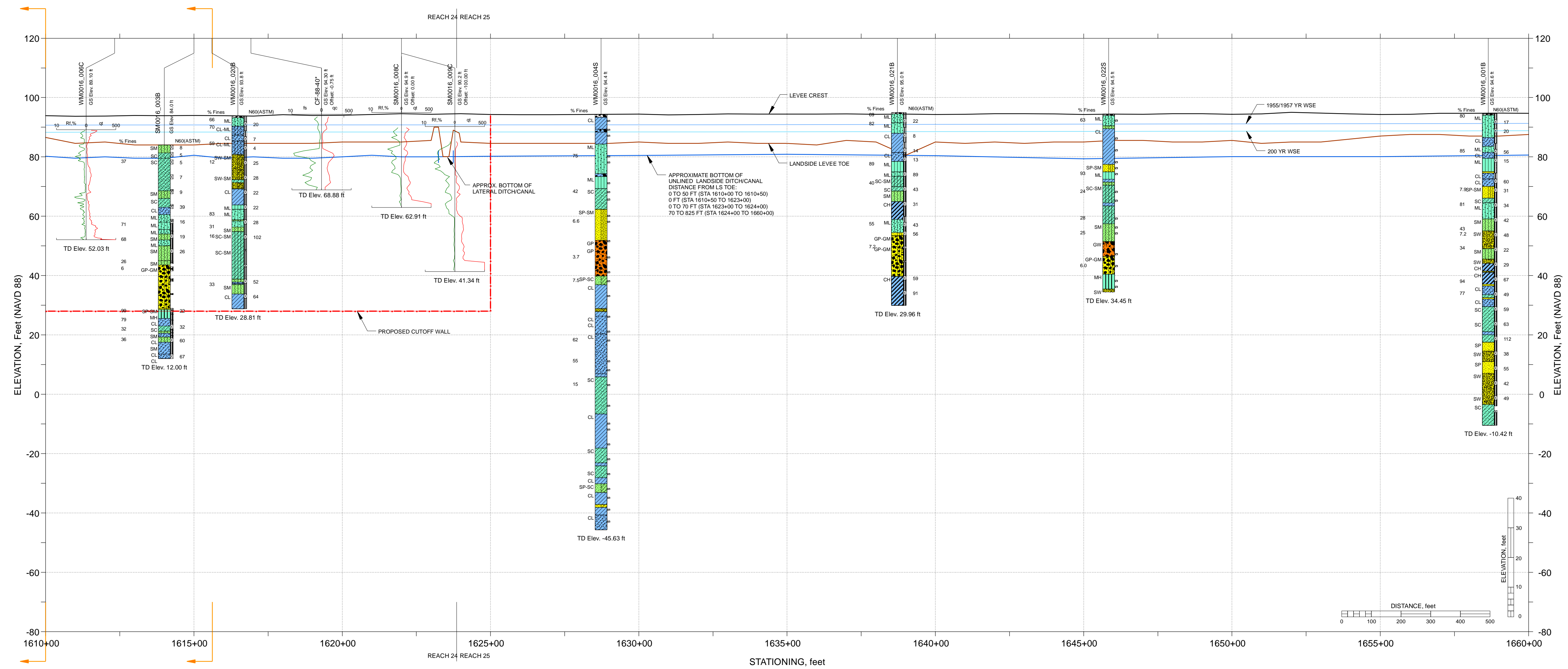
**Sutter Butte Flood Control Agency**  
FEATHER RIVER WEST LEVEE PROJECT

Appendix  
A33

L:\Projects\SBFCA\Drawings\SBFCA\_Plan\_Maps\map\_R1\_26\_Mar\_2013\_SAC



- NOTES:
- Elevations of levee crown and landside toe are approximate. These elevations were obtained from DWR CVFED or ULE LIDAR data and used for geotechnical analyses and report purpose only. For detail crown elevation and landside toe information, please refer to the FRWL Project civil drawings.
  - The water surface elevations are based on information provided by Peterson Brustad, Inc. in their July 26, 2012 report entitled "Design Water Surface Profiles for the Feather River West Levee Rehabilitation Project Addendum #1".
  - Locations of explorations are approximate. Stick logs represent general soil conditions encountered at the time of exploration. For more detailed information on the materials encountered, refer to boring and CPT logs in the Geotechnical Data Report for the FRWL Project. No warranty is provided regarding the continuity of soil conditions between individual explorations.
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  - These drawings do not include all historical explorations on the profile view. Historical explorations from the DWR ULE project are shown; "other" historical explorations are identified by an asterisk (\*) in the exploration ID. For these "other" historical borings, blow counts are field blow counts (Nf) and USCS classifications are visual classifications.
  - USCS classification labels are not presented on the stick logs for soil lenses (thickness less than 1.5 feet).
  - This is a color figure. Black and white reproduction should not be relied upon as data will be lost.
  - To prevent scale distortion, this map should be printed on a "D" size sheet (22x34 inches).
  - Surficial geology was mapped at 1:20,000 scale. (Source: SGDR for DWR ULE Project, URS, 2010).
  - The information provided in these plans and stick-log plates has been compiled from a variety of sources. URS does not attest to the accuracy, completeness, or reliability of geotechnical exploration and other subsurface data by others that are included or referenced in these plates.
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  - The canal/ditch elevations are approximate. These elevations were estimated from the topography.



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**APPENDIX A4**

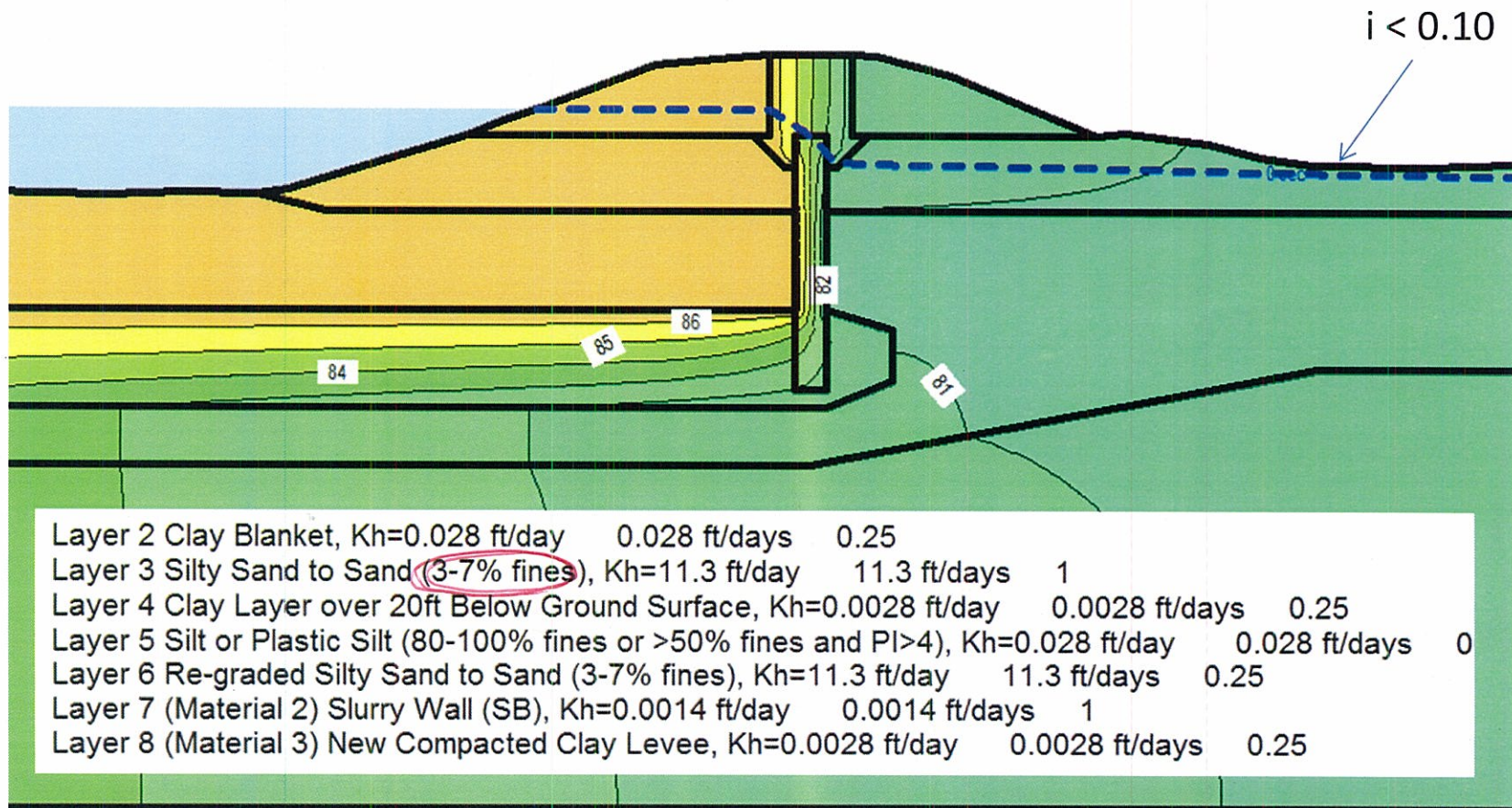
**Sensitivity Analysis**

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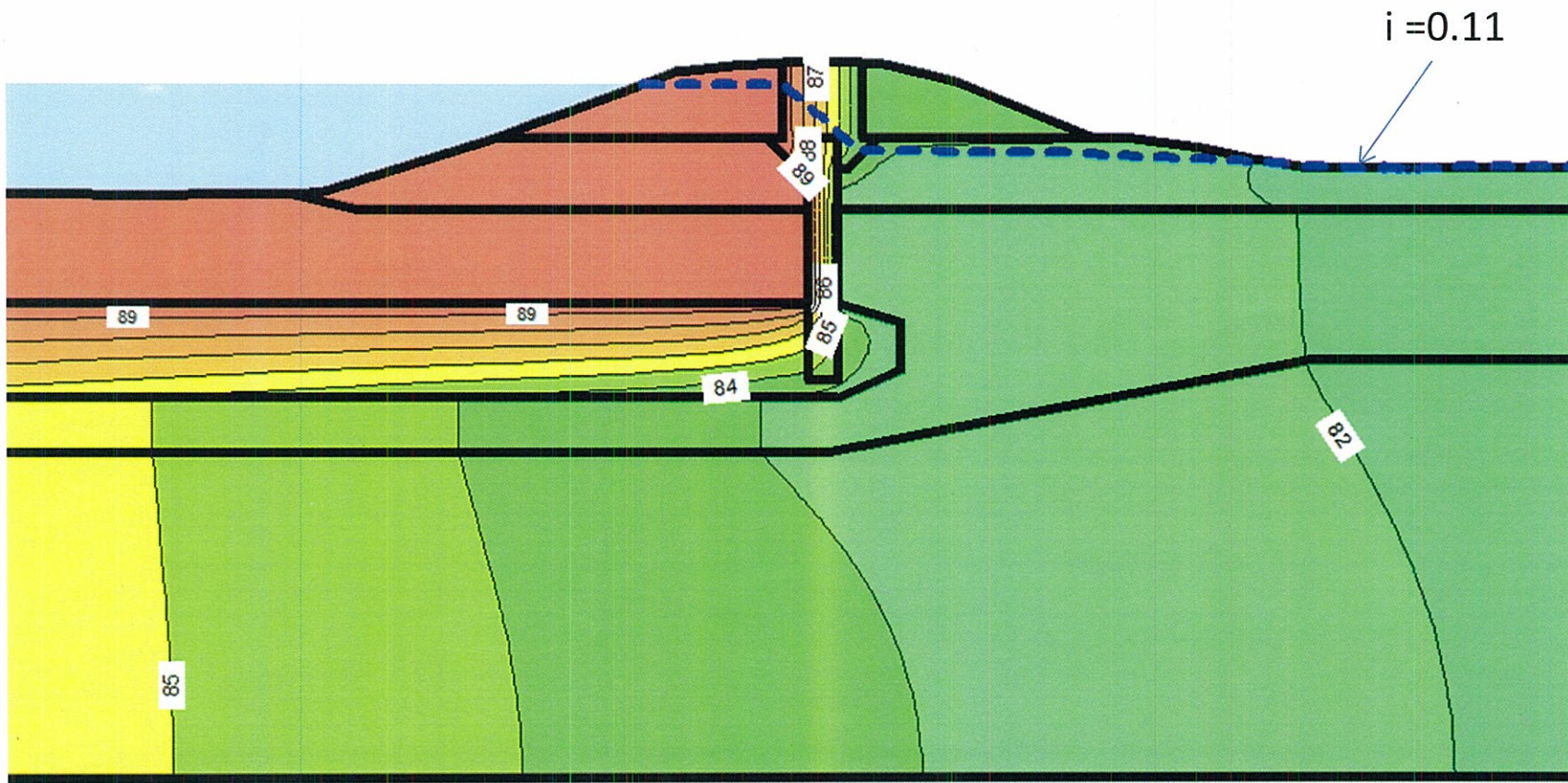
Reach 23

FRWL Sta. 1522+00: with landside ditch 500 feet from toe  
(200yr+1)



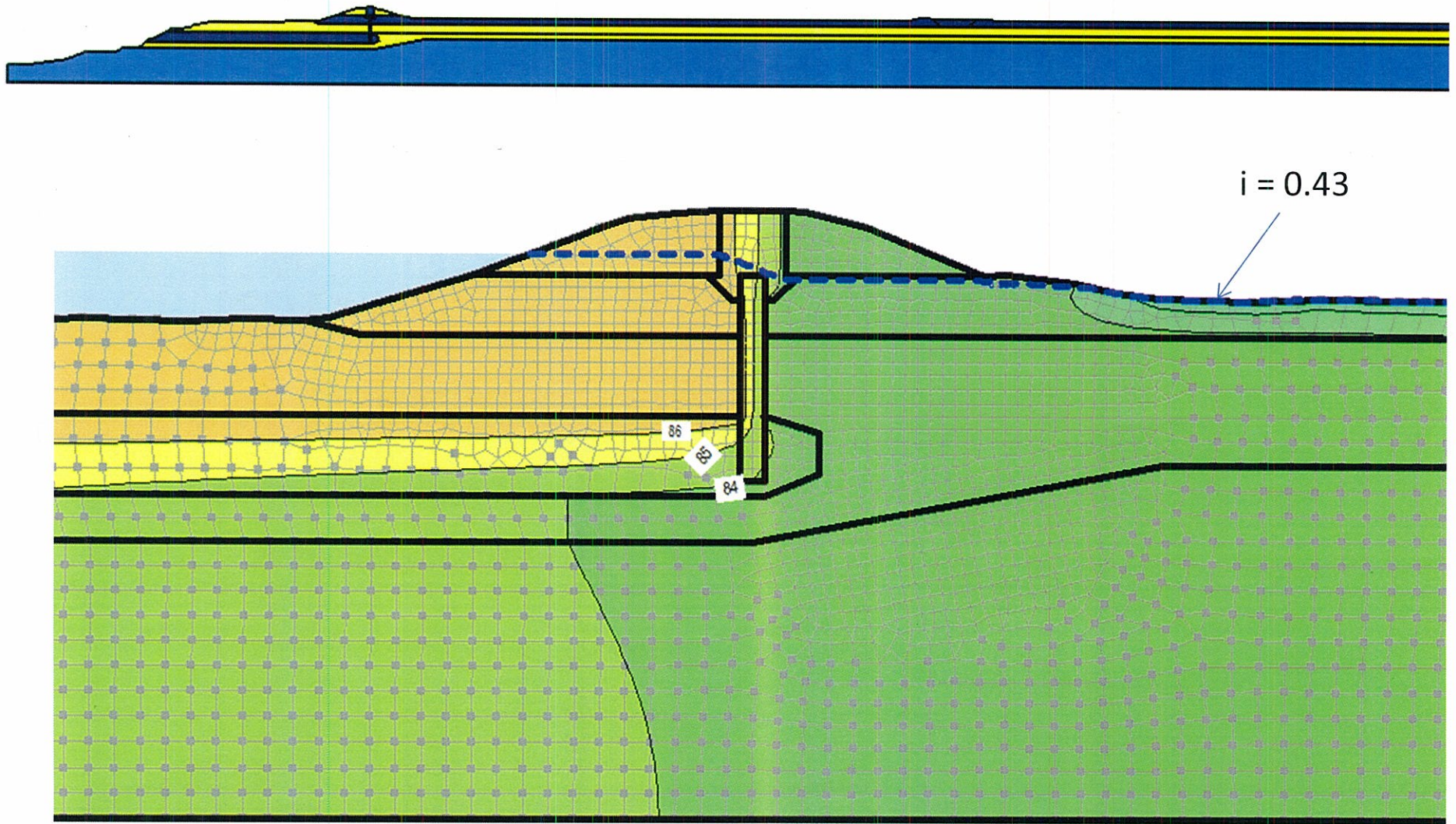
Reach 23

FRWL Sta. 1522+00: with landside ditch 500 feet from toe  
(200yr+4)



Reach 23

FRWL Sta. 1522+00: without landside ditch 500 feet from toe  
(200yr+1)



Reach 23

FRWL Sta. 1522+00: without landside ditch 500 feet from toe  
(200yr+4)

