Engineer's Report

Star Bend Setback Levee

Urban Levee Design Criteria Compliance

Sutter Butte Flood Control Agency

Sutter and Butte Counties, California

July 1, 2016

Letter of Transmittal

WOOD RODGERS
DEVELOPING INNOVATIVE DESIGN SOLUTIONS

Date: July 1, 2016

Job No. 8455.018

To: Sutter Butte Flood Control Agency
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Re: **Star Bend Setback Levee – Engineer's Report - Final**

We are sending you:
via: FedEx - Standard

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I. INTRODUCTION

A. Purpose

The purpose of this Draft Engineer's Report (Report) is to document substantial evidence of compliance with the Urban Levee Design Criteria (ULDC) in the record following the EVD-1 procedure in the California Department of Water Resources (DWR) Urban Level of Flood Protection (ULOP) Criteria for the Star Bend Setback Levee from Station 6+95 to 50+00 (Setback Levee Stations). It is noted that the Star Bend Setback Levee Project is located within the limits of Feather River West Levee Project Stations 473+75 and 512+00.

As stated in the ULOP, the EVD-1 procedure is as follows:

"EVD-1: Substantial evidence in the record to support a finding related to an urban level of flood protection based on flood management facilities providing the required level of flood protection shall include the following, at a minimum:

1. A report prepared by a Professional Civil Engineer registered in California to document the data and analyses for demonstrating that the property, development project, or subdivision has an urban level of flood protection.

2. A report by an Independent Panel of Experts on the review of the report prepared by the Professional Civil Engineer.

3. A response by the Professional Civil Engineer to the comments from the Independent Panel of Experts.

4. Any additional data and information that cities or counties use to make the finding."

This report is intended to serve as the first item of the above list. The report is prepared by the Sutter Butte Flood Control Agency's (SBFCA's) consultant, Wood Rodgers Inc. (Wood Rodgers), and the Report serves as the Engineer's Report for the Star Bend Setback Levee. A separate report is being prepared by the SBFCA design team consisting of HDR, Wood Rodgers, AECOM, MHM, Inc., and Peterson Brustad, Inc. (PBI) for the FRWL P1, which extends from the north end of the Star Bend Setback Levee to the Thermalito Afterbay.

B. Background

In 2007, the California Legislature passed, and the Governor signed, six bills related to flood protection. Senate Bill 5 (SB5) mandates that levees within the Sacramento-San Joaquin Valley protecting urban or urbanizing areas (defined as those areas that have or are projected to have populations of 10,000 persons or more) shall have a 200-year level

of flood protection by the year 2025. As amended, SB5 requires that cities and counties (land use decision making entities) make a finding related to an urban level of flood protection before approving development in urban and urbanizing areas. Developed areas that have or are projected to have populations of 10,000 persons or more within ten (10) years must have a 200-year level of flood protection, or have adequate progress toward a 200-year level of flood protection. The California Code of Regulations Sections 65865.5, 65962, and 66474.5 require that cities and counties make a finding related to flood protection before making development decisions after July 2, 2016.

SB 5 also authorized the DWR to develop criteria for an urban level of flood protection. In May 2012, DWR issued the ULDC, which provides technical criteria for designing, constructing, operating, and maintaining a levee or floodwall for protection against a flood with a 1-in-200 annual chance of occurrence (i.e., a 200-year flood). In November 2013, DWR issued ULOP criteria, which are procedural criteria for developing findings related to 200-year protection.

C. Project Background

In 2006, the U. S. Army Corps of Engineers (USACE) reinitiated the Sutter Basin Feasibility Study to evaluate alternatives to reduce flood damage in the Sutter Basin, which encompasses the urbanizing communities of Yuba City and Live Oak in Sutter County. A setback levee at Star Bend, located approximately seven miles south of Yuba City, is included as a component of 23 of the 24 preliminary alternatives developed for the study (USACE and the California Reclamation Board 2006). The USACE, as well as the Central Valley Flood Protection Board (CVFPB) (formerly known as the State Reclamation Board), characterized a setback levee at Star Bend as both an ecosystem restoration measure and a vital flood reduction structural measure for Levee District No. 1 of Sutter County (LD1). The setback levee would reduce the risk of flooding on 84.5 square miles of land in the southern portion of the Sutter Basin, between the southern portions of Yuba City and the confluence of the Feather River with the Sutter Bypass. In the Sutter Basin Pre-F4 document, dated November 2006, the USACE and CVFPB state that the project "would provide dual benefits of ecosystem restoration and flood damage reduction."

Concurrent with the development of the Sutter Basin Feasibility Study, local agencies identified a number of early implementation projects that are needed to correct known deficiencies, including the Star Bend Setback Levee (DWR 2008). In addition, California Governor Arnold Schwarzenegger signed legislation leading to the development of a comprehensive Central Valley Flood Protection Plan (CVFPP). On February 6, 2008, Governor Schwarzenegger announced that his administration was expediting funds to four critical early implementation projects, including $16.33 million to the CDWR to fund the construction of a setback levee at Star Bend. On April 23, 2008, DWR approved a funding agreement with LD1 and noted that the setback levee: (1) should be carried out

expeditiously prior to completing the CVFPP due to current conditions of the levee system; (2) would reduce risks to human lives in Yuba City; and, (3) would not impair or impede future changes to regional flood protection or the CVFPP. DWR's determinations indicated that setting back the levee at Star Bend had independent utility outside of the CVFPP or the Sutter Basin Feasibility Study processes and that implementation of the Star Bend Setback Levee could not wait for either planning process to be completed in another two to four years.

D. Project Description

The new setback levee consists of a 20 to 25-foot high earthen levee beginning at the intersection of Star Bend Road and the existing right bank of the Feather River and continuing in a southeasterly direction to the approximate intersection of the extension of Tudor Road with the Right bank of the Feather River. The total length of the setback is approximately 3,450 feet. The project is located within the limits of Sutter County, northeast of the intersection of State Highway 99 and the Garden Highway, south of Yuba City, Township 13 North, Range 3 East.

Civil Engineering Design and Project Management was the responsibility of Wood Rodgers. Geotechnical Engineering was performed by Blackburn Consulting (BCI). The Construction Manager on the Project was MHM, Inc. An Independent Panel of Experts consisting of Mr. Donald Babbitt, PE, and Dr. Faiz Makdisi, PhD, PE, D.GE, was convened for review of the project design and construction. Construction on the setback levee was completed in 2009.

The setback levee geometry consists of a levee top width of 20 feet, and side slopes that are 3 horizontal to 1 vertical (3:1). The foundation of the levee was excavated to provide an inspection trench (approximately 12 to 15 feet wide by 2 feet deep), and to construct a soil-bentonite (SB) cutoff wall to a depth of up to 65 feet below existing grade. The embankment was constructed with homogenous material meeting the type, permeability, and gradation requirements specified by USACE and DWR criteria.

Soil-Cement-Bentonite (SCB) cutoff walls were constructed at the tie-ins to the existing levee. These walls overlap the setback levee foundation cutoff wall by a minimum of 50 feet and extend into the existing levee embankments a minimum of 200 feet. To install the cutoff walls, the existing levee was degraded to a depth equal to 1/3 the levee height (as measured from the landside toe). The cutoff wall was constructed to a depth of 58 feet from the cutoff wall working platform at the north tie-in and 79 feet at the south tie-in. A total of 44,050 square feet of SCB Cutoff Wall and 181,076 square feet of SB cutoff wall were installed as part of the project.

Levee material for the project was obtained from the existing levee and borrow sources containing low-permeability soils within the O'Conner Lakes area, where material had

been borrowed previously for the USACE Shanghai Bend Setback Levee Project. Some additional material (approximately 51,000 cubic yards) was obtained from the Reclamation District 1001 borrow site located near State Highway 99 and Striplin Road (more specifically along Pacific Avenue). Material for construction of the slurry cutoff wall was excavated from the cutoff wall trench and mixed with bentonite slurry, cement (at the cutoff wall tie-in locations), and water to form an impermeable barrier three feet in width.

The completed setback levee was topped with an all-weather surface and the levee embankments were protected by applying erosion control seeding. The levee experienced good vegetative growth following seeding application. The existing levee embankment not borrowed for the construction of the new levee was disposed of by placing it as backfill at the on-site borrow sources.

E. 200-Year Floodplain Map

As a stand-alone project, the Star Bend Setback Levee does not provide 200-year protection to the areas landward of the new levee. However, as a component of the overall Feather River West Levee Project, the Star Bend Setback Levee provides 200-year protection to the southern portion of the Sutter Butte Basin.

II. DOCUMENTATION

This chapter is sub-divided into the respective criteria and guidance sections as outlined in Section 7.0 of the ULDC. For each section, a summary of the applicable ULDC criteria and references to documentation where detailed analyses have been performed and developed are provided in order to demonstrate compliance with the ULDC. At the end of each section, a ULDC Compliance Statement is provided and stamped by the registered professional engineer(s) in responsible charge of the project component.

A. Design Water Surface Elevation (ULDC Section 7.1)

1. Applicable ULDC Requirements

The ULDC offers two options for determining the Design Water Surface Elevation (DWSE) for levee system design in urban and urbanizing areas:

a. Federal Emergency Management Agency (FEMA) Approach

b. USACE Approach

For an urban or urbanizing area, the entire levee system needs to be designed to provide a ULOP Finding using only one of the two options. For the Star Bend Setback Levee Project, the FEMA approach, as summarized below, was used.

a. FEMA Approach – The DWSE should be computed using the median 200-year discharge rate for the design storm event at the site. Appropriately configured channel models are to be used for computation of the elevation that corresponds to that discharge, as described below. The median discharge rate is to be determined from the best available results of recent flood-frequency studies, and the channel models are to be configured using, or adjusted for, channel roughness values consistent with vegetation that is anticipated or likely to grow over the next 20 years.

The hydraulic models are to use the following assumptions:

a. Upstream, downstream, and nearby levees and floodwalls protecting urban areas are assumed to be raised to the median 200-year water surface elevation plus 3 feet and not allowed to breach, even if overtopped. Overtopping flows are assumed to leave the channel and remain in the 200-year floodplain.

b. All project levees and floodwalls are to be modeled to incorporate a minimum crown elevation equal to the authorized (usually the 1955/1957) USACE design profiles. Overtopping flows are assumed to leave the channel and remain in the 200-year floodplain.

c. Non-project levees and floodwalls in non-urbanized areas in the region, to the extent they may affect the DWSE, are to be modeled at their existing or authorized height, whichever is higher, and to act as weirs without breaching if overtopped.

d. Debris loading on bridges must be considered.

The median 200-year water surface elevation becomes the unadjusted DWSE, and the civil engineer considers adjustments described in the following Section.

a. DWSE Adjustments and Other Considerations

The civil engineer needs to consider making adjustments to the DWSE, and he needs to determine whether or not there are other scenarios that could increase the DWSE as a result of nearby or upstream levee or floodwall breaches, as discussed below.

The above procedures should generally result in a conservative DWSE. However, the civil engineer also needs to address two other situations: 1) whether upstream levee or floodwall breaches could produce overland flows that would reach the area protected by the levee system or increase the water surface elevation along the levee system; and (2) whether flooding in a nearby leveed area could fill that area and breach a nearby levee or floodwall, returning flow to the stream and increasing the DWSE for a portion of the levee system.

2. Documentation of ULDC Compliance

The following provides a summary of the detailed analyses and documentation that were performed and developed in order to bring the Star Bend Setback Levee into compliance with the ULDC. The section also provides a reference to the location where relevant documentation can be found as it pertains to ULDC Section 7.1.

The DWSE for the Star Bend Setback Levee is the USACE 1957 Feather River Hydraulic Design Flow Profile (see the Design Water Surface Profiles by PBI, **Reference 3**). The 1957 Hydraulic Design Flow Profile was obtained from Mr. Ethan Thompson, a hydraulic engineer from the USACE Sacramento office. The 1957 Hydraulic Design Flow Profile values provided by the USACE were compiled for the USACE's Yuba General Reevaluation Report. See **Exhibit 1** for the design water surface elevations along the FRWL right bank near Star Bend.

The minimum freeboard for the new setback levee is three feet above the USACE 1957 Hydraulic Design Flow Profile, including an adjustment of one foot of elevation for uncertainty and climate change (see **Section S – Sea Level Rise**). The top-of-

levee elevation for the proposed setback levee was set to be at least as high as the top-of-levee indicated in the USACE 1957 Design Profile exhibits. In all locations, the new top-of-levee elevation provides freeboard in excess of 3.60 feet (3.60 feet at the north tie-in point to 4.10 feet at the south tie-in point) over the USACE 1957 Hydraulic Design Flow Profile, see **Exhibit 2** and the Hydraulic and Hydrology Analysis (**Reference 2**).

It should be noted that the USACE 1957 Hydraulic Design Flow Profile at this location is higher in elevation than the 1-in-200 Annual Chance of Exceedance (ACE) event as calculated by PBI for the FRWL Project 1.

3. Conclusions

The Star Bend Setback Levee meets the DWSE requirements as prescribed in ULDC Section 7.1.

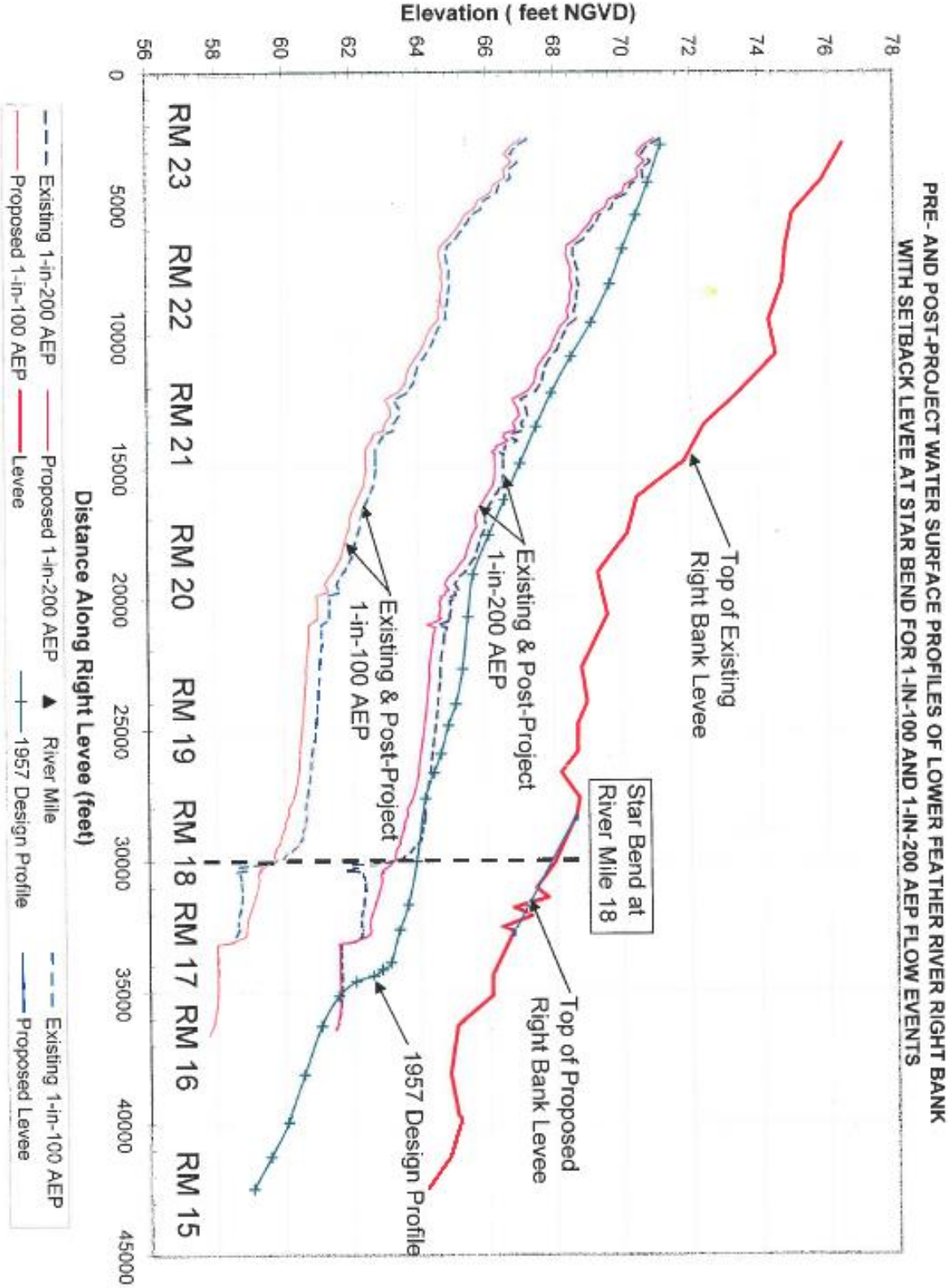

Exhibit 1: Setback Levee at Star Bend WSE Exhibit

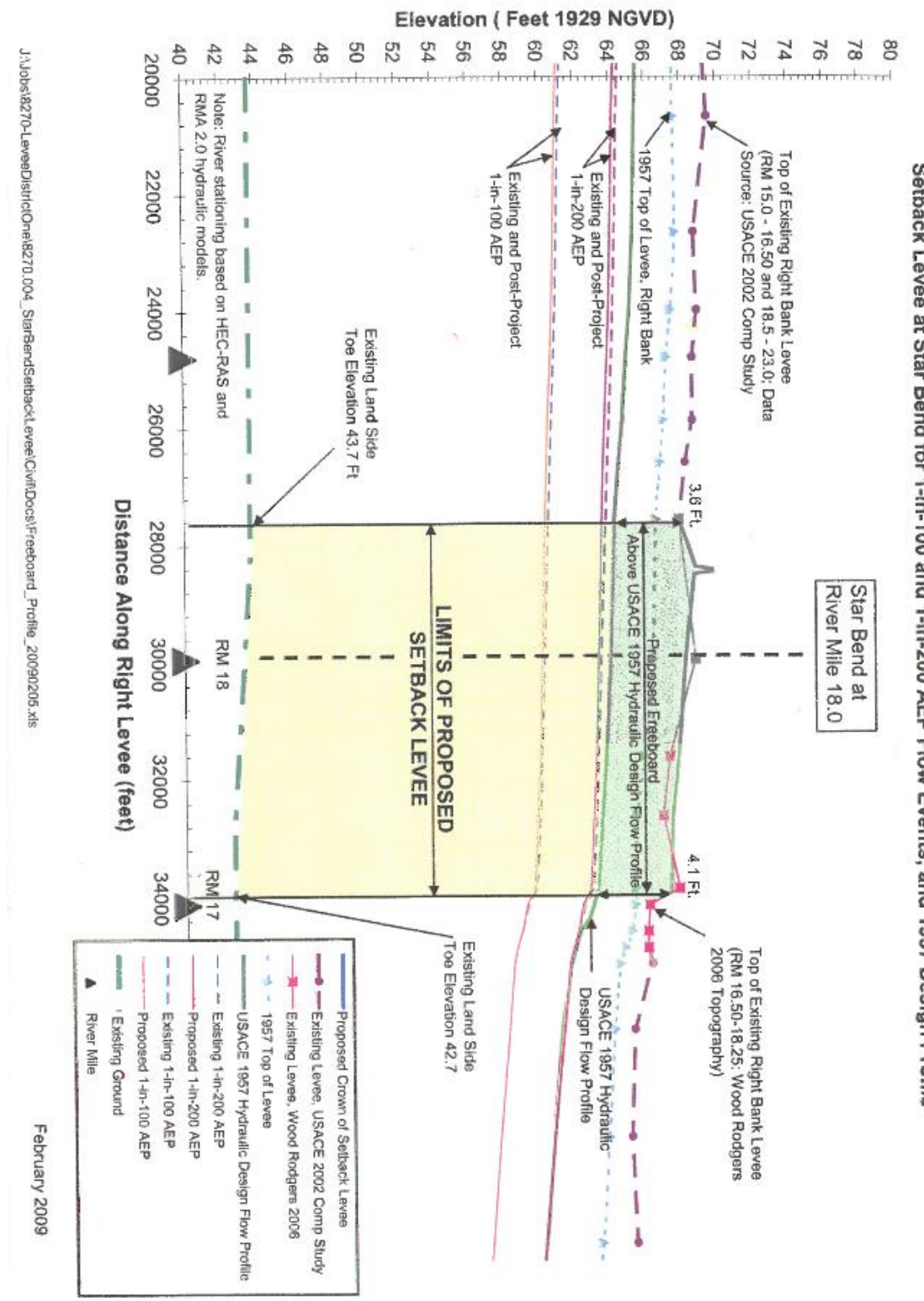

Exhibit 2: Water Surface Profiles and Freeboard

4. ULDC Compliance Statement

ATTACHMENT A
STAR BEND SETBACK LEVEE
DWR ULDC COMPLIANCE STATEMENT
SECTION 7.1 – DWSE

CALIFORNIA DEPARTMENT OF WATER RESOURCES
URBAN LEVEE DESIGN CRITERIA COMPLIANCE STATEMENT
SECTION 7.1 – DWSE

STAR BEND SETBACK LEVEE

As documented in this report entitled: *Star Bend Setback Levee Project, Urban Levee Design Criteria Compliance,* the Star Bend Setback Levee, a portion of the Feather River West Levee, complies with the requirements of California's May 2012 Urban Levee Design Criteria (ULDC) Section 7.1 – DWSE.

Professional Engineer in Responsible Charge:

June 30, 2016

Name: Jonathan L. Kors Date
California Professional Engineer No. C59538

B. Minimum Top-of-Levee (ULDC Section 7.2)

1. Applicable ULDC Requirements

The minimum top-of-levee (MTOL), which may be measured either along the levee centerline or the levee shoulder (and may include the roadway surface), is a required minimum elevation for the physical top of the levee to provide an adequate factor of safety that the levee will contain the 200-year flood without being overtopped. Under the FEMA Approach, freeboard is used to provide this factor of safety. Under the USACE Approach, this factor of safety is provided by a combination of freeboard and use of a DWSE with a high degree of assurance (either 90-percent assurance or 95-percent assurance). Levees that meet the MTOL requirement are considered to be high enough to keep water out of the leveed area for the 200-year flood. Conversely, levees that are lower than the MTOL lack an adequate factor of safety for containment and are less likely to keep water out of the leveed area for the 200-year flood. Unless such levees are designed for overtopping, they cannot be assumed to sustain overtopping during the 200-year flood without substantial damage or breaching. Levees that fail to meet elevation requirements are not generally accredited under FEMA or USACE guidelines for FEMA flood insurance studies (so the floodplain mapping study would assume the levee is absent or breached). There may be rare situations, however, where it is prohibitively expensive to meet the MTOL requirement, and an alternative engineering solution can be employed (for example, where clearance requirements for overhead power lines are a constraint). Such cases must be approved as an exception and must address the prospect that the 200-year flood could overtop the levee and flood property in the leveed area, and could also breach the levee.

Using the FEMA Approach, the MTOL is the higher of the DWSE plus 3 feet, or the DWSE plus the computed wind setup and wave run-up.

Specific wind-wave analyses need to be completed using the DWSE. For the special case of the DWSE being fully contained within the channel, so that the reach of levee is only providing freeboard, it is recognized that floodplain mapping procedures generally would not require such a levee. This is because floodplain mapping procedures would identify the 200-year floodplain as being fully contained within the channel, with no overbank flow. Therefore, a city or county that chooses not to find that the freeboard levee complies with the ULDC can still find that the area that would have been protected by the freeboard levee has an urban level of flood protection (if it is not subject to flooding from other sources). The civil engineer should carefully consider providing a freeboard levee in this case, weighing the consequences of flooding caused by waves or by water surface elevations that exceed the DWSE in the event it is underestimated or exceeded by a larger flood.

Using the USACE Approach, the MTOL is the higher of either: (1) the DWSE, (2) the median 200-year water surface elevation plus adjustments and 3 feet, or (3) the median 200-year water surface elevation plus adjustments and computed wind setup and wave run-up. Specific wind and wave analyses need to be completed using the median 200-year water surface elevation after adjustment. A lower MTOL is allowed if it is both: 1) at or above the 95-percent assurance, 200-year water surface elevation; and, 2) at least two feet above the median 200-year water surface elevation, plus any additional height needed to account for wind setup and wave run-up. Under this approach, a freeboard levee is required if the median 200-year water surface elevation is less than two feet below the top-of-bank; and it may be required for a lower median 200-year water surface elevation.

2. Documentation of ULDC Compliance

The following provides a summary of the detailed analyses and documentation that were performed and developed in order to bring the Star Bend Setback Levee into compliance with the ULDC. The section also provides a reference to the location where relevant documentation can be found as it pertains to ULDC Section 7.2.

MTOL for the setback levee was determined by matching the existing top-of-levee at each end of the levee. Construction of the cutoff wall at the north end of the levee reconfigured the existing Star Bend Road levee crossing, and the levee was constructed to produce a straight-line grade between the top-of-levee at the south and north ends of the Project (see SBSL Basis of Design, **Reference 1**). This profile was then compared to the design water surface elevations for the Setback Levee Project (see **Section A – Design Water Surface Elevation**). It was determined that the straight-line grading between the project start and end points provided more than three feet of freeboard above the DWSE. The DWSE was based on the 1957 hydraulic design flow profile. At this location, the USACE 1957 hydraulic design flow profile was higher in elevation than the 1-in-200 ACE water surface (see **Reference 3**) including an adjustment of one foot of elevation for uncertainty and sea level rise (see **Section S – Sea Level Rise**). A wind and wave analysis was performed (see **Section Q – Wind Setup & Wave Run-up**), which confirmed that the three feet of freeboard was adequate.

The analysis showed that levee height set by matching the exiting levee height at the beginning and end of the project met all the necessary design criteria for the MTOL. See **Exhibit 3**.

3. Conclusion

The Star Bend Setback Levee meets the MTOL requirements described in ULDC Section 7.2.

4. ULDC Compliance Statement

ATTACHMENT A
STAR BEND SETBACK LEVEE
DWR ULDC COMPLIANCE STATEMENT
SECTION 7.2 – MINIMUM TOP-OF-LEVEE

CALIFORNIA DEPARTMENT OF WATER RESOURCES
URBAN LEVEE DESIGN CRITERIA COMPLIANCE STATEMENT
SECTION 7.2 - Minimum Top-of-Levee

STAR BEND SETBACK LEVEE

As documented in this report entitled: *Star Bend Setback Levee Project, Urban Levee Design Criteria Compliance,* the Star Bend Setback Levee, a portion of the Feather River West Levee, complies with the requirements of California's May 2012 Urban Levee Design Criteria (ULDC) Section 7.2 – Minimum Top-of-Levee.

Professional Engineer in Responsible Charge:

REGISTERED PROFESSIONAL ENGINEER
JONATHAN L. KORS
C59538
EXP. 12-31-17
CIVIL
STATE OF CALIFORNIA

June 30, 2016

Name: Jonathan L. Kors *Date*
California Professional Engineer No. C59538

C. Soil Sampling, Testing and Logging (ULDC Section 7.3)

1. Applicable ULDC Requirements

Per ULDC Section 7.3, soil sampling, testing, and logging should follow standard procedures described in current guidance documents from USACE; U.S. Department of the Interior, Bureau of Reclamation; DWR; and others – such as the USACE Sacramento District's Geotechnical Levee Practice Standard Operating Procedures and DWR's Division of Flood Management Soil and Rock Logging, Classification, Description and Presentation Manual (2009), exercising proper care to:

- Sample soils, especially soft soils, used for strength and deformation analysis in a way that minimizes disturbance.
- Evaluate hydraulic conductivity using appropriate grain size analyses (including hydrometer) along with confirmatory laboratory permeability testing. Where appropriate, perform field pumping/infiltration testing to measure in-situ properties.
- Perform consolidation tests that ensure the strain level exceeds virgin compression.
- Conduct strength tests with appropriately low strain rates and reflective of the low confining pressures near the landside levee toe.
- Use an appropriate field logging manual, such as appropriate American Society for Testing and Materials (ASTM) guidance and DWR's Division of Flood Management Soil and Rock Logging, Classification, Description and Presentation Manual.

The Sacramento District Geotechnical Levee Practice Standard Operating Procedures suggests that explorations should generally be located on 1,000 to 2,000 feet horizontal spacing, at the waterside toe, levee crown, landside toe, and on the landside of the levee.

2. Documentation of ULDC Compliance

This section describes the quantity and type of subsurface explorations performed, the quantity and type of laboratory tests performed, and the type and general results of tests performed during the Star Bend Setback Levee design and construction. See the Soil Sampling, Testing and Logging Technical Memorandum by BCI (**Reference 4**) for additional details.

a. Soil Sampling and Logging

BCI performed a total of 13 exploratory borings, 13 Cone Penetrometer Tests (CPTs), and 36 test pits for the Star Bend Setback Levee design in 2006 and 2007 to obtain subsurface soil and ground water information and samples for laboratory tests. An experienced BCI engineer/geologist logged the soils encountered in the exploratory borings and test pits consistent with the Unified Classification System (USCS) and BCI's field logging manual, and obtained pocket penetrometer measurements on fine-grained soil samples. BCI made ground water observations in the borings during drilling operations. Design explorations included:

- 11 exploratory borings and CPTs to depths of 61.5 to 105.5 feet below the ground surface (bgs) along the new setback levee alignment.
- 4 exploratory borings and CPTs to depths of 26.5 to 76.5 feet bgs waterside of the new setback alignment on the old, existing levee crown.
- 11 exploratory borings and CPTs to depths of 6.5 to 90 feet bgs landside of the new setback levee alignment.
- 9 test pits to depths of 5.5 to 13 feet bgs along the new setback levee alignment.
- 27 test pits to depths of 5 to 19 feet bgs in waterside borrow areas.

BCI also used 7 explorations performed by URS for the DWR Urban Levee Evaluation Program. These explorations along the old, existing levee crown (waterside of the new Setback Levee alignment) ranged in depth from 110 to 140 feet bgs. The explorations included 3 exploratory boring and 4 CPTs. See Soil Sampling TM (**Reference 4**) for the exploration boring logs and CPT plots.

b. Laboratory Testing

Design – BCI performed laboratory tests on representative soil samples obtained from the exploratory borings and test pits. Tests included:

- Moisture content and dry unit weight (ASTM D2216) to estimate in-situ soil conditions and design parameters.
- Sieve analyses (ASTM D422) and percent finer than the No. 200 sieve (ASTM D1140) to estimate particle size distribution for hydraulic conductivity correlations and liquefaction analysis.

- Atterberg limits (ASTM D4318) to determine the liquid limit, plastic limit and plasticity index for hydraulic conductivity correlations and settlement parameter correlations.
- Optimum moisture and maximum density compaction curves (ASTM D698) to estimate parameters for remolded triaxial compression tests and stability analysis.
- Unconfined compressive strength (ASTM D2166) to estimate strength parameters for stability analysis and settlement parameter correlations.
- Consolidated undrained triaxial compression with pore-water pressure measurements (ASTM D4767) to estimate strength parameters for stability analysis.

BCI performed laboratory tests in accordance with current ASTM test methods. See the Soil Sampling TM (**Reference 4**) for the complete lab result reports. **Table 1** presents the BCI Star Bend Setback Levee test quantities.

Table 1: Quantity of Geotechnical Laboratory Tests Performed for Design

Moisture Content and Dry Unit Weight	Sieve Analyses	Atterberg Limits	Strength Tests (UC and CUw/PP)	Compaction Curves
42	29	56	11	4

Construction – The Star Bend Setback Levee embankment and slurry cutoff wall construction included Quality Control (QC) and Quality Assurance (QA) tests to document compliance with the contract plans and specifications. **Table 2** through **Table 4** summarize the quantity of tests performed and test result statistics from the construction closeout report.

Table 2: Levee Embankment Material						
	Liquid Limit	**Plastic Limit**	**Plasticity Index**	**Passing No. 200 (%)**	**Max Dry Density (pcf)**	**Relative Compaction (%)**
No. of Tests	1,262	1,262	1,262	1,259	901	901
Average Test Result	31	17	14	73	115	102
Median Test Result	31	17	14	72	115	102
Maximum Test Result	45	27	29	94	128	112
Minimum Test Result	22	12	7	22	102	94

Table 3: Soil Bentonite Cutoff Wall (42.1 ft) Station 11+16 to 30+00		
	Hydraulic Conductivity (cm/sec)	
	QC Testing	**QA Testing**
No. of Tests	38	9
Average Test Result	3.80E-08	4.38E-08
Median Test Result	3.64E-08	3.70E-08
Maximum Test Result	6.73E-08	6.70E-08
Minimum Test Result	2.32E-08	2.80E-08

Table 4: Soil Bentonite Cutoff Wall (65.0 ft) Station 29+50 to 46+00		
	Hydraulic Conductivity (cm/sec)	
	QC Testing	**QA Testing**
No. of Tests	33	7
Average	5.62E-08	6.64E-08
Median	5.87E-08	6.90E-08
Maximum	8.72E-08	8.40E-08
Minimum	3.07E-08	4.10E-08

3. Conclusions

BCI performed soil sampling, testing and logging during the Star Bend Setback Levee design in accordance with generally accepted geotechnical engineering principles and practices. These practices substantially meet the May 2012 ULDC, Section 7.3 criteria.

More specifically:

- BCI's soil sampling and logging procedures substantially comply with current USACE and DWR guidance documents.
- BCI's soil sampling, including soft soil sampling, for strength and deformation analysis are performed in a way that minimizes sample disturbance such as Shelby Tube sampling for soft soil.
- BCI used grain size analyses and correlations with the Sutter County USDA for hydraulic conductivity values. BCI compared these values with those used in the area for the Star Bend Setback Levee ULOP Underseepage Analysis for Intermittently Loaded Levees TM consistent with standard of care in the area for levee design.
- BCI performed the Star Bend Setback Levee settlement evaluation using estimated settlement parameters based on published correlations with in-situ test data and SPT data. No detrimental settlement has occurred since construction in 2009.
- BCI performed strength tests at appropriately low strain rates.
- BCI's field logging procedures substantially meet ASTM guidance as well as the DWR Manual.

Testing performed during levee embankment and slurry cutoff wall construction documents that the Star Bend Setback Levee was constructed in compliance with the contract plans and specifications.

4. ULDC Compliance Statement

ATTACHMENT A
STAR BEND SETBACK LEVEE
DWR ULDC COMPLIANCE STATEMENT
SECTION 7.3 –SOIL SAMPLING, TESTING, AND LOGGING

CALIFORNIA DEPARTMENT OF WATER RESOURCES
URBAN LEVEE DESIGN CRITERIA COMPLIANCE STATEMENT
SECTION 7.3 – SOIL SAMPLING, TESTING, AND LOGGING

STAR BEND SETBACK LEVEE

As documented in this report entitled: *Star Bend Setback Levee Project, Urban Levee Design Criteria Compliance,* the Star Bend Setback Levee, a portion of the Feather River West Levee, complies with the requirements of California's May 2012 Urban Levee Design Criteria (ULDC) Section 7.3 – Soil Sampling, Testing and Logging.

Professional Engineer in Responsible Charge:

June 30, 2016

Name: Robert B. Lokteff, P.E., G.E. *Date*
California Geotechnical Engineer No. 2589

D. Slope Stability for Intermittently Loaded Levees (ULDC Section 7.4)

1. Applicable ULDC Requirements

a. Landside Slope Stability

Landside slope stability analyses are to use appropriate phreatic surfaces based on the DWSE and Hydraulic Top-of-Levee (if the HTOL is more than 0.5 foot above the DWSE – otherwise a separate slope stability analysis with the HTOL is not required). A minimum factor of safety of 1.4 is required for failure surfaces based on the DWSE that intersect the levee crown and are greater than a few feet deep in the levee slope. A minimum factor of safety of 1.2 is required for failure surfaces based on the HTOL that intersect the levee crown and are greater than a few feet deep in the levee slope, as discussed later.

b. Waterside Slope Stability

A rapid lowering of water level from a sustained high water condition causes rapid drawdown loading of a levee's waterside slope. This condition may occur due to either a decrease in upstream reservoir releases, decreases in surface drainage inflow, or as a result of a levee or floodwall breach in an adjacent/upstream levee reach. The rapid drawdown shall be considered from the DWSE. The amount of drawdown should be established based on site-specific data and/or hydrologic and hydraulics studies, using sound engineering judgment. As per USACE guidance, a factor of safety for stability of 1.0 to 1.2 is required, depending on the extent to which the DWSE may have saturated the waterside levee slope.

2. Documentation of ULDC Compliance

This section contains BCI's evaluation of the Star Bend Setback Levee with respect to its ability to provide an urban level of flood protection meeting the ULDC Slope Stability Criteria for Intermittently Loaded Levees.

a. Cross Section Development

BCI conducted slope stability evaluations using cross-sections developed for BCI's underseepage evaluation at Sta. 20+46.18 and Sta. 39+46.18. For BCI's slope stability analysis, BCI assumed that the setback levee material properties and geometry are generally consistent along the entire alignment.

See our concurrent Underseepage Analysis for Intermittently Loaded Levees Technical Memorandum (Reference 5) for information on how we developed

the cross-sections and subsurface characterization profiles used in this analysis, as well as the geologic profiles corresponding to the project site.

BCI presents the cross-section for Sta. 20+46.18 including explorations and subsurface characterization in Figure 4, and the cross-section for Sta. 39+46.18 including explorations and subsurface characterization in Figure 5. The boring logs and CPT plots BCI used to develop the cross-sections are included in the Underseepage Analysis TM (**Reference 5**). Relevant laboratory test results are included in the Slope Stability for Intermittently Loaded Levees TM (**Reference 5**).

b. Water Surface Elevations

Table 5 presents the water surface elevation (WSE) and rapid drawdown (RDD) conditions considered for this analysis.

Wood Rodgers provided 200-year-flood and 500-year-flood WSEs as determined by PBI for the Feather River West Levee Project. At the direction of Wood Rodgers, BCI added 1 foot to the 200-year WSE to account for climate change, potential hydrologic/hydraulic model variations, or sea-level rise. For the HTOL underseepage analyses BCI used the lower of the 200-year-flood WSE + 3 feet and 500-year-flood WSE as specified in the ULDC.

The URS approach for Rapid Drawdown Analysis Technical Memorandum (December 2011) provided Feather River West Levee rapid drawdown analysis and water level drop recommendations. URS identified that a 200-year flood is likely a short lasting high stage event. URS based their recommendations for water surface drop and average WSEs from available hydrographs along the Feather River West Levee. For this RDD analysis, BCI used the DWSE condition with a 26-foot-drop level consistent with the December 2011 URS TM.

Table 5: Water Surface Conditions Used in This Slope Stability Analysis

Cross-Section	HEC-RAS SBFCA/ FRWL Station	DWSE (NAVD 88)	HTOL (NAVD 88)		RDD
		200-yr. + 1' (feet)	500-yr. WSE (feet)	200-yr. + 3' (feet)	Drop Level (feet)
Station 20+46.18	RM 18.30	67.20	70.74	69.20	26.0
Station 39+46.18	RM 17.86	66.09	69.49	68.09	26.0

c. Strength Parameter Selection

To determine strength parameters, BCI compared the 2006 Geotechnical Report and its 2007 Addendum No. 1 material properties and laboratory test results with SBFCA FRWL evaluations, Urban Levee Evaluation (ULE) Guidance Document and the Star Bend Setback Levee Construction Completion Report. A tabulated comparison of these strength parameters is included in Appendix D of the Slope Stability for Intermittently Loaded Levees TM (**Reference 5**).

Recommended material strength parameters are presented in **Table 6** and are followed by the parameter selection rationale.

Table 6: Strength Parameters Used in This Slope Stability Analysis

USCS Designation		Soil Description	Unit Weight	ϕ' (deg)	c' (psf)	ϕ^{total} (deg)	c^{total} (psf)
(1) SB Cutoff Wall		Soil bentonite cutoff wall	100	0	300	0	300
(2) CL		Newly compacted clay levee fill	130	33	100	15	100
(3) CL		Deeper clay	115	31	100	17	150
(4) CL/ML		Soft or desiccated clay/silt blanket, upper layers	120	31	75	18	150
(5) CL/MH		Sandy clay/plastic silt	125	31	75	18	150
(6) SP		Poorly-graded sand (Less than 5% fines)	120	36	0	---	---
(7) SP-SM		Poorly-graded sand with silt (5% - 12% fines)	120	35	0	---	---
(8) SM		Silty sand with variable percent fines	120	33	0	---	---

d. Strength Parameter Selection Rationale

SB Cutoff Wall: BCI recommends a 0° effective and total friction angle and 300 psf effective and total cohesion for the SB slurry wall strength parameters consistent with the ULE Guidance document and the previous SBFCA FRWL evaluations.

Mechanically compacted levee fill (CL): Construction records show that the levee fill consists of lean clay, silt, sandy lean clay, clayey sand, and sandy silt

compacted to an average 102% relative compaction based on ASTM D 698. The records also indicate a Liquid Limit (LL) range from 22 to 45 with an average of 31, a Plasticity Index (PI) range from 7 to 29 with an average of 14, and a fines content (% Fines) range from 22% to 94% with an average of 73%.

BCI performed consolidated, undrained compressive strength tests on remolded samples from borrow sites as part of the 2006-2007 Star Bend Setback Levee design. One sample, B1-06 Bulk #1 (LL = 38, PI = 13, % Fines = 75%), had similar index properties to the material used in the SBSL construction and strength values similar to those previously used in the SBFCA FRWL levee evaluations. BCI recommends an effective friction angle of 33°, an effective cohesion of 100 psf, a total friction angle of 15°, and a total cohesion of 100 psf, consistent with the triaxial test results.

Deeper clay (CL): Using subsurface explorations deeper than 50 feet, BCI identified a stiff high plasticity soil. BCI recommends an effective friction angle of 31°, an effective cohesion of 100 psf, a total friction angle of 17°, and a total cohesion of 150 psf. These strength values are similar to those previously used in the SBFCA FRWL levee evaluations and are bracketed by the recommended ULE Guidance Document design strength values.

Soft or desiccated clay/silt blanket (CL/ML): Existing borings and test pits indicate an approximately 10-foot-thick clay and silt blanket. BCI recommends an effective friction angle of 31°, an effective cohesion of 75 psf, a total friction angle of 18°, and a total cohesion of 150 psf. These strength values are similar to those previously used in the SBFCA FRWL levee evaluations and are bracketed by the recommended ULE Guidance Document design strength values.

Sandy clay/elastic silt (CL/MH): Existing subsurface explorations indicate a stiff sandy clay or elastic silt layer. BCI recommends an effective friction angle of 31°, an effective cohesion of 75 psf, a total friction angle of 18°, and a total cohesion of 150 psf. These strength values are similar to those previously used in the SBFCA FRWL levee evaluations and are bracketed by the recommended ULE Guidance Document design strength values.

Poorly-graded sand (SP): BCI identified material as relatively clean poorly-graded sand with apparent density varying from very loose to dense. For this analysis, BCI used an effective friction angle of 36°. This effective friction angle is similar to friction angles for clean, poorly-graded sands used in the previous SBFCA FRWL levee evaluations.

Poorly-graded sand with silt (SP-SM): BCI identified material below the relatively impermeable cutoff layer as medium dense to dense poorly-graded sand with few fines. BCI recommends an effective friction angle of 35°, similar to values used in the SBFCA FRWL levee evaluations.

Silty sand (SM): BCI identified material as silty sand with varying fines. BCI recommends an effective friction angle of 33°, similar to values used in the SBFCA FRWL levee evaluations.

e. Analysis Methodology

BCI performed two-dimensional, finite element analysis using SLOPE/W, Version 7.23, with the proposed strength values presented in **Table 6**.

For landside steady-state slope stability analysis, BCI used:

- The Spencer limit-equilibrium method of analysis,
- Effective shear strengths as shown in **Table 6**,
- Pore pressures imported from the SEEP/W models,
- A tension crack search, which prevents the application of unrealistic tensile strengths in the levee embankment,
- Failure surfaces that intersect the levee crown and are greater than a few feet deep in the levee slope.
- ULDC DWSE Steady-State Landside Slope Stability Criteria: Factor of Safety greater than 1.4.
- ULDC HTOL WSE Steady-State Landside Slope Stability Criteria: Factor of Safety greater than 1.2

For rapid drawdown waterside slope stability analysis, BCI used:

- The three-stage rapid drawdown method in SLOPE/W, which follows the method developed by Duncan, Wright, and Wong.
- Both the effective and total strengths shown in Table 6, in accordance with the three-stage method.
- Pre-drawdown WSE equal to the DWSE and a 26-foot drop level as recommend by URS.
- Considered short period pool levels per USACE Manual for Levee Design and Construction (April 2010).

- ULDC RDD Waterside Slope Stability Criteria for short period pool levels: Factor of Safety greater than 1.0.

f. Analysis Results

We present the summary of BCI's Slope/W steady-state landside slope stability analysis results using DWSE seepage conditions in **Table 7**, the summary of Slope/W steady-state landside slope stability analysis results using HTOL seepage conditions in **Table 8** and the summary of rapid drawdown slope stability analysis results are presented in **Table 9**. A discussion of the results for each cross-section follows.

Table 7: DWSE Landside Steady-State Slope Stability Results

Location	DWSE 200-yr.+1' (NAVD 88) (feet)	Landside Steady-State Factor of Safety	*ULDC Factor of Safety Requirement*
Station 20+46.18	67.20	2.28	*≥ 1.4*
Station 39+46.18	66.09	2.24	*≥ 1.4*

Table 8: HTOL Landside Steady-State Slope Stability Results

Location	HTOL 200-yr.+3' (NAVD 88) (feet)	Landside Steady-State Factor of Safety	ULDC Factor of Safety Requirement
Station 20+46.18	69.20	2.26	≥ 1.2
Station 39+46.18	68.09	2.19	≥ 1.2

Table 9: Rapid Drawdown Waterside Slope Stability Results

Location	Rapid Drawdown WSE		Waterside Factor of Safety	ULDC Factor of Safety Requirement for Short Lasting High Stage Event [a]
	DWSE 200-yr.+1' (NAVD 88) (feet)	Water Surface Drop (feet)		
Station 20+46.18	67.20	26	1.18	≥ 1.0
Station 39+46.18	66.09	26	1.14	≥ 1.0

[a]Table 7-2. Urban Levee Design Criteria Summary for Intermittently Loaded Levees, May 2012 ULDC

g. Station 20+46.18

For the DWSE of 67.20 feet, the calculated factor of safety of 2.28 meets the ULDC factor of safety criterion of ≥ 1.4.

For the HTOL WSE of 69.20 feet, the calculated factor of safety of 2.26 meets the ULDC factor of safety criterion of ≥ 1.2.

For the DWSE WSE of 67.20 feet and a 26-foot water surface drop, the calculated factor of safety of 1.18 meets the ULDC factor of safety criterion of ≥ 1.0.

h. Station 39+46.18

For the DWSE of 66.09 feet, the calculated factor of safety of 2.24 meets the ULDC factor of safety criterion of ≥ 1.4.

For the HTOL WSE of 68.09 feet, the calculated factor of safety of 2.19 meets the ULDC factor of safety criterion of ≥ 1.2.

For the DWSE WSE of 66.09 feet and a 26-foot drop, the calculated factor of safety of 1.14 meets the ULDC factor of safety criterion of ≥1.0.

3. Conclusions

Our analysis indicates the Star Bend Setback Levee meets the ULDC Slope Stability Criteria for intermittently loaded levees.

4. ULDC Compliance Statement

ATTACHMENT A
STAR BEND SETBACK LEVEE
DWR ULDC COMPLIANCE STATEMENT
SECTION 7.4 –SLOPE STABILITY FOR INTERMITTENTLY LOADED LEVEES

CALIFORNIA DEPARTMENT OF WATER RESOURCES URBAN LEVEE DESIGN CRITERIA COMPLIANCE STATEMENT SECTION 7.4 – SLOPE STABILITY FOR INTERMITTENTLY LOADED LEVEES

STAR BEND SETBACK LEVEE

As documented in this report entitled: *Star Bend Setback Levee Project, Urban Levee Design Criteria Compliance,* the Star Bend Setback Levee, a portion of the Feather River West Levee, complies with the requirements of California's May 2012 Urban Levee Design Criteria (ULDC) Section 7.4 – Slope Stability for Intermittently loaded Levees.

Professional Engineer in Responsible Charge:

_____ June 30, 2016

Name: Robert B. Lokteff, P.E., G.E. *Date*
California Geotechnical Engineer No. 2589

E. Under-seepage for Intermittently Loaded Levees (ULDC Section 7.5)

1. Applicable ULDC Requirements

Per ULDC Section 7.5, levee underseepage criteria for intermittently loaded levees are as follows:

- The underseepage exit gradient for levees is required to be 0.5 or less at the landside levee toe using a steady-state seepage analysis for a water surface set at the DWSE. For levees with a landside blanket layer with a saturated unit weight less than 112 pounds per cubic foot (pcf), a minimum factor of safety for underseepage of 1.6 is required at the landside levee toe.

- The underseepage exit gradient is required to be 0.8 or less at the toe of a seepage berm less than 300 feet wide using steady-state seepage analysis for a water surface set at the DWSE. If the saturated unit weight of the blanket layer is less than 112 pcf, a minimum factor of safety for underseepage of 1.0 is required at the toe of the seepage berm.

- Sound engineering judgment should be applied where the DWSE results in an elevated seepage gradient beyond the toe of a 300-footwide seepage berm (i.e., greater than 0.8 or a factor of safety of less than 1.0 for blanket layer soils with saturated unit weight of less than 112 pcf).

- Before a computed seepage gradient above 0.8 for the DWSE should be allowed beyond the toe of a 300-foot-wide seepage berm, a sensitivity analysis of the seepage model should be performed.

- Where a seepage berm is needed, the required minimum berm width is four times the levee height.

- The allowable underseepage exit gradient through the combined seepage berm/blanket layer between the levee toe and the seepage berm toe for a water surface set at the DWSE is determined by interpolation, using 0.5 at the levee toe and 0.8 at the seepage berm toe. The evaluation is to be done throughout the seepage berm, paying close attention to areas where the blanket layer is thinnest. If the saturated unit weight of either the blanket layer or seepage berm material is less than 112 pcf, the minimum factor of safety for underseepage through the combined seepage berm/blanket layer is 1.6 at the levee toe and 1.0 at the seepage berm toe, with linear interpolation applying between.

- Underseepage exit gradient and factor of safety criteria also apply within a ditch, canal, or depression near either the levee toe or seepage berm toe.

2. Documentation of ULDC Compliance

This section contains BCI's evaluation of the Star Bend Setback Levee with respect its ability to meet the ULDC Underseepage Criteria for Intermittently Loaded Levees.

Cross-Section Development – We selected two reasonably critical locations for underseepage analysis based on:

- Site subsurface conditions,
- Site geology and geomorphology (See Appendix B),
- Existing seepage cutoff wall depths,
- Landside and waterside features that influence seepage such as borrow site depressions and distance to the river channel.

The analysis cross-section locations are shown in the Underseepage Evaluation TM (**Reference 6**).

Wood Rodgers provided surface profiles for the two analysis locations extending from the center of the Feather River channel to 2,000 feet landward of the existing levee centerline. BCI included these profiles in Appendix D.

BCI developed a subsurface characterization profile for each analysis cross-section based on:

- Subsurface data contained in the 2006 Geotechnical Report and 2007 Geotechnical Report Addendum for design of the Star Bend Setback Levee.
- Setback levee and SB slurry wall construction details contained in the Construction Completion Report for Levee District No. 1 of Sutter County Lower Feather River Setback Levee at Star Bend by MHM (December, 2010).
- Existing explorations provided in Phase 1 Geotechnical Data Report (P1GDR) of the Sutter Study Area for the Urban Levee Geotechnical Evaluations Program by URS (November, 2008)

Boring logs and CPT plots used to develop BCI's cross sections are included in the Underseepage Evaluation TM (**Reference 6**).

Station 20+46.18 – BCI selected a cross-section at Station 20+46.18 due to the relatively thin blanket, shallow aquifer and 42-foot deep SB slurry cutoff wall. To develop the subsurface characterization profile, BCI used two BCI borings (B5-06

and B2-07), one BCI CPT sounding (CPT3-07), one boring from the P1GDR (WL0001_039B) and one CPT from the P1GDR (WL0001_040C).

The subsurface characterization profile used in BCI's Station 20+46.18 analysis is included in **Table 10**.

Table 10: Station 20+46.18 Subsurface Characterization Profile			
USCS Designation		**Profile Description**	**Elevation (feet) (NAVD 88)**
(1) SB Cutoff Wall		Traditional SB slurry cutoff wall; Approximately 42 feet deep by 38 inches wide.	47.4 to 5.3
(2) CL		Newly compacted clay levee fill; Approximately 23 feet tall with a 20-foot crest and 3:1 slopes; Average relative density of 102% of ASTM 698.	71.04 to 47.4
(4) CL/ML		*Blanket***:** Soft/desiccated clay/silt	47.4 to 40.0
(6) SP		*Aquifer:* Poorly-graded sand (Less than 5% fines)	40.0 to 17.5
(5) CL/MH		*Key:* Sandy clay/elastic silt	17.5 to -20.0
(7) SP-SM		Poorly-graded sand with silt (5% - 12% fines)	-20.0 to -50.0
(3) CL		Deeper clay	-50.0 to -69.0

Station 39+46.18 – BCI selected a cross-section at Sta. 39+46.18 due to the relatively thin blanket, relatively thick aquifer and deeper SB slurry cutoff wall. To develop the subsurface characterization, BCI used three BCI borings (B3-06, B6-06 and B4-07), one BCI CPT (CPT4-07), and one CPT from the P1GDR (WL0001_037C).

The results of the subsurface characterization profile used in BCI's Station 39+46.18 analysis is presented in **Table 11**.

Table 11: Station 39+46.18 Subsurface Characterization Profile			
USCS Designation		**Profile Description**	**Elevation (feet) (NAVD 88)**
(1) SB Cutoff Wall		Traditional SB slurry cutoff wall; Approximately 65.0 feet deep by 38 inches wide.	47.4 to -17.6
(2) CL		Newly compacted clay levee fill; Approximately 23 feet tall with a 20-foot crest and 3:1 slopes; Average relative density of 102% of ASTM 698.	70.23 to 47.4
(4) CL/ML		*Blanket*: Soft/desiccated clay/silt	47.4 to 35.0
(8) SM		Silty sand with variable percent fines	35 to 22.5
(6) SP		*Aquifer:* Poorly-graded sand (Less than 5% fines)	22.5 to -12.5
(5) CL/MH		*Key:* Sandy clay/elastic silt	-12.5 to -28.5
(8) SM		Silty sand with variable percent fines	-28.5 to -41.0

Water Surface Elevations – The water surface elevation (WSEs) used in BCI's analysis is shown in **Table 12**.

Wood Rodgers provided the 200-year-flood and 500-year-flood WSEs as determined by PBI for the Feather River West Levee. BCI added 1 foot to the 200-year WSE to account for climate change, potential hydrologic/hydraulic model variations, or sea-level rise. For the HTOL underseepage analyses BCI used the lower of the 200-year-flood WSE + 3' and 500-year-flood WSE as specified in the ULDC.

Table 12: Water Surface Elevations Used In This Underseepage Analysis				
Cross-Section	**HEC-RAS SBFCA/ FRWL Station**	**DWSE (NAVD 88)**	**HTOL (NAVD 88)**	
		200-yr. + 1' (feet)	**500-yr. WSE (feet)**	**200-yr. + 3' (feet)**
Station 20+46.18	RM 18.30	**67.20**	**70.74**	**69.20**
Station 39+46.18	RM 17.86	66.09	69.49	68.09

Hydraulic Conductivity Selection – The hydraulic conductivity values used in this evaluation are presented in **Table 13**, followed by BCI's rationale in selecting the values.

To determine hydraulic conductivity values appropriate for this analysis, BCI compared hydraulic conductivity values used in the 2006 Geotechnical Report for Star Bend Setback Levee underseepage evaluation with SBFCA FRWL evaluations, ULE Guidance Document and Star Bend Setback Levee Construction Completion Report. A tabulated comparison of these hydraulic conductivity values is included in Underseepage Evaluation TM (**Reference 6**).

Table 13: Hydraulic Conductivity Values Used In This Underseepage Analysis

USCS Designation		Soil Description	Kh (ft/day)	Kh (cm/s)	Kv/Kh	Kv (cm/s)
(1) SB Cutoff Wall		Soil bentonite slurry	0.00024	8.7×10^{-8}	1	8.7×10^{-8}
(2) CL		Mechanically compacted levee fill	0.028	1.0×10^{-5}	0.25	2.5×10^{-6}
(3) CL		Deeper clay	0.0112	4.0×10^{-6}	0.25	1.0×10^{-6}
(4) CL/ML		Soft or desiccated clay/silt blanket, upper layers	0.028	1.0×10^{-5}	0.25	2.5×10^{-6}
(5) CL/MH		Sandy clay/elastic silt	0.028	1.0×10^{-5}	0.25	2.5×10^{-6}
(6) SP		Poorly-graded sand (Less than 5% fines)	112	4.0×10^{-2}	0.25	1.0×10^{-2}
(7) SP-SM		Poorly-graded sand with silt (5% - 12% fines)	56.7	2.0×10^{-2}	0.25	5.0×10^{-3}
(8) SM		Silty sand with variable percent fines	11.2	4.0×10^{-3}	0.25	1.0×10^{-3}

<u>Hydraulic Conductivity Selection Rationale</u>

SB Cutoff Wall: BCI selected the highest hydraulic conductivity from QC/QA testing of SB slurry wall during construction of the Star Bend Setback Levee cutoff wall.

Mechanically compacted levee fill (CL): Construction records show that the levee fill consists of lean clay, silt, sandy lean clay, clayey sand, and sandy silt compacted to an average 102% relative compaction based on ASTM D 698. The records also show a Liquid Limit ranging from 22 to 45 with an average of 31, a Plasticity Index ranging from 7 to 29 with an average of 14, and a fines content ranging from 22% to

94% with an average of 73%. Based on this information, BCI selected a Kv value of $2.5x10^{-6}$ cm/sec, which is comparable to values used in the area for this type of compacted levee fill and is the same value used in the 2006 Geotechnical Report.

Deeper clay (CL): Subsurface explorations deeper than 50 feet identified a stiff high plasticity soil. The ULE recommends a range of Kv values from $1.0x10^{-6}$ cm/sec to $1.0x10^{-8}$ cm/sec for lean clay. For this analysis, BCI used Kv = 1.0x10-6 cm/sec which is the same value used in BCI's 2006 Geotechnical Report.

Soft or desiccated clay/silt blanket (CL/ML): Borings and test pits identify a 10-foot thick clay and silt blanket. From the 2006 Geotechnical Report, which used field measured permeability correlations for soils and rocks per Milligan 1975, Kv values range from $7.0x10^{-3}$ cm/sec to $1.0x10^{-6}$ cm/sec. Similarly, the ULE recommends a range of Kv values from $1.0x10^{-5}$ cm/sec to $1.0x10^{-7}$ cm/sec and varying Kv/Kh from 0.25 to 1.0 to simulate full depth desiccation cracks. The SBFCA FRWL evaluations used a Kv value of $2.5x10^{-6}$ cm/sec for desiccated blanket layers, which is within range of the recommend ULE values. BCI conducted its analysis using Kv value of $2.5x10^{-6}$ cm/sec with a Kv/Kh value of 0.25, which is more conservative than the analysis from the 2006 Geotechnical Report.

Sandy clay/elastic silt (CL/MH): From the 2006 Geotechnical Report, Kv values range from $7.0x10^{-3}$ cm/sec to $1.0x10^{-6}$ cm/sec for elastic silts and $1.0x10^{-6}$ cm/sec to $1.0x10^{-8}$ cm/sec for homogeneous clays. Materials within this layer typically have higher blow counts ($N_{1,60} \geq 20$) and were encountered anywhere from 20 to 60 feet below the ground surface. BCI selected a Kv value of $2.5x10^{-6}$ cm/sec, which is near the lower extreme for silt and upper range for the homogeneous clay.

Poorly-graded sand (SP): Relatively clean poorly-graded sand with apparent density varying from very loose to dense. The ULE recommends a range from $5.0x10^{-1}$ cm/sec to $1.0x10^{-3}$ cm/sec. BCI conducted its analysis using a Kv = $1.0x10^{-2}$.

Poorly-graded sand with silt (SP-SM): Poorly-graded sand with few fines and apparent density varying from medium dense to dense and located below the key layer. The ULE recommends a range varying from 1.0x10-2 cm/sec to 1.0x10-5 cm/sec. BCI selected a value of 5.0x10-3 cm/sec to conduct the analysis.

Silty sand (SM): Silty sand with varying fines. Material apparent density varies from loose to dense. The ULE recommends a range varying from 1.0x10-3 cm/sec to 1.0x10-6 cm/sec. BCI conducted its analysis using the conservative value of Kv = 1.0x10-3 cm/sec.

Analysis Methodology – We performed two-dimensional, finite element underseepage analysis using SEEP/W, Version 7.23, with the hydraulic conductivity

values presented in **Table 13**. BCI considered steady-state seepage conditions and applied the following boundary conditions to the models:

- Fixed-head set to the Feather River water surface elevation along the boundary nodes of the waterside levee slope and channel bottom,
- No-flow condition along the bottom of the model, and along both the waterside and landside vertical edge of the model,
- Potential seepage surface for nodes on the landside levee slope, ditches, basins, and ground surface.

The underseepage exit gradient is calculated as the difference in total head though a blanket layer divided by the thickness of the blanket layer. BCI calculated underseepage conditions at the landside levee toe and at landside depressions up to 300 ft from the levee toe.

The ULDC specifies that for DWSE conditions the maximum allowable exit gradient at the landside levee toe is 0.5. For depressions landside of the levee toe, the maximum allowable exit gradient should be determined by interpolating between the maximum allowable exit gradient at the landside levee toe of 0.5 and the maximum allowable exit gradient at 150 feet landside of the levee toe of 0.8.

The ULDC specifies that for HTOL conditions the maximum allowable exit gradient at the landside levee toe is 0.6. For depressions landside of the levee toe, the maximum allowable exit gradient should be determined by increasing the maximum allowable gradient for the DWSE condition by 20%.

Analysis Results – A summary of the SEEP/W underseepage analysis results using the DWSE is presented in **Table 14** and a summary of the SEEP/W underseepage analysis using the HTOL elevation is presented in **Table 15**. A discussion of the results for each cross-section follows.

Table 14: DWSE Underseepage Analysis Results

Cross-section	**DWSE 200-yr.+1' (NAVD 88) (feet)**	**Exit gradient, i**			
		At Landside Toe	*ULDC Criteria*	Landside Depression	*ULDC Criteria*
Station 20+46.18	67.20	< 0.05	*≤ 0.5*	< 0.05	*≤ 0.57* [a]
Station 39+46.18	66.09	< 0.05	*≤ 0.5*	0.11	*≤ 0.68* [b]

[a] Interpolated for the distance of 37 feet from the landside levee toe to landside depression
[b] Interpolated for the distance of 90 feet from the landside levee toe to landside depression

Table 15: HTOL Underseepage Analysis Results					
Cross-section	**HTOL 200-yr.+3' (NAVD 88) (feet)**	**Exit gradient, i**			
		At Landside Toe	*ULDC Criteria*	Landside Depression	*ULDC Criteria*
Station 20+46.18	69.20	< 0.05	*≤ 0.6*	< 0.05	*≤ 0.69* [c]
Station 39+46.18	68.09	< 0.05	*≤ 0.6*	0.13	*≤ 0.82* [c]

[c] 20% Higher than DWSE ULDC Criteria.

Station 20+46.18 – The calculated exit gradient of < 0.05 at the levee toe for the DWSE underseepage analysis meets the ULDC exit gradient criterion of ≤ 0.5. At the depression, 37 feet landside of the levee toe, the calculated exit gradient of < 0.05 meets the ULDC exit gradient criterion of ≤ 0.57.

The calculated exit gradient of < 0.05 at the levee toe for the HTOL underseepage analysis meets the ULDC exit gradient criterion of ≤ 0.6. At the depression 37 feet landside of the levee toe, the calculated exit gradient of < 0.05 meets the ULDC exit gradient criterion of ≤ 0.69.

Station 39+46.18 – The calculated exit gradient of < 0.05 at the levee toe for the DWSE underseepage analysis meets the ULDC exit gradient criterion of ≤ 0.5. At the depression 90 feet landside of the levee toe, the calculated exit gradient of 0.11 meets the ULDC exit gradient criterion of ≤ 0.68.

The calculated exit gradient of < 0.05 at the levee toe for the HTOL underseepage analysis meets the ULDC exit gradient criterion of < 0.6. At the depression 90 feet landside of the levee toe, the calculated exit gradient of 0.13 meets the ULDC exit gradient criterion of < 0.82.

3. Conclusions

Based on BCI's analysis presented above, the Star Bend Setback Levee meets the ULDC underseepage criteria for intermittently loaded levees.

4. ULDC Compliance Statement

ATTACHMENT A
STAR BEND SETBACK LEVEE
DWR ULDC COMPLIANCE STATEMENT
SECTION 7.5 – UNDERSEEPAGE FOR INTERMITTENTLY LOADED LEVEES

CALIFORNIA DEPARTMENT OF WATER RESOURCES URBAN LEVEE DESIGN CRITERIA COMPLIANCE STATEMENT SECTION 7.5 – UNDERSEEPAGE FOR INTERMITTENTLY LOADED LEVEES

STAR BEND SETBACK LEVEE

As documented in this report entitled: *Star Bend Setback Levee Project, Urban Levee Design Criteria Compliance,* the Star Bend Setback Levee, a portion of the Feather River West Levee, complies with the requirements of California's May 2012 Urban Levee Design Criteria (ULDC) Section 7.5 – Underseepage for Intermittently Loaded Levees.

Professional Engineer in Responsible Charge:

_____ June 30, 2016

Name: Robert B. Lokteff, P.E., G.E. *Date*
California Professional Engineer No. 2589

F. Frequently Loaded Levees (ULDC Section 7.6)

1. Applicable ULDC Requirements

Frequently loaded levees are defined by the ULDC to be levees that experience water surface elevations of one foot or higher above the landside levee toe at least once a day for more than 36 days per year on average. In addition to levee design criteria for intermittently loaded levees as provided in the ULDC, the criteria for frequently loaded levees includes more stringent requirements.

2. Documentation of ULDC Compliance

Per section 3.6 Frequently Loaded Levees of the SBFCA Engineer's Report for the Feather River West Levee Phase I, ULDC Compliance Report, the FRWL does not experience a water surface elevation of one foot or higher above the landside toe at least once a day more than 36 days per year on average. Therefore it is not a frequently loaded levee. As the Star Bend Setback Levee is a section of the FRWL, it is not considered a frequently loaded levee and, therefore it is not required to meet the additional requirements described in ULDC Section 7.6.

3. Conclusions

The Star Bend Setback Levee is not required to meet the additional requirements described in ULDC Section 7.6.

4. ULDC Compliance Statement

ATTACHMENT A
STAR BEND SETBACK LEVEE
DWR ULDC COMPLIANCE STATEMENT
SECTION 7.6 – FREQUENTLY LOADED LEVEES

CALIFORNIA DEPARTMENT OF WATER RESOURCES
URBAN LEVEE DESIGN CRITERIA COMPLIANCE STATEMENT
SECTION 7.6 - Frequently Loaded Levees

STAR BEND SETBACK LEVEE

As documented in this report entitled: *Star Bend Setback Levee Project, Urban Levee Design Criteria Compliance,* the Star Bend Setback Levee, a portion of the Feather River West Levee, complies with the requirements of California's May 2012 Urban Levee Design Criteria (ULDC) Section 7.6 – Frequently Loaded Levees.

Professional Engineer in Responsible Charge:

June 30, 2016

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California Professional Engineer No. C59538

G. Seismic Vulnerability (ULDC Section 7.7)

1. Applicable ULDC Requirements

Per ULDC Section 7.7, a seismic vulnerability analysis of the levee system for 200-year return period ground motions is required to meet the urban level of flood protection. Peak ground accelerations can be estimated from the most current information developed by:

- U.S. Geological Survey
- DWR's ULE Program's Development of a 200-year Return Period Seismic Hazard Map (2012) for projects in the Sacramento-San Joaquin Valley
- USACE's Guidelines for Seismic Stability Evaluation of USACE Levees (2011)

The seismic vulnerability analysis should employ typical summer and winter WSEs or mean annual high and low tides over the period of gage record. Additionally, potential damages due to either tsunami or seiche wave loading must be considered for levees potentially exposed to such loading.

The seismic vulnerability analyses must make use of the most current seismologic interpretations of potential faulting and earthquake sources, together with recent acceleration and velocity attenuation relationships for the soil profiles being analyzed. In some cases, simplified analyses (e.g., Liquefaction Resistance of Soils: Summary Report from the 1996 NCEER and 198 NCEER/NSF Workshops on Evaluation of Liquefaction Resistance of Soils (2001)) may be used, while other cases may require dynamic response analyses, pseudo-static slope stability analyses used in conjunction with Newmark-style displacement analyses, and other more detailed numerical displacement analyses. Detailed analysis using the finite element method may be justified by potential savings in seismic remediation work when simplified analyses identify the need for significant seismic remediation. All such analyses should employ recent correlations between field testing (e.g., Standard Penetration Test (SPT) and Cone Penetration Test (CPT) penetration results) and liquefaction triggering and residual shear strengths.

The end product of these analyses should be estimates of the ranges of deformations along the levee system and an overall estimate of the amount of damage that could be sustained during a 200-year earthquake. In many cases, an estimate regarding potential longitudinal and transverse cracking should also be made, particularly for transverse cracking between liquefied levee reaches and un-liquefied levee reaches and at locations where liquefied levee reaches contain or abut appurtenant structures with rigid or deep foundations.

For intermittently loaded levees (and floodwalls), if seismic damage from 200-year-return-period ground motions is expected after the urban level of flood protection is achieved, a post-earthquake remediation plan is required as part of a flood safety plan that is developed in coordination with pertinent local, State, and federal agencies.

Although the post-earthquake remediation plan must address 200-year-return-period ground motions at a minimum, the Civil Engineer should consider a range of earthquakes significantly exceeding the 200-year return period. At a minimum, the post-earthquake remediation plan must contain provisions for emergency preparations, mobilization, data gathering, actions, interim repairs, long-term repairs, and public notifications. Included in this plan is an estimate of the amount and extent of damage that might be sustained following an earthquake, and the general magnitude of earth and other materials that would be required to restore a modest level of flood protection within 8 weeks. This plan must also include a general set of repair procedures for the interim remediation of cracked and slumped levee sections, including general procedures for excavating and filling cracks, removing disturbed or slumped ground, and keying in new fill.

During each periodic review, the post-earthquake remediation plan needs to be reviewed and updated as appropriate. Similarly, if appropriate for amendments to the general plan and/or zoning ordinances, such amendments should address the availability and preservation of sources of post-earthquake construction materials. Specific considerations for the interim repairs for intermittently loaded levees include:

- An estimate is to be developed of the general magnitude and locations of damage expected throughout the levee system along with the amounts and locations of material needed to restore the levee system's grade and dimensions (e.g., appropriate crown width – such as 20 feet along a major stream – and 3H:1V levee slopes) sufficient for protection against the 10-year flood, with 3 feet of freeboard.
- The interim repairs would need to restore 10-year grade and dimensions within 8 weeks or less to avoid prolonged exposure of the community during flood season.
- Borrow areas and/or stockpiles that could easily provide the materials needed for interim repairs need to be identified. Such materials should meet the levee fill requirements of the USACE Sacramento District's Geotechnical Levee Practice Standard Operating Procedures.
- Haul routes for fill placement need to be identified.
- Slope protection for the newly placed fill needs to be included.

- To the extent that seismic damage to the levee system would be so significant and widespread that it would be infeasible to restore 10-year grade and dimensions within eight weeks, seismic strengthening is required to provide the urban level of flood protection.
- The public should be informed as quickly as possible after a damaging earthquake as to system damages and the resulting interim level of protection that will be provided.

2. Documentation of ULDC Compliance

This section contains BCI's Star Bend Setback Levee evaluation to provide an urban level of flood protection meeting the ULDC Seismic Vulnerability Criteria for Intermittently Loaded Levees. Additional details are contained in the Seismic Vulnerability Criteria for Intermittently Loaded Levees TM by BCI (**Reference 7**).

Site-Specific Ground Motion – Peak horizontal ground acceleration (PGA) and earthquake moment magnitude (Mw) are needed to perform liquefaction analysis and seismic vulnerability evaluation. URS (2015) prepared 200-year Return Period Mean PHA [or PGA] Hazard maps for the Marysville, Sacramento and Stockton Regions that show PGA contours for a Vs30 condition of 335 meters per second (m/s) (Figure 6-2 of the ULE Guidance Document). The document estimates 0.125g PGA for the Star Bend Setback Levee site.

BCI calculated a site specific Vs30 equal to 250m/s (approximately 820 feet per second) based on estimates from blow count data shown on the exploratory borings completed for the project by BCI and URS (2007). The 250 m/s velocity corresponds to a Site Class D (Stiff Soil site). BCI performed a site-specific probabilistic analysis because the calculated site Vs30 profile is different than that used to develop the URS PGA map. BCI used a location near the central portion of the Star Bend Setback Levee for the analysis. BCI used the USGS 2008 Interactive Deaggregations website (https://geohazards.usgs.gov/deaggint/2008/) to complete the analysis and develop the PGA at the Star Bend site for an earthquake with a 200-year return period. The USGS program is based on source and attenuation models as presented in Petersen, M. and others, 2008, "Documentation for the 2008 Update of the National Seismic Hazard Maps, USGS OFR 08–1128," available on the web at http://pubs.usgs.gov/of/2008/1128/.

The difference in PGA values (0.125g compared to 0.13g) is likely due to the base ground condition modeled (slightly higher Vs30) in the URS model and conservatisms built into the USGS probabilistic analysis. The USGS database for probabilistic analysis does not include the Midland Fault, a recently considered

seismic source. The Midland Fault is a concealed, north-south trending reverse or reverse-oblique fault located near Rio Vista. BCI compared the PGA values obtained in this TM with the URS (2015) study, which included the Midland Fault as a seismic source. Based on BCI's comparison, the inclusion of this seismic source does not significantly increase the 200-year return period PGA for the project.

Based on the above, BCI recommend a 200-year return period PGA of 0.13g for the Star Bend seismic evaluation. BCI also recommends a moment magnitude (Mw) of 6.5 in accordance with Section 6.7.2 of URS's (2015) ULE Guidance Document.

The locations of the faults are based on the U.S. Geological Survey and California Geological Survey, 2010, Quaternary fault and fold database for the United States (USGS web site: http//earthquakes.usgs.gov/hazards/qfaults/).

Water Surface Elevations – We present the water surface elevation (WSE) conditions considered for analysis in **Table 16**.

URS provided the Average Winter and Average Summer WSEs for the Feather River West Levee in their Water Surface Elevations Used for Geotechnical Analysis – Sutter Study Area Technical Memorandum (May 2010). BCI used the higher of the two seasonal averages to conduct BCI's liquefaction potential analysis.

Table 16: Water Surface Conditions Used in This Seismic Vulnerability Analysis

Cross-Section	HEC-RAS SBFCA/ FRWL Station	Average Winter WSE (NAVD 88) (feet)	Average Summer WSE (NAVD 88) (feet)
Station 20+46.18	RM 18.30	29.70	28.58
Station 39+46.18	RM 17.86	29.48	28.28

Liquefaction Potential Evaluation – BCI performed liquefaction potential evaluation for a 200-year-return period seismic event with consideration of the ULDC and ULE Guidance Document. BCI evaluated liquefaction potential at seven boring locations based on geologic conditions, site location and the availability of quality field and laboratory data.

Initial Soil Type Screening – The ULE Guidance Document Segment 6.7.1 presents screening criteria for materials not critical to seismic performance. BCI present these screening criteria in **Table 17** below. BCI screened Star Bend Setback Levee field explorations with consideration of these criteria prior to BCI's liquefaction analysis.

BCI considered materials identified as not critical to the levee seismic performance to be non-liquefiable or less likely liquefiable during BCI's liquefaction potential analysis.

Table 17: Guidelines for Screening Levee Soils Not Critical to Liquefaction Potential Evaluation	
Site Conditions Not Critical to Liquefaction Potential Evaluation	**Soils Not Susceptible to Liquefaction**
• Unsaturated soils located above the analysis WSE. • Soils located below the greater of the following depths: o 50 feet below the landside levee toe, o Two times the levee height below the landside levee toe, or o Bottom of the river channel.	• All soils with $(N_1)_{60\text{-}CS} \geq 23$ • All soils classified as CH or MH • All soils classified as CL or ML with the following properties: o Plastic Index ≥ 10 o Liquid Limit ≥ 35 o Water Content ≤ 0.8 x (Liquid Limit) • Compacted Fine-Grained Soil • Clayey Sand (SC) with ≥ 20% fines

Analysis Spreadsheet Development – We developed spreadsheets to identify the liquefaction potential of the subsurface soil using the following:

- 1996 NCEER and 1998 NCEER/NSF Workshop on evaluation of Liquefaction Resistance of Soils by Youd et al (October 2001).
- Standard Penetration Test-Based Probabilistic and Deterministic Assessment of Seismic Soil Liquefaction Potential by Cetin et al (December 2004).
- CPT and SPT Based Liquefaction Trigger Procedures by R.W. Boulanger and I.M. Idriss (April 2014).

The liquefaction analysis spreadsheet input includes:

- Consideration of the log of soil borings with field notes.
- Sample depths and blow counts.
- Laboratory test data.
- Assumed unit weights per Table 6-2 of ULE Guidance Document.
- The higher of either the Average Winter WSE of Average Summer WSE.
- Groundwater elevation at time of drilling.
- Earthquake magnitude (Mw) of 6.5.

- PGA of 0.13g.
- Distance to fault of 33.6 miles.

The liquefaction analysis spreadsheet calculates and reports a soil layer's factor of safety against liquefaction. BCI classifies the soil's liquefaction potential based on the calculated factor of safety as presented in **Table 18**.

Table 18: Liquefaction Potential Criterion	
Liquefaction Potential Classification	**Factor of Safety against Liquefaction**
Non-Liquefiable	≥ 1.2
Likely Liquefiable	≤ 1.0
Less Likely Liquefiable	1.0 – 1.2

Results – Our liquefaction potential evaluation results are presented in **Table 19** followed by a discussion of the results.

Table 19: Liquefaction Potential Results						
Cross-Section	**Boring**	**Presence of Likely or Less Likely Liquefiable Soils (Yes/No)**	**Liquefaction Potential**	**Thickness of Zone (Feet)**	**USCS**	**Factor of Safety against Liquefaction**
Station 20+46.18	B5-06	Yes	Less Likely	3.0'	SP	1.14 (Cetin) 1.15 (NCEES) 1.32 (Boulanger)
	B1-07	No	---	---	---	---
	B2-07	No	---	---	---	---
	WL0001_039B	No	---	---	---	---
Station 39+46.18	B6-06	No	---	---	---	---
	B3-07	No	---	---	---	---
	B4-07	No	---	---	---	---

BCI identified a 3-foot thick potentially liquefiable layer in Boring B5-06. This layer classified as “Less Likely Liquefiable” to “Non-Liquefiable” with a factor of safety against liquefaction between 1.14 and 1.32. BCI evaluated this potentially liquefiable zone for continuity with surrounding borings and subsurface information and determined that this zone is likely isolated within a non-liquefiable layer. BCI therefore determined that this isolated, relatively thin layer with a borderline factor of safety does not pose a detrimental liquefaction threat.

Other than the borderline case discussed above, the remaining evaluated soil layers classify as non-liquefiable. Therefore, seismic deformation analysis is not needed for this stretch of levee.

3. Conclusions

BCI’s seismic vulnerability evaluation indicates that the site soils are not susceptible to detrimental liquefaction and seismic deformation per the 2012 ULOP criteria. BCI therefore classify the Star Bend Setback Levee as having a low seismic vulnerability and a seismic site safety plan is not needed.

4. ULDC Compliance Statement

ATTACHMENT A
STAR BEND SETBACK LEVEE
DWR ULDC COMPLIANCE STATEMENT
SECTION 7.7 – SEISMIC VULNERABLILITY

CALIFORNIA DEPARTMENT OF WATER RESOURCES
URBAN LEVEE DESIGN CRITERIA COMPLIANCE STATEMENT
SECTION 7.7 – SEISMIC VULNERABILITY

STAR BEND SETBACK LEVEE

As documented in this report entitled: *Star Bend Setback Levee Project, Urban Levee Design Criteria Compliance,* the Star Bend Setback Levee, a portion of the Feather River West Levee, complies with the requirements of California's May 2012 Urban Levee Design Criteria (ULDC) Section 7.7 – Seismic Vulnerability.

Professional Engineer in Responsible Charge:

June 30, 2016

Name: Robert B. Lokteff, P.E., G.E. *Date*
California Geotechnical Engineer No. 2589

H. Levee Geometry (ULDC Section 7.8)

1. Applicable ULDC Requirements

Based on the ULDC for new levees or levees with extensive reconstruction that are situated along major waterways, a minimum 20-foot-wide crown width and 3:1 waterside and landside slopes (4:1 waterside slope for bypass levees) is required. However, exceptions may be allowed for reconstruction of existing levees where the authorized geometry provides for a steeper slope or narrower crown, the levee has performed well and meets stability and seepage criteria.

Steeper slopes may be allowed in circumstances where limited space is available and where levees are demonstrated to meet minimum seepage and stability criteria. Steeper waterside levee slopes may be acceptable where stability criteria are met and where either slope protection is provided or it is determined that wave wash erosion for a water surface at or below the DWSE could not result in breaching of the levee. For example, levees with slopes steeper than new minimum requirements may be acceptable with elements such as central clay cores, seepage cutoff walls, landside filters or drains, or with soil reinforcement that substantially decreases seepage hazards and increases slope stability.

2. Documentation of ULDC Compliance

The following provides a summary of the detailed analyses and documentation that have been performed and developed in order to bring the Star Bend Setback Levee into compliance with ULDC. The section also provides a reference to the location where relevant documentation can be found as it pertains to ULDC Section 7.8.

The setback levee was designed and constructed with a minimum top width of 20 feet and side slopes of 3:1, as described in the basis of design report (**Reference 1)**. At the tie-in points where the existing levee was degraded to add the cutoff wall interfaces (see **Section I – Interfaces and Transitions**), the levee was reconstructed to match the existing levee geometry. The geometry of the surrounding FRWL will be assessed/improved as necessary as part of the FRWL Phase 1 project. Per the as-built plans (see **Reference 8)**, the constructed levee meets the geometry requirements of the ULDC. The typical levee cross sections are shown on **Figure 1** (attached).

3. Conclusion

The Star Bend Setback Levee meets the levee geometry requirements as prescribed in ULDC Section 7.8.

4. ULDC Compliance Statement

ATTACHMENT A
STAR BEND SETBACK LEVEE
DWR ULDC COMPLIANCE STATEMENT
SECTION 7.8 – LEVEE GEOMETRY

CALIFORNIA DEPARTMENT OF WATER RESOURCES
URBAN LEVEE DESIGN CRITERIA COMPLIANCE STATEMENT
SECTION 7.8 - Levee Geometry

STAR BEND SETBACK LEVEE

As documented in this report entitled: *Star Bend Setback Levee Project, Urban Levee Design Criteria Compliance,* the Star Bend Setback Levee, a portion of the Feather River West Levee, complies with the requirements of California's May 2012 Urban Levee Design Criteria (ULDC) Section 7.8 – Levee Geometry.

Professional Engineer in Responsible Charge:

June 30, 2016

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I. Interfaces and Transitions (ULDC Section 7.9)

1. Applicable ULDC Requirements

The civil engineer must consider, evaluate, and design explicitly for interfaces and transitions between different types of levee sections and features along a levee system. Appropriate overlaps, transitions, and connections between features must be evaluated and designed to ensure that the levee system functions holistically, so that no levee reach is more susceptible to problems than an adjacent reach due to gaps in features, loading/demand concentrations, or other three-dimensional effects. Such interfaces, transitions, and connections commonly occur at the ends of seepage berms, seepage cutoff walls, revetments, and floodwalls.

2. Documentation of ULDC Compliance

The following provides a summary of the detailed analyses and documentation that have been performed and developed in order to bring the Star Bend Setback Levee into compliance with the ULDC. The section also provides a reference to the location where relevant documentation can be found as it pertains to ULDC Section 7.9.

The tie-in points for the Setback Levee along the existing alignment of the Feather River West Levee were degraded and a Soil-Cement-Bentonite (SCB) cutoff wall was constructed (overlapping with the Setback Levee foundation cutoff wall), to provide sufficient length for tie-in of the future FRWL Project cutoff walls. The tie-in on the north side of the cutoff wall occurred in 2015. BCI performed subsurface explorations and a seepage analysis at the north and south tie-in points of the levee to determine the appropriate depth of the tie-ins and the required overlap at the transitions. See North and South Tie-In Point Analysis in "Addendum No. 1 to Geotechnical Report for Star Bend Setback Levee" (**Reference 9**).

The SCB cutoff walls were constructed to overlap the setback levee foundation SB cutoff wall by a minimum of 50 feet and to extend into the existing levee embankments a minimum of 200 feet. Where the SB cutoff wall degrade ties in with the existing levee, the levee was reconstructed to match the existing levee geometry. See **Section H – Levee Geometry** for details of the tie in geometry, and **Exhibit 4** and **Exhibit 5** for plan and profile views of the interface and cutoff wall overlap.

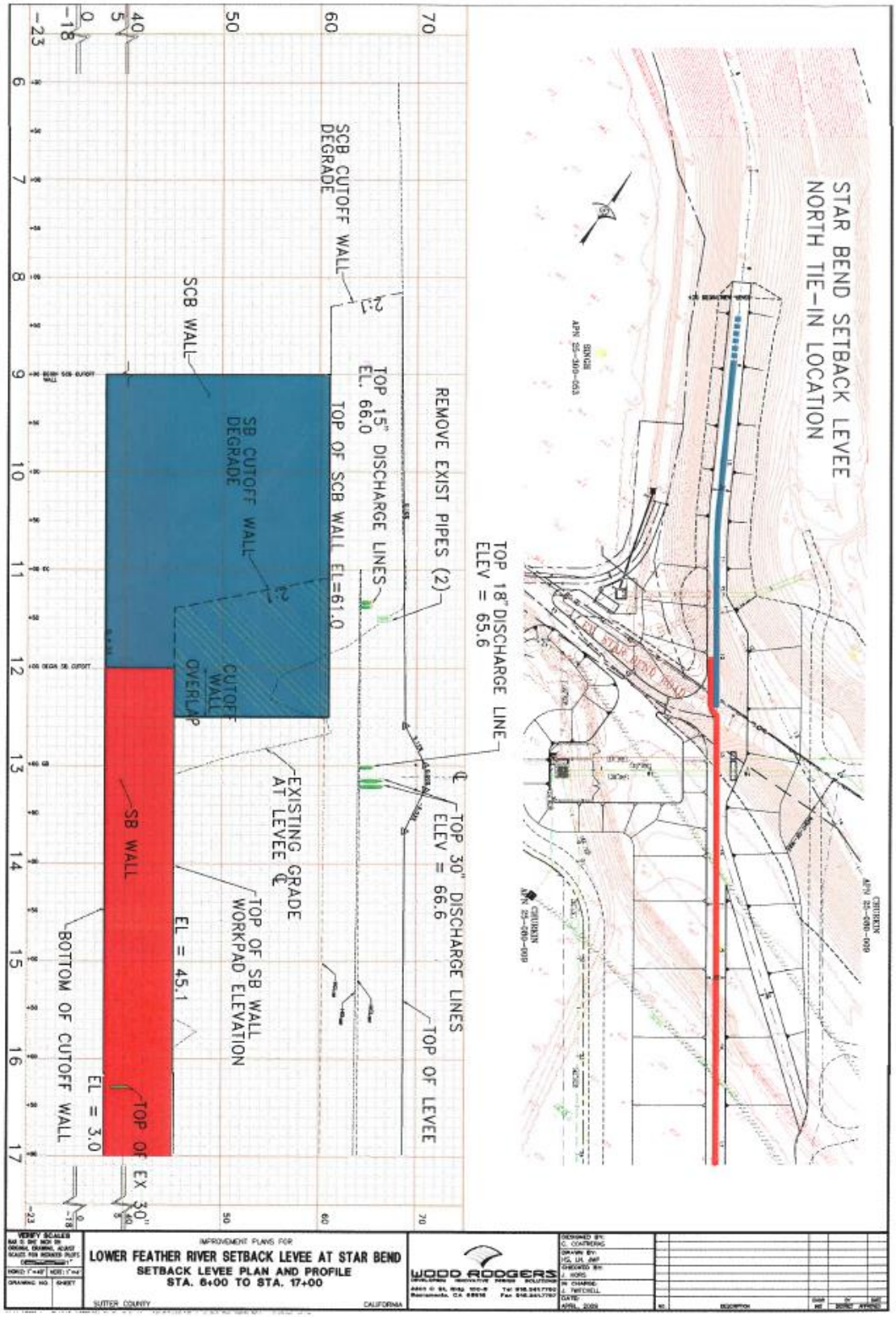

Exhibit 3: Cutoff Wall Transition at Northern Tie-In Interface

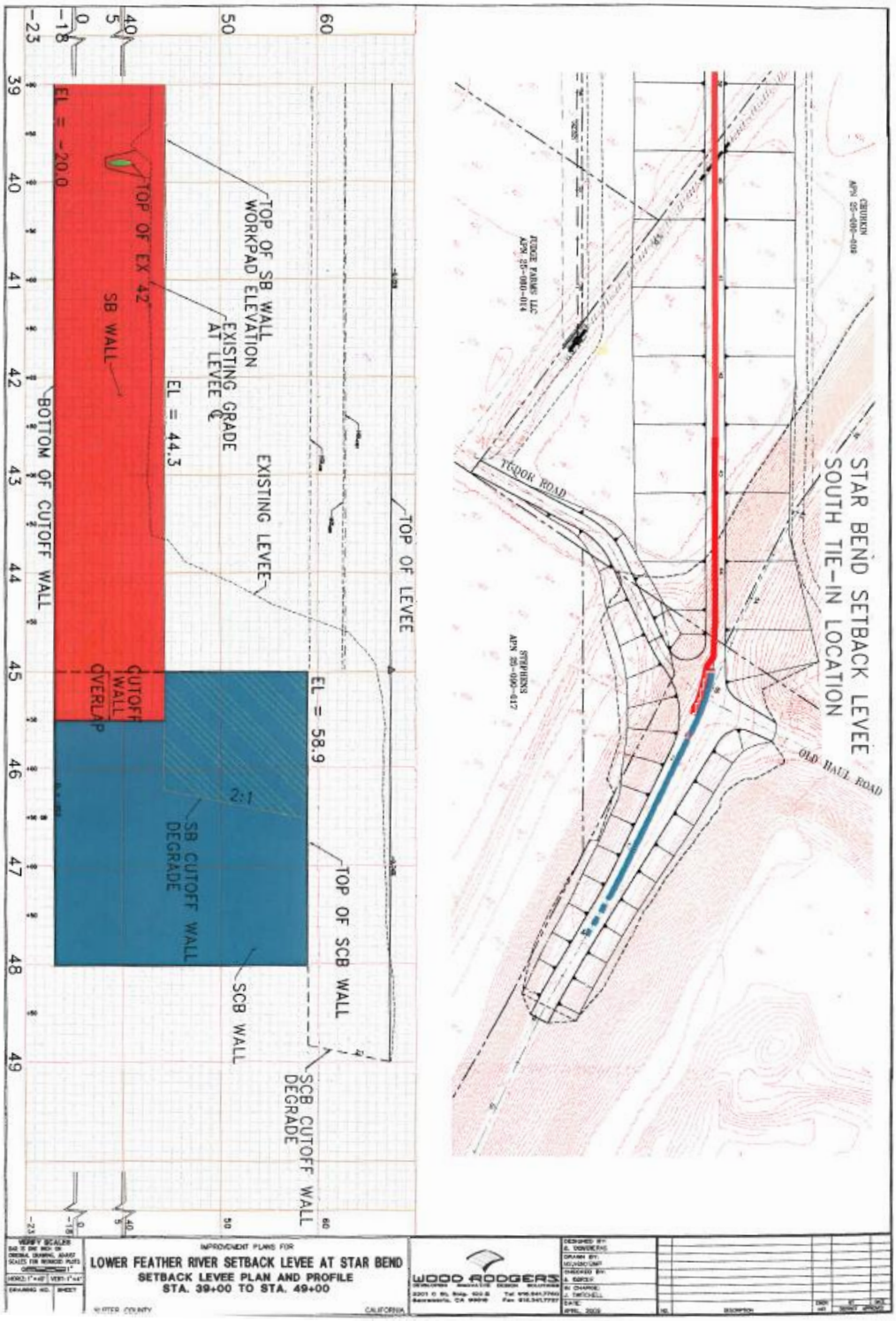

Exhibit 4: Cutoff Wall Transition at Southern Tie-In Interface

There is one transition point in the depth of the SB foundation cutoff wall along the setback levee alignment. BCI performed an analysis and determined that there was an impermeable soil layer of sufficient thickness at a shallower elevation over half the site allowing for a shallower cutoff wall to be constructed where the layer was present. The deeper cutoff wall was designed to extend laterally into this shallower layer a sufficient distance to prevent end-around seepage at this point of transition. See the End-Around Seepage Analysis in the geotechnical report (**Reference 10**) and the cutoff wall sub-surface profile shown on **Figure 2** (attached).

3. Conclusions

The Star Bend Setback Levee interfaces and transitions meet the ULDC as prescribed in its Section 7.9.

4. ULDC Compliance Statement

ATTACHMENT A
STAR BEND SETBACK LEVEE
DWR ULDC COMPLIANCE STATEMENT
SECTION 7.9 – INTERFACES AND TRANSITIONS

CALIFORNIA DEPARTMENT OF WATER RESOURCES
URBAN LEVEE DESIGN CRITERIA COMPLIANCE STATEMENT
SECTION 7.9 - Interfaces and Transitions

STAR BEND SETBACK LEVEE

As documented in this report entitled: *Star Bend Setback Levee Project, Urban Levee Design Criteria Compliance,* the Star Bend Setback Levee, a portion of the Feather River West Levee, complies with the requirements of California's May 2012 Urban Levee Design Criteria (ULDC) Section 7.9 – Interfaces and Transitions.

Professional Engineer in Responsible Charge:

June 30, 2016

Name: Jonathan L. Kors *Date*
California Professional Engineer No. C59538

J. Erosion (ULDC Section 7.10)

1. Applicable ULDC Requirements

According to the ULDC, the potential for erosion damage must be evaluated and addressed. Erosion damage to riverine levees is usually due to the following conditions: 1) high velocity flows coupled with erosive levee materials and/or poor hydraulic conditions; 2) large waves developed by wind over large, open bodies of water like a bypass; and 3) boat wakes. Erosion hazard is increased by a number of factors, which include:

a. Compromised levee prism geometry.

b. Geomorphologic trends as indicated by channel migration and historical damage.

c. Loss or narrowing of the natural berm located between the levee and stream bank.

d. Streamflow velocity, depth, duration, and shear.

e. Wind-wave shear stress.

f. Levees constructed from erodible materials, particularly low cohesion sands/silts or dispersive soils.

g. Stream banks or berms composed of erodible materials such as mining debris.

h. Detrimental hydraulic anomalies, such as encroachments.

i. Absence of beneficial vegetation or other slope protection.

j. Boat wakes.

Levees that pose an immediate erosional breaching hazard during either a flood or normal flow conditions need to be repaired based on analysis of the above hazard factors. Similarly, levees that are likely to be significantly damaged during either a flood or normal flow conditions should be protected with appropriate slope treatments. Field surveys of bank conditions and near-bank bathymetry may reveal new or worsened vulnerabilities after high-flow events. Operation and maintenance of flood protection features should be implemented in a forward-looking manner that identifies potential levee safety risks due to erosion. Performance-based analyses and predictive models should be considered. At a minimum, the civil engineer's analyses should consider the annual erosion surveys conducted under USACE's Sacramento

River Bank Protection Project and the DWR erosion surveys utilized on the San Joaquin River flood protection system. The downward projection of the theoretical 3h:1v has traditionally been considered to represent a minimum element of slope stability for the overlying levee fill.

Velocity and shear stress computations for assessment of erosion potential should follow the methods described in EM 1110-2-1913 and EM 1110-2-1601. River channel hydraulics and migration can be assessed using the methods described in EM 1110-2-1416 and EM 1110-2-1418. Hydraulic models developed for the Sacramento River Bank Protection Project are available from USACE Sacramento District or from DWR.

2. Documentation of ULDC Compliance

The following provides a summary of the detailed analyses and documentation that have been performed and developed in order to bring the Star Bend Setback Levee into compliance with ULDC. The section also provides a reference to the location where relevant documentation can be found as it pertains to ULDC Section 7.10.

As a newly constructed setback levee section, the project mitigated an area of active erosion. The reduced flow velocity associated with the new levee alignment, along with the materials used in the setback levee's construction and the establishment of good vegetative growth after construction, significantly reduced the probability for erosion to occur in the future.

a. Compromised Levee Prism Geometry

The Star Bend Setback Levee is a newly constructed levee, and it meets all of the ULDC levee geometry requirements. See **Section H – Levee Geometry.**

b. Geomorphologic Trends

Site geomorphology is discussed in the hydraulic report. Channel migration has been identified, and it is one of the reasons for the construction of the setback levee as this channel migration threatened the previous levee alignment. The setback levee alignment was selected to allow room for channel migration, and the reduced flow velocities from the setback levee mitigate geomorphologic risks to the newly constructed levee.

c. Loss of Natural Berm

An analysis of the erosion rates for the previous levee alignment determined that the levee would likely be at risk due to stream bank erosion within approximately 35 years. The setback levee provides significant additional buffer (approximately

600 feet at the north end of the levee, to over 1,200 additional feet at the midpoint) to allow for future channel migration compared to the previous levee, and was found to be safe from stream bank erosion within the lifespan of the project.

d. Streamflow Velocity, Depth, Duration, and Shear

The setback levee reduces the peak water elevation along the majority of the length of the levee, reduces flow velocities, and reduces shear stress indices in the river channel and overbank areas at, and just upstream of, the Star Bend area. See the hydraulic report (**Reference 2)** for more details.

e. Wind-Wave Shear Stress

See **Section Q – Wind Setup and Wave Run-up** for details of the wind-wave analysis.

f. Levee Materials

Levee embankment material for the project was obtained from the existing levee and borrow sources containing low-permeability soils within the O'Conner Lakes area, where material had been borrowed previously for the USACE Shanghai Bend Setback Levee Project. Some additional material (approximately 51,000 cubic yards) was obtained from the Reclamation District 1001 borrow site located near State Highway 99 and Striplin Road (more specifically along Pacific Avenue). Material for construction of the slurry cutoff wall was excavated from the cutoff wall trench and mixed with bentonite slurry, cement (at the cutoff wall tie-in locations), and water to form an impermeable barrier three feet in width. The completed setback levee was topped with an all-weather surface, and the levee embankments were protected by applying erosion control seeding.

g. Stream Banks or Berms Composed of Erodible Materials such as Mining Debris

The stream banks are naturally occurring materials, but are susceptible to erosion. See Item b (above) for discussion of the geomorphologic trends and channel migration.

h. Detrimental Hydraulic Anomalies, such as Encroachments

The waterside of the levee consists of flat, open ground with some vegetation that does not present a particular risk of erosion. There are pipe crossings at the north end of the setback levee, which have been designed according to USACE and ULDC guidelines and are discussed in **Section M – Penetrations**.

i. Vegetation

The levee has been hydroseeded with vegetation appropriate to protect the levee from erosion. Because the velocities at this location are less than five feet per second, the hydro-seeding and vegetation in place are adequate to protect the setback levee from erosion. There was, therefore, no need to place rock slope protection along the levee landside slope.

j. Boat Wakes

The main river channel is more than 1,000 feet away from the setback levee, and the water level is far below the setback levee during normal flows. Therefore, the potential for erosion damage from boat wakes is negligible during normal flows. Additionally, the existing stream bank is lined with trees which would impede wakes from reaching the setback levee. During high flows, boats are not likely to be present on the river.

3. Conclusions

The Star Bend Setback Levee meets the requirements described in ULDC Section 7.10.

4. ULDC Compliance Statement

ATTACHMENT A
STAR BEND SETBACK LEVEE
DWR ULDC COMPLIANCE STATEMENT
SECTION 7.10 – EROSION

CALIFORNIA DEPARTMENT OF WATER RESOURCES
URBAN LEVEE DESIGN CRITERIA COMPLIANCE STATEMENT
SECTION 7.10 - Erosion

STAR BEND SETBACK LEVEE

As documented in the Technical Memorandum entitled: *Star Bend Setback Levee Project, Urban Levee Design Criteria Compliance, Section 7.10 – Erosion*, the Star Bend Setback Levee, a portion of the Feather River West Levee, complies with the requirements of California's May 2012 Urban Levee Design Criteria (ULDC) Section 7.10 – Erosion.

Professional Engineer in Responsible Charge:

June 30, 2016

Name: Jonathan L. Kors *Date*
California Professional Engineer No. C59538

K. Right-of-Way (ULDC Section 7.11)

1. Applicable ULDC Requirements

Right-of-way criteria for levees and floodwalls in urban and urbanizing areas need to meet the following objectives:

a. Allow adequate room for maintenance, inspection, patrolling during high water, and flood-fighting.

b. To the extent practical, adequate right-of-way should be available to provide additional room to expand facilities in the future. Reasons to expand the facilities might include:

- Desire by the community to provide higher levels of flood protection
- Changes in design criteria, poor performance during high water, updated hydrology and/or hydraulics, or other data that would indicate that additional modifications are necessary to maintain the urban level of flood protection

c. Prohibit excavations and land modifications that would endanger the integrity of the levee or floodwall.

2. Documentation of ULDC Compliance

The following provides a summary of the detailed analyses and documentation that have been performed and developed in order to comply with ULDC ROW criteria. The section also provides a reference to the location where relevant documentation can be found as it pertains to ULDC Section 7.11.

The right of way acquired for the Star Bend Setback Levee is described in the Land Acquisition Plan – Volume 1 by Wood Rodgers (**Reference 11**).

a. Inspection and Maintenance

- The Land Acquisition plans provides for a 50-foot ROW at the toe of the levee on both water- and landside, with an access road and vegetation to be maintained by LDI to allow for inspection and maintenance of the levee. Additionally, there is a 20-foot easement in the adjacent landside properties for the pump station distribution waterlines.

b. Future Levee Expansion

- There are no structures within 50 feet of the toe of the levee on both the landside and the waterside (see As-Builts, **Reference 8**). The Tudor Mutual Water Company (TMWC) and Volcano Vista pump discharge distribution boxes and other irrigation facilities were constructed with 50 feet of clearance from the landside levee toe. See **Reference 19** for the TMWC pumping plant basis of design.

c. City/County Restrictions

- Any significant excavation or land modifications will require a grading permit from Sutter County. As part of the permitting process, LD1 and/or SBFCA will be consulted on any projects that might affect the levee, and will ensure that excavations and land modifications near the levee are not detrimental to the levee. Additionally, a CVFPB permit would also be required for any excavation or grading near the levee. The CVFPB requires a geo-technical assessment to be performed to make sure that such activities will not be detrimental to the levee. The CVFPB also coordinates their permit applications with the local levee maintaining agencies before issuing permits. As part of the permitting process, LD1 would be brought in on such projects and would ensure that the levee integrity is not compromised.

3. Conclusions

The Star Bend Setback Levee meets the requirements described in ULDC Section 7.11.

4. ULDC Compliance Statement

ATTACHMENT A
STAR BEND SETBACK LEVEE
DWR ULDC COMPLIANCE STATEMENT
SECTION 7.11 – RIGHT-OF-WAY

CALIFORNIA DEPARTMENT OF WATER RESOURCES
URBAN LEVEE DESIGN CRITERIA COMPLIANCE STATEMENT
SECTION 7.11 – Right-of-Way

STAR BEND SETBACK LEVEE

As documented in this report entitled: *Star Bend Setback Levee Project, Urban Levee Design Criteria Compliance,* the Star Bend Setback Levee, a portion of the Feather River West Levee, complies with the requirements of California's May 2012 Urban Levee Design Criteria (ULDC) Section 7.11 – Right-of-Way.

Professional Engineer in Responsible Charge:

June 30, 2016

Name: Jonathan L. Kors *Date*
California Professional Engineer No. C59538

L. Encroachments (Excluding Penetrations, Closure Structures, and Levee Vegetation) (ULDC Section 7.12)

1. Applicable ULDC Requirements

a. Assessment of Existing Encroachments

The civil engineer needs to assess existing encroachments and render an opinion as to their impact on the reliable performance of the levee/floodwall for the full range of loading up to the HTOL. The opinion needs to consider all encroachments within the channel, on the levee, and within the landside ROW identified in Section 7.11, irrespective of whether or not the property rights have been acquired. Due to the limitations of the analytical tools used for assessing the impacts of encroachments, the civil engineer needs to exercise sound engineering judgment in rendering this opinion. The civil engineer shall consider the following when rendering this opinion: type, age, condition, performance history of the encroachment, impacts on the levee/floodwall structural integrity, impacts on the hydraulic effect on the channel and floodway, and impacts on the operation and maintenance of the levee/floodwall.

b. New Encroachments

All new (proposed) encroachments within the levee ROW, 20-foot-wide visibility zone, and the future needs area, shall meet current USACE guidance for design and construction unless otherwise authorized by the agency responsible for permitting encroachments along the levee (or floodwall). All new encroachments should be properly permitted.

2. Documentation of ULDC Compliance

The following provides a summary of the detailed analyses and documentation that have been performed in order to bring the Star Bend Setback Levee into compliance with ULDC upon completion of construction. The section also provides a reference to the location where relevant documentation can be found as it pertains to ULDC Section 7.12

As the Star Bend Setback Levee was a newly constructed levee in 2009, there were no previous encroachments except for a water supply pipe crossing and a discharge pipe system. Both of these items are discussed in **Section M – Penetrations**. However, there are four main easements identified in the Land Acquisition Plan (from **Reference 11**, see **Exhibit 3** below): 1) the Volcano Vista waterline easement; 2) the TMWC and Volcano Vista overlapping access easement; 3) the Singh & Judge Farms LLC & TMWC access easement; and, 4) the Tudor Mutual Water Co.

Waterline Easement, all of which run along the landside of the levee. Combined, these easements are 20 feet wide and are located 50 feet from the landside toe of the levee. The Churkin & Tudor overlapping access easement, Churkin Waterline easement, and Tudor Mutual Water Co. Waterline Easement also encompass the access road and the pumping station pipes and structures at the northern end of the site and connect to the existing pumping plant. There is also a public access easement at Shannon Road. Any future encroachments will require the appropriate permit from the CVFPB ensuring that LD1 and other agencies will review any proposed encroachments.

3. Conclusions

The Star Bend Setback Levee meets the requirements described in ULDC Section 7.12.

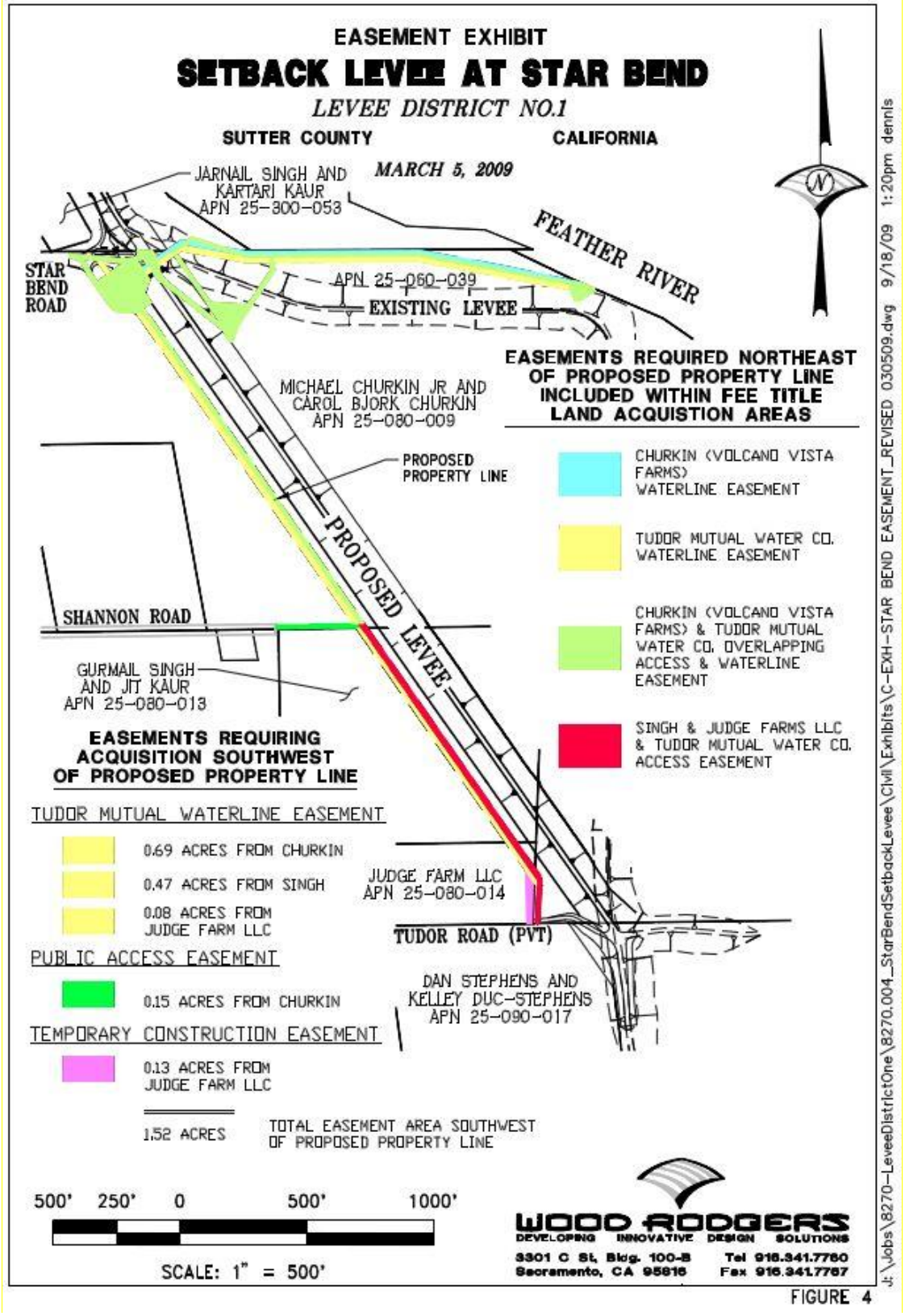

Exhibit 5: Setback Levee at Star Bend Easement Exhibit

4. ULDC Compliance Statement

ATTACHMENT A
STAR BEND SETBACK LEVEE
DWR ULDC COMPLIANCE STATEMENT
SECTION 7.12 – ENCROACHMENTS (EXCLUDING PENETRATIONS, CLOSURE STRUCTURES, AND LEVEE VEGETATION)

CALIFORNIA DEPARTMENT OF WATER RESOURCES
URBAN LEVEE DESIGN CRITERIA COMPLIANCE STATEMENT
SECTION 7.12 – Encroachments (Excluding Penetrations, Closure Structures, and Levee Vegetation)

STAR BEND SETBACK LEVEE

As documented in this report entitled: *Star Bend Setback Levee Project, Urban Levee Design Criteria Compliance,* the Star Bend Setback Levee, a portion of the Feather River West Levee, complies with the requirements of California's May 2012 Urban Levee Design Criteria (ULDC) Section 7.12 – Encroachments (Excluding Penetrations, Closure Structures, and Levee Vegetation).

Professional Engineer in Responsible Charge:

REGISTERED PROFESSIONAL ENGINEER
JONATHAN L. KORS
C59538
EXP. 12-31-17
CIVIL
STATE OF CALIFORNIA

_____ June 30, 2016

Name: Jonathan L. Kors *Date*
California Professional Engineer No. C59538

M. Penetrations (ULDC Section 7.13)

1. Applicable ULDC Requirements

a. Assessment of Existing Penetrations

Penetrations typically include pipe crossings through the levee embankment and its foundation as well as transportation structures over or through part of the levee/floodwall. Penetrations have the potential to produce rapid breaching because they can provide a preferential seepage path or an open conveyance for floodwaters. The civil engineer needs to assess existing penetrations and render an opinion as to their impact on the reliable performance of the levee/floodwall for the full range of loading up to the HTOL. Due to the limitations of analytical tools for assessing the impacts of penetrations, the civil engineer needs to exercise sound engineering judgment in rendering this opinion.

A hazard assessment needs to be performed for each penetration, whether permitted or not. Penetrations with a potential to be a high hazard need to have a full engineering evaluation in order to demonstrate that either the hazard is acceptable or that it must be removed or modified. All penetrations are to be authorized by the agency responsible for permitting penetrations along the levee (or floodwall), removed, or properly abandoned. Operation and maintenance of the penetration shall comply with the conditions required by the approved permit application.

b. Pipes and Culverts

The civil engineer shall consider guidance in Chapter 8 of EM 1110-2-1913 and the following when assessing pipes and culverts and rendering an opinion: the type of utility, pipe diameter, pipe material, pipe joint type, number of joints, angles, thrust protection, pipe bedding and method, age, degree of corrosion, location and depth below the DWSE, performance history, pipe testing or inspection (including video inspection) results, and remaining life of the facility.

c. New Penetrations

All new (proposed) penetrations are to be authorized by the agency responsible for permitting penetrations along the levee (or floodwall). All new penetrations need to meet current USACE guidance for design and construction. For smaller diameter pipes installed in larger diameter pipes through the levee or its foundation, the annular space between the two pipes must be fully grouted along the entire portion crossing the levee or its foundation. No plastic pipes are

permitted for new or replacement construction. New penetrations should be designed to allow for interior video access for inspection purposes. In addition, new pressurized pipelines must have their invert placed above the DWSE and must not be located in the actual levee prism or its foundation unless the civil engineer provides a professional opinion that the pipe or culvert will not have an adverse impact on the integrity/operation of the flood control system. EM 1110-2-1913 specifies the conditions of a pressurized pipe in order for it to be accepted in the levee foundation. All new pressurized pipes need to be equipped with a positive closure at the waterside edge of the levee crest. Any gravity- flowing pipe needs to be provided with a flap gate at the waterside outlet and a sluice gate located in a gatewell at the waterside edge of the levee crest. The positive closures and the sluice gates need to be accessible during high water stages.

2. Documentation of ULDC Compliance

The following provides a summary of the detailed analyses and documentation that have been performed and developed in order to bring the Star Bend Setback Levee into compliance with the ULDC upon completion of construction. The section also provides a reference to the location where relevant documentation can be found as it pertains to ULDC Section 7.13.

A pipe crossing for the existing Tudor Mutual Water Company Star Bend Pumping Plant has been constructed according to USACE and CVFPB guidelines containing two 30" and one 18" irrigation pipes. At the levee slopes, the flowline of the pipes were designed to be outside of the minimum levee template as described in the ULDC, and the flowlines of the pipes at the levee crown were constructed above the DWSE per ULDC requirements. See the pumping plant basis of design (**Reference 19**), and **Figures 3** and **4**, attached.

A pair of 15" discharge pipes cross the existing levee where the Star Bend Setback Levee ties in to the existing north levee. By way of both the Star Bend Setback Levee and FRWL Project, these pipes have been reconstructed to meet USACE and CVFPB guidelines along with the levee degrade and cutoff wall construction. See **Figures 3** and **5**, attached.

3. Conclusions

The Star Bend Setback Levee Project meets the requirements described in ULDC Section 7.13.

4. ULDC Compliance Statement

ATTACHMENT A
STAR BEND SETBACK LEVEE
DWR ULDC COMPLIANCE STATEMENT
SECTION 7.13 – PENETRATIONS

CALIFORNIA DEPARTMENT OF WATER RESOURCES
URBAN LEVEE DESIGN CRITERIA COMPLIANCE STATEMENT
SECTION 7.13 - Penetrations

STAR BEND SETBACK LEVEE

As documented in this report entitled: *Star Bend Setback Levee Project, Urban Levee Design Criteria Compliance,* the Star Bend Setback Levee, a portion of the Feather River West Levee, complies with the requirements of California's May 2012 Urban Levee Design Criteria (ULDC) Section 7.13 – Penetrations.

Professional Engineer in Responsible Charge:

June 30, 2016

Name: Jonathan L. Kors *Date*
California Professional Engineer No. C59538

N. Floodwalls, Retaining Walls, and Closure Structures (ULDC Section 7.14)

1. Applicable ULDC Requirements

Based on the ULDC, current USACE design guidance for special features such as floodwalls, retaining walls, and closure structures is to be followed. This information is included in EM 1110-2-1913, EM 1110-2-2502, EC 1110-2-6067, and ETL 1110-2-571. Because design considerations for floodwalls and closure structures have continued to evolve since the 2005 New Orleans flood, and are still evolving, caution should be used when designing and assessing these structures. All global slope stability and embankment through-seepage and underseepage safety criteria requirements are applicable for floodwalls, retaining walls, and closure structures on levees. In addition, the civil engineer must evaluate and address the potential for the floodwall to induce settlement in the levee.

Floodwalls and retaining walls should only be used where it is impractical to use a conventional earth embankment (for instance, where there is insufficient space due to pre-existing improvements). If floodwalls are proposed on a levee, they should only be used for supplemental freeboard along the levee crest and account for impacts on operation and maintenance.

For closure structures, the civil engineer needs to provide the following information: maintaining entity, levee mile, Global Positioning System coordinates, Board permit number (if applicable), structure details, length of time to close structure, location and type of materials for closure, structure dimensions, age, and performance history.

Closure structures need to be tested at least once a year prior to the flood season so that crews responsible for implementing the structures are familiar with their operation and to provide assurance that all parts are present and in working order.

2. Documentation of ULDC Compliance

The following provides a summary of the detailed analyses and documentation that have been performed and developed in order to bring the Star Bend Setback Levee into compliance with ULDC upon completion of construction. The section also provides a reference to the location where relevant documentation can be found as it pertains to ULDC Section 7.14.

There are no retaining walls, flood walls, or closure structures in the Star Bend Setback Levee. Any future structures will require the appropriate permits to ensure that they meet the ULDC requirements.

3. Conclusions

The Star Bend Setback Levee meets the Floodwall, Retaining wall, and Closure Structure requirements as prescribed in ULDC Section 7.14.

4. ULDC Compliance Statement

ATTACHMENT A
STAR BEND SETBACK LEVEE
DWR ULDC COMPLIANCE STATEMENT
SECTION 7.14 – FLOODWALLS, RETAINING WALLS, AND CLOSURE STRUCTURES

CALIFORNIA DEPARTMENT OF WATER RESOURCES URBAN LEVEE DESIGN CRITERIA COMPLIANCE STATEMENT SECTION 7.14 – Floodwalls, Retaining Walls, and Closure Structures

STAR BEND SETBACK LEVEE

As documented in this report entitled: *Star Bend Setback Levee Project, Urban Levee Design Criteria Compliance,* the Star Bend Setback Levee, a portion of the Feather River West Levee, complies with the requirements of California's May 2012 Urban Levee Design Criteria (ULDC) Section 7.14 – Floodwalls, Retaining Walls, and Closure Structures.

Professional Engineer in Responsible Charge:

June 30, 2016

Name: Jonathan L. Kors *Date*
California Professional Engineer No. C59538

O. Animal Burrows (ULDC Section 7.15)

1. Applicable ULDC Requirements

Burrowing animals can present a significant threat to levee integrity; therefore, proactive animal control and damage repair are two required levee maintenance practices where burrowing animals are present. The potential for burrowing animal damage and associated remediation should also be considered during design. USACE's *Levee Owner's Manual for Non-federal Flood Control Works* (2006) states that burrowing animal control techniques involving fumigation, bait stations, bait broadcasting, or trapping have proven effective in certain situations, but regulatory agencies over various jurisdictions may have different requirements for environmental compliance. The issues to consider during levee design and evaluation include:

a. Individual or networked animal burrows may completely traverse a levee section.

b. There is no effective method to completely exclude burrowing animals from occupying grass-covered levees.

c. Rodenticide-treated baits are the most economical of all approaches to rodent population reduction.

d. DWR and other flood control agencies have found that 1) excavating and backfilling; and, 2) grouting are effective methods for repairing burrows. Grouting is more cost effective. A common and effective grout mix is made up of nine parts cement, one part bentonite, and enough water added to achieve 8 to10 inches of slump. Grout is pumped at low pressures to avoid damaging the embankment, starting low and proceeding up the levee slope.

e. Levee dragging should only occur after burrows are repaired.

f. Burrows temporarily covered for fumigation should be marked for later excavation and repair.

g. Extra vigilance in monitoring and repair of burrows is needed for frequently loaded levees.

h. For certain situations, such as short levee reaches, permanent burrowing animal barriers should be considered in designs.

2. Documentation of ULDC Compliance

The following provides a summary of the detailed analyses and documentation that have been performed and developed in order to bring the Star Bend Setback Levee into compliance with ULDC upon completion of construction. The section also provides a reference to the location where relevant documentation can be found as it pertains to ULDC Section 7.15.

Based on the DWR recent inspection reports, rodent infestation has not been identified for this reach of the levee. Additionally, LD1 has a good inspection program for detecting rodent activities and taking appropriate steps to eradicate burrowing rodents (see inspection report, **Reference 14**).

Per the Vegetation Monitoring Plans (see **Reference 12**), the levee is regularly inspected for potential issues including animal burrows (Section 10.1.1, Types of Inspections, and Erosion Control and Repair). LD1 takes appropriate steps for controlling rodent infestation as outlined in Appendix C 'Superintendent's Guide to Operation & Maintenance of California's Flood Control Projects' (**Reference 13**) Section 5 Rodent Control.

3. Conclusions

The Star Bend Setback Levee meets the requirements described in ULDC Section 7.15.

4. ULDC Compliance Statement

ATTACHMENT A
STAR BEND SETBACK LEVEE
DWR ULDC COMPLIANCE STATEMENT
SECTION 7.15 – ANIMAL BURROWS

CALIFORNIA DEPARTMENT OF WATER RESOURCES
URBAN LEVEE DESIGN CRITERIA COMPLIANCE STATEMENT
SECTION 7.15 – Animal Burrows

STAR BEND SETBACK LEVEE

As documented in this report entitled: *Star Bend Setback Levee Project, Urban Levee Design Criteria Compliance,* the Star Bend Setback Levee, a portion of the Feather River West Levee, complies with the requirements of California's May 2012 Urban Levee Design Criteria (ULDC) Section 7.15 – Animal Burrows.

Professional Engineer in Responsible Charge:

June 30, 2016

Name: Jonathan L. Kors *Date*
California Professional Engineer No. C59538

P. Levee Vegetation (ULDC Section 7.16)

1. Applicable ULDC Requirements

The California Department of Water Resources and the Sutter Butte Flood Control Agency are committed to developing flood risk reduction solutions that also integrate environmental stewardship. Guidance for levee vegetation management is focused on improving public safety. This is done by providing for levee integrity; visibility; and accessibility for inspections, maintenance, and flood fight operations; while, at the same time, critical environmental resources are protected, including the remaining shaded riverine aquatic habitat along many levees.

Policies and criteria regarding the removal of trees and other woody vegetation growing on levees are evolving and will be informed by ongoing and future research. Engineers and levee maintaining agencies have been instructed to consider the results of this research when deciding how to manage trees and other woody vegetation on levees.

The policy directives for managing vegetation on State Plan of Flood Control levees are incorporated into the 2012 CVFPP, and the criteria is defined in the ULDC. LD1 follows the ULDC criteria for managing vegetation on its levees.

2. Documentation of ULDC Compliance

a. Engineering Evaluation

The Star Bend Setback Levee is newly constructed, so all existing vegetation within the construction limits of the levee was removed to allow for construction. The newly constructed levee was hydro-seeded to provide slope stability, and no woody vegetation that might compromise the levee integrity was planted within the construction limits of the levee.

b. Routine Inspection

As part of the operation and maintenance responsibilities, LD1 routinely inspects the Star Bend Setback Levee for the growth of trees or other undesirable vegetation, as outlined in the Vegetation Monitoring Plan (**Reference 12**), Section 10.1.1.

c. Lower Waterside Vegetation

The lower waterside vegetation has been cleared outside of approximately 50 feet of the waterside levee toe. Brushy and woody vegetation over one inch in diameter and all weeds or excessively tall vegetation within this area have been removed by LD1 per the Vegetation Monitoring Plan

(**Reference 12**). The vegetation in the overflow area on the waterside of the levee is also maintained by California Department of Fish and Wildlife (CDFW) to preserve the project design floodplain and freeboard levels. See the Vegetation Monitoring Plan for more details. This plan adequately meets the requirements outlined by the ULDC.

3. Conclusions

The Star Bend Setback Levee meets the requirements described in ULDC Section 7.16.

4. ULDC Compliance Statement

ATTACHMENT A
STAR BEND SETBACK LEVEE
DWR ULDC COMPLIANCE STATEMENT
SECTION 7.16 – LEVEE VEGETATION

CALIFORNIA DEPARTMENT OF WATER RESOURCES
URBAN LEVEE DESIGN CRITERIA COMPLIANCE STATEMENT
SECTION 7.16 –Levee Vegetation

STAR BEND SETBACK LEVEE

As documented in this report entitled: *Star Bend Setback Levee Project, Urban Levee Design Criteria Compliance,* the Star Bend Setback Levee, a portion of the Feather River West Levee, complies with the requirements of California's May 2012 Urban Levee Design Criteria (ULDC) Section 7.16 – Levee Vegetation.

Professional Engineer in Responsible Charge:

_____ June 30, 2016

Name: Jonathan L. Kors *Date*
California Professional Engineer No. C59538

Q. Wind Setup and Wave Run-up (ULDC Section 7.17)

1. Applicable ULDC Requirements

Wind-wave analysis is required, as noted elsewhere in these criteria. The wind setup and wave run-up distances must be computed and added to the median 200-year still water surface elevation in order to determine the required elevation of the MTOL or floodwall. The setup and run-up also must be computed and considered for analysis of erosion and overtopping impacts.

While the civil engineer has discretion in selection of the method to use, guidance for computing setup and run-up distances is provided in USACE's *Shore Protection Manual* (1984), EM 1110-2-1100, and EC 1110-2-6067. Other guidance is provided in the following publications: *Wave Overtopping of Sea Defenses and Related Structures: Assessment Manual* (2007); *Final Draft Guidelines for Coastal Flood Hazard Analysis and Mapping for the Pacific Coast for the United States* FEMA (2005); and *Mississippi Coastal Flood Hazard Project: Wave Run-up Method* (2008).

The setup and run-up computations require specification of potential wind speed and direction, fetch length, and water depth along the fetch. Standard practice should be followed to determine fetch length and water depths for the computations, consistent with the references cited above.

The wind speed to be used for setup and run-up computations is based on design practice for bank protection on the Sacramento River. The wind speed to be used is that which has a 50-percent probability of not being exceeded in any 50-year design period. This criterion yields a design wind speed with a return period of 72.6 years, or annual probability of 0.0138. This design wind speed should be used for design of levees covered by the criteria in this document. Per USACE guidance, a limited amount of levee overtopping can be allowed without armoring, depending on levee geometry, soil conditions, and ground cover. Ground cover typically ranges between 0.01 cubic feet per second per foot (cfs/ft) and 0.1 cfs/ft.

To estimate the maximum wave run-up for setting the elevation of the physical top of the levee or floodwall, a design wind speed duration of less than one hour should be used, consistent with historical bank protection design.

For setup and run-up computations for erosion protection design, and particularly for estimating median stone weight for armoring a levee, the duration of the wind should be the shortest length of time that would yield significant levee erosion; four-hour and six-hour durations have been used previously by USACE along the Sacramento River.

In performing these computations, the civil engineer should consider the duration of the hydrograph, as well as that this method is based on open water and can result in excessive wave heights for riverine environments. Civil engineers should use caution in specifying excessive freeboard for wave run-up until further research is performed. Based on the long history of performance of the Sacramento River Flood Control Project, six feet of freeboard should be considered sufficient, except in unusual circumstances.

2. Documentation of ULDC Compliance

The following provides a summary of the detailed analyses and documentation that have been performed and developed in order to bring the Star Bend Setback Levee into compliance with ULDC upon completion of construction. The section also provides a reference to the location where relevant documentation can be found as it pertains to ULDC Section 7.17.

Per the PBI Wind Setup and Wave Run-up Analysis Technical Memo (**Reference 15**), the minimum freeboard requirement for the events outlined in the ULDC requirements is the greater of the wind setup plus wave run-up, or a total of three feet.

Wind data was collected from the California Irrigation Management Information System (CIMIS) Nicolaus Number 30 weather station, and was analyzed per USACE guidelines to determine top wind speeds and directions. The wind setup was then calculated in accordance with USACE EM 1110-2-1420 and was determined to vary between 0.1 and 0.5 feet.

The wave run-up was calculated according to the USACE EM 1110-2-1110 equations and methodology, and was adjusted to account for areas of vegetation that might reduce wave run-up (see the Wind Setup and Wave Run-up analysis, **Reference 15**). The wave run-up was then determined to be between 0.7 and 2.2 feet depending on the direction of the wave.

The combined totals of the wind setup and wave run-up were found to vary between 0.8 and 2.6 feet. Because this is less than the DWSE plus three-foot, the requirements for Section 7.17 Wind Setup and Wave Run-up are satisfied.

3. Conclusion

The Star Bend Setback Levee meets the requirements described in ULDC Section 7.17.

4. ULDC Compliance Statement

ATTACHMENT A
STAR BEND SETBACK LEVEE
DWR ULDC COMPLIANCE STATEMENT
SECTION 7.17 – WIND SETUP AND WAVE RUNUP

CALIFORNIA DEPARTMENT OF WATER RESOURCES
URBAN LEVEE DESIGN CRITERIA COMPLIANCE STATEMENT
SECTION 7.17 - Wind Setup and Wave Run-up

STAR BEND SETBACK LEVEE

As documented in this report entitled: *Star Bend Setback Levee Project, Urban Levee Design Criteria Compliance,* the Star Bend Setback Levee, a portion of the Feather River West Levee, complies with the requirements of California's May 2012 Urban Levee Design Criteria (ULDC) Section 7.17 – Wind Setup and Wave Run-up.

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June 30, 2016

Name: Jonathan L. Kors *Date*
California Professional Engineer No. C59538

R. Security (ULDC Section 7.18)

1. Applicable ULDC Requirements

A security plan is required to protect urban and urbanizing area levee systems (including closure structures and other appurtenances) from acts of terrorism and other malicious or negligent acts. The security plan is to identify security personnel, responsibilities, resources, and measures. The security plan should be made available to qualified officials within and outside of the levee maintaining agency. Security measures should be increased for frequently loaded levees and floodwalls, elevated threat periods, and during high water on intermittently loaded levees and floodwalls. In developing the security plan, the agency/agencies responsible for levee maintenance must consider and prioritize vulnerabilities and employ an array of security measures from four basic categories to address vulnerabilities:

a. Networked detection

b. Deterrence

c. Physical security

d. Intrusion interdiction during high threat periods

Some security measures, such as signs and access controls, fall into several of these categories. Each levee maintaining agency must appoint a security director who will manage the security planning efforts and establish a chain of command for emergency operations. The security director will be responsible for an annual review and update of the security plan.

2. Documentation of ULDC Compliance

a. LD1 Security Plan

For the Star Bend Setback Levee, LD1 utilizes their Flood Safety Pan (**Reference 16**) as their "Security Plan". This plan describes the resources available to cope with various emergencies, and measures applicable to each type of emergency or security threat. LD1 has developed close working relationships with law enforcement, fire, and emergency response organizations to assist in any emergency or during security threat situations. Until a permanent security director has been assigned for the overall Feather River West Levee system, the LD1 General Manager serves as the security director for the Star Bend Setback Levee.

The Flood Safety Plan outlines LD1's planned response to flood emergencies in Sutter County or those emergencies affecting LD1's responsibilities in Sutter

County. The Flood Safety Plan provides information, policies, and procedures that will guide and assist LD1 in efficiently handling flood emergencies. The plan addresses flood preparedness, levee patrols, flood fight, evacuation procedures, floodwater removal, and related subjects. This plan allows implementation of the California Standardized Emergency Management System (SEMS). When used in conjunction with the California Emergency Plan and other local emergency plans, it will facilitate multi-agency and multi-jurisdictional coordination, particularly among LD1, local governments, and State agencies in flood emergency operations.

Although this is a public document, appendices contain specific procedures to be followed in flood response. The appendices include sensitive material, such as personal contact information. Therefore, they are subject to restricted-use handling procedures. Edited copies deleting restricted data may be obtained from the LD1 main office located at 243 Second Street, Yuba City, CA 95991.

b. The LD l Flood Safety Plan:

- Establishes the emergency management organization to respond to a flood emergency affecting LD1.
- Identifies the policies, responsibilities, and procedures required to protect the health and safety of LD1 from the effects of flood emergencies.
- Establishes operational procedures associated with field response to flood emergencies and the recovery process.
- Identifies policies for after-action analyses and follow-on activities.

Agriculture is the primary land use on the landside of the levee, and habitat enhancement projects exist on the waterside of the levee. All access points from public roadways are through pipe gates with locks that are protected by lock wells. Appropriate signage is present at each access point informing the public that the levees are not for public access or travel.

During periods of high water, the levees are patrolled more frequently by LD1 personnel and volunteers in order that each reach of levee is traversed on the average of once every four hours. These patrols are to look for any signs of levee distress as well as security threats including suspicious or unauthorized activity.

c. Organization and Assignment of Responsibilities

LD1 is responsible for the setback levee in coordination with MHM Engineers, Sutter County Operational Area, DWR, and USACE, and may request additional mutual aid partners via Inland Region's Regional Emergency Operations Center REOC.

d. Direction, Control, and Coordination

LD1 establishes overall policies and priorities, and its General Manager will assume responsibility during emergencies. An Incident Commander will be appointed and report to the General Manager during emergencies. The Incident Commander will coordinate individual flood fight crews, including those acquired under Mutual Aid from other agencies.

e. Communications

A Public Information Officer (PIO) will coordinate communications, and may request additional personnel from the local Radio Amateurs Civil Emergency Services (RACES) and via Mutual Aid. They will utilize the Emergency Alert System (EAS) and Emergency Digital Information Service (EDIS), as well as local radio systems, to distribute information.

f. Administration, Finance, and Logistics

LD1 has developed and maintains the Flood Safety Plan in accordance with California Master Mutual Aid Agreement, and is responsible for record keeping and resource tracking.

g. Plan Development and Maintenance

LD1's General Manager has primary responsibility for the plan development, review and maintenance, training and exercise, and evaluation of the Flood Safety Plan and its updates.

h. Authorities and Maintenance

See the Flood Safety Plan for a list of sources providing authority for planning, conducting, and/or supporting flood emergency operations at the federal, state, and local level.

i. Flood Fight Plan Element

At the River Warning Stages or by notification of a potential problem by a levee patrol, LD1 shall establish necessary staging areas for supplies, equipment, and

personnel. Emergency responders will be dispatched as needed from these locations to address any problems that arise.

j. Floodwater Removal Element

LD1 may employ relief cuts and/or temporary pumping as needed to remove floodwater.

k. Evacuation Plan

Sutter County EOC is responsible for the decision to evacuate, and will relay evacuation instructions to the public via the POI, the Joint Information Center, and the EOC.

l. Requirements for Siting New Essential Services Buildings

Enforcement of the new Flood Safety Plan will not require any new service buildings.

m. Levee Patrol Element

LD1 shall patrol the levee when water levels meet specific criteria, with patrol frequencies increasing as water levels rise.

3. Conclusion

LD1 has adequate plans and features to address as best possible the security of the Star Bend Setback Levee system and meets the intent of the ULDC for security.

4. ULDC Compliance Statement

ATTACHMENT A
STAR BEND SETBACK LEVEE
DWR ULDC COMPLIANCE STATEMENT
SECTION 7.18 – SECURITY

CALIFORNIA DEPARTMENT OF WATER RESOURCES
URBAN LEVEE DESIGN CRITERIA COMPLIANCE STATEMENT
SECTION 7.18 - Security

STAR BEND SETBACK LEVEE

As documented in this report entitled: *Star Bend Setback Levee Project, Urban Levee Design Criteria Compliance,* the Star Bend Setback Levee, a portion of the Feather River West Levee, complies with the requirements of California's May 2012 Urban Levee Design Criteria (ULDC) Section 7.18 – Security.

Professional Engineer in Responsible Charge:

June 30, 2016

Name: Jonathan L. Kors *Date*
California Professional Engineer No. C59538

S. Sea Level Rise (ULDC Section 7.19)

1. Applicable ULDC Requirements

The effects of sea level rise are to be estimated and addressed for the period during which a Finding that the urban level of flood protection exists may be valid. For example, if the effect of sea level rise on the levee or floodwall is estimated to be one inch on the DWSE during the period in which a Finding may be valid, then the levee or floodwall design must be for the DWSE that includes the inch of sea level rise. It is advisable to consider a range of estimates and prepare for future expansion and structural raises to address long-term sea level rise. The Ocean Protection Council adopted guidance on March 11, 2011 for sea level rise along California's coast.

The guidance is available at:
http://www.opc.ca.gov/webmaster/ftp/pdf/docs/OPC_SeaLevelRise_Resolution_Adopted031111.pdf

USACE guidance is provided in EC 1165-2-212.

2. Documentation of ULDC Compliance

The following provides a summary of the detailed analyses and documentation that have been performed and developed in order to bring the Star Bend Setback Levee into compliance with ULDC upon completion of construction. The section also provides a reference to the location where relevant documentation can be found as it pertains to ULDC Section 7.19.

Sea level rise guidance is provided in USACE's ETL 1100-2-1. In addition, a sensitivity analysis was recently completed by DWR as part of the *Sacramento River Basin-Wide Feasibility Study* (BWFS) to evaluate how far upstream the backwater could extend up the Yolo Bypass and how sea-level rise could potentially impact levee freeboard. The BWFS used mean estimates of sea-level rise in 2062 (38.8 centimeters, or 1.27 feet) for the primary climate change analysis, with select additional runs with a high estimate of 83.1 centimeters, or 2.73 feet for sensitivity studies. The BWFS estimates for 2062 exceed the required timeframe stated in ULDC (20-year maximum) and are thus conservative for the FRWL Project

DWR's results indicate that the extremely high tidal condition would not propagate upstream past the Yolo Bypass Lisbon gage which confirms the stages at the gage will be controlled by riverine flows even with sea level rise. The Star Bend Setback Levee is upstream of the Lisbon gage and is outside the influence of sea level rise.

In addition, the water surface elevation (see **Section B – MTOL**) used to determine the top-of-levee elevation includes an additional one-foot of height to account for uncertainties which would include possible climate change. As there is at least three feet of freeboard above the DWSE (including the one foot of additional height), the project has appropriately accounted for sea level rise for the lifespan of the project.

3. Conclusions

The Star Bend Setback Levee meets the requirements described in ULDC Section 7.19.

4. ULDC Compliance Statement

ATTACHMENT A
STAR BEND SETBACK LEVEE
DWR ULDC COMPLIANCE STATEMENT
SECTION 7.19 – SEA LEVEL RISE

CALIFORNIA DEPARTMENT OF WATER RESOURCES
URBAN LEVEE DESIGN CRITERIA COMPLIANCE STATEMENT
SECTION 7.19 - Sea Level Rise

STAR BEND SETBACK LEVEE

As documented in this report entitled: *Star Bend Setback Levee Project, Urban Levee Design Criteria Compliance,* the Star Bend Setback Levee, a portion of the Feather River West Levee, complies with the requirements of California's May 2012 Urban Levee Design Criteria (ULDC) Section 7.19 – Sea Level Rise.

Professional Engineer in Responsible Charge:

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T. Emergency Actions (ULDC Section 7.20)

1. Applicable ULDC Requirements

As per ULDC, the emergency actions for the following should be developed before making a Finding of urban level of flood protection.

a. Closure structures that meet the requirements contained in the "Floodwalls, Retaining Walls, and Closure Structures" section may be assumed effective and relied upon for performing as designed.

b. Flood relief structures such as culverts, gates, weirs, pumping plants, and levee relief cuts may be assumed effective and relied upon for performing as designed provided they are identified in an approved flood relief plan in the operation and maintenance manual (and/or in the flood safety plan) for the project.

ULDC Section 7.20.1 outlines the requirements for flood relief structures. ULDC Section 7.20.2 also states that each public agency with the responsibility for public safety for residents protected by the levees and floodwalls must have a plan for flood events and other natural or man-made flood-related incidents that could result in human casualties, property destruction and economic losses. ULDC Section 7.20.2 lists the important components of a flood safety plan.

2. Documentation of ULDC Compliance

The following provides a summary of the detailed analyses and documentation that have been performed and developed in order to bring the Star Bend Setback Levee into compliance with ULDC upon completion of Construction. The section also provides a reference to the location where relevant documentation can be found as it pertains to ULDC Section 7.20.

There are no floodwalls or closure structures on the Star Bend Setback Levee.

The TMWC Star Bend Pumping Plant discharge pipes contain a positive closure device at the waterside crown hinge point that may be closed in the event of a flood. Procedures for operating the positive closure devices are contained within the TMWC Star Bend Pumping Plant and Discharge Piping System Operation and Maintenance Manual (**Reference 18**).

See **Section R - Security** for details of the LD1 Flood Safety Plan (**Reference 16**).

3. Conclusions

The Star Bend Setback Levee meets the requirements described in ULDC Section 7.20.

4. ULDC Compliance Statement

ATTACHMENT A
STAR BEND SETBACK LEVEE
DWR ULDC COMPLIANCE STATEMENT
SECTION 7.20 – EMERGENCY ACTIONS

CALIFORNIA DEPARTMENT OF WATER RESOURCES
URBAN LEVEE DESIGN CRITERIA COMPLIANCE STATEMENT
SECTION 7.20 - Emergency Actions

STAR BEND SETBACK LEVEE

As documented in this report entitled: *Star Bend Setback Levee Project, Urban Levee Design Criteria Compliance,* the Star Bend Setback Levee, a portion of the Feather River West Levee, complies with the requirements of California's May 2012 Urban Levee Design Criteria (ULDC) Section 7.20 – Emergency Actions.

Professional Engineer in Responsible Charge:

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U. Operations, Maintenance, Inspection, Monitoring, and Remediation of Poor Performance (ULDC Section 8.0)

1. Applicable ULDC Requirements

At a minimum, the following operation and maintenance-related requirements apply:

a. The levee system must have an operation and maintenance manual consistent with USACE requirements (except as may be appropriate to deviate from those requirements to comply with the ULDC).

b. All facilities necessary for providing the urban level of flood protection must be operated and maintained by an identified public agency with the authority and resources to do so.

c. USACE standard inspection requirements for project levees are applicable for all levees and floodwalls considered to provide the urban level of flood protection, including that a public agency (or agencies) routinely operates and maintains the levee system and inspects the entire levee system at least every 90 days and after every high water event.

d. Damage and maintenance inadequacies identified from inspections should be prioritized and addressed in a timely manner, not awaiting the periodic review process.

e. It is almost never practical or possible to completely know all of the engineering properties of levees and their foundations. Consequently, there will almost always be some degree of uncertainty that justifies both robust regular inspections and high water monitoring programs for levees and floodwalls protecting urban and urbanizing areas, with all of the attendant appurtenances and features (such as all-weather access roads on levee crowns and near the toe of wide landside berms).

f. Monitoring during high water needs to provide for a thorough visual inspection of both the waterside and landside levee slope (and landside berm toe area) at intervals of no more than 1 hour.

g. The levee system must have a levee security plan that meets the requirements described in Section 7.18.

h. The levee system must have a flood safety plan that meets the requirements described in Section 7.20.

Other requirements - such as for a post-earthquake remediation plan, right-of-way plan, encroachment remediation plan, penetration remediation plan, or flood relief plan - may also apply, depending on the situation.

2. Documentation of ULDC Compliance

The following provides a summary of the detailed analyses and documentation that have been performed and developed in order to bring the Star Bend Setback Levee into compliance with ULDC upon completion of construction. The section also provides a reference to the location where relevant documentation can be found as it pertains to ULDC Section 7.16.

a. The levee system must have an operation and maintenance manual consistent with USACE requirements.

   This project is covered by an addendum to the O&M manual for Unit No. 144; the Addendum to: Supplement to Standard Operation and Maintenance Manual Unit No. 144 (**Reference 17**).

b. All facilities necessary for providing the urban level of flood protection must be operated and maintained by an identified public agency with the authority and resources to do so.

   Levee District 1 (Sutter County) is the responsible public agency.

c. USACE standard inspection requirements for project levees are applicable for all levees and floodwalls considered to provide the urban level of flood protection.

   As prescribed in the USACE O&M manuals, DWR and respective local levee maintaining agencies inspect the entire levee system 4 time every year and after every high water event. The fall and the spring inspections are conducted jointly by DWR and local maintaining agency personnel and the other two inspections are done by local levee maintaining agency staff.

d. Damage and maintenance inadequacies identified from inspections should be prioritized and addressed in a timely manner, not awaiting the periodic review process.

   The local maintaining agency will adopt a policy to address damage and inadequacies according to this standard.

e. Inspections must account for design uncertainties.

The local maintaining agency will adopt inspection standards appropriate for the project.

f. Monitoring during high water needs to provide for a thorough visual inspection of both the waterside and landside levee slope (and landside berm toe area) at intervals of no more than 1 hour.

Local maintaining agency staff patrols the levee during high water situations. Protocols have been well established using Standardized Emergency Management System (SEMS) to seek state and federal assistance when needed.

g. The levee system must have a levee security plan that meets the requirements described in Section 7.18.

See **Section R – Security** for details of levee security plan

h. The levee system must have a flood safety plan that meets the requirements described in Section 7.20.

See **Section T – Emergency Actions** for details of the flood safety plan **(Reference 16)**.

3. Conclusions

The Star Bend Setback Levee meets the requirements described in ULDC Section 7.16.

4. ULDC Compliance Statement

ATTACHMENT A
STAR BEND SETBACK LEVEE
DWR ULDC COMPLIANCE STATEMENT
SECTION 8.0 – OPERATIONS, MAINTENANCE, INSPECTION, MONITORING, AND REMEDIATION OF POOR PERFORMANCE

CALIFORNIA DEPARTMENT OF WATER RESOURCES
URBAN LEVEE DESIGN CRITERIA COMPLIANCE STATEMENT
SECTION 8.0 – Operations, Maintenance, Inspection, Monitoring, and Remediation of Poor Performance

STAR BEND SETBACK LEVEE

As documented in this report entitled: *Star Bend Setback Levee Project, Urban Levee Design Criteria Compliance,* the Star Bend Setback Levee, a portion of the Feather River West Levee, complies with the California's May 2012 Urban Levee Design Criteria (ULDC) Section 8.0 – Operations, Maintenance, Inspection, Monitoring, and Remediation of Poor Performance.

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June 30, 2016

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California Professional Engineer No. C59538

III. REFERENCES

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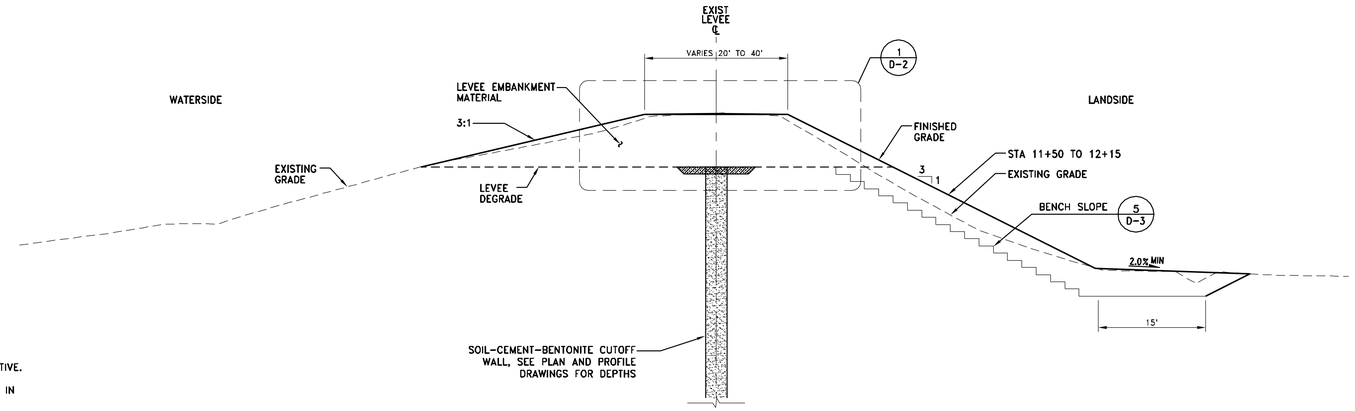
19. Wood Rodgers, Inc., Levee District No. 1 of Sutter County, Basis of Design Report for TMWC System Modifications, September 2010.

* No electronic copies. Hard copies are available on request.
** Available on DWR's website; http://www.water.ca.gov/

AS-BUILT



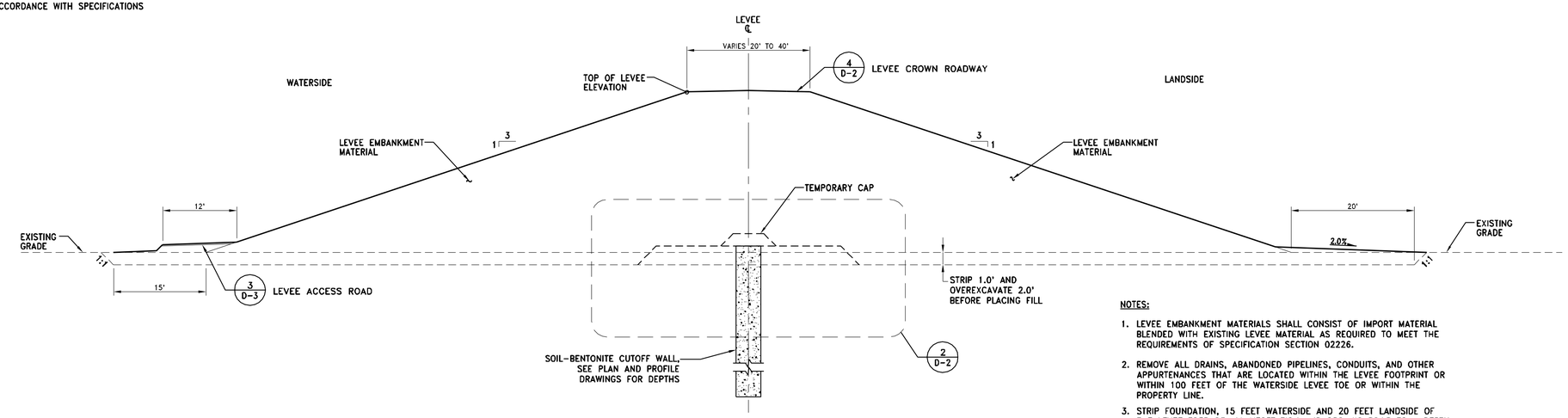
LEVEE CROSS SECTION - TYPICAL (1 / –)

SCALE AT FULL SIZE: 1"=10'-0"

STA 11+50 – STA 12+00

CONSTRUCTION SEQUENCE:

1. TRENCH AND COORDINATE INSPECTION WITH OWNER'S REPRESENTATIVE.
2. BACKFILL INSPECTION TRENCH WITH LEVEE EMBANKMENT MATERIAL IN ACCORDANCE WITH SECTION 02226.
3. CONSTRUCT CUTOFF WALL WORK PAD.
4. CONSTRUCT CUTOFF WALL.
5. COVER TOP OF WALL WITH 2 FT OF LEVEE EMBANKMENT FILL EXTENDING A MINIMUM OF 3 FT BOTH SIDES OF CUTOFF WALL.
6. ALLOW WALL TO CONSOLIDATE IN ACCORDANCE WITH SPECIFICATIONS SECTION 02352.
7. REMOVE TEMPORARY CAP.



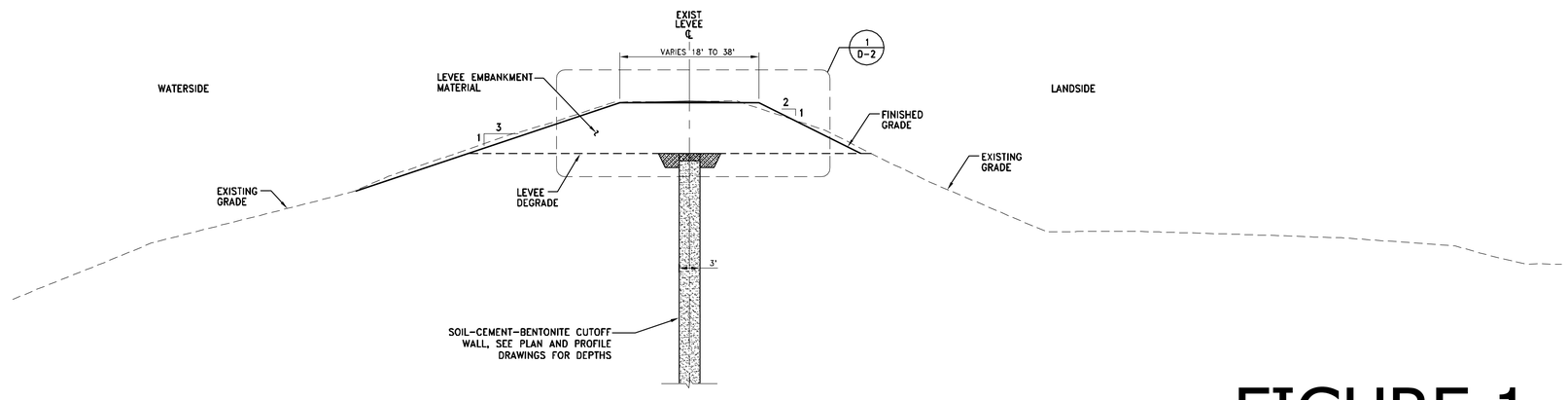
LEVEE CROSS SECTION - TYPICAL (2 / –)

SCALE AT FULL SIZE: 1"=10'-0"

STA 12+00 – STA 45+50

NOTES:

1. LEVEE EMBANKMENT MATERIALS SHALL CONSIST OF IMPORT MATERIAL BLENDED WITH EXISTING LEVEE MATERIAL AS REQUIRED TO MEET THE REQUIREMENTS OF SPECIFICATION SECTION 02226.
2. REMOVE ALL DRAINS, ABANDONED PIPELINES, CONDUITS, AND OTHER APPURTENANCES THAT ARE LOCATED WITHIN THE LEVEE FOOTPRINT OR WITHIN 100 FEET OF THE WATERSIDE LEVEE TOE OR WITHIN THE PROPERTY LINE.
3. STRIP FOUNDATION, 15 FEET WATERSIDE AND 20 FEET LANDSIDE OF THE LEVEE TOES OF ALL VEGETATION AND ORGANIC SOILS TO A DEPTH OF 1 FOOT MINIMUM AND REMOVE TREE ROOTS.
4. BACKFILL ALL HOLES, DEPRESSIONS AND DITCHES IN THE FOUNDATION WITHIN 100 FEET OF THE LEVEE TOES WITH NATIVE MATERIAL AND COMPACT IN ACCORDANCE WITH THE SPECIFICATIONS.



LEVEE CROSS SECTION - TYPICAL (3 / –)

SCALE AT FULL SIZE: 1"=10'-0"

STA 9+00 – STA 11+10

STA 45+00 – STA 48+00

FIGURE 1

WOOD RODGERS, INC.

REGISTERED PROFESSIONAL ENGINEER JONATHAN L. KORS No.C59538 Exp. 12/31/09 CIVIL STATE OF CALIFORNIA

DATE: OCTOBER 19, 2009

REV.	DESCRIPTION	BY	CHK.	APPR.	DATE
1	AS-BUILT	LCS	GP	JK	12/13/10
0	CONFORMED SET	HS	JT	JK	07/08/09

DESIGNED BY: R. CONN
DRAWN BY: RC
CHECKED BY: J. KORS
IN CHARGE: J. TWITCHELL
DATE: DECEMBER 13, 2010

WOOD RODGERS
DEVELOPING INNOVATIVE DESIGN SOLUTIONS
3301 C St, Bldg. 100-B Tel 916.341.7760
Sacramento, CA 95816 Fax 916.341.7767

IMPROVEMENT PLANS FOR
LOWER FEATHER RIVER SETBACK LEVEE AT STAR BEND

SETBACK LEVEE
TYPICAL SECTION & DETAILS

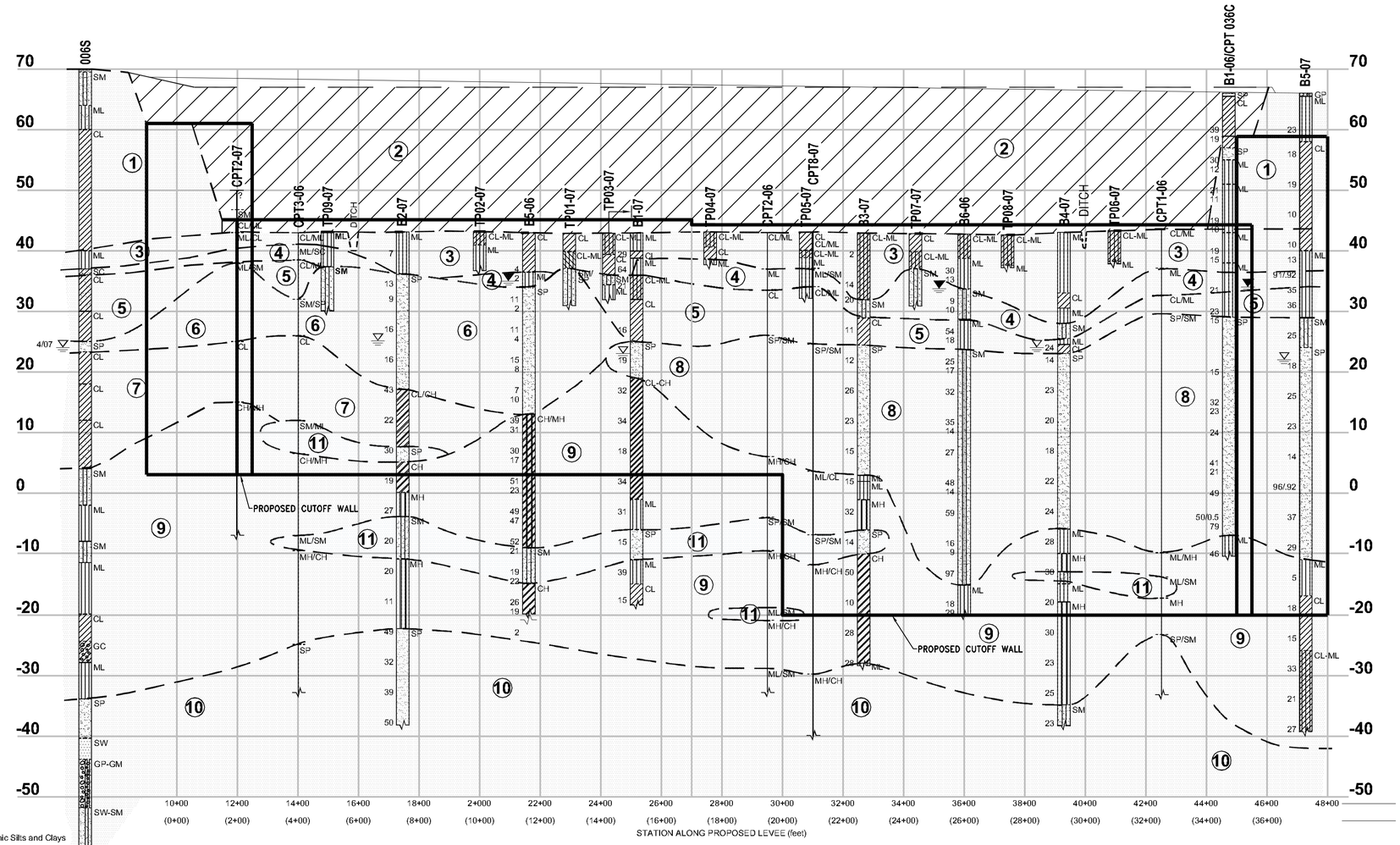
SUTTER COUNTY CALIFORNIA

VERIFY SCALES
BAR IS ONE INCH ON ORIGINAL DRAWING. ADJUST SCALES FOR REDUCED PLOTS
0 1"

HORIZ: 1"=40' VERT: 1"=4'
DRAWING NO. D-1
SHEET 33

J:\Jobs\8270-LeveeDistrictOne\8270.004_StarBendSetbackLevee\Civil\Dwg\As_Built\C-33-SD01_SBSL_ASBLT.dwg 1/03/11 3:00pm pirest

AS-BUILT



Boring Legend

B2-07 ← Borehole ID

Sample blow count 14

- OH, Moderate to Highly Plastic Organic Silts and Clays
- CH, Fat Clay
- MH, Elastic Silt
- OL, Low Plasticity Organic Silts and Clays
- CL, Lean Clay or Sandy Lean Clay
- ML, Silt or Sandy Silt
- CL-ML, Clayey Silt/Silty Clay
- SC, Clayey Sand
- SM, Silty Sand, Silty Sand with Gravel
- SP, Poorly Graded Sand, Poorly Graded Sand with Gravel
- SW, Well Graded Sand, Well Graded Sand with Gravel
- GC, Clayey Gravel
- GM, Silty Gravel, Silty Gravel with Sand
- GP, Poorly Graded Gravel, Poorly Graded Gravel with Sand
- GW, Well Graded Gravel, Well Graded Gravel with Sand

LEGEND

1. Existing Levee Fill (Variable medium dense to dense sand/silty sand, stiff to very stiff silt/lean clay)
2. New Setback Levee Fill

Alluvium (Qa/Qm)

3. Silt/Clayey Silt/Silty Clay (Stiff to very hard, slight to strong cementation)
4. Sand, Silty Sand, Sandy Silt (Loose to medium dense)
5. Lean Clay/Silt (Locally Cemented) (Stiff to very hard, slight to strong cementation)
6. Sand/Silty Sand (Loose to medium dense)
7. Clay (Very stiff to hard)

Modesto Formation (Qm)

8. Sand/Silty Sand (Medium dense to dense)
9. Clay/Silt (Stiff to hard)
10. Sand/Gravelly Sand/Sandy Gravel (Medium dense to dense)
11. Discontinuous Sand/Silty Sand Seams

▼ Groundwater Elevation in May 2006

▽ Groundwater Elevation in September 2007

HORIZONTAL SCALE: 1 inch = 400 ft.

VERTICAL SCALE: 1 inch = 10 ft.

NOTE:
1. BORING LOGS AND CUTOFF WALL PROFILE PROVIDED BY BLACKBURN CONSULTING, INC.
2. SOIL TYPE BOUNDARIES ARE APPROXIMATE AND BASED ON INTERPRETATION BETWEEN BORINGS.
3. DEPTH OF PROPOSED CUTOFF WALL SHOWN IS AS DESIGNED, SEE PP-1 TO PP-4 FOR AS-BUILT INFORMATION. LEAD-IN TRENCH/WALL NOT SHOWN

FIGURE 2

WOOD RODGERS, INC.

REGISTERED PROFESSIONAL ENGINEER JONATHAN L. KORS No.C59538 Exp. 12/31/09 CIVIL STATE OF CALIFORNIA

DATE: OCTOBER 19, 2009

REV.	DESCRIPTION	BY	CHK.	APPR.	DATE
1	AS-BUILT	LCS	GP	JK	12/13/10
0	CONFORMED SET	HS	JT	JK	07/08/09

DESIGNED BY: R. CONN
DRAWN BY: RC
CHECKED BY: J. KORS
IN CHARGE: J. TWITCHELL
DATE: DECEMBER 13, 2010

WOOD RODGERS
DEVELOPING INNOVATIVE DESIGN SOLUTIONS
3301 C St, Bldg. 100-B Sacramento, CA 95816
Tel 916.341.7760 Fax 916.341.7767

IMPROVEMENT PLANS FOR
LOWER FEATHER RIVER SETBACK LEVEE AT STAR BEND
CUTOFF WALL SUBSURFACE PROFILE
SUTTER COUNTY CALIFORNIA

VERIFY SCALES
BAR IS ONE INCH ON ORIGINAL DRAWING. ADJUST SCALES FOR REDUCED PLOTS
0 1"

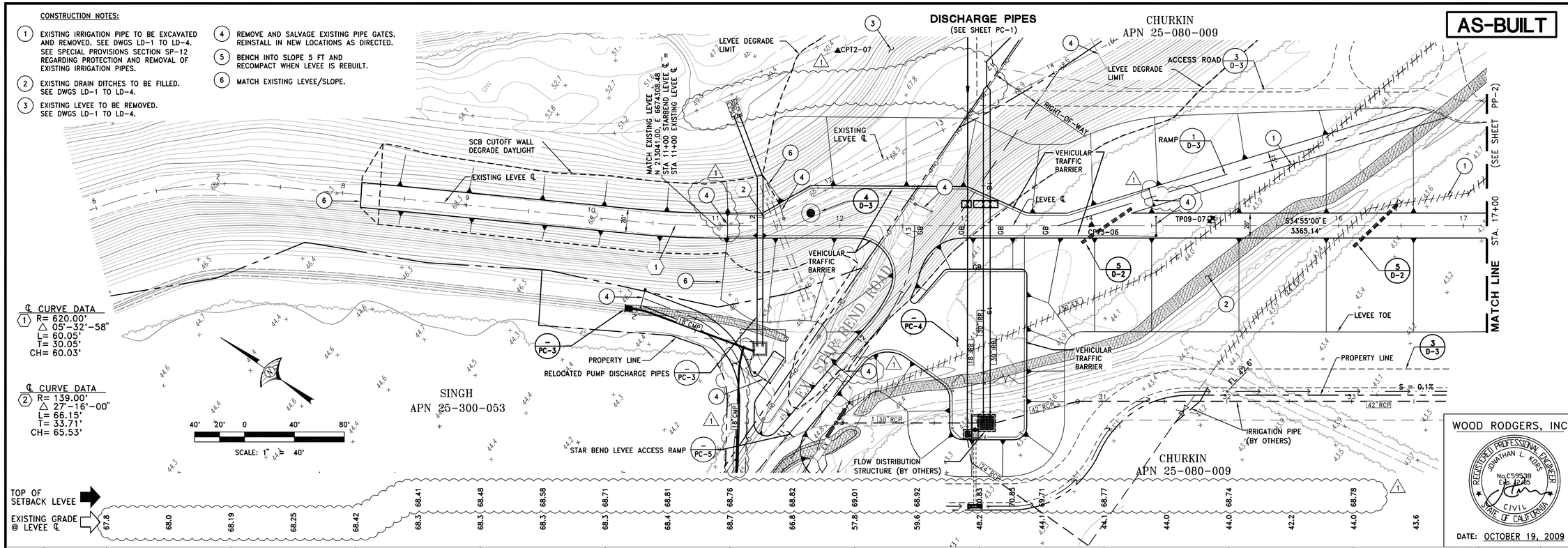
DRAWING NO. PP-6
SHEET 22

z:\jobs\3270-LeveeDistrictOne\3270.004_StarBendSetbackLevee\Civil\Dwg\As_Built\C-22-PP06_SBSL_ASBLT.dwg 1/03/11 2:38pm jprest

AS-BUILT

CONSTRUCTION NOTES:

1. EXISTING IRRIGATION PIPE TO BE EXCAVATED AND REMOVED. SEE DWGS LD-1 TO LD-4. SEE SPECIAL PROVISIONS SECTION SP-12 REGARDING PROTECTION AND REMOVAL OF EXISTING IRRIGATION PIPES.
2. EXISTING DRAIN DITCHES TO BE FILLED. SEE DWGS LD-1 TO LD-4.
3. EXISTING LEVEE TO BE REMOVED. SEE DWGS LD-1 TO LD-4.
4. REMOVE AND SALVAGE EXISTING PIPE GATES. REINSTALL IN NEW LOCATIONS AS DIRECTED.
5. BENCH INTO SLOPE 5 FT AND RECOMPACT WHEN LEVEE IS REBUILT.
6. MATCH EXISTING LEVEE/SLOPE.



WOOD RODGERS, INC.

REGISTERED PROFESSIONAL ENGINEER JONATHAN L. KORS No. C59539 Exp. 12/31/10 CIVIL STATE OF CALIFORNIA

DATE: OCTOBER 19, 2009

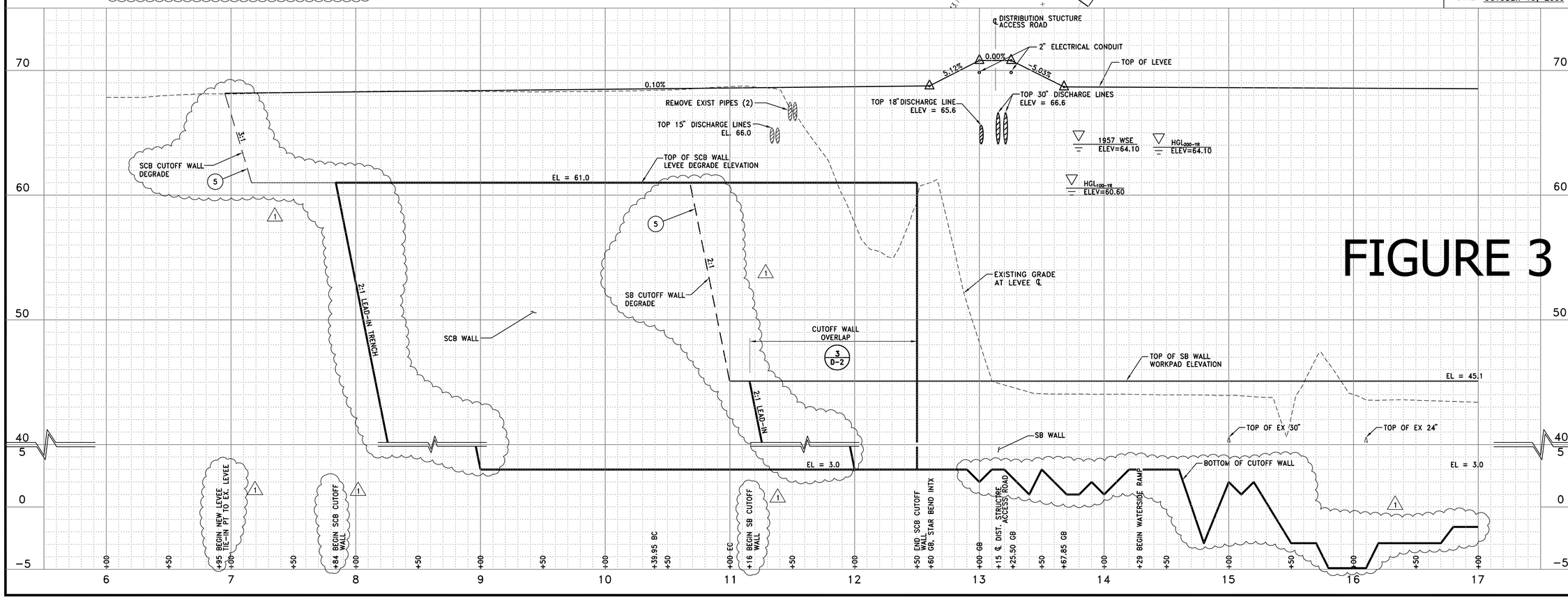


FIGURE 3

REV.	DESCRIPTION	BY	CHK.	APPR.	DATE
1	AS-BUILT, REV. ACC. RD., CUTOFF WALL, LEVEE TOP	LCS	GP	JK	12/13/10
0	CONFORMED SET	HS	JT	JK	07/08/09

DESIGNED BY: R. CONN
DRAWN BY: RC
CHECKED BY: J. KORS
IN CHARGE: J. TWITCHELL
DATE: DECEMBER 13, 2010

WOOD RODGERS
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3301 C St, Bldg. 100-B Tel 916.341.7760
Sacramento, CA 95816 Fax 916.341.7767

IMPROVEMENT PLANS FOR

LOWER FEATHER RIVER SETBACK LEVEE AT STAR BEND
SETBACK LEVEE PLAN AND PROFILE STA. 6+00 TO STA. 17+00

SUTTER COUNTY CALIFORNIA

VERIFY SCALES BAR IS ONE INCH ON ORIGINAL DRAWING ADJUST SCALES FOR REDUCED PLOTS 0 1"

HORIZ: 1"=40' VERT: 1"=4'

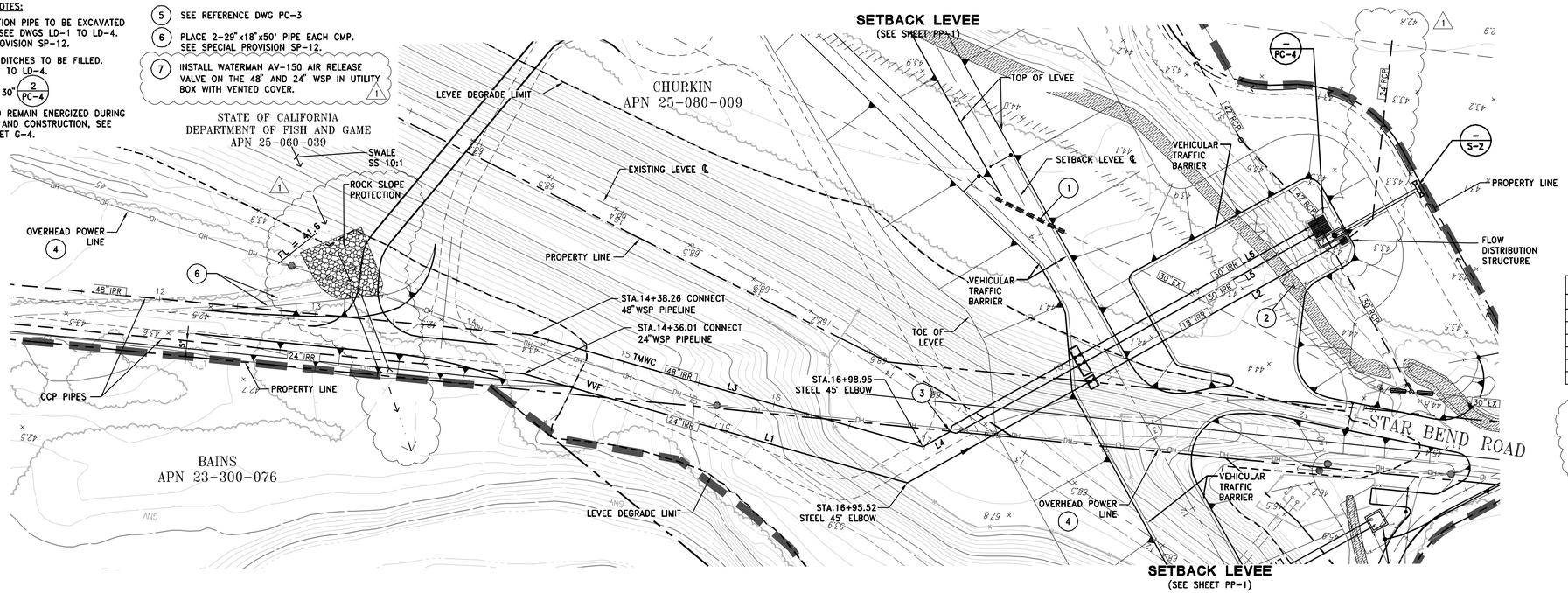
DRAWING NO. PP-1 SHEET 17

J:\Jobs\8270-LeveeDistrict1One\8270.004_StarBendSetbackLevee\Civil\Dwg\As_Built\C-17-PP01_SBSL_ASBLT.dwg 1/03/11 2:28pm jprlest

CONSTRUCTION NOTES:

1. EXISTING IRRIGATION PIPE TO BE EXCAVATED AND REMOVED. SEE DWGS LD-1 TO LD-4. SEE SPECIAL PROVISION SP-12.
2. EXISTING DRAIN DITCHES TO BE FILLED. SEE DWGS LD-1 TO LD-4.
3. WYE 48"x 30"x 30" (2/PC-4)
4. POWER LINES TO REMAIN ENERGIZED DURING LEVEE DEGRADE AND CONSTRUCTION, SEE NOTE 1 ON SHEET G-4.
5. SEE REFERENCE DWG PC-3
6. PLACE 2-29"x18"x50' PIPE EACH CMP. SEE SPECIAL PROVISION SP-12.
7. INSTALL WATERMAN AV-150 AIR RELEASE VALVE ON THE 48" AND 24" WSP IN UTILITY BOX WITH VENTED COVER. (1)

AS-BUILT



SCALE: 1" = 40'

WATER PIPE LINE TABLE		
LINE	LENGTH	BEARING
L1	255'	N79°59'38"W
L2	313'	S55°05'00"W
L3	261'	N79°59'38"W
L4	20'	S55°05'00"W
L5	258'	N55°05'00"E
L6	258'	S55°05'00"W

NOTE:
PIPE SHOWN ON THE PLANS AS BEING WELDED STEEL PIPE OR WSP IS MORTAR-LINED AND COATED-WELDED STEEL PIPE WITH WELDED BUTT JOINTS. ALL CONCRETE CYLINDER PIPE SHALL BE DESIGNED FOR A PRESSURE OF 100 PSI.

WOOD RODGERS, INC.

REGISTERED PROFESSIONAL ENGINEER
JONATHAN L. KORS
No. C59538
Exp. 12-31-05
CIVIL
STATE OF CALIFORNIA

DATE: OCTOBER 19, 2009

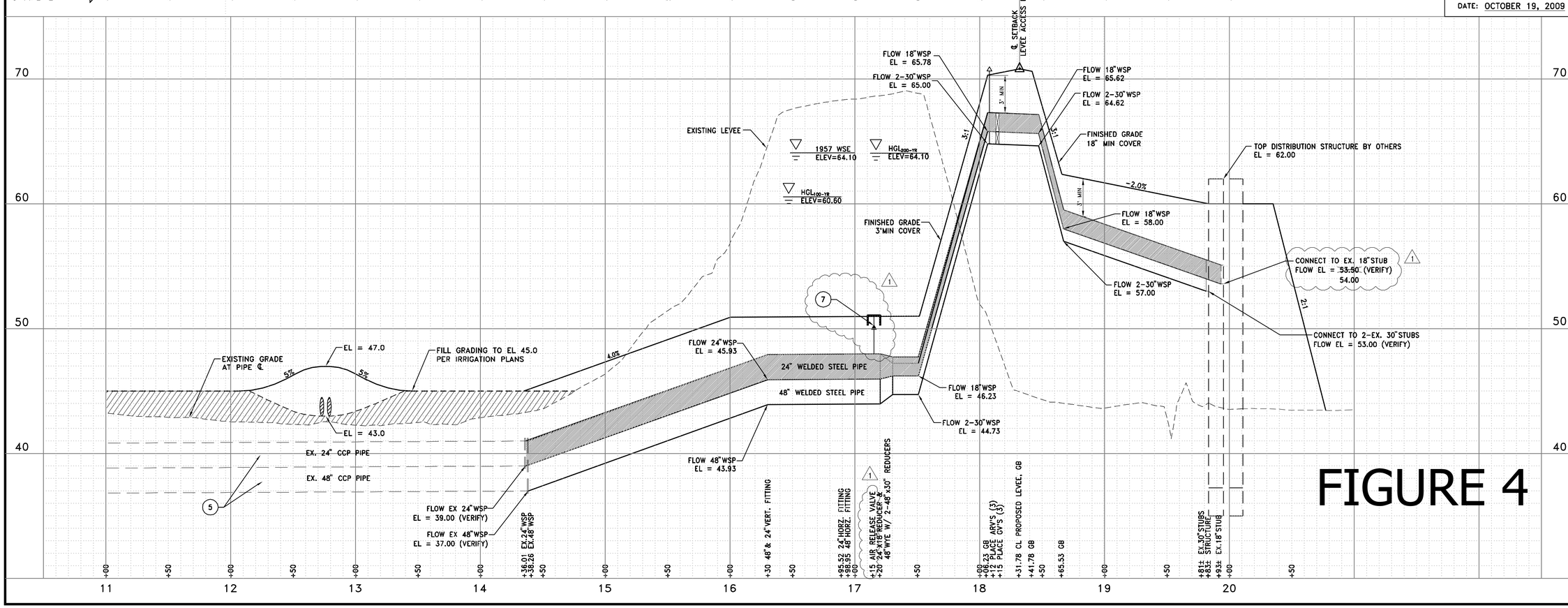


FIGURE 4

REV.	DESCRIPTION	BY	CHK.	APPR.	DATE
1	AS-BUILT, REV. IRR. PIPE TYPE, ARV, DRAINAGE SWALE	LCS HS	GP JT	JK JK	12/13/10 07/08/09
0	CONFORMED SET				

DESIGNED BY: R. CONN
DRAWN BY: RC
CHECKED BY: J. KORS
IN CHARGE: J. TWITCHELL
DATE: DECEMBER 13, 2010

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IMPROVEMENT PLANS FOR

LOWER FEATHER RIVER SETBACK LEVEE AT STAR BEND
PUMP DISCHARGE PIPE PLAN AND PROFILE
STA. 11+00 TO STA. 20+00

SUTTER COUNTY CALIFORNIA

VERIFY SCALES
BAR IS ONE INCH ON ORIGINAL DRAWING. ADJUST SCALES FOR REDUCED PLOTS
0 1"

HORIZ: 1"=40' VERT: 1"=4'

DRAWING NO. PC-1 SHEET 36

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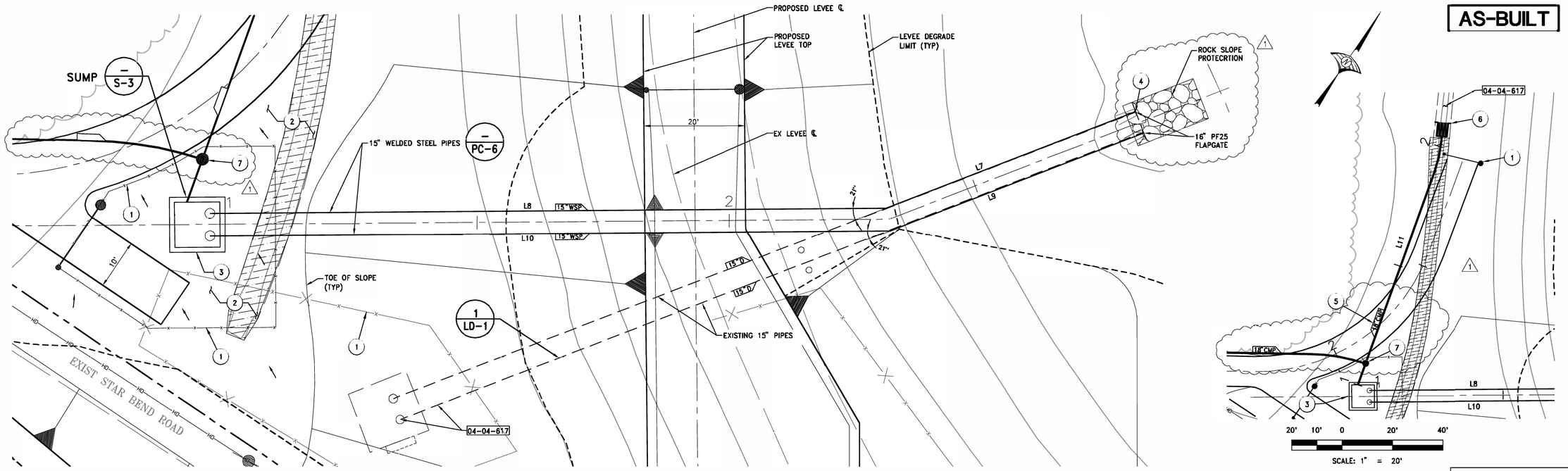
AS-BUILT



CONSTRUCTION NOTES:

1. SALVAGE AND REINSTALL ON NEW POSTS CHAIN LINK FENCE AND ACCESS GATES.
2. GRADE TO DRAIN TOWARDS EXISTING ORCHARD, 2% MIN.(TYP)
3. PROPOSED SUMP STRUCTURE, SEE DWG S-3.
4. EXISTING EROSION PROTECTION BLANKET TO REMAIN. CONTRACTOR TO MATCH EXISTING FIELD CONDITIONS WITH NEW 15" PIPE AT OUTLET.
5. CONSTRUCT 104 LF OF 18" CMP DRAIN PIPE
   FL @ DITCH INLET = (MATCH EXISTING)
   FL @ SUMP STRUCTURE = 42.00'
6. CONSTRUCT NEW CONCRETE HEADWALL AND SAFETY RACK IN ACCORDANCE WITH REFERENCE DRAWINGS. C-5/15
7. TYPE GMP PIPE INLET, MATCH EXISTING INVERT. 1
8. ALL 18" DRAIN PIPE IS 12 Ga CMP 1

10' 5' 0 10' 20'
SCALE: 1" = 10'

WATER PIPE LINE TABLE

LINE	LENGTH	BEARING
L7	53'	N34°30'12"E
L8	134'	N55°11'11"E
L9	54'	N34°30'12"E
L10	135'	N55°11'11"E

DRAIN PIPE LINE TABLE

L11	104'	N15°45'26"W

WOOD RODGERS, INC.

REGISTERED PROFESSIONAL ENGINEER JONATHAN L. KORS No.C59538 Exp. 12/31/09 CIVIL STATE OF CALIFORNIA

DATE: OCTOBER 19, 2009

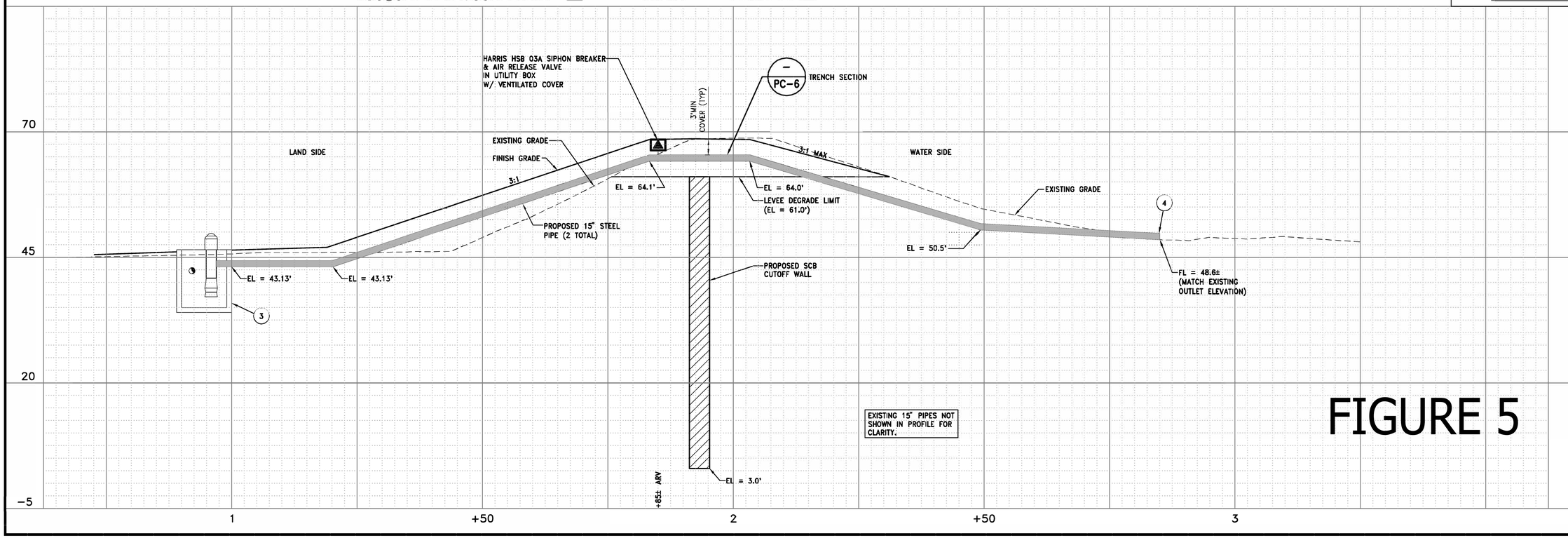


FIGURE 5

REV.	DESCRIPTION	BY	CHK.	APPR.	DATE
1	AS-BUILT, ADD DRAIN PIPE & INLET, REV OUTFALL	LCS	GP	JK	12/13/10
0	CONFORMED SET	HS	JT	JK	07/08/09

DESIGNED BY: R. CONN
DRAWN BY: RC
CHECKED BY: J. KORS
IN CHARGE: J. TWITCHELL
DATE: DECEMBER 13, 2010

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PUMP DISCHARGE PIPE PLAN AND PROFILE

SUTTER COUNTY CALIFORNIA

VERIFY SCALES BAR IS ONE INCH ON ORIGINAL DRAWING ADJUST SCALES FOR REDUCED PLOTS 0 1"
HORIZ:1" = 10 VERT:1" = 10

DRAWING NO. PC-3 SHEET 38

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